RULES
R001-2025

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2025

Effective from 1 July 2025

Beijing

EXPLANATION

The Rules for Classification of Sea-going Steel Ships is the basic rules of CCS to provide classification services for sea-going ships engaged on international voyages, including classification conditions and scope and supporting technical requirements. The Rules specifies technical and construction standards, survey and test requirements for ship construction, hull structure, machinery and electrical equipment and systems, fire safety, environmental protection etc., as well as conditions to maintain them in good conditions, which are intended to control the safety and quality of ships to an appropriate level and receive wide recognition by the industry.

The Rules for Classification of Sea-going Steel Ships applies to classed sea-going ships of 20 m in length and over. Unless otherwise specified, it does not apply to military ships, wooden ships, non-commercial yachts, high-speed craft, small waterplane area craft, sailboat.

The Rules for Classification of Sea-going Steel Ships (2025) incorporates 2025 amendments to the Rules for Classification of Sea-going Steel Ships, 2024 RCN No.3, 2025 RCN No.1 and 2025 RCN No.2 related thereto, on the basis of the Rules for Classification of Sea-going Steel Ships (2024).

Upon effective, the Rules for Classification of Sea-going Steel Ships (2025) supersedes the Rules for Classification of Sea-going Steel Ships (2024).

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2025

PART ONE PROVISIONS OF CLASSIFICATION

CONTENTS

CHAPTER 1 GENERAL 1-1
Section 1 CHINA CLASSIFICATION SOCIETY AND ITS MAIN SERVICES 1-1
Section 2 COUNCIL AND COMMITTEES 1-2
CHAPTER 2 SCOPE AND CONDITIONS OF CLASSIFICATION 1-3
Section 1 GENERAL PROVISIONS 1-3
Section 2 RULES FOR CLASSIFICATION 1-4
Section 3 CHARACTERS OF CLASSIFICATION AND CLASS NOTATIONS 1-6
Section 4 APPLICATION AND FEES 1-8
Section 5 SUBMISSION AND EXAMINATION OF PLANS 1-8
Section 6 CLASSIFICATION SERVICES 1-10
Section 7 STATUTORY SERVICES 1-10
Section 8 APPROVAL OF SUPPLIERS 1-11
Section 9 ASSIGNMENT, MAINTENANCE, SUSPENSION, CANCELLATION AND REINSTATEMENT OF CLASS 1-12
Section 10 CERTIFICATES AND REPORTS 1-15
Section 11 REGISTER OF SHIPS AND LISTS OF APPROVED MARINE PRODUCTS 1-15
Section 12 AVAILABILITY AND CONFIDENTIALITY OF INFORMATION 1-16
Section 13 LIABILITY, DISAGREEMENT AND ARBITRATION 1-18
Appendix 1 LIST OF CLASS NOTATIONS FOR SEA-GOING SHIPS 1-20
Appendix 2 DIAGRAMS OF MANDATORY SHIP TYPES FOR SHIPS HAVING ESP NOTATION 1-62
CHAPTER 3 INSPECTIONS OF PRODUCTS 1-65
Section 1 GENERAL PROVISIONS 1-65
Section 2 UNIT/BATCH INSPECTIONS 1-73
Section 3 DESIGN APPROVAL 1-76
Section 4 TYPE APPROVAL 1-77
Section 5 WORKS APPROVAL 1-80
Section 6 PRODUCT DRAWING EXAMINATION 1-82
Section 7 APPROVAL OF SERVICE FIRM OF INSPECTION AND TESTING 1-83
Section 8 CLASS NOTATIONS FOR PRODUCTS 1-85
Section 9 REQUIREMENTS FOR QUALITY SYSTEM CHECK 1-87
Section 10 ALTERNATIVE CERTIFICATION SCHEME 1-88
Section 11 PRINCIPLE APPROVAL 1-89
Appendix 1A LIST OF CERTIFICATION REQUIREMENTS FOR CLASSED MARINE PRODUCTS 1-93
Appendix 1B LIST OF CERTIFICATION REQUIREMENTS FOR STATUTORY MARINE PRODUCTS 1-101
Appendix 1C LIST OF CERTIFICATION REQUIREMENTS FOR LIFTING APPLIANCES 1-108
Appendix 1D LIST OF CERTIFICATION REQUIREMENTS FOR LIQUEFIED NATURAL GAS SPECIALIZED PRODUCTS 1-109
Appendix 1E LIST OF CERTIFICATION REQUIREMENTS FOR METHANOL FUEL SYSTEM SPECIALIZED PRODUCTS 1-116
Appendix 1F LIST OF CERTIFICATION REQUIREMENTS FOR AMMONIA TRANSPORT AND AMMONIA FUEL SPECIALIZED PRODUCTS 1-120
Appendix 2A LIST OF CERTIFICATION REQUIREMENTS FOR CLASSED MARINE PRODUCT PARTS 1-127
Appendix 2B LIST OF CERTIFICATION REQUIREMENTS FOR STATUTORY MARINE PRODUCT PARTS 1-144
Appendix 2C LIST OF CERTIFICATION REQUIREMENTS FOR LIFTING APPLIANCE PARTS 1-154
CHAPTER 4 SURVEYS DURING CONSTRUCTION 1-157

Section 1 GENERAL PROVISIONS 1-157
Section 2 SURVEYS AND TESTS 1-157
Section 3 TESTING PROCEDURES OF WATERTIGHT COMPARTMENTS 1-159
Section 4 DOCUMENTATION 1-168
Section 5 ASSIGNING CLASS FOR A NEW BUILDING PROJECT WHEN THE DESIGN IS ALREADY APPROVED BY AN INITIAL SOCIETY 1-169
Section 6 ASSIGNING DUAL CLASS FOR A NEW BUILDING 1-171
Appendix 1 HULL SURVEY FOR NEW CONSTRUCTION 1-172
Appendix 2 SHIPBUILDING AND REPAIR QUALITY STANDARD 1-201
Appendix 3 SURVEYS OF WATERTIGHT CABLE TRANSITS 1-247
CHAPTER 5 SURVEYS AFTER CONSTRUCTION 1-248
Section 1 GENERAL PROVISIONS 1-248
Section 2 TYPES AND PERIODS OF SURVEYS 1-275
Section 3 RETROSPECTIVE REQUIREMENTS FOR EXISTING SHIPS 1-278
Section 4 HULL AND EQUIPMENT SURVEYS 1-287
Section 5 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF GENERAL DRY CARGO SHIPS 1-297
Section 6 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF OIL TANKERS 1-305
Section 7 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF BULK CARRIERS 1-319
Section 8 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF CHEMICAL TANKERS 1-337
Section 9 SURVEYS OF MACHINERY 1-346
Section 10 SURVEYS OF ELECTRICAL INSTALLATIONS 1-352
Section 11 SURVEYS OF THE OUTSIDE OF THE SHIP'S BOTTOM AND RELATED ITEMS 1-354
Section 12 SURVEYS OF PROPELLER SHAFTS AND TUBE SHAFTS 1-355
Section 13 BOILER SURVEYS 1-363
Section 14 INITIAL CLASSIFICATION SURVEYS OF SHIPS CONSTRUCTED NOT UNDER THE SUPERVISION OF CCS 1-366
Section 15 OTHER SURVEYS 1-371
Section 16 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF LIQUEFIED GAS CARRIERS 1-372
Section 17 ADDITIONAL REQUIREMENTS FOR SURVEYS OF RO-RO SHIPS 1-376
Section 18 ADDITIONAL REQUIREMENTS FOR SURVEYS OF LIVESTOCK CARRIERS 1-379
Appendix 1 CRITERIA FOR RENEWAL OF HULL STRUCTURAL MEMBERS 1-380
Appendix 2 CRITERIA FOR LONGITUDINAL STRENGTH OF HULL GIRDER FOR OIL TANKERS 1-383
Appendix 3 GUIDELINES FOR MEASURING SCANTLINGS OF THE TRANSVERSE WATERTIGHT VERTICALLY CORRUGATED BULKHEAD BETWEEN CARGO HOLDS NOS.1 AND 2 OF BULK CARRIERS 1-387
Appendix 4 RUDDER BEARING WEAR CLEARANCE 1-389
Appendix 5 WEAR CLEARANCE OF BEARINGS OF PROPELLER SHAFTS OR TUBE SHAFTS 1-391
Appendix 6 GUIDELINES FOR THE GAUGING OF SIDE SHELL FRAMES AND BRACKETS IN SINGLE SIDE SKIN BULK CARRIERS REQUIRED TO COMPLY WITH UR S31 1-392
Appendix 7 GUIDELINES FOR THE SURVEY OF VOYAGE REPAIRS 1-396
Appendix 8 PROCEDURAL REQUIREMENTS FOR SERVICE SUPPLIERS 1-398
Appendix 9 CALIBRATION OF MEASURING EQUIPMENT 1-419
Appendix 10 PROCEDURES FOR CERTIFICATION OF FIRMS ENGAGED IN THICKNESS MEASUREMENT OF HULL STRUCTURES 1-420
Appendix 11 ESP SURVEY REPORTING PRINCIPLES 1-421

Appendix 11A SURVEY PROGRAMME 1-434
Appendix 11B SURVEY PLANNING QUESTIONNAIRE 1-439
Appendix 12 GUIDELINES FOR TECHNICAL ASSESSMENT IN CONJUNCTION WITH PLANNING FOR ENHANCED SURVEYS AND OWNER'S INSPECTION REPORT 1-443
Appendix 13 RECOMMENDED PROCEDURES FOR THICKNESS MEASUREMENTS 1-451
Appendix 14 GUIDELINES FOR SCREWSHAFT CONDITION MONITORING SYSTEM ... 1-611
Appendix 15 GUIDELINES FOR LUBRICATING OIL CONDITION MONITORING SYSTEM OF DIESEL ENGINES 1-623
Appendix 16 GUIDELINES FOR SURVEY OF PLANNED MAINTENANCE SCHEME（PMS） FOR MACHINERY 1-632
Appendix 17 S19 EVALUATION OF SCANTLINGS OF THE TRANSVERSE WATERTIGHT CORRUGATED BULKHEAD BETWEEN CARGO HOLDS NOS. 1 AND 2, WITH CARGO HOLD NO. 1 FLOODED, FOR EXISTING BULK CARRIERS 1-652
Appendix 18 S22 EVALUATION OF ALLOWABLE HOLD LOADING OF CARGO HOLD NO.1 WITH CARGO HOLD NO.1 FLOODED, FOR EXISTING BULK CARRIERS 1-664
Appendix 19 S23 IMPLEMENTATION OF IACS UNIFIED REQUIREMENTS S19 AND S22 FOR EXISTING SINGLE SIDE SKIN BULK CARRIERS 1-668
Appendix 20 S31 RENEWAL CRITERIA FOR SIDE SHELL FRAMES AND BRACKETS IN SINGLE SIDE SKIN BULK CARRIERS AND SINGLE SIDE SKIN OBO CARRIERS NOT BUILT IN ACCORDANCE WITH UR S12 REV.1 OR SUBSEQUENT REVISIONS 1-670
Appendix 21 GUIDELINES FOR PILOT SCHEMES OF EXTENDED INTERVAL BETWEEN SURVEYS IN DRY-DOCK − EXTENDED DRY-DOCKING (EDD) SCHEME .. 1-680
Appendix 22 CONDITION MONITORING AND CONDITION BASED MAINTENANCE ... 1-683
Appendix 23 REQUIREMENTS FOR NDT SERVICE SUPPLIERS 1-687
Appendix 24 REMOTE CLASSIFICATION SURVEYS 1-691
CHAPTER 6 SURVEYS RELATED TO CLASS NOTATIONS 1-700
Section 1 GENERAL PROVISIONS 1-700
Section 2 SURVEYS RELATED TO CLASS NOTATIONS FOR SPECIAL DUTIES 1-700
Section 3 SURVEYS RELATED TO CLASS NOTATIONS FOR SPECIAL EQUIPMENT AND SYSTEM 1-705
Section 4 SURVEYS RELATED TO CLASS NOTATIONS FOR AUTOMATIC CONTROL ... 1-708
Section 5 SURVEYS RELATED TO CLASS NOTATIONS FOR GREEN ECO-SHIPS 1-709
Section 6 SURVEYS RELATED TO CLASS NOTATIONS FOR REFRIGERATED CARGO INSTALLATIONS 1-709
Section 7 SURVEYS RELATED TO CLASS NOTATIONS FOR EOM 1-712
Appendix 1 REQUIREMENTS FOR INSTALLATION OF FLOWMETER 1-715
Appendix 2 SUMMARY OF PARAMETERS OF ENERGY EFFICIENCY EQUIPMENT 1-717
Appendix 3 CHECKLIST OF SYSTEM FUNCTIONS OF EOM SOFTWARE 1-721

CHAPTER 1 GENERAL

Section 1 CHINA CLASSIFICATION SOCIETY AND ITS MAIN SERVICES

1.1.1 Classification Societies

1.1.1.1 Classification societies are independent and impartial organizations that undertake classification services for ships and offshore installations. Classification societies have no commercial interests related to design, building, ownership, operation, management, maintenance or repairs, financing, insurance or chartering of ships and offshore installations.

1.1.1.2 Classification societies work for the safety of ships and offshore installations and environmental protection, and make a unique contribution to maritime safety and the development of classification rules through technical support, compliance verification and research and development. Classification societies provide classification services, statutory services and other services for clients in accordance with the classification rules published by them.

1.1.1.3 Classification societies furnish reasonable standards – the classification rules, which are generally accepted and recognized, for ships, shipbuilding, marine exploitation and related manufacturing industries as well as insurance, financing and other related sectors, carry out plan approval in ship design and surveys during and after construction so as to ascertain that ships are in compliance with the requirements of the classification rules, and issue classification certificates independently, in accordance with such rules.

1.1.1.4 When authorized by the Government of the flag State, classification societies carry out statutory services in accordance with the requirements of the Government of the flag State with a view to ascertaining the ships' compliance with the requirements of international conventions and/or relevant regulations of the flag State, and issue statutory certificates.

1.1.2 China Classification Society

1.1.2.1 China Classification Society (hereinafter referred to as CCS) is a specialized technical organization, authorized under the relevant laws of China and registered in accordance with the laws for providing classification services and statutory services for ships and offshore installations.

1.1.2.2 CCS mainly undertakes classification services, certification surveys and surveys relating to notarial matters for ships, offshore installations, containers and the related industrial products both at home and abroad, and performs specific services such as statutory services, etc., on behalf of the Chinese Government and the governments of foreign countries or regions when so authorized, and other services approved by the relevant administrations.

1.1.3 Objectives

1.1.3.1 The objectives of CCS are, by furnishing reasonable and reliable technical rules for ships, offshore installations, containers and related industrial products and conducting in an independent, impartial and honest manner classification, certification and technical services, to provide services for the shipping, marine exploitation and related manufacturing industries as well as marine insurance, for the promotion of safety of life and property on waters and for the protection of marine environment and other environments.

1.1.4 Main services

1.1.4.1 The services of CCS are mainly as follows:

(1) Classification services for ships, offshore installations and related industrial products (including containers): development and maintenance of rules, plan approval, surveys and certification;

(2) Statutory services for ships, offshore installations and related industrial products, when so authorized: development of technical regulations for statutory surveys, plan approval, surveys and certification;

(3) Surveys and certification delegated by other ship survey organizations, surveys related to notarial matters and safety assessment as well as verification surveys and certification of ships and offshore installations , and investigation of major maritime safety accidents;

(4) Verification, surveys and certification of related industrial facilities and products used on land, and surveys and certification delegated by foreign ship survey organizations for marine facilities and products as well as related industrial facilities and products used on land;

(5) ISM audit and certification;

(6) ISPS audit and certification;

(7) Maritime Labor Convention (MLC) inspection and certification;
(8) Services for EU Regulations on the monitoring, reporting and verification (MRV) of CO_2 emissions from maritime transport and IMO Data collection system for fuel oil consumption of ships (DCS);
(9) Survey and assessment of ship's technical conditions;
(10) Certification of quality management systems and environmental management systems in accordance with ISO 9000 and ISO 14000 series or equivalent standards;
(11) Technical research for classification of ships and offshore installations, safety on waters and environmental protection, survey of marine facilities and products as well as related industrial facilities and products used on land, and research on the application of information technology;
(12) Other services.

Section 2 COUNCIL AND COMMITTEES

1.2.1 Council

1.2.1.1 The Council of CCS is composed of the representatives from Government departments concerned, CCS, shipping, shipbuilding, marine exploitation and related manufacturing industries as well as insurance, financing and other related sectors.
1.2.1.2 The Council is entitled to:
(1) develop and update the Articles of Association of CCS;
(2) consider the work report of CCS;
(3) decide on other major issues of CCS.

1.2.2 Technical Committee

1.2.2.1 The Technical Committee of CCS is composed of the persons in charge of technical work from Government departments concerned, CCS, shipping, shipbuilding and marine exploitation industries, design institutes, universities, research institutes and related manufacturing industries. Specialized subcommittees may be set up as appropriate.
1.2.2.2 The Technical Committee is entitled to:
(1) make comments or recommendations on CCS technical policy and development plan for rules and research;
(2) review and approve the main technical rules developed by CCS for ships and offshore installations;
(3) organize technical analysis and investigation of major accidents of the ships and offshore installations classed with CCS;
(4) make recommendations on developing and amending the rules based on experience in application, market demand and development in science and technology;
(5) examine the major research achievements intended to be incorporated into CCS rules for ships and offshore installations, and make recommendations on such incorporation.

1.2.3 Class committee

1.2.3.1 The Class Committee of CCS is composed of the representatives from Government departments concerned, CCS, owners, oil companies, administrations as well as insurance, financing, law and other related sectors.
1.2.3.2 The Class Committee is entitled to:
(1) examine and adopt the working procedure of the Committee and the procedure for CCS classification management;
(2) examine the relevant provisions of CCS for classification of ships and offshore installations and make recommendations on modifications and additions in light of the latest development in science and technology;
(3) accept and confirm the reports submitted by CCS on assignment, suspension, cancel or reinstatement of class of ships and offshore installations;
(4) make comments on the certificates and various survey documents of ships and offshore installations.

CHAPTER 2 SCOPE AND CONDITIONS OF CLASSIFICATION

Section 1 GENERAL PROVISIONS

2.1.1 Principle of classification

2.1.1.1 Classification is a representation by CCS, in accordance with its rules, that the structural strength and integrity of essential parts of the ship's hull and its appendages, and the reliability and the function of the propulsion and steering systems, power generation and those other features and auxiliary systems which have been built into the ship, identified by various characters and notations, are sufficient for maintaining essential services on board.

2.1.2 Process of classification

2.1.2.1 The process of classification consists of:

(1) the development of rules;

(2) the plan approval and survey during construction to verify compliance with such rules;

(3) the assignment of class and issuance of a classification certificate when such compliance has been verified;

(4) the endorsement or issuance of a classification certificate by survey after construction to verify compliance with such rules; and

(5) the application of information.

2.1.3 Definitions

2.1.3.1 Unless expressly provided otherwise, for the purpose of the Rules:

(1) **Classification** means the technical service provided by a classification society to clients in accordance with the rules published by it.

(2) A **classed ship** is a ship to which a classification certificate is issued by a classification society in accordance with its rules.

(3) A **non-classed ship** is any ship which is not classed.

(4) A **convention ship** is a ship holding an international certificate issued according to a relevant international convention.

(5) A **non-convention ship** is any ship which is not a convention ship.

(6) **Unrestricted service** means that the areas for navigation are not limited.

(7) **Restricted service** is a generic term of the service categories 1, 2 and 3 as shown in table 2.1.3.1 below:

Table 2.1.3.1

Category	Limitation for navigation	
	Distance to land (n mile)	
Service category 1	200 (summer/tropical*)	100 (winter*)
Service category 2	20 (summer/tropical*)	10 (winter*)
Service category 3	Sheltered waters**	

Notes:

* Seasonal areas as specified in Annex II to the International Convention on Load Lines, 1966.

** Sheltered waters include the sea areas between an island and the shore and between islands with a distance of less than 10 n miles in between, which forms a comparatively good sheltered or similar condition with a little wave.

(8) **National waters** mean the waters of a flag State, as specified by the Government of that State.

(9) **Specified route service** means the service between two or more designated ports.

(10) A **passenger** is every person other than the master and the members of the crew or other persons employed or engaged in any capacity on board a ship on the business of that ship; or a child under one year of age.

(11) A **passenger ship** is a ship which carries more than twelve passengers.

(12) A **ro-ro passenger ship** is a passenger ship with ro-ro cargo spaces or special category spaces.

(13) A **cargo ship** is any ship which is not a passenger ship.

(14) A **tanker** is a cargo ship which is constructed primarily to carry liquid cargoes in bulk.

(15) **Oil** means petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products (other than those petrochemicals which are subject to the provisions of MARPOL Annex II).

(16) An **oil tanker** is a ship which is constructed primarily to carry oil in bulk and includes ship types such as combination carriers (ore/oil ships etc.).

(17) A **ro-ro ship** is a ship which utilizes a loading ramp to enable wheeled vehicles to be rolled on and

rolled off the ship.
(18) A **container ship** is a ship constructed for the carriage of containers in holds and on deck.
(19) A **fishing vessel** is a vessel used for commercially catching fish or other living resources of the sea.
(20) A **chemical tanker** is a cargo ship constructed for the carriage in bulk of any liquid products listed in Chapter 17 of the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code). The provisions of the Code are contained in CCS Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk.
(21) A **liquefied gas carrier** is a cargo ship constructed for the carriage in bulk of any liquefied gas or other products listed in Chapter 19 of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code). The provisions of the Code are contained in CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.
(22) A **bulk carrier** is a ship which is constructed generally with single deck, double bottom, topside tanks and hopper side tanks in cargo spaces, and is intended primarily to carry dry cargo in bulk. Combination carriers are included. Common Structural Rules[①] does not apply to ore carriers and combination carriers.
(23) A **new ship** means a ship contracted for construction on or after the date of entry into force of the Rules.
(24) An **existing ship** means a ship which is not a new ship.
(25) **Product** is a generic term of materials, equipment and systems.
(26) The term **rules** is a generic term of the classification rules, special rules, guidelines and computer software released by CCS.
(27) **Force majeure** means damage to the vessel; unforeseen inability of CCS Surveyors to attend the vessel due to the governmental restrictions on right of access or movement of personnel; unforeseeable delays in port or inability to discharge cargo due to unusually lengthy periods of severe weather, strikes, civil strife; acts of war, or other cases of force majeure.
(28) **Exceptional circumstances** mean one or more of the following cases:
① unavailability of dry-docking facilities;
② unavailability of repair facilities;
③ unavailability of essential materials, equipment or spare parts;
④ delays incurred by action taken to avoid severe weather conditions.
(29) A **double classed ship** is one which is classed by two Societies and where each Society works as if it is the only Society classing the ship, and does all surveys in accordance with its own Rules, requirements and schedule.
(30) A **dual class ship** is one which is classed by two Societies. These Societies have a written bilateral agreement that outlines sharing of work, including a working plan, and procedures and, in case of newbuilding, a written trilateral agreement with the shipyard.
(31) **Bilateral Agreement** is an agreement adopted by the two Societies with Dual Class Vessels.
(32) **Trilateral Agreement** is an agreement adopted by the shipyard and the two Societies involved in dual class arrangement (first Society and second Society) for describing the responsibilities between the two Societies during new construction of a vessel.
(33) **First Society** is a Society classing a vessel which, under request of the Owner, enters a double or dual class arrangement with another Society.
(34) **Second Society** is a Society which is requested by an Owner to accept a vessel already classed, or to be classed, by another Society into its class under double or dual class arrangement.
(35) **Conditions of class** are requirements to the effect that specific measures, repairs, surveys etc., are to be carried out within a specific time limit in order to retain class.
(36) A **CSR ship** is a ship complying with the requirements of Common Structural Rules[①].
(37) The term "**not in class (disclassed)**" means class being suspended or canceled (withdrawn).
(38) **Critical structural areas** are locations which have been identified from calculations to require monitoring or from the service history of the subject ship or from similar or sister ships (if available) to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the ship.

Section 2 RULES FOR CLASSIFICATION

2.2.1 Basis for classification

① PART TEN of the Rules (2012 version) and its 2013 and 2014 amendments or PART NINE of the Rules (2015 version) and its subsequent versions (including amendments).

2.2.1.1 “Classification rules” are such provisions that have entire content comprising conditions and scope of classification and supporting technical requirements. The aim of the rules is to ensure the safety and quality to be controlled to an appropriate level, and to be generally acknowledged.
2.2.1.2 The rules and relevant applicable guidelines published by CCS are the basis and criteria for classification.
2.2.1.3 CCS rules stipulate the scantlings of hull structures and essential machinery, the quality and structure of material employed, the standards of machinery manufacturing, requirements for classification and tests as well as maintenance conditions.
2.2.1.4 “Special rules” are such provisions that have special content and will be used in combination with the classification rules.
2.2.1.5 For those not covered in CCS present rules, or the principled requirements therein which need to be further defined in details, or where specific applicability of the rules is needed, or for novel ships or equipment or systems, CCS will develop appropriate guidelines or use IACS Recommendations① to facilitate classification. Where any “guidelines” or IACS Recommendations are referred to in the rules, the paragraphs related to classification in such “guidelines” or IACS Recommendations constitute requirements of the rules.
2.2.1.6 CCS COMPASS computer software system covers structural calculation and evaluation, ship characteristics, calculation of shafting vibration and strength and calculation of short-circuit current. The computer software plays an essential role in plan approval and surveys during and after construction.

2.2.2 Rules development

2.2.2.1 The main input for development of the rules is as follows:
(1) experience in application;
(2) relevant scientific theories and research findings;
(3) the applicable part of the relevant conventions, codes and resolutions adopted by IMO (International Maritime Organization), and unified requirements by IACS (International Association of Classification Societies).
2.2.2.2 The drafts of CCS rules or their amendments will be distributed to the Administration, CCS, shipping, shipbuilding, design institutes, universities, research institutes and related manufacturing industries related to ships and marine products for comments.
2.2.2.3 The drafts of CCS rules or their amendments are to be further supplemented and improved based on analysis of the expert comments or recommendations from the above-mentioned sources, followed by a final review by CCS Technical Committee or its subcommittee(s), and then issued after being approved and signed by CCS President.
2.2.2.4 Where any part of CCS rules related to the classification needs to be amended, as shown by experience in application, safety aspects covered by investigation of accidents, or due to entry into force of relevant resolutions, codes, etc., of IMO, or upon acceptance of unified requirements adopted by IACS, CCS will directly publish amendments thereto.

2.2.3 Entry into force of rules

2.2.3.1 Unless stated otherwise, the rules (including their amendments) will generally come into force in 3 months after being published. The effective date will be indicated on the first page of the corresponding PART or on the title page of the publication.
2.2.3.2 Unless stated specially, the rules are applicable to newbuildings and new marine products.
2.2.3.3 With the consent of the shipyard and the owner, the requirements of the new rules may be adopted for the ship under construction; and where the requirements in the new rules are reasonable and practicable, CCS may agree that these requirements be adopted for the ship under construction. In any case, this is to be indicated in the corresponding technical documents.
2.2.3.4 The date of entry into force of the rules is subject only to the date of approval for publishing the rules, not to the date of entry into force of any other statutory requirements.

2.2.4 Application

2.2.4.1 The Rules apply to classed sea-going ships.
2.2.4.2 The Rules apply to new ships. All ships constructed before the date of entry into force of the Rules are to continue to comply with the requirements previously applicable to them.
For ships which have undergone modification of a major character, the modified and related portions are to comply with the new Rules. The previous Rules are still applicable to those ships of which the midship

① IACS Recommendations are available on IACS website: http://iacs.org.uk.

section plan or an equivalent structural plan has been approved.
2.2.4.3 The requirements of relevant chapters in this PART also apply to existing ships, including chemical tankers and liquefied gas carriers.
2.2.4.4 The intact stability, subdivision and damage stability, fire safety are the conditions of classification of ships and are to comply with PART TWO and PART SIX of the Rules (while for fishing vessels, provisions of Chapter 5 of PART EIGHT of the Rules are to be complied with; for ships in restricted service, provisions of PART TEN of the Rules are to be complied with), with attention being paid to the relevant requirements of the flag Administration, if any.
2.2.4.5 Chemical tankers and liquefied gas carriers are also to comply respectively with CCS Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk and Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.
2.2.4.6 Unless otherwise specially required, materials and welding are to comply with CCS Rules for Materials and Welding.
2.2.4.7 The Rules, unless expressly provided otherwise, do not apply to:
(1) military vessels;
(2) wooden ships;
(3) pleasure yachts not engaged in trade;
(4) high speed craft;
(5) small waterplane area craft;
(6) sailing boats;
(7) ships of less than 20 m in length.

2.2.5 Equivalent and exemption
2.2.5.1 Any ship which embodies structure and features of a novel kind may be exempted from any requirement of CCS rules if the application of which might seriously impede the incorporation of its features or its service, subject to agreement of CCS Headquarters.
2.2.5.2 Any fitting, material, appliance or apparatus, other than that required in CCS rules, may be allowed to be fitted in a ship, if it is satisfied by trial thereof or otherwise that such fitting, material, appliance or apparatus is at least as effective as that required in CCS rules.
2.2.5.3 Equivalence or substitution to those methods of calculation, criteria of evaluation, manufacturing procedures, materials, survey and test requirements specified by CCS rules may be accepted subject to agreement of CCS Headquarters, when relevant tests, theoretical basis or experience in application is provided, or recognized effective standards are available.

2.2.6 References in the Rules
2.2.6.1 References to relevant documents in the Rules constitute requirements of the Rules. For references with no date indication, their latest version applies to the Rules.

2.2.7 Qualification of new technology applications
2.2.7.1 For the qualification of new technology products and relevant technology solutions that lack specific technical requirements and relevant criteria in the rules and relevant recognized standards, refer to CCS Guidelines for Qualification of New Technology Applications.

Section 3 CHARACTERS OF CLASSIFICATION AND CLASS NOTATIONS

2.3.1 Characters of classification
2.3.1.1 Characters of classification are indicative of main features of the ship and mandatory.
2.3.1.2 The hull (including equipment) and machinery (including electrical installations) of a ship that comply with CCS rules, guidelines or equivalent provisions will be assigned appropriate characters of classification and class notations by CCS.
2.3.1.3 The hull (including equipment) and machinery (including electrical installations) of a ship that are classed with CCS will be assigned one of the following characters of classification as appropriate according to different conditions:

★ CSA

★ CSM

or

★ CSA
★ CSM
or
★ CSA
★ CSM

The meanings of the characters of classification are:

★ CSA — indicating that the ship's hull structure and equipment have been constructed with plan approval by and under the supervision of CCS and comply with CCS rules. Under special circumstances, the ship's hull structure and equipment have been found upon classification survey by CCS to be in compliance with rules which is at least as effective as that required in CCS rules shortly before delivery of the ship, ★ is replaced by $\overline{★}$;

★ CSA — indicating that the ship's hull structure and equipment have been constructed not with plan approval by and not under the supervision of CCS, and that they have been found upon classification survey by CCS to be in compliance with CCS rules;

★ CSM — indicating that the ship's propulsion and essential auxiliary machinery have been inspected by CCS, and that its machinery and electrical installations have been constructed with plan approval by and under the supervision of CCS and comply with CCS rules. Under special circumstances, the ship's machinery (including electrical installations) have been found upon classification survey by CCS to be in compliance with rules which is at least as effective as that required in CCS rules shortly before delivery of the ship, ★ is replaced by $\overline{★}$;

★ CSM — indicating that the ship's propulsion and essential auxiliary machinery have not been inspected by CCS, and that its machinery and electrical installations have been constructed with plan approval by and under the supervision of CCS and comply with CCS rules;

★ CSM — indicating that the ship's machinery and electrical installations have been constructed not with plan approval by and not under the supervision of CCS, and that they have been found upon classification survey by CCS to be in compliance with CCS rules.

2.3.2 Class notations

2.3.2.1 Class notations indicate different features of a ship in sequence, and will be appended to the characters of classification. Class notations may be divided into necessary notations and optional ones.

2.3.2.2 At the request of the owner and upon plan approval and surveys by CCS, optional class notation(s) will be assigned by CCS if it is satisfied that the relevant requirements of CCS rules are complied with.

2.3.2.3 One or one group class notations may be assigned to indicate ship type, cargo and loading characteristics, special duties, special features, service, service restriction or other meanings.

2.3.2.4 At the request of the owner, CCS will append appropriate class notations to the hull, machinery and electrical installations for ships built in accordance with the relevant rules published by CCS or other acceptable standards.

2.3.2.5 Appendix 1 of this Chapter contains a list of class notations for sea-going ships and such notations may be entered only in English into classification certificates. The list is divided into the following tables:

Table A: Type notation: For all ships, the type notation is to be added;

Table B: Special duties notation: Ships, which have been designed and constructed in accordance with relevant rules and guidelines for their special purposes, may be assigned appropriate notations respectively;

Table C: Service or service restriction notations: Ships, the service of which is restricted within a specified area or to a specified route due to certain reasons, may be assigned appropriate notations respectively;

Table D: Notation of cargo and loading characteristics: Ships, which have been constructed in accordance with particular rules to carry one or more particular cargoes, may be assigned appropriate notations respectively;

Table E: Special features notations: Ships, which incorporate special features significantly affecting the design, may be assigned appropriate notations respectively, of which the ice service notations Ice Class B1*, Ice Class B1, Ice Class B2, Ice Class B3 correspond respectively to IA Super, IA, IB, IC in the Finnish-Swedish Ice Class Rules;

Table F: Automation notation: Automatic and remote controls, dynamic positioning systems, one man bridge operated ships, etc., may be assigned appropriate notations respectively;

Table G: Special equipment and system notation: Where a relevant device or instrument for special

purposes has been installed, appropriate notations may be assigned respectively; for ships of which the longitudinal strength calculation is required, the relevant loading guidance is to be included in the loading manual provided to the master and/or the loading computer, if fitted. The system of the onboard loading computer is, if assigned a relevant notation for longitudinal strength calculation or stability evaluation or both, to be verified according to CCS longitudinal strength calculation programme and stability evaluation programme;

Table H: Special survey notation: For alternative methods or special requirements of survey, appropriate notations may be assigned respectively; self-propelled oil tankers, oil/bulk carriers, oil/bulk/ore carriers, chemical tankers and bulk carriers are subject to an enhanced survey programme; structural diagrams are given in Appendix 2 of this Chapter for mandatory ship types to which the ESP is assigned;

Table I: Environmental protection notation: Ships complying with the relevant requirements of CCS rules may be assigned appropriate notations;

Table J: Refrigerated cargo installation notation: Ships fitted with a refrigerating plant for carrying refrigerated cargo and ships carrying refrigerated containers in holds may be assigned appropriate notations respectively.

Section 4 APPLICATION AND FEES

2.4.1 Application

2.4.1.1 Applicants requesting services from CCS are to submit a written application or a completed application form to CCS or one of its local branches or the units designated by it, and/or sign a contract/agreement with CCS.

2.4.1.2 The responsibilities of both parties, characters of classification and class notations, particulars of the ship, etc., are to be clearly specified in the application or contract/agreement. Submitting the application or signing the contract/agreement means that the applicant will have no objection that the representative(s) of third-party independent audit organizations, e.g. representative(s) of an Accredited Certification Body (ACB), IACS observer(s), etc., and the representative(s) of the European Commission (EC), representative(s) of the flag State, assessor(s) of the Entity for the Quality Assessment and Certification of Organisations Recognised by the European Union(QACE), IMO observer(s) and representative(s) of IACS QSCS (Quality System Certification Scheme) Advisory Committee (AVC) may visit onboard or a manufacturer or a shipyard to carry out an audit or an assessment as provided in Article 8(1) of Regulation (EC) No. 391/2009, and will facilitate such audit/assessment.

2.4.1.3 Applicants are to submit plans and technical documents necessary for the requested services.

2.4.1.4 CCS has established an Occupational Health and Safety Management System for the purpose of guaranteeing the occupational health and safety of Surveyors. An application for any classification or statutory survey service by CCS means that the applicant respects this system of CCS and that he is committed to provide conditions for the safety of CCS Surveyors entering the facilities related to the requested survey service in accordance with the national requirements of the State of nationality of the Surveyor and the State where the survey unit is located and/or the technical safety requirements developed by the local competent authorities or equivalent technical standards①, including permanent or temporary means of access and facilities for inspections, compartment environment and safety precautions. CCS Surveyors will confirm the safety of survey conditions with the applicant and persons designated by him prior to performing specific surveys.

2.4.2 Fees

2.4.2.1 Applicants are to pay survey fees, traffic fees and other necessary expenses in accordance with CCS Provisions of Survey Fees and/or the contract/agreement.

2.4.2.2 For any service provided beyond the contract/agreement or any service provided anew due to the reasons on the part of the party receiving such service, CCS has the right to charge additional fees from the applicant.

Section 5 SUBMISSION AND EXAMINATION OF PLANS

2.5.1 General requirements

① Refer to CCS Guidelines for Site Safety of Survey.

2.5.1.1 For new ships of which the plan approval is requested on or after 1 January 2005, the applicant is to provide the appropriate "date of contract for construction".

2.5.1.2 Date of "contract for construction" is defined as follows:

(1) The date of "contract for construction" of a ship is the date on which the contract to build the ship is signed between the prospective owner and the shipbuilder. This date and the construction numbers (i.e. hull numbers) of all the vessels included in the contract are to be declared to CCS by the party applying for the assignment of class to a newbuilding.

(2) The date of "contract for construction" of a series of ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective owner and the shipbuilder.

For the purpose of this requirement, ships built under a single contract for construction are considered a "series of ships" if they are built to the same approved plans for classification purposes. However, ships within a series may have design alterations from the original design provided:

① such alterations do not affect matters related to classification; or

② if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the shipbuilder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to CCS for approval.

The optional ships will be considered part of the same series of ships if the option[①] is exercised not later than 1 year after the contract to build the series was signed.

(3) If a contract for construction is later amended to include additional ships or additional options, the date of "contract for construction" for such ships is the date on which the amendment to the contract is signed between the prospective owner and the shipbuilder. The amendment to the contract is to be considered as a "new contract" to which (1) and (2) above apply.

(4) If a contract for construction is amended to change the ship type, the date of "contract for construction" of this modified ship, or ships, is the date on which revised contract or new contract is signed between the owner, or owners, and the shipbuilder.

2.5.2 Examination of plans and documents

2.5.2.1 Prior to commencement of construction of the ship, the applicant is to submit the application together with the plans and documents in triplicate according to the relevant requirements of the Rules to a plan approval unit designated by CCS for examination. Where the plans will be submitted in batches, at least the necessary hull plans and documents are to be submitted first.

Copies of the plans to be submitted for approval for a series of ships or ships to be additionally constructed within one year in accordance with the approved main structural plans may be reduced or such submission exempted according to the specific conditions.

2.5.2.2 The ship's list of survey and test items, as well as the technical documents, such as welding procedure, welding specifications, NDT diagrams, installation procedure of machinery (excluding reasonable alignment of shafting), inclination testing programme, and mooring test and sea trial programme, are to be submitted to CCS attending Surveyors for examination. CCS plan approval units are responsible for examining welding specifications for CSR ships.

2.5.2.3 Necessary scantlings and relevant data as required by the Rules are to be indicated on the plans and documents submitted.

2.5.2.4 The term "approval" means that the plans and documents have been examined and found in compliance with CCS rules. The approval of plans and documents by CCS covers only the items as required by CCS rules, excluding any items not required by CCS rules. Where CCS undertakes statutory surveys at the same time, the "approval" by CCS is to cover the items related to the statutory requirements.

2.5.2.5 The plans and documents as deemed to comply with the Rules upon examination, are to be stamped with APPROVED seal. The approval conditions and restrictions may be written on the plans and documents, or stated in the plan approval letters with appropriate notes being added on the plans and documents.

2.5.2.6 The term "Used for information" means that the plans and documents have been examined and only used as supporting information to the approval of other relevant plans and documents.

2.5.3 Validity of approved plans

---

① The "option" means that an option for building additional ships to the same approved plans is given in the contract for construction signed between the owner and the shipbuilder.

2.5.3.1 The approved plans are valid only for construction in the designated shipyard, the construction project number or the number of ships to be constructed as specified in the application or contract/agreement for plan approval.
2.5.3.2 The approved plans for classification purposes will be invalid automatically in one of the following cases:
(1) after 4 years since the approval date of plans, except for ships for which commencement of construction has begun;
(2) after 1 year since the approval date of sectional plans of newbuildings where the entry into force of new rules including their amendments affects such plans;
(3) the construction of the ship(s) for the project number or the number of ships as specified in the application or contract/agreement for plan approval has been completed;
(4) the approved shipyard or construction project number has been changed, or the number of ships constructed is exceeded;
(5) the ship is not constructed under the supervision of CCS.
2.5.3.3 Where the statutory requirements of the flag State or the international conventions, codes accepted by it and the entry into force of the amendments thereto affect the validity of the approved plans, the approved statutory plans will be invalid automatically.

Section 6 CLASSIFICATION SERVICES

2.6.1 General requirements
2.6.1.1 Ship designers are to establish an appropriate quality assurance system for the design quality of ships and products.
2.6.1.2 Shipyards and manufacturers are to establish an appropriate quality assurance system for the construction and manufacturing quality of ships and products. They are also to provide a list of their suppliers and general documentation (e.g. brief introduction, information on quality management system).
2.6.1.3 Suppliers providing essential services to the ship, such as measurements, tests or maintenance of safety systems and equipment, the results of which will be used by CCS as the basis for survey, are subject to approval by CCS (see Section 8 of this Chapter). Otherwise such services are to be performed in the presence of the Surveyor.

2.6.2 Assessment and examination prior to commencement of construction
2.6.2.1 Prior to commencement of construction of the ship, CCS will send its Surveyors to assess the capability of the shipyards and manufacturers, and/or carry out an examination prior to commencement of construction.

2.6.3 Surveys
2.6.3.1 For the materials, equipment, systems and other products required by the Rules, product survey by CCS are to be requested in accordance with Chapter 3 of this PART.
2.6.3.2 For the ships intended to be classed with CCS, initial classification surveys by CCS are to be requested in accordance with the relevant requirements of Chapters 4 and 5 of this PART.
2.6.3.3 For maintaining the validity of classification, surveys after construction by CCS are to be requested in accordance with Chapter 5 of this PART.

Section 7 STATUTORY SERVICES

2.7.1 General requirements
2.7.1.1 Upon the authorization by the Government of the flag State, and at the request of the owner or ship designer or shipyard or upon contract/agreement with them, CCS will undertake a part of or all statutory services for ships.
2.7.1.2 When so authorized, CCS will issue/endorse appropriate statutory certificates and/or reports, upon completion of plan approval, surveys during and after construction, and confirmation that the classed portions of the ship are in compliance with CCS classification rules and the relevant statutory requirements.
2.7.1.3 For ships requesting to be classed with CCS, where statutory services for such ships are or the assessment of relevant statutory requirements is delegated to CCS, CCS will carry out the classification services in conjunction with the statutory services or assessment of statutory requirements.

2.7.1.4 For ships receiving both classification and statutory services by CCS, where the classification certificate is invalidated and this will affect the conditions for issuance of the relevant statutory certificates, the relevant statutory certificates or documents of compliance (e.g. for safety and load lines) will be invalidated simultaneously.

2.7.2 Basis for statutory services

2.7.2.1 The statutory requirements for convention ships are referred to international conventions or codes and the amendments thereto, mainly including:

— International Convention on Load Lines, 1966 and the Protocol of 1988 relating to the International Convention on Load Lines, 1966;
— International Convention for the Safety of Life at Sea, 1974;
— International Convention on Tonnage Measurement of Ships, 1969;
— International Convention for the Prevention of Pollution from Ships, 1973, as modified by the 1978 and 1997 Protocols;
— International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk;
— International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk;
— International Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001;
— International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004;
— International Regulations for Preventing Collisions at Sea, 1972.

2.7.2.2 The statutory requirements for non-convention ships and ships navigating in national waters are referred to the relevant statutory requirements of the Government of the flag State.

2.7.2.3 The applicable statutory requirements are to be clearly specified in the application form or contract/agreement.

2.7.2.4 For authorized statutory service, the statutory requirements for convention ships are to include those contained in the Guidelines for Implementation of Statutory Surveys for Ships Engaged on International Voyages[①], unless provided with written instruction to apply a different interpretation with regard to the conventions referred to in 2.7.2.1 by the flag Administration.

2.7.3 Responsibilities of parties concerned

2.7.3.1 The right to interpret the statutory requirements rests with the Administration of the flag State.

2.7.3.2 The Administration of the flag State is responsible for the equivalence and exemption covered by the statutory requirements.

2.7.3.3 In carrying out statutory services, CCS will not be liable for any modification costs of any ship or any loss caused by traceability of the statutory requirements of the Administration of the flag State to existing ships.

2.7.4 Assessment of statutory requirements at the request of client

2.7.4.1 At the request of or upon a contract/agreement with the client, CCS may carry out the assessment of the relevant statutory requirements which are not delegated by the flag Administration, or the compliance of which is voluntarily requested by the client.

2.7.4.2 When assessment of statutory requirements is requested by the client, CCS will issue appropriate statutory certificates and/or reports, upon completion of plan approval, surveys during and after construction, and confirmation that the classed portions of the ship are in compliance with CCS classification rules and the relevant statutory requirements.

2.7.4.3 According to the statutory requirements as requested by the client, CCS will issue appropriate documents of compliance and/or reports, the acceptability of which to the flag Administration is, however, not warranted by CCS.

2.7.4.4 Paragraphs 2.7.1.3, 2.7.1.4 and 2.7.3.3 of this Section also apply to the assessment of statutory requirements.

Section 8 APPROVAL OF SUPPLIERS

2.8.1 General requirements

① Guidelines for Implementation of Statutory Surveys for Ships Engaged on International Voyages are available on CCS website: http://www.ccs.org.cn.

2.8.1.1 Suppliers providing services on behalf of the owner to CCS, such as measurements, tests or maintenance of safety systems and equipment, the results of which will be used by CCS Surveyors as the basis for surveys, are subject to approval by CCS as evidence for their capabilities to provide the approved services.
2.8.1.2 Where such services are used by CCS in making decisions affecting statutory certificates, the suppliers are subject to approval by CCS. In addition, CCS may accept the suppliers recognized by the flag Administration or an organization authorized by it.
2.8.1.3 Suppliers do not act on behalf of CCS and are responsible for the services provided by them and the results thereof.

2.8.2 Requirements for approval
2.8.2.1 Any supplier requesting approval is to meet the following conditions:
(1) sufficient competent technicians, operators, inspectors and supervisors are available for providing approved services;
(2) necessary and appropriate equipment and facilities are in place;
(3) an effective and documented quality assurance system has been established and is being maintained.
2.8.2.2 The scope and procedure of approval of suppliers are to be in compliance with Appendix 8 — Procedural Requirements for Approval of Service Suppliers and Appendix 23 — Requirements for NDT Suppliers to Chapter 5 of this PART.

2.8.3 List of approved suppliers
2.8.3.1 CCS publishes and maintains a list of suppliers approved by CCS①.

Section 9 ASSIGNMENT, MAINTENANCE, SUSPENSION, CANCELLATION AND REINSTATEMENT OF CLASS

2.9.1 Assignment and maintenance of class
2.9.1.1 Where the hull (including equipment) and machinery (including electrical installations) are found in compliance with the relevant provisions of CCS rules after plan approval and surveys, the characters of classification and corresponding class notations will be assigned, and the classification certificate will be issued by CCS.
2.9.1.2 Owners are to ensure proper maintenance of the ship and to operate according to the conditions specified in the classification certificate.
2.9.1.3 The CCS class assigned to a ship which is found to comply with the Rules upon surveys after construction will continue to be valid, and CCS will endorse or renew the classification certificate.
2.9.1.4 CCS reserves the right to perform unscheduled surveys of the ship when CCS has reasonable cause to believe that the ship has the possibilities of affecting class maintenance between two periodical surveys. The notice for arranging an unscheduled survey will be sent in writing by CCS to the owner who is to promptly arrange the survey and has the obligation to pay the related expenses.

2.9.2 Suspension and cancel of class
2.9.2.1 Suspension of class
(1) When a ship is operating beyond the service limitation defined by its characters of classification and class notations or any other additional condition as approved, its class will be suspended and its classification certificate invalidated.
(2) Any damage, defect, failure or grounding that may affect the validity of the assigned class may, if not reported to CCS without inappropriate delay or prior agreement of CCS to foreseen repairs not obtained, lead to suspension of the class and invalidation of the classification certificate.
(3) Under the following circumstances, the class will be subject to a suspension procedure, unless the ship is attended by the Surveyor for completion of the overdue surveys:
① when any condition of class imposed by CCS is not fulfilled by a specified due date (the Owner will be notified of the date), and no extension is granted by CCS;
② when any continuous survey item due or overdue at time of annual survey has not been dealt with, and no extension is granted by CCS at the time of an annual survey;
③ when surveys after construction other than annual, intermediate or special surveys are overdue, and

① The list of suppliers approved by CCS is available on CCS website: http://www.ccs.org.cn.

no extension is granted by CCS;

④ when repairs of any damage, defect, failure or grounding have not been completed and surveyed as specified;

⑤ failure to permit the unscheduled surveys referred to in 2.9.1.4 above;

⑥ when the laying-up maintenance programme agreed by CCS has not been implemented or the laying-up survey has not been performed within the specified time limit during the laying-up period of the ship.

(4) Under the following circumstances, the class will be subject to automatic suspension and the classification certificate is subject to invalidation:

① when an annual survey has not been completed within 3 months of the due date of the annual survey, unless the ship is under attendance for completion of the annual survey;

② when an intermediate survey has not been completed within 3 months of the due date of the third annual survey in each special survey period (5 years), unless the ship is under attendance for completion of the intermediate survey;

③ when a special survey has not been completed within the period of time specified by CCS (the Owner will be notified that the 5-year class certificate becomes invalid) and no extension is granted by CCS, unless the ship has been under attendance for completion of the special survey prior to resuming trading, by the due date.

a. Under "exceptional circumstances", CCS may grant an extension not exceeding 3 months to allow for completion of the special survey, provided that the ship is attended and the attending Surveyor so recommends upon satisfactory survey to the following extent:
   (a) annual survey;
   (b) re-check of conditions of class;
   (c) progression of the special survey as far as practicable;
   (d) where the docking survey is due prior to the expiry date of the extension, an underwater examination is to be carried out by an approved diving company. Such underwater examination may be dispensed with in the case of extension of docking survey not exceeding 36 months provided the ship is without any condition of class regarding underwater parts.

b. In the case that the class certificate will expire when the ship is expected to be at sea, an extension to allow for completion of the special survey may be granted provided there is documented agreement to such an extension prior to the expiry date of the certificate, and provided that positive arrangements have been made for attendance of the Surveyor at the first port of call, and provided that CCS is satisfied that there is technical justification for such an extension. However, if owing to "exceptional circumstances" the special survey cannot be completed at the first port of call, the subparagraph a. above may be followed, but the total period of extension shall in no case be longer than 3 months after the original due date of the special survey;

④ when it is confirmed that the Surveyor has boarded the ship before the survey is due, but the ship is put into service before the satisfactory completion of the corresponding overdue survey.

(5) If, due to circumstances reasonably beyond the owner's or CCS control, the ship is not in a port where the overdue surveys can be completed at the expiry of the periods allowed above, CCS may allow the ship to sail, in class, directly to a discharge port, and if necessary, hence, in ballast, to a port at which the survey will be completed, at request of the owner and provided that:

① relevant records are examined;

② the due and/or overdue surveys and examination of conditions of class are carried out by CCS at the next port of call when there is an unforeseen inability of CCS to attend the ship at the present port;

③ upon review of the ship's history and survey at the present port, the attending Surveyor is satisfied that the ship is in condition to sail for one trip to a discharge port and if necessary, hence, in ballast to a repair facility, and this is to be confirmed by the Headquarters of CCS. Where there is an unforeseen inability of CCS to attend the ship at the present port, the master is to confirm that his ship is in condition to sail to the nearest port of call.

The above-mentioned overdue surveys to be carried out are to be based upon the survey requirements at the original date due and not on the age of the vessel when the survey is carried out. Such surveys are to be credited from the date originally due. If class has already been automatically suspended in such cases, it may be reinstated subject to the conditions prescribed above.

(6) Where a ship has been detained following a Port State Control inspection on two occasions in one year or three occasions in two years, with serious deficiencies found, then the class will be liable to be

suspended, at the discretion of CCS, and a corresponding note will be given in the Register of Ships.
(7) When a ship is dual classed and in the event that one of the Societies involved takes action to suspend the class of the ship for technical reasons, the Society concerned is to advise the other Society of the reasons for such action and the full circumstances within five (5) working days. The other Society is, upon receipt of this advice, also to suspend the class of the ship, unless it can otherwise document that such suspension is incorrect.
(8) The class of ships which are laid up in accordance with CCS Rules prior to surveys becoming overdue need not be suspended when surveys addressed above become overdue. However, the class of ships which are laid up after being suspended as a result of surveys going overdue, remain suspended until the overdue surveys are completed.
(9) When a ship is intended for a demolition voyage with any periodical survey overdue, the ship's class suspension may be held in abeyance and consideration may be given to allow the ship to proceed on a single direct ballast voyage from the lay-up or final discharge port to the demolition yard. In such cases a short-term class certificate with conditions for the voyage noted may be issued provided the attending Surveyor finds the ship in satisfactory condition to proceed for the intended voyage.
(10) When a ship is intended for a single voyage from laid-up position to a repair yard or another lay-up site with any periodical survey overdue, the ship's class suspension may be held in abeyance and consideration may be given to allow the ship to proceed on a single direct ballast voyage from the site of lay up to a repair yard or another lay-up site, upon agreement with the flag Administration, provided CCS finds the ship in satisfactory condition after surveys, the extent of which are to be based on surveys overdue and duration of lay-up. A short term Class Certificate with conditions for the intended voyage may be issued. This does not apply to ships whose class was already suspended prior to being laid-up.
2.9.2.2 Cancel of class
(1) The class of a ship will be cancelled in any one of the following cases:
① at the request of the owner;
② the circumstances leading to suspension of class are not corrected within the time specified;
③ a ship's class will be canceled immediately when the ship proceeds to sea without having completed conditions of class which were required to be dealt with before leaving port;
④ when class has been suspended for a period of six (6) months due to overdue annual, intermediate, special surveys or other surveys after construction as required by the Rules and/or overdue conditions of class.
A longer suspension period may be granted for ships which are either laid up, awaiting disposition of a casualty or under attendance for reinstatement;
⑤ where hull, equipment or machinery (including electrical installations) is so badly damaged or in other conditions (e.g. sinking, scrapping, etc.) that continuing operation of the ship is confirmed as not possible;
⑥ when the payment of survey fees is not made in time.
(2) Where a ship has been detained following a Port State Control inspection on two occasions in one year or three occasions in two years, with serious deficiencies found, then the class will also be liable to be canceled, at the discretion of CCS, and a corresponding note will be given in the Register of Ships.
2.9.2.3 If survey requirements related to maintenance of class notations are not carried out in any case of suspending or canceling class stated above, the suspension or cancellation is to be limited to those class notations only.
2.9.2.4 Notification of suspension or cancellation of class
(1) Cancellation of class of a ship will be indicated correspondingly in CCS Register of Ships or its supplements.
(2) When the class of a ship is suspended or cancelled, CCS will send written notification to the owner and the Administration of the flag State, and make an announcement on CCS website available to the underwriters and other interested parties concerned.
(3) For ships to which SOLAS applies, the notification will state that certain statutory certificates are implicitly invalidated by the suspension or withdrawal of class.

2.9.3 Reinstatement of class
2.9.3.1 The class of a ship may be reinstated in any one of the following cases:
(1) class will be reinstated upon satisfactory completion of the overdue surveys. The overdue surveys to be carried out are to be based upon the survey requirements at the original date due and not on the age of the ship when the survey is carried out. Such surveys are to be credited as of the original due date. However, the ship is disclassed from the date of suspension until the date class is reinstated;

(2) class will be reinstated upon verification that the due or overdue continuous survey items have been satisfactorily dealt with;
(3) class will be reinstated upon verification that due or overdue condition of class has been satisfactorily dealt with. However, the ship is disclassed from the date of suspension until the date class is reinstated.
2.9.3.2 When the class of a ship is reinstated, CCS will send written notification to the owner and the Administration of the flag State, and make an announcement on CCS website available to the underwriters and other interested parties concerned.
2.9.3.3 When either Society decides to reinstate class, it is to inform the other Society.

Section 10 CERTIFICATES AND REPORTS

2.10.1 Certificates
2.10.1.1 A classification certificate indicates only that the items covered by it, as verified during plan approval and classification surveys, are in compliance with CCS rules and fit for their intended purposes.
2.10.1.2 Classification certificates and related reports are issued by CCS independently.
2.10.1.3 The classification certificate is to contain the terms and conditions as agreed between both parties.

2.10.2 Duration and validity of certificates
2.10.2.1 The period of validity of classification certificates of ships is in general not to exceed 5 years.
2.10.2.2 The period of validity of classification certificates is to be harmonized with that of statutory certificates of the ship as possible.
2.10.2.3 When the special survey is completed within three months before the expiry date of the existing certificate, the new classification certificate is to be valid to a date not exceeding five years from the date of expiry of the existing certificate.

2.10.3 Issue and endorsement of classification certificates
2.10.3.1 Upon completion of classification surveys, the survey unit is to issue the classification certificate together with records, reports and other technical documents to the related department of CCS Headquarters for review and then submitted by the department to the Class Committee and upon approval by the Committee, the classification of a ship will be finally confirmed by the President of CCS or person(s) authorized by him.
2.10.3.2 The classification certificate is to be endorsed by the Surveyor as required after completion of the survey after construction as specified in Chapter 5 of this PART.
2.10.3.3 Where a new classification certificate cannot be issued to the ship before the expiry date of the existing classification certificate after completion of the special survey, the existing classification certificate may be endorsed by the Surveyor, which is to be valid within 5 months from its expiry date.
2.10.3.4 Upon completion of the special survey, the survey unit is to submit a report and other technical documents to the related department of CCS Headquarters or another designated survey unit for review, and upon satisfactory review a new classification certificate will be issued by the President of CCS or a person authorized by him.
2.10.3.5 Notwithstanding the provision of 2.10.2.1, CCS may, when applying 2.10.3.4, determine a period of validity less than 5 years for the classification certificate and/or take any other necessary restrictive measure (e.g. service restriction(s) being noted on the newly issued classification certificate), based on a comprehensive consideration of the available information on other aspects of safe operation of the ship (safety inspections by the flag/port State, safety management of the shipping company, etc.). Where the period of validity is shortened, it is to be harmonized with the intervals between classification/statutory surveys so far as practicable and regular reports are to be sent to the Class Committee.

Section 11 REGISTER OF SHIPS AND LISTS OF APPROVED MARINE PRODUCTS①

① CCS Register of Ships and Lists of Approved Marine Products are available on CCS website: http://www.ccs.org.cn.

2.11.1 Register of Ships

2.11.1.1 CCS will enter main characteristic particulars and details of all ships classed with CCS, after they are assigned characters of classification and class notations, into the Register of Ships of CCS to provide information for those related to ships, such as shipbuilders, owners, underwriters, shippers and charterers.

2.11.1.2 Subsequently, in case changes concerning ships or their characteristic particulars are made, CCS will renew the Register of Ships in time.

2.11.2 Lists of Approved Marine Products

2.11.2.1 CCS will enter the names, main characteristic particulars and details of related products as well as detailed information on their manufacturers in respect to those factories and plants and their marine products approved by CCS into the Lists of Approved Marine Products of CCS to provide information for ship-designing institutes, shipbuilders, owners, traders and exporters.

2.11.2.2 Subsequently, in case changes concerning performance of the approved products are made or their scope is extended, CCS will renew the Lists of Approved Marine Products in time.

Section 12 AVAILABILITY AND CONFIDENTIALITY OF INFORMATION

2.12.1 Availability of information

2.12.1.1 The party who makes any information available to CCS as required for classification of the ship shall be responsible for the truthfulness, timeliness and completeness of such information.

2.12.2 Disclosure of information

2.12.2.1 CCS will not disclose any information obtained for classification of the ship to any other party not specified in the contract and Tables 2.12.2.2(1) and 2.12.2.2(2), except in the following cases:

(1) when the class of the ship is transferred from CCS to another member society of IACS, the relevant class information together with survey reports for the ship are to be made available to that society;

(2) as required by IACS, the updated data related to the Register of Ships, the data of class suspension and survey status, and the information on failure incidents of ships are to be communicated to IACS;

(3) the owners, ship operators are to authorize CCS to accepting the representative(s) of third-party independent audit organizations, e.g. representative(s) of an Accredited Certification Body (ACB), IACS observer(s), etc., and the representative(s) of the European Commission (EC) may, during their audit or assessment of CCS, have access to the certificates, documents and other information related to the ships classed with CCS;

(4) the flag State has special legal provisions for the disclosure, or the court having jurisdiction or the owner agrees in writing to the disclosure.

2.12.2.2 The concerned parties who are entitled to have access to such information are given in Tables 2.12.2.2(1) and 2.12.2.2(2).

Information Available to Parties Concerned① **Table 2.12.2.2(1)**

Information in question	Information available to:				
	Owners	Flag State	Port State	Insurance Company*	Shipyards
1. CCS standing documents					
Rules & Guidelines (class and statutory requirements)	1	1	1	1	1
Instructions to Surveyors		1			
Quality Manual	1	1	1	1	1
Register Book	1	1	1	1	1
2. Ship related information					
A. New buildings					
Approved drawings	6	1			7
Formal approval letters	1				7
Certificates of important equipment	2				7
B. Ships in operation					
Class services					
—Date(month and year) of all class surveys	7	1	1	1	

① It is applicable to all types of ships with the exception of oil tankers and bulk Carriers subject to SOLAS Regulation II-1/3-10 (Goal-based ship construction standards for bulk carriers and oil tankers).

Information in question	Information available to:				
	Owners	Flag State	Port State	Insurance Company*	Shipyards
—Expiry date of class certificates	7	7**	1	1	
—Certificates/Reports	7	1	6	5	
—Overdue surveys	7	7**	1	1	
—Text of conditions of class	7	1	1	5	
—Text of overdue conditions of class	7	1	1	1	
—Executive hull summary	7	3	3	3	
Statutory services					
—Due dates of statutory surveys	7	7**	1	1	
—Expiry date of statutory certificates	7	7**	1	1	
—Registered statutory condition	7	7**	1	5***	
—Overdue statutory condition	7	7**	1	1***	
3. Other information					
Correspondence file with Yard and/or Owner	6	6		5&6	
Audit of CCS QA System	4	4	4	4	
Class transfer reporting	7	7	7	7	
Class withdrawal information	7	7	7	7	

Notes:
* = Insurance Company means P&I Clubs and Hull Underwriters;
** = if stated in Agreement;
*** = unless prevented by the agreement with the flag State.
1. Available upon request.
2. At delivery of the ship by Shipyard.
3. Available under visit on board.
4. Result of audit available on request.
5. When accepted by Owners – or through special clause in insurance contract.
6. When accepted by Owner (Master) or Shipyard as applicable.
7. Automatically available.

Information Available to Parties Concerned① **Table 2.12.2.2(2)**

Information in question	Information available to:				
	Owners	Flag State	Port State	Insurance Company*	Shipyards
1. CCS standing documents					
Rules and Guidelines (class and statutory requirements)	1	1	1	1	1
Instructions to Surveyors		1			
Quality Manual	1	1	1	1	1
Register Book	1	1	1	1	1
2. Ship related information					
A. New buildings					
Approved drawings	1	1			7
Formal approval letters	1	1			7
Certificates of important equipment	2	1			7
SCF	2	8			7
Formal review letters in relation with SCF	2	2			7
B. Ships in operation					
Class services					
—Date (month and year) of all class surveys	7	1	1	1	
—Expiry date of class certificate	7	7**	1	1	
—Certificates/Reports	7	1	6	5	
—Overdue surveys	7	7**	1	1	
—Text of conditions of class	7	1	1	5	
—Text of overdue conditions of class	7	1	1	1	
—Executive hull summary	7	3	3	3	
Statutory services					
—Due dates of statutory surveys	7	7**	1	1	
—Expiry date of statutory certificates	7	7**	1	1	
—Registered statutory condition	7	7**	1	5***	

① It is applicable to oil tankers and bulk carriers subject to SOLAS Regulation II-1/3-10 (Goal-based ship construction standards for bulk carriers and oil tankers).

Information in question	Information available to:				
	Owners	Flag State	Port State	Insurance Company*	Shipyards
—Overdue statutory condition	7	7**	1	1***	
3. Other information					
Correspondence file with Yard and/or Owner	1	1		5&6	
Updated modifications to SCF	7****	8			
Audit of CCS QA System	4	4	4	4	
Class transfer reporting	7	7	7	7	
Class withdrawal information	7	7	7	7	

Notes:
* = Insurance Company means P&I Clubs and Hull Underwriters;
** = If stated in Agreement;
*** = Unless prevented by the agreement with the flag State;
**** = By Owner or Shipyard.
1. Will be available upon request.
2. At delivery of the ship by Shipyard.
3. Available under visit on board.
4. Result of audit available on request.
5. When accepted by Owners − or through special clause in insurance contract.
6. When accepted by Owner (Master) or Shipyard as applicable.
7. Automatically available.
8. Available through Owner upon request.

2.12.2.3 Notwithstanding the general duty of confidentiality owed by CCS to its client in accordance with its Rules, CCS' clients hereby accept that CCS will implement IACS' Procedure for Early Warning① which requires each IACS Member to provide its fellow IACS Members with relevant technical information on serious failures of hull structures and engineering systems, as defined in the IACS' Procedure for Early Warning (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilized. CCS will provide its client with written details of such information upon sending the same to IACS Members.

Section 13 LIABILITY, DISAGREEMENT AND ARBITRATION

2.13.1 Liability of each party

2.13.1.1 CCS rules are the basis for the design, building, manufacturing and testing of ships and related products, but not the sole basis for the design. The rules can neither replace the control of technological process and quality by builders or manufacturers, nor diminish their liability in this respect or absolve them therefrom.

2.13.1.2 CCS rules do not cover every piece of structure or item of equipment on board a ship, nor do they cover operational elements, or activities which fall outside the scope of classification and include such items as design and manufacturing processes, choice of type and power of machinery and certain equipment, number and qualification of crew or operating personnel, form and cargo-carrying capacity of the ship and manoeuvring performance, cargo securing, hull and equipment vibrations, noises, spare parts, life-saving appliances and maintenance equipment.

2.13.1.3 CCS will not be liable for any loss of any result of applying CCS rules by any third party without plan approval or ship surveys by CCS.

2.13.1.4 The classification of ships undertaken by CCS is carried out on the basis that the designers, builders, owners, manufacturers, sellers, suppliers, repairers, operators and other parties fulfill their respective responsibilities. The contents of any reports, documents and certificates issued by CCS do not mean to diminish any liability of any party mentioned above or absolve it therefrom.

2.13.1.5 Any survey-related document issued by CCS only reflect the status at the time when the survey is carried out.

2.13.1.6 The classification certificate (with characters of classification and class notations thereon) is only an attestation that the ship is in compliance with the applicable CCS classification rules and/or other standards agreed in writing by CCS and the applicant for CCS service. If the ship is not in compliance with such rules or standards, CCS has the power to withhold, suspend or withdraw the characters of

① For details, refer to IACS PR2A "Procedure for Hull Failure Incident Reporting" and PR2B "Procedure for Early Warning of Serious Hull Failure Incidents - "Early Warning Scheme – EWS".

classification and class notations.
2.13.1.7 Except as required by CCS rules, CCS will make no representations beyond the relevant reports, statements, plan approval, surveys, certification or other services. The application of the information supplied by CCS in documents other than classification certificates and reports is at the discretion of the users, and CCS is not liable for the results of such actions.
2.13.1.8 CCS is to provide service(s) based on the contract only, in no case shall CCS be liable for any loss of any party who has no direct contractual relations with CCS.
2.13.1.9 The owner and/or the shipyard is to promptly feed back to the manufacturer and CCS any problem revealed in operation of marine products so as to facilitate improvement by the manufacturer.
2.13.1.10 CCS' omission or failure to carry out or observe any stipulation, condition, or obligation to be performed under the contract will not give rise to any claim against CCS or be deemed to be a breach of contract if the omission or failure arises from causes beyond CCS' reasonable control.
2.13.1.11 CCS does not promise the safety of life and property at sea and the seaworthiness of ships, because CCS is not the principal part operating and maintaining the ship between surveys.
2.13.1.12 Shipowners have the obligation to maintain the validity of class and statutory certificates.

2.13.2 Disagreement

2.13.2.1 The right of interpretations on the rules published by CCS is to be left solely to CCS Headquarters. CCS rules are translated by CCS into English. In case of any different understanding to the English version, the currently effective Chinese version of the rules is to be considered as solely authoritative.
2.13.2.2 Where there is disagreement between the Surveyor and the interested party during survey, which affects the project schedule, the latter is to promptly appeal in writing to the unit where the Surveyor serves. Where the handling of the appeal by the unit is not considered satisfactory by the interested party, it may appeal in writing to CCS Headquarters along with detailed background materials. The Headquarters will decide on the matter, and this ruling will be final.
2.13.2.3 The costs arising from any examinations carried out by the Headquarters on request are to be paid by the appellant, except for those cases in which the appeal proves justified.

2.13.3 Arbitration

2.13.3.1 CCS will be liable only for the loss or damage resulting directly from its negligent act. In no event shall CCS be liable for any indirect or consequential losses or damages.
2.13.3.2 Notwithstanding the previous paragraph, CCS will be liable for the loss or damage due to negligent act judicially attributed exclusively to CCS or its employees, agents or other parties acting on behalf of CCS. And in no case shall the amount of this liability exceed five times the fee(s) charged by CCS in respect of the service(s) in question or 2,000,000 RMB in maximum. CCS liability for the loss or damage is specially excluded when such loss or damage arises out of an act:
(1) by an employee of CCS acting outside the terms or scope of his/her employment; or
(2) by any agent or other party acting on behalf of CCS, when such act exceeds the authority granted in writing by CCS to such agent or party.
2.13.3.3 Any claim for any loss or damage set forth above is to be made in writing within six months of the date the damage first discovered or the loss occurred; failure of doing so will be deemed as an absolute waiver of this right.
2.13.3.4 Unless otherwise agreed with CCS, any dispute of whatsoever nature in respect to the Rules or the service(s) provided in accordance with the Rules shall be referred to China Maritime Arbitration Commission and arbitrated in accordance with its arbitration rules effective at the time of request for arbitration. The arbitration award shall be final and binding upon both interested parties.

2.13.4 Applicable laws

2.13.4.1 The laws of the People's Republic of China shall apply.

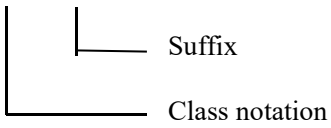
Appendix 1 LIST OF CLASS NOTATIONS FOR SEA-GOING SHIPS

Ships or machineries (including electrical installations) constructed or manufactured in accordance with relevant rules issued by CCS or other equivalent regulations accepted by it will be assigned appropriate class notations by CCS. CCS class notations in use for sea-going ships are listed in this Appendix for reference and application.

General principles for identification of class notations are as follows:

1. Class notations are marked after characters of classification, where the notations for type of ship, hull and service restriction or limitation, features, equipment, cargo and loading characteristics, survey, etc., are marked after the characters ★CSA and the notations for automation and special equipment of machinery, machinery survey, green ecology, etc., are marked after the characters ★CSM.
2. The class notations for type of ship and/or special duties and service or service restriction are necessary notations and are to be assigned together with characters of classification.
3. Where a class notation (other than those referred to in 2 above) assigned to a specific ship together with characters of classification is required by the rules to which the ship is subject, such notation is a necessary one for this ship, or an optional one.
4. Where multiple class notations for type of ship are assigned, such individual notations are to be separated by the sign "/", i.e. Tug/ Offshore Supply ship.
5. Any suffix to a class notation is to be bracketed and every two suffixes are to be separated by a comma ",", i.e.:

Loading Computer (S, I);



6. Every two sets of class notations are to be separated by a semicolon ";".
7. Unless specifically stated otherwise, class notations are generally given in the sequence A ~ K as shown in the table below:

Types of class notations	Type of ship	Special duties	Service or service restriction	Cargo and loading characteristics	Special features	Automation	Special equipment and system	Special survey	Green ecology	Refrigerated cargo installation	Other notations
Table	Table A	Table B	Table C	Table D	Table E	Table F	Table G	Table H	Table I	Table J	Table K

For example, in respect to a bulk carrier constructed under supervision of CCS according to CSR rules, engaged in non-restricted service and service in floating ice condition, with design check by COMPASS-Structure software, with loading computer for calculation of overall strength, intact stability and bulk grains, machinery space periodically unattended, screwshaft condition monitoring and subject to in-water survey, the following characters of classification and class notations are to be assigned:

★CSA Bulk Carrier; CSR; BC-A (Holds Nos. 2, 4 and 6 may be empty); COMPASS (R, D, F); GRAB［20］; Ice Class B; Loading Computer (S, I, G); ESP; In-Water Survey

★CSM AUT-0; SCM

Type Notations① **Table A**

Class notation	Description		Technical requirements②
General Dry Cargo Ship	General dry cargo ships	Ships intended primarily to carry dry cargo, and also liquid cargo contained in vessels, other than bulk carriers, container ships, ro-ro cargo ships, refrigerated cargo ships, cement carriers, livestock carriers, wood chip carriers, deck cargo ships and general dry cargo ships of double side skin construction. For general dry cargo ships of double side-skin construction, with double side-skin extending for the entire length of the cargo area, and for the entire height of the cargo hold to the upper deck, the notation "Double Side Skin" is to be added after their type notation and separated by a comma ",", i.e. General Dry Cargo Ship, Double Side Skin.	Ch. 2, Pt. 2 of the Rules
Cement Carrier	Cement carriers	Ships designed and constructed specifically for the carriage of cement	Ch. 2, Pt. 2 of the Rules
Deck Cargo Ship	Deck cargo ships	Ships designed for the carriage of cargo exclusively above deck with no cargo hold fitted	Ch. 2, Pt. 2 of the Rules
Refrigerated Cargo Ship	Refrigerated cargo ships	Ships fitted with refrigerated cargo installations, dedicated to the carriage of perishable goods such as fish, meat, fruits, vegetables, etc.	Ch. 2, Pt. 2, Ch. 1 to Ch. 3, Pt. 5 of the Rules
Livestock Carrier	Livestock carriers	Ships designed and constructed specifically for the carriage of livestock such as cattle, sheep, etc.	Ch. 2, Pt. 8 of the Rules
Passenger Ship	Passenger ships	Ships carrying more than 12 passengers	Ch. 9, Pt. 2 of the Rules
RO-RO Ship	Ro-ro ships	Ships carrying vehicles or cargo in pallet form or in containers and loaded/unloaded by wheeled vehicles	Ch. 9, Pt. 2 of the Rules
RO-RO Passenger Ship	Ro-ro passenger ships	Passenger ships with ro-ro cargo spaces or special category spaces and capable of carrying road vehicles	Ch. 9, Pt. 2 of the Rules
Train/RO-RO Passenger Ship	Train and ro-ro passenger ships	Ro-ro ships carrying more than 12 passengers and capable of carrying trains	Ch. 9, Pt. 2 of the Rules
Ferry	Ferries	Ships having a continuous deck and carrying passengers (without sleeping berths) and/or vehicles for regular voyages between two sides of straits or islands	1. For ships not less than 20 m in length, in accordance with Ch. 9, Pt. 2 of the Rules; 2. For ships less than 20 m in length, in accordance with Rules for Classification of Sea-going Boats. Where more than 12 passengers are carried, technical requirements for passenger ships need to be satisfied, unless special provisions are specified by the Administration. In this case, only the Passenger Ship/Boat notation is assigned
Ferry Passenger Ship	Ferry passenger ships	Ferry carrying more than 12 passengers	Ch. 9, Pt. 2 of the Rules
Bulk Carrier	Bulk carriers	Ships carrying mainly dry cargo in bulk, normally constructed with single deck, topside tanks,	Ch. 8, Pt. 2 of the Rules

① For high speed craft complying with the provisions of the Rules for Classification of Sea-going Boats, the suffix (HSC) will be added after the type notation.

② The technical requirements listed in this Table are the basic ones for ships assigned to the notation; in other special cases involving ship types, special consideration is to be given by CCS according to the ship's specific conditions.

Class notation	Description		Technical requirements②
		hopper tanks and double bottom in cargo spaces, cargo holds bounded by side shell. For bulk carriers, of which all cargo holds are bounded by double side skin construction of not less than 1000 mm breadth at any location within the hold length, the notation “Double Side Skin” is to be added after their type notation and separated by a comma “,”, i.e. Bulk Carrier, Double Side Skin. For sea-going self-propelled ships intended to carry and self-unload dry cargoes in bulk, the class notation “Self-Unloading Bulk Carriers” is to be assigned	
Ore Carrier	Ore carriers	Ships constructed with single deck, 2 longitudinal bulkheads and a double bottom throughout the centre hold and intended primarily to carry ore cargoes in the centre holds only	Ch. 16, Pt. 2 of the Rules; for ore carriers of 250 m and over in length and engaged in unrestricted service, in accordance with Rules for Structures of Ore Carriers
Water Tanker	Water tankers	Tankers carrying fresh water	Ch. 2 and applicable sections of Ch. 5 & 6, Pt. 2 of the Rules
Oil Tanker	Oil tankers	Ships carrying crude oil or oil products, note to be added according to flash point of oil carried: ① flash point above 60℃: F.P. > 60℃ ② flash point up to 60℃: F.P. ≤ 60℃	Ch. 6, Pt. 2 of the Rules
		For ships with distance between two hulls in compliance with the Rules, single deck and small-size hatches, carrying crude oil or oil products, the notation “Double Hull” may be added and separated by a comma “,”, i.e. Oil Tanker, Double Hull	Ch. 5, Pt. 2 of the Rules
Ore/Oil Carrier	Ore/oil carriers	Ships with single hull, single deck, 2 longitudinal bulkheads and double bottom, all or most of center holds used for carrying ore, side or side and some centre holds used for carrying oil	Ch. 5, Ch. 6 & Ch. 16, Pt. 2 of the Rules
Ore/Bulk/Oil Carrier	Ore/bulk/oil carriers	Ships with double hull, single deck, double bottom, topside tanks and hopper tanks, carrying oil or dry bulk cargo (including ore)	Ch. 5, Ch. 6 , Ch. 8 & Ch.16, Pt. 2 of the Rules
Container Ship	Container ships	Ships having double bottom and double side skin construction with torsion box girders fitted at top sides, large deck openings, carrying containers, or as alternative, single side skin construction with double bottom and torsion box girders or equivalent structure	Ch. 7, Pt. 2 of the Rules
Car Carrier	Car carriers	Ships specially designed and constructed for carriage of commercial wheeled vehicles	Guidelines for Hull Structure of Car Carriers
Open-Top Container Ship	Open-top container ships	Ships having double bottom and double side skin construction with torsion box girders fitted at top sides, large deck openings, carrying containers, or as alternative, single side skin construction with double bottom and torsion box girders or equivalent structure, but no hatch covers for holds	Ch. 6, Pt. 8 of the Rules
Timber Carrier	Timber carriers	Dedicated log or timber carriers, provided with securing equipment, for which the notation Log Carrier may also be used	Ch. 2, Pt. 2 of the Rules, Guidelines for the Preparation of the Cargo Securing Manual
Barge	Barges	Ships not provided with main propulsion machinery used for navigation purposes. Where such ships are dedicated to carriage of a specific cargo, they may be identified, as necessary, by the notation X Barge where X is the name of the specific cargo	Ch. 12, Pt. 2 of the Rules

Class notation	Description		Technical requirements②
Oil Barge	Oil barges	Barges carrying crude oil or oil products within holds	Ch. 12, Pt. 2 of the Rules
Floating Concrete Mixer	Floating concrete mixers	Barges mixing concrete on the water and depositing concrete directly at the construction site	Ch. 12, Pt. 2 of the Rules
Chemical Barge	Chemical barges	Barges carrying chemicals within holds	Ch. 12, Pt. 2 of the Rules
Gas Barge	Gas barges	Barges carrying liquefied gases within holds	Ch. 12, Pt. 2 of the Rules
Pontoon Barge	Pontoon barges	Square barges carrying water-resistant cargoes on deck	Ch. 12, Pt. 2 of the Rules
Launch Barge	Launch barges	Barges dedicated to carriage of offshore jacket structures and for launching such jackets, which will be slid into water through trim of the barge by stern	Ch. 12, Pt. 2 of the Rules
Shipborne Barge	Shipborne Barge	Barges carried onboard ship and generally carrying general dry cargoes in the cargo holds	Ch. 12, Pt. 2 of the Rules
Barge Carrier	Barge carriers	Dedicated cargo barge and heavy cargo carriers with large deck area	Ch. 2, Pt. 2 of the Rules
Bridge Crane and Heavy Equipment Carrier	Bridge equipment carriers	Carriers having large deck areas and exclusively engaged in loading/unloading on decks and long-distance transportation by sea of complete sets of heavy equipment and project facilities with large dimension/heavy weight such as bridge cranes and heavy equipment	Ch. 18, Pt. 8 of the Rules
Live Fish Carrier	Live fish carriers	Ships fitted with live fish holds, provided with water cycling or exchanging, in some cases provided with devices for increasing oxygen, purifying water and/or reducing temperature, dedicated to carry live fish	Ch. 2, Pt. 2 of the Rules
Semi-Submersible Vessel	Semi-submersible vessels	Ships capable of being semi-submersible when needed during loading and unloading or operation	Ch. 15, Pt. 2 of the Rules
Tug	Tugs	Ships fitted with towing equipment, dedicated to towing ships or other floating objects on water	Ch. 10, Pt. 2 of the Rules
Chemical Tanker	Chemical tankers	Ships similar as oil tankers, provided with cargo containment system, dedicated to carry liquid cargoes as listed in IBC Code. Chemical tankers constructed on or after 1 July 1986 and complying with IBC Code are to be assigned the following notations respectively, depending on the category of chemicals carried: ① Type 1: Carrying chemicals with very severe environmental and safety hazards, fitted with integral and independent tanks; ② Type 2: Carrying chemicals with appreciably severe environmental and safety hazards, fitted with integral and independent tanks; ③ Type 3: Carrying chemicals with sufficiently severe environmental and safety hazards, fitted with integral and independent tanks. Chemical tankers constructed before 1 July 1986 and complying with BCH Code are to be assigned the notations of Type I/Type II/Type III respectively instead of Type 1/Type 2/Type 3	Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk
Liquefied Gas Carrier	Liquefied gas carriers	Ships provided with cargo containment system, dedicated to carry liquefied gases or other cargos as listed in the Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. Liquefied gas carriers constructed on or after 1 July 1986 and complying with IGC Code are to be assigned the following notations respectively, depending on the preventive measures to preclude the escape of cargo: ① Type 1G: Maximum preventive measures are required to preclude the escape of cargo; ② Type 2G: Significant preventive measures are	Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk

Class notation	Description		Technical requirements②
		required to preclude the escape of cargo; Type 2PG: For gas carriers of 150 m in length or less and significant preventive measures are required to preclude the escape of cargo, the products are carried in type C independent tanks designed for a MARVS of at least 0.7 MPa gauge with a MARVS of 7 bar gauge and a cargo containment system design temperature of -55℃ or above; ③ Type 3G: Moderate preventive measures are required to preclude the escape of cargo. Liquefied gas carriers constructed before 1 July 1986 and complying with GC Code are to be assigned the notations of Type IG/Type IIG/Type IIPG/ Type IIIG respectively instead of Type 1G/Type 2G/Type 2PG/ Type 3G. The following notations are to be assigned respectively, depending on the type of cargo containment systems: Type A Independent Tank Type B Independent Tank Type C Independent Tank Integral Tank Membrane Tank Semi-Membrane Tank Ships primarily intended to carry one or more products as listed in Chapter 19, PART THREE of the Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk may be assigned "for + product name(s)" after "Carrier". The product name(s) is/are to be in accordance with column a, Summary of minimum requirements, Chapter 19, PART THREE of the Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, e.g.: Liquefied Gas Carrier for Ethane Liquefied Gas Carrier for Butane, Butane and Propane mixture	
LNG Carrier	LNG carriers	Liquefied gas carriers dedicated to carrying liquefied natural gas. The notations Type 1G/Type 2G/Type 2PG/ Type 3G or Type IG/Type IIG/Type IIPG/ Type IIIG are to be added for preventive measures to preclude the escape of cargo, as stated in column Description for the notation Liquefied Gas Carrier	Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk; Ch.20, Pt.2 of the Rules
		Where LNG carriers are adapted for FSUs, the notation "LNG-FSU" (Liquefied Nature Gas-Floating Storage Unit) is to be added after LNG Carrier and separated by a comma ",", i.e. LNG Carrier, LNG-FSU	Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk; Implementation Guidelines for Liquefied Nature Gas Carriers Adapted for Floating Storage Units
		Where LNG carriers are fitted with LNG regasification systems, the notation "REGAS" is to be added after LNG Carrier and separated by a comma ",", i.e. LNG Carrier, REGAS	Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk; Chapters 1 and 4 of the Rules for Construction and Equipment of Liquefied Natural Gas Floating Storage and Regasification Units; Section 4, Chapter 7 of

Class notation	Description		Technical requirements②
			the Rules for Offshore Oil and Gas Processing Systems
CNG Carrier	CNG carriers	Liquefied gas carriers dedicated to carrying compressed natural gas. The notations Type 1G/Type 2G/Type 2PG/ Type 3G or Type IG/Type IIG/Type IIPG/ Type IIIG are to be added for preventive measures to preclude the escape of cargo, as stated in column Description for the notation Liquefied Gas Carrier	Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
Woodchip Carrier	Woodchip carriers	Ships designed and constructed for the carriage of woodchips	Guidelines for Hull Structure of Woodchip Carriers
Asphalt Carrier	Petroleum asphalt carriers	For ships dedicated to carrying melted petroleum asphalt, this type notation is to be assigned and the following notations are to be added: ① for independent tanks: independent tank, or ② for integral tanks: Integral tank; ③ for maximum cargo temperature: Max. Cargo Temperature ×××℃; In accordance with the flashpoint of petroleum asphalt, the following notations may be added respectively: ① for flash point above 60℃: F.P. > 60℃; ② where the maximum cargo temperature cannot be lower than the petroleum asphalt flash point by at least 15℃: F.P. ≤ 60℃. The notation of thermal stress calculation may be assigned if the requirements of Section 24, Chapter 2, PART TWO of the Rules are complied with. For ships with distance between two hulls in compliance with the Rules, the notation “Double Hull” may be added and separated by a comma “,”, i.e. Asphalt Carrier, Double Hull	Ch. 10, Pt. 8 of the Rules
Offshore Supply Ship	Offshore supply ships	Ships dedicated to supplying food, stores, etc., to installations and ships engaged in offshore operations	Ch. 11, Pt. 2 of the Rules
Offshore Tug/Supply Ship	Offshore tug and supply ships	Ships capable of operating as offshore supply ships and of towing operations	Ch. 11, Pt. 2 of the Rules
Geotextiles Layer	Geotextiles layers	Ships provided with special equipment for laying geotextiles, which are engaged in operations of laying soft mattress related to construction of cofferdams on land and floating structure projects under different environmental conditions such as coastal shoals and deep-water harbors	Ch. 17, Pt. 8 of the Rules
Stand-by Ship	Stand-by ships	Ships providing rescue operations and supporting services for mobile offshore drilling units or offshore oil/gas production facilities. Additional auxiliary functions such as fire fighting, towing, oil recovery, supply may be provided according to design purposes and multiple type notations may be assigned accordingly. For towing capacity fully complying with Chapter 10, PART TWO of the Rules, the notation Stand-by Ship/Tug may be assigned; and for towing capacity complying only with the requirements for towing arrangements in Chapter 10, PART TWO of the Rules, the suffix T may be added	Ch. 24, Pt. 8 of the Rules
Floating Dock with F_L (××× t)	Floating docks with F_L (××× t)	A building used for shipbuilding and ship repairs, capable of being semi-submersible in or floating on water, with its special hull being open on both	Rules for Classification of Floating Docks

Class notation	Description		Technical requirements②
		ends and corrugated in transverse section. The hull structure of the dock consists of wing walls and the dock's bottom. Wing walls and the dock's bottom are pontoons consisting of longitudinal or transverse members and face plates, divided transversely and longitudinally into watertight compartments. With water being filled into or discharged from the compartments, the amount of ballast water in the dock is increased or decreased so that the dock submerges into or rises out of water	
Cable Layer	Cable layers	Ships provided with special systems/equipment for cable laying	Ch. 28, Pt. 8 of the Rules
Pipe Layer	Pipe layers	Ships provided with special systems/operation lines for laying pipes	Ch. 29, Pt. 8 of the Rules
Chemical/Oil Tanker	Chemical/oil tankers	Tankers capable of carrying both chemicals and oil products	Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk
Fishing Vessel	Fishing vessels	Vessels provided with fishing machinery, engaged in fishery production activities and used for commercially catching fish or other living resources of the sea	Rules for Construction of Ocean-going Steel Fishing Vessels; Ch. 5, Pt. 8 of the Rules
Floating Crane	Floating cranes	Ships fitted with lifting appliances on deck, dedicated to hoisting operations on water. The notation Lifting Appliance is to be added. For floating cranes operating in restricted service, one of the following service notations is to be assigned: (1) Lifting Within R1; (2) Lifting Within R2; (3) Lifting Within R3; (4) Lifting Within Harbor	Ch. 13, Pt. 2 and Ch. 2, Pt. 10 of the Rules, Rules for Lifting Appliances of Ships and Offshore Installations
Salvage Ship	Salvage ships	Ships provided with equipment for salvaging sunken ships or other objects	Ch. 13, Pt. 2 of the Rules
Rescue Ship	Rescue ships	Ships engaged in rescue operations at sea for ships and crew in distress	Ch. 24, Pt. 8 of the Rules
Pile Driving Barge	Pile-driving barges	Barges fitted with pile driving equipment at end or centre of deck, dedicated to pile driving in water	Ch. 13, Pt. 2 of the Rules
Dredger	Dredgers	Ships fitted with dredging equipment, in general not operating independently	Ch. 14, Pt. 2 of the Rules
Trailing Suction Hopper Dredger	Trailing suction dredgers	Ships fitted with drag head and other dredging equipment	
Cutter Suction Dredger	Cutter suction dredgers	Ships fitted with cutter head and other dredging equipment	
Bucket Dredger	Bucket dredgers	Ships fitted with bucket and other dredging equipment	
Grab Dredger	Grab dredgers	Ships fitted with one or more grab machines	
Dipper Dredger	Dipper dredgers	Ships fitted with dippers. Where a back hoe is fitted, the notataion "Back-hoe Dredger" may also be assigned	
Cutter Wheel Dredger	Cutter wheel dredgers	Ships fitted with cutter-wheel dredging apparatus	
Reclamation Craft	Reclamation craft	Ships fitted with suction pipes, nozzles, etc.	
Split Hopper Dredger	Split hopper dredgers	Ships with entire main hull being opened along longitudinal centerline for unloading	
Hopper Barge	Hopper barges	Barges dedicated to carrying mud. If self-propelled, the word "ship" is to be used in place of the word "barge"	
Split Hopper Barge	Split hopper barges	Barges with entire main hull being opened along longitudinal centerline for unloading. If self-propelled, the word "ship" is to be used in place of the word "barge"	
Wave Pierce Craft	Wave piercing craft	A special type of catamaran high | HSC are ships with maximum speed not less	Rules for Construction and Classification of

Class notation	Description			Technical requirements②
		speed craft with large aspect ratio and small waterplane area	than $3.7\nabla^{0.1667}$ m/s. For passenger ships as defined in 2.1.3.1(18) of Rules for Construction and Classification of Sea-Going High Speed Craft, the service notation Passenger A is to be added after type notation and where such ships are fitted with ro-ro spaces or special category spaces, the notation Ro-Ro Passenger A is to be added. For passenger ships as defined in 2.1.3.1(19) of Rules for Construction and Classification of Sea-Going High Speed Craft, the service notation Passenger B is to be added after type notation and where such ships are fitted with ro-ro spaces or special category spaces, the notation Ro-Ro Passenger B is to be added. For high speed cargo craft, the notation Cargo is to be added after type notation	Sea-Going High Speed Craft
Air Cushion Craft	Air cushion craft	High speed craft wholly supported by air cushion		
Surface Effect Ship	High speed surface effect craft (side wall hovercraft)	High speed craft with its air cushion being totally or partially retained by permanently immersed hard structure		
Trimaran HSC	High speed trimaran craft	A vessel with three hulls of displacement form, a main centre hull stabilized by two much smaller side hulls, connected by connection bridge		
Catamaran HSC	High speed catamaran craft	High speed craft with upper parts of two parallel hulls being connected by strength framing		
Mono-Hull HSC	High speed mono-hull craft	High speed craft with a single hull		
Hydrofoil Craft	Hydrofoil craft	Ships supported completely clear above water surface in non-displacement mode by hydrodynamic forces generated on foils		
SWATH-HSC	High speed small waterplane area twin hull craft	A special type of catamaran with small waterplane area, and with underwater portions of hulls being formed in shape of torpedo		Guidelines for Small Waterplane Area Twin Hull Craft
SWATH	Small waterplane area twin hull craft	A special type of catamaran with small waterplane area, and with underwater portions of hulls being formed in shape of torpedo		
Wing In Ground Craft	Wing-in-ground craft	Ships, which are supported by using ground effect above the water or some other surface, without constant contact with such a surface and supported in the air, mainly, by an aerodynamic lift generated on a wing (wings) which are intended to utilize the ground effect action, must be assigned this type notation with one of following suffixes being added thereafter: A — for craft certified for operation only in ground effect; B — for craft certified to temporarily increase its altitude to a limited height beyond ground effect but not exceeding a certain distance		Guidelines for Survey of Wing-in-Ground Craft
Passenger Boat	Passenger boats	Boats carrying more than 12 passengers		Rules for Classification of Sea-going Boats
Cargo Boat	Cargo boats	Boats used for carrying cargoes		Rules for Classification of Sea-going Boats
Non-propulsion Boat	Non-propulsion boats	Boats not fitted with propulsion equipment for the purpose of navigation		Rules for Classification of Sea-going Boats
Sailing Boat	Sailing boats	Boats for which the primary means of propulsion is by wind power	Where more than 12 passengers are carried,	Rules for Classification of Sea-going Boats
Tourist Boat	Tourist boats	Boats fitted with sightseeing		Rules for Classification

Class notation	Description			Technical requirements②
		areas and for the purpose of sightseeing	technical requirements for passenger ships need to be satisfied, unless special provisions are specified by the Administration. In this case, only the Passenger Boat notation is assigned	of Sea-going Boats
Windfarm Service Boat	Windfarm service boats	Boats used for offshore windfarm service		Rules for Classification of Sea-going Boats
Wooden Boat	Wooden boats	Boats the main hull of which is constructed with wooden materials		Rules for Classification of Sea-going Boats
Passenger Submersible Craft	Submersible passenger craft	Self-propelled free submersibles transporting or carrying passengers and capable of underwater sightseeing		Rules for Classification of Diving Systems and Submersibles
Rigid Connection PB Combination — Pusher	Rigid combination: Pusher tug	A combination consisting of a pusher tug and a barge wherein the pusher tug is secured in the barge notch by mechanical means. There is no relative motion between the tug and the barge, resulting in the two vessels acting as a single unit in a seaway. The pusher tug is a component part of the combination		Ch. 7, Pt. 8 of the Rules
Rigid Connection PB Combination — Barge	Rigid combination: Barge	A combination consisting of a pusher tug and a barge wherein the pusher tug is secured in the barge notch by mechanical means. There is no relative motion between the tug and the barge, resulting in the two vessels acting as a single unit in a seaway. The barge is a component part of the combination		Ch. 7, Pt. 8 of the Rules
Articulated Connection PB Combination — Pusher	Articulated combination: Pusher tug	A combination consisting of a pusher tug and a barge wherein the pusher tug is secured in the barge notch by mechanical means, allowing pitch between the tug and the barge in only one degree of freedom. The two vessels act as a single unit in a seaway and when disconnected from each other, both may moor or operate independently. The pusher tug is a component part of the combination		Ch. 7, Pt. 8 of the Rules
Articulated Connection PB Combination — Barge	Articulated combination: Barge	A combination consisting of a pusher tug and a barge wherein the pusher tug is secured in the barge notch by mechanical means, allowing pitch between the tug and the barge in only one degree of freedom. The two vessels act as a single unit in a seaway and when disconnected from each other, both may moor or operate independently. The barge is a component part of the combination		Ch. 7, Pt. 8 of the Rules
Aquatic Product Carrier	Aquatic product carriers	Dedicated to transporting aquatic products, characterized by using physical media such as ice, instead of refrigerating plant, for cold storage of aquatic products, with insulation layers fitted on inner surface of holds		Ch. 2, Pt. 2 of the Rules
Yacht	Pleasure craft	A boat engaged in uncommercial entertainment activities such as touring, leisure and sightseeing. High speed yachts are to be assigned the **High Speed Yacht** notation. Sailing craft constructed in accordance with CCS Guidelines for Survey of Sailing Craft is to be assigned the **Sailing Craft** notation. According to the structural type, the following notations are to be added respectively: ① Mono-Hull ② Catamaran ③ Multi-hull According to the design category, the following notations are to be added respectively:		Rules for Construction and Classification of Yachts

Class notation	Description		Technical requirements②
		① Design Category I（Hs= ×× m）③ ② Design Category II（Hs= ×× m） ③ Design Category III（Hs= ×× m） ④ Design Category IV（Hs= ×× m） ⑤ Design Category V（Hs= ×× m）	
Offshore Engineering Support Ship	Offshore engineering support ships	Ships providing multi-function support to offshore engineering operations, e.g. offshore installation, survey and repair of structures, as well as underwater robot operation, diving operation, etc.	Ch. 2, Pt. 2 of the Rules
Launching Work Barge	Launching work barges	Work barges dedicated to launching ships, offshore installations or other heavy cargoes within shipyard and/or port waters. Such operation may also include cargo moving from water to shore and short-distance movement of cargoes within above- mentioned waters (The ship does not have self-propulsion capability, and movement is driven by other power ships such as tugs or other facilities)	Ch. 17, Pt. 2 of the Rules
Catamaran	Catamarans	Ships with upper parts of two separate hulls being connected by strength framing	Ch. 18, Pt. 2 of the Rules
Sand Carrier	Sand carriers	Ships designed and constructed specifically for the carriage of sand, which is to be surveyed according to the requirements for double hull bulk carrier	Ch. 19, Pt. 2 of the Rules
Diving Support Vessel	Diving support vessels	Ships provided with permanent diving support system to be assigned class notation DSV-Sat (saturation diving system)	Ch. 25, Pt. 8 of the Rules
Icebreaker	Icebreakers	Polar Class ships which are assigned a class notation for having an operational profile that includes escort or ice management functions and powering and dimensions that allow it to undertake aggressive operations in ice-covered waters. Relevant polar class is to be affixed after the class notation, e.g. Icebreaker; PC3	Ch. 13, Pt. 8 of the Rules
Icebreaker*	Strengthened icebreakers	Ships for which relevant requirements are expanded and supplemented regarding general and arrangement, structure, propulsion power, machinery installations, steering systems and equipment based on Icebreaker	Rules for Heavy Icebreakers
Oil FSV fixed at XXX Anchorage	Oil floating storage vessels fixed at anchorage	This notation is to be assigned to oil floating storage vessels (FSV) satisfying the following conditions: (1) Double hull oil tankers engaged in cargo oil transportation between various ports / locations; (2) Berthing in a dedicated location, which means the sheltered water area designated by the Administration of the coastal State, or an anchorage location that enables the vessels to quickly move away from a severe weather conditions	Guidelines for Oil Floating Storage Vessels Fixed at Anchorage
Power Barge (X_1, …, X_N)	Power Vessel	The barges or self-propelled ships on which a power plant using natural gas or fuel oil as a fuel is installed to serve as a power generation resource supplying external power. For self-propelled ships, the word 'ship' is to be used in place of the word 'barge'. Meanings of X_N are as follows: Natural Gas Fuel: for power vessels using natural gas as a fuel; HV: for power vessels with an output voltage above 15 kV; S: for power vessels supplying power to ships fitted with high voltage shore connection (HVSC)	Guidelines for Survey of Power Vessels

③ "H_S=××m" means the design significant wave height corresponding to the design category.

Class notation	Description		Technical requirements②
		systems in compliance with IEC 80005-1. Note: The above X_N are all optional	
Fire Fighting Ship N	Fire fighting ships of Grade N	Ships capable of fire fighting are to be assigned this notation, with N being one of the following: 1 – for early stage fire fighting; 2 – for large fire fighting; 3 – for large and oil fire fighting. For ships provided with a water spraying system for delivering efficient cooling water spraying over all the exposed vertical surfaces of the hull so as to enable the ship to approach the burning object for fire-fighting and/or rescue purposes, the notation Water Spraying may be added after the above notation	Ch. 1, Pt. 8 of the Rules
Training Ship	Training ships	Ships dedicated to training of marine personnel	Ch. 2, Pt. 2 of the Rules, Code of Safety for Special Purpose Ships (where applicable)
Fish-Factory Ship	Fisheries processing ships	Specialized in fish processing	
Research Ship	Research ships	Ships specialized in marine research and study, survey, exploration, etc., are to be assigned this notation	Ch. 2 and/or Ch. 9, Pt. 2 of the Rules, Code of Safety for Special Purpose Ships (where applicable)
Oil Recovery Ship with Cargo Tank	Oil recovery ships equipped with means for the recovery and discharge of oil as well as with tanks for storing the recovered oil	Steel ships equipped for the recovery of oil floating on the sea with a flash point not exceeding 60℃ (closed-cup test) and a Reid vapour pressure below atmospheric pressure	Ch. 3, Pt. 8 of the Rules
Oil Recovery Ship without Cargo Tank	Oil recovery ships without tanks for storing the recovered oil and equipped with means for the recovery, but not for discharge of oil	Steel ships equipped for the recovery of oil floating on the sea with a flash point not exceeding 60℃ (closed-cup test) and a Reid vapour pressure below atmospheric pressure	Ch. 3, Pt. 8 of the Rules
Oil Recovery Ship not suitable for products with a flash point of 60℃ and less	Oil recovery ships equipped with means for the recovery of oil with a flash point exceeding 60℃	Steel ships equipped for the recovery of oil floating on the sea with a flash point exceeding 60℃ (closed-cup test) and a Reid vapour pressure below atmospheric pressure	Ch. 3, Pt. 8 of the Rules
Sewage Recovery Vessel	Sewage recovery ships	Ships dedicated to recovery of sewage	Ch. 2, Pt. 2 of the Rules
Well Stimulation	Well stimulation	Offshore engineering support ships used for or designed to be used for the operation of offshore well stimulation	Guidelines for Well Stimulation
LNG Bunkering Ship	LNG bunkering ships	Ships with the function of LNG bunkering	Rules for LNG Bunkering Ships
Windfarm Service Vessel	Windfarm service vessels	Vessels that provide support and guarantee services for the operation and maintenance of offshore wind farms	Ch. 38, Pt. 8 of the Rules
Pontoon	Pontoons	Rectangular flat-bottomed non-self-propelled ships without power units, usually moored stationary along the shore or at a dock, and used as floating installation	Requirements for inshore floating installations in Chapter 6 of Pt. 11 and special requirements for floating parking installation in Pt. 14 of

Class notation	Description		Technical requirements②
			the Rules for Classification of Offshore Floating Installation

Special Duties Notations **Table B**

Class notation	Description		Technical requirements①
Traffic Ship②	Traffic ships	For transporting personnel, but not as passenger transport service	1. For ships not less than 20 m in length, in accordance with Ch. 2, Pt. 2 of the Rules; for high speed craft, in accordance with Rules for Construction and Classification of Sea-Going High Speed Craft. 2. For ships less than 20 m in length, in accordance with Rules for Classification of Sea-going Boats. In this case, sea-going boats are only assigned Traffic Boat notation. 3. For transporting more than 12 personnel, in accordance with technical requirements for passenger ships, unless specially provided by the Administration. In this case, sea-going boats are only assigned Passenger Boat notation
Public Affair Ship	Public affair ships	Ships used for administrative purposes of the Government	1. For ships not less than 20 m in length, in accordance with Ch. 8, Pt. 8 of the Rules; for high speed craft, in accordance with Rules for Construction and Classification of Sea-Going High Speed Craft. 2. For ships less than 20 m in length, in accordance with Rules for Classification of Sea-going Boats. In this case, sea-going boats are only assigned Public Affair Boat notation. 3. For ships carrying more than 12 passengers, in accordance with technical requirements for passenger ships. In this case, sea-going boats are only assigned Passenger Boat

① The technical requirements listed in this Table are the basic ones for ships assigned to the notation; in other special cases involving ship types, special consideration is to be given by CCS according to the ship's specific conditions.

② The notation "Crew Boat" is used for traffic ships flying the flag of Saint Vincent and Grenadines.

Class notation	Description		Technical requirements①
			notation. 4. Where special provisions are specified by the Administration, such provisions are to be implemented for paragraphs 1 to 3 above
× Boat	Work boats	Ships dedicated to specific services. × is to be substituted by a specific service, e.g.: Pilot Boat: Ships dedicated to pilot service; Anchor Boat: Ships dedicated to operations related to anchoring and mooring; Light Boat: Ships dedicated to serving as navigational marks; Diving Boat: Work boats dedicated to diving operations	1. For ships not less than 20 m in length, in accordance with Ch. 2, Pt. 2 of the Rules; for high speed craft, in accordance with Rules for Construction and Classification of Sea-Going High Speed Craft. 2. For ships less than 20 m in length, in accordance with Rules for Classification of Sea-going Boats. 3. For ships carrying more than 12 passengers, in accordance with technical requirements for passenger ships. In this case, sea-going boats are only assigned Passenger Boat notation
SPS	Special purpose ships	This notation may be assigned to ships for which the Special Purpose Ship Safety Certificate is issued according to IMO Code of Safety for Special Purpose Ships or a standard acceptable to the Administration. This notation may be assigned separately, or as a special duty notation for certain ship types	Code of Safety for Special Purpose Ships or a standard acceptable to the Administration
IP	International ships carrying industrial personnel	This notation may be assigned to ships for which the Industrial Personnel Safety Certificate is issued according to IMO Code of Safety for Ships Carrying Industrial Personnel	International Code of Safety for Ships Carrying Industrial Personnel
Cruise	Cruise ships	For sea-going passenger ships which provide travel and leisure services, e.g. culture, sports, dining, shopping, accommodation and sightseeing for passengers through various living and recreational facilities provided on board, the notation “Cruise” may be added after the class notation “Passenger Ship”. Other ships (e.g. ro-ro passenger ships) having functions of cruise ship may also be assigned corresponding class notations in relation to cruise ships	Ch. 2, Ch. 3 and Ch. 4 of Rules for Cruise Ships

Service or Service Restriction Notations **Table C**

Class notation	Description			Technical requirements
R1	Service category 1	Within 200 (summer / tropical*) or 100 (winter*) n mile off the shore	1.*Seasonal areas as specified in Annex II to the International Convention on Load Lines, 1966. **Sheltered waters include the sea areas between an island and the shore and	Chapter 0, Pt. 10 of the Rules
R2	Service category 2	Within 20 (summer / tropical*) or 10 (winter*) n mile off the		

Class notation	Description			Technical requirements
		shore	between islands with a distance of less than 10 n miles in between, which forms a comparatively good sheltered or similar condition with a little wave. 2.Working ships may be assigned service categories applicable for transit and operation respectively, e.g. R2 for Transiting and R3 for Operation. 3.For ships engaged on non-international voyages, notations for service category 1/2/3 are R1(D)/ R2(D)/ R3(D) respectively	
R3	Service category 3	Sheltered waters**		
×× — ×× service	Specified route service	On specified route service, e.g. Shanghai — Osaka Service		The Rules
SZ(XX)	Specific service area	Strength assessment of container ships and ore carriers with specific service area in accordance with the Guidelines for Strength Assessment of Ships with Specific Service Area or Service Route or Service Life. Where XX is service area identification, e.g. SZ(Bohai)		Guidelines for Strength Assessment of Ships with Specific Service Area or Service Route or Service Life
SL(XX-YY)	Strength assessment of ships with specific service route	Strength assessment of container ships and ore carriers with specific service route in accordance with the Guidelines for Strength Assessment of Ships with Specific Service Area or Service Route or Service Life. Where XX and YY are names of arrival and departure ports and other restricted information (e.g. information on port of call/location) for ships with specific service route, e.g. SL (Yantai-Dalian)		Guidelines for Strength Assessment of Ships with Specific Service Area or Service Route or Service Life
Open Sea Service Restriction	Open sea service restriction	The service in the sea area within 300 nautical miles off the shore, and a passenger craft does not proceed in the course of its voyage more than 4 h, or a cargo craft 8 h, at operational speed from a place of refuge when fully laden. Where the sea state of some service areas above-mentioned is heavier, more stringent requirements may be made by CCS to the distance above-mentioned, depending on the specific cases. When special provisions for the service area are stipulated by the Administration of the flag State or by the coastal Authority in charge of the service area, the provisions are to be observed.		Rules for Construction and Classification of Sea-Going High Speed Craft
Greater Coastal Service Restriction	Greater coastal service restriction	For craft engaged on voyages in the sea area within 200 nautical miles off the shore, which proceed in the course of a voyage for a time specified below, at operational speed from a place of refuge when fully laden: ① not more than 4 h for passenger craft; ② not more than 8 h for cargo craft		Rules for Construction and Classification of Sea-Going High Speed Craft, Rules for Classification of Sea-going Boats
Coastal Service Restriction	Coastal service restriction	For craft engaged on voyages in the sea area within 20 nautical miles off the shore, which proceed in the course of a voyage for a time specified below, at operational speed from a place of refuge when fully laden: ① not more than 4 h for passenger craft; ② not more than 8 h for cargo craft		Rules for Construction and Classification of Sea-Going High Speed Craft, Rules for Classification of Sea-going Boats
Sheltered Water Service Restriction	Sheltered water service restriction	For craft engaged on voyages in the sea areas between islands and the shore and between islands with a distance of less than 10 n miles in between, which forms a comparatively good sheltered condition with a little wave, or within 10 nautical miles off the shore. Such craft do not proceed in the course of a voyage more than 2 h at operational speed from the shore when		Rules for Construction and Classification of Sea-Going High Speed Craft, Rules for Classification of Sea-going Boats

Class notation	Description		Technical requirements
		fully laden, with wind force not exceeding Beaufort scale 6 and visual wave height not more than 2.0 m	
Calm Water Service Restriction	Calm water service restriction	For craft engaged on voyages in the sea areas within 5 nautical miles off the shore. Such craft do not proceed in the course of a voyage more than 2 h at operational speed from the shore when fully laden, with wind force not exceeding Beaufort scale 6 and visual wave height not more than 1.0 m	Rules for Construction and Classification of Sea-Going High Speed Craft, Rules for Classification of Sea-going Boats
Weather Restriction N	Weather restriction	Weather restriction for wing-in-ground craft, with N being one of the following: I: Significant wave height not exceeding 3.0 m and wind force not exceeding Beaufort scale 7 for the restricted service II: Significant wave height not exceeding 2.0 m and wind force not exceeding Beaufort scale 6 for the restricted service III: Significant wave height not exceeding 1.0 m and wind force not exceeding Beaufort scale 5 for the restricted service IV: Significant wave height not exceeding 0.5 m and wind force not exceeding Beaufort scale 4 for the restricted service	Guidelines for Survey of Wing-in-Ground Craft
Dredging Within R3	Operation within R3 service area	Restricted service area for dredgers	Ch. 2, Pt. 10 of the Rules
Dredging Within R2	Operation within R2 service area	Restricted service area for dredgers	Ch. 2, Pt. 10 of the Rules
Dredging Within R1	Operation within R1 service area	Restricted service area for dredgers	Ch. 2, Pt. 10 of the Rules
Dredging Within Harbor	Operation in harbor water only	Restricted service area for dredgers	Ch. 2, Pt. 10 of the Rules

Cargo and Loading Characteristics Notations **Table D**

Class notation	Description		Technical requirements
BC-A	Harmonized notation BC-A	Bulk carriers are to be assigned this notation, provided they ① are designed to carry dry bulk cargoes of density 1.0 t/m^3 and above; ② have specified holds empty at maximum draught; ③ have BC-B requirements included in loading conditions	Ch. 8, Pt. 2 of the Rules For CSR ships, in accordance with Ch. 1, Pt. 9-1 of the Rules
BC-B	Harmonized notation BC-B	Bulk carriers are to be assigned this notation, provided they ① are designed to carry dry bulk cargoes of density of 1.0 t/m^3 and above; ② have all cargo holds loaded; ③ have BC-C requirements included in loading conditions	Ch. 8, Pt. 2 of the Rules For CSR ships, in accordance with Ch. 1, Pt. 9-1 of the Rules
BC-C	Harmonized notation BC-C	Bulk carriers are to be assigned this notation, provided they ① are designed to carry dry bulk cargoes of density less than 1.0 t/m^3	Ch. 8, Pt. 2 of the Rules For CSR ships, in accordance with Ch. 1, Pt. 9-1 of the Rules
Maximum cargo density x.y t/m^3)	Maximum cargo density x.y t/m^3	This notation is to be added after a harmonized notation to show the limitation when maximum design cargo density for bulk carrier is less than 3.0 t/m^3, and maximum allowed cargo density is to be indicated. This notation is applicable only to BC-A and BC-B. For general dry cargo ships intended to carry cargoes in bulk, this notation is assigned to show the limitation when maximum design bulk cargo density is less than 3.0 t/m^3, and maximum allowed bulk cargo density is to be indicated	Ch.2 or Ch. 8, Pt. 2 of the Rules For CSR ships, Ch. 1, Pt. 9-1 of the Rules

Class notation	Description		Technical requirements
No MP	No loading and unloading in multiple ports	This notation is to be added after a harmonized notation to show the limitation when the bulk carrier has not been designed for loading and unloading in multiple ports in accordance with the Rules. This notation is applicable to all harmonized notations BC-A, BC-B, BC-C. This notation is to be assigned to show the limitation when the ore carrier has not been designed for loading and unloading in multiple ports in accordance with the Rules. For general dry cargo ships intended to carry cargoes in bulk, this notation is assigned to show the limitation when the bulk cargo loading condition has not been designed for loading and unloading in multiple ports in accordance with the Rules	Ch.2 or Ch. 8 or Ch.16, Pt. 2 of the Rules For CSR ships, Ch. 1, Pt. 9-1 of the Rules For ore carriers of 250 m and over in length and engaged in unrestricted service, in accordance with Chapters 6 and 7 of Rules for Structures of Ore Carriers
Holds Nos. ×××a, b, … may be empty	Holds Nos. ×××a, b, … may be empty	This notation is to be added after a harmonized notation when specified empty holds are allowed in design of bulk carrier to specify the empty hold No.. The notation is applicable only to BC-A. For general dry cargo ships intended to carry cargoes in bulk, this notation may be assigned to specify the empty hold No. when specified empty holds are allowed in design of bulk cargo loading condition	Ch.2 or Ch. 8, Pt. 2 of the Rules For CSR ships, Ch. 1, Pt. 9-1 of the Rules
Block loading	Block loading	This notation is to be added after a harmonized notation when the design condition of the bulk carrier allows the loading of two adjacent cargo holds while the cargo holds next to them are empty. The notation is applicable to BC-A	For CSR ships, Ch. 1, Pt. 9-1 of the Rules
Holds Nos. ××× May Be Empty With Restrictions Imposed By SOLAS XII/14	Restrictions from sailing with any hold empty	Existing ships, if not meeting the structural strength requirements for with standing flooding of any one cargo hold as specified in SOLAS regulation XII/5.1 and the strength standards and renewal criteria for single-side skin construction as specified in resolution MSC.168(79), are not to sail with any cargo hold loaded to less than 10% of the hold's maximum allowable cargo weight when in the full load condition, on and after 1 July 2006 or reaching 10 years of age, whichever is later	SOLAS XII/14
Max. Cargo Density ××× t/m^3	Maximum cargo density associated with a full tank ××× t/m^3	For bulk chemical tankers, scantlings of structural members of cargo tanks are determined to the maximum design pressure, maximum cargo temperature and maximum cargo density associated with a full tank, in accordance with the characteristics of cargoes intended to be carried. Where the maximum permissible pressure/vacuum relief valve setting (gauge) of all tanks is combined with the associated maximum cargo density, the combination is to be marked: Max. Pressure XX MPa & Max. Cargo Density YY t/m^3 Where the maximum permissible pressure/vacuum relief valve setting (gauge) of a certain group of tanks is combined with the associated maximum cargo density, the combination is to be marked: Max. Pressure XX MPa & Max. Cargo Density YY t/m^3 for Cargo Tanks No.ZZa, ZZb	Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk
Max. Pressure ××× MPa	Maximum pressure ××× MPa		
Max. Cargo Temperature ×××℃	Maximum cargo temperature ×××℃		
Max. Cargo Density ××× t/m^3	Maximum cargo density ××× t/m^3	For liquefied gas carriers, scantlings of structural members of cargo tanks are determined to the maximum design pressure, maximum cargo density and minimum cargo temperature, in accordance with the characteristics of cargoes intended to be designed to be carried	Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
Max. Vapour Pressure ××× MPa	Maximum vapour pressure ××× MPa		
Min. Cargo Temperature ×××℃	Minimum cargo temperature ×××℃		

Class notation	Description		Technical requirements
Max. Cargo Density in ××× Tank (×× t/m^3)	Maximum cargo density in tank	××× tank is designed to carry liquid cargo of density less than ×× t/m^3, the notation is only to be added after "Offshore Supply Ship"	Sec 13, Ch. 2, Pt. 2 of the Rules
EL100	Easy loading	Ore carriers meeting the requirements for easy loading may be assigned this notation	Ch. 16, Pt. 2 of the Rules; for ore carriers of 250 m and over in length and engaged in unrestricted service, in accordance with Section 2, Chapter 12 of Rules for Structures of Ore Carriers
INF 1	Aggregate activity of INF cargo carried	For the ships which are certified to carry INF cargo with an aggregate activity less than 4,000 TBq	Guidelines for Survey of Irradiated Nuclear Fuel Carriers
INF 2		For the ships which are certified to carry irradiated nuclear fuel or high-level radioactive wastes with an aggregate activity less than 2×10^6 TBq and ships which are certified to carry plutonium with an aggregate activity less than 2×10^5 TBq	
INF 3		For the ships which are certified to carry irradiated nuclear fuel or high-level radioactive wastes and ships which are certified to carry plutonium with no restriction of the maximum aggregate activity of the materials	
NEV Carriage (X)	Carriage of new energy vehicles	The notation is assigned to vehicle carriers and ro-ro passenger ships ro-ro carrying new energy vehicles which comply with the Technical Guidelines for the Safety of Ro-ro Carriage of New Energy Vehicles(NEVs). X means the type of NEVs, which may be B, H, N, or a combination of them. B stands for lithium battery-powered electric vehicles, H for hydrogen-powered vehicles, and N for natural gas-powered vehicles.	Technical Guidelines for the Safety of Ro-ro Carriage of New Energy Vehicles
SOLAS XII	SOLAS XII bulk cargo loading	The notation is assigned to ships intended to carry dry cargo in bulk, with a configuration different from that defined in 8.1.1.1, Chapter 8, Pt. 2 of the Rules, provided that the requirements of Chapter 37, Pt. 8 of the Rules are satisfied	Chapter 37, Pt. 8 of the Rules

Special Features Notations **Table E**

Class notation	Description		Technical requirements
Strengthened for Heavy Cargoes	Strengthened for heavy cargoes	Ships with longitudinal framing for strength deck and bottom within cargo area, and double bottom and strengthening for bottom framing within cargo area, may be assigned this notation. For ore carriers of 250 m and over in length and engaged in unrestricted service, this notation is mandatory for strengthening of double bottom and bottom framing within cargo area. Where the requirements of Section 3 [3], Chapter 12 of Rules for Structures of Ore Carriers are satisfied, (IB) suffix may be added after this notation	1. Sec. 22, Ch. 2, Pt. 2 of the Rules 2. For ore carriers of 250 m and over in length and engaged in unrestricted service, in accordance with Section 3, Chapter 12 of Rules for Structures of Ore Carriers
COMPASS	COMPASS	For ships the design of which has been checked using CCS COMPASS-Structure software, one or more of the following suffixes R, D and F are to be added. Meanings of the suffixes are as follows: R: for ships the check of which against rules has been performed using COMPASS-Structure; D: for ships of which hull structure direct calculations have been performed using COMPASS-Structure; F: for ships of which hull structure fatigue strength assessment has been performed using	COMPASS-Structure software

Class notation	Description		Technical requirements
		COMPASS-Structure. Such notation is necessary for CSR ships	
ERS	Emergency response service	Upon prior ERS agreement between the owner and CCS and an electronic database for stability and structural strength of a ship, CCS will in case of emergency of the ship, e.g. collision at sea, grounding, oil spillage, etc., and at request of the owner, initiate an emergency response procedure to provide calculation and analysis for damage stability, structural strength and spillage, giving technical support to the ship in getting out of danger and recommendations to the owner/master in making final decision	ERS agreement or statement signed by shipping company or shipping operator and CCS is to be provided onboard the ships①
ERS*	Emergency response service	Where ERS agreement or statement is signed by shipping company or shipping operator and ERS onshore service unit designated by the Administration, the notation may be added with the application of the owner	ERS agreement or statement signed by shipping company or shipping operator and ERS onshore service unit designated by the Administration is to be provided onboard the ships
Icebreaking	Capable of breaking ice	Operation in first-year ice conditions and having independent icebreaking capability. This notation is to be used in conjunction with ice notations and added before the type notation, e.g. Icebreaking Tug, Ice Class B1	Ch. 9, Pt. 8 of the Rules
Bottom Strengthened for Operating Aground	Bottom strengthened for operating aground	Bottom of dredgers strengthened for operating aground	Ch. 14, Pt. 2 of the Rules
GRAB [X]	Structural strengthening for loading/unloading by grabs	Strengthening of inner bottom plating, lower strake of hopper tank sloping plate and transverse lower stool plating for holds designed for loading/unloading by grabs having a maximum weight up to × tons ×-unladen grab weight	Sec. 1, Ch. 1, Pt. 9-1 of the Rules
Grab*(×)	Structural strengthening for loading/unloading by grabs	Strengthening of inner bottom plating, lower strake of hopper tank sloping plate and transverse lower stool plating for holds of non-CSR ships designed for loading/unloading by grabs having a maximum weight up to × tons ×-unladen grab weight For ore carriers of 250 m and over in length and engaged in unrestricted service, this notation is mandatory, meaning strengthening of inner bottom plating, lower strake of longitudinal bulkhead and transverse lower stool plating for holds of ships designed for loading/unloading by grabs having a maximum weight up to × tons ×-unladen grab weight	1. Sec. 23, Ch. 2, Pt. 2 of the Rules 2. For ore carriers of 250 m and over in length and engaged in unrestricted service, in accordance with Section 4, Chapter 12 of Rules for Structures of Ore Carriers
CSR	Common Structural Rules	For ships designed and constructed in accordance with Common Structural Rules, this notation is to be added after type notation	Pt. 9 or 10 of the Rules (2012 version) and its 2013 and 2014 amendments or Pt. 9 of the Rules (2015 version) and its subsequent versions (including amendments)
Stainless Steel	Stainless steel	Cargo spaces of bulk chemical tankers are constructed of stainless steel	Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk
Lined with Corrosion Resistant Lining	Lined with corrosion resistant lining	Cargo spaces of bulk chemical tankers are fitted with corrosion resistant lining	
PSPC	Protective coating	Ships of which specific spaces comply with IMO Performance Standard for Protective Coatings	PSPC(B) and PSPC(D) are to comply with the

① Refer to IACS Rec.145 “Recommendation for the Operation of Shore-Based Emergency Response Services”.

Class notation	Description		Technical requirements
		may be assigned this notation, with one or more of suffixes B, C, D and V being added thereafter. Meanings of the suffixes are as follows: B: protective coatings applied in dedicated seawater ballast tanks of all types of ships; C: protective coatings applied in cargo oil tank spaces of crude oil tankers; D: protective coatings applied in double-side skin spaces; V: protective coatings applied in void spaces of bulk carriers and oil tankers. Note: B, C, D and V can operate both separately and together	requirements of IMO resolution MSC.215(82); PSPC(C) is to comply with the requirements of IMO resolution MSC.288(87); PSPC(V) is to comply with the requirements of IMO resolution MSC.244(83)
SOLAS II-2 Reg. 19	Fit for carriage of dangerous goods	Ships fit for carriage of dangerous goods in packaged form or solid dangerous goods in bulk and holding a certificate of fitness for carriage of dangerous goods, may be assigned this notation at the request of the owner	SOLAS Reg. II-2/19
AS	Autonomous ships	Ships complying with the Guidelines for Autonomous Cargo Ships are assigned this notation, which is appended to the ship type notation. For ships designed and constructed in accordance with the Common Structural Rules, it is appended to the class notation CSR	Guidelines for Autonomous Cargo Ships
SAF	Hull structure fatigue strength assessment taking into account linear springing	This notation may be assigned to large ships subject to hull structure fatigue strength assessment taking into account linear springing in accordance with the relevant technical requirements *Notes:* *1. for container ships satisfying the relevant requirements in 1.1.3, Appendix A of Rules for Structures of Container Ships, hull structure fatigue strength assessment taking into account linear springing is carried out, and this notation is mandatory;* *2. for ore carriers satisfying the relevant requirements in 1.1.3, Appendix A of Rules for Structures of Ore Carriers, hull structure fatigue strength assessment taking into account linear springing is carried out, and this notation is mandatory*	Guidelines for Direct Calculation Assessment of Springing and Whipping of Hull Structures *Notes:* *1. for container ships engaged in unrestricted service and of 150 m and over in length, in accordance with Appendix A of Rules for Structures of Container Ships* *2. for ore carriers engaged in unrestricted service and of 250 m and over in length, in accordance with Appendix A of Rules for Structures of Ore Carriers*
SWAF	Hull structure fatigue strength assessment taking into account whipping and springing	This notation may be assigned to large ships subject to hull structure fatigue strength assessment taking into account whipping and springing in accordance with the relevant technical requirements *Notes:* 1. *for container ships satisfying the relevant requirements in 1.1.3, Appendix A of Rules for Structures of Container Ships, hull structure fatigue strength assessment taking into account whipping and springing is carried out, and this notation is mandatory;* 2. *for ore carriers satisfying the relevant requirements in 1.1.3, Appendix A of Rules for Structures of Ore Carriers, hull structure fatigue strength assessment taking into account whipping and springing is carried out, and this notation is mandatory;*	Guidelines for Direct Calculation Assessment of Springing and Whipping of Hull Structures *Notes:* 1. *for container ships engaged in unrestricted service and of 150 m and over in length, in accordance with Appendix A of Rules for Structures of Container Ships* 2. *for ore carriers engaged in unrestricted service and of 250 m and over in length, in accordance with Appendix A of Rules for Structures of Ore Carriers*
WAU	Hull girder ultimate strength	This notation may be assigned to large ships subject to hull girder ultimate strength assessment	Guidelines for Direct Calculation Assessment of

Class notation	Description		Technical requirements
	assessment taking into account whipping	taking into account whipping in accordance with the relevant technical requirements *Notes:* 1. *for container ships satisfying the relevant requirements in 1.1.3, Appendix A of Rules for Structures of Container Ships, hull girder ultimate strength assessment taking into account whipping is carried out, and this notation is mandatory;* 2. *for ore carriers satisfying the relevant requirements in 1.1.3, Appendix A of Rules for Structures of Ore Carriers, hull girder ultimate strength assessment taking into account whipping is carried out, and this notation is mandatory*	Springing and Whipping of Hull Structures *Notes:* 1. *for container ships engaged in unrestricted service and of 150 m and over in length, in accordance with Appendix A of Rules for Structures of Container Ships;* 2. *for ore carriers engaged in unrestricted service and of 250 m and over in length, in accordance with Appendix A of Rules for Structures of Ore Carriers*
Anchor Handling	Handling of anchors	Ships capable of handling anchors	Ch. 20, Pt. 8 of the Rules
CM	Monitoring of construction of hull structure	Ships for which the control of structural precision at critical locations of hull (including alignment, fitting-up, edge treatment and technological standards) is in accordance with an approved plan. For tankers and bulk carriers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10 (Goal-based ship construction standards for bulk carriers and oil tankers) this class notation is necessary	Guidelines for Construction Monitoring of Hull Structures
PC1	Operation in polar waters covered by multi-year ice	Year-round operation in all polar waters	Ch. 13, Pt. 8 of the Rules
PC2		Year-round operation in moderate multi-year ice conditions	
PC3		Year-round operation in second-year ice which may include multi-year ice inclusions	
PC4		Year-round operation in thick first-year ice which may include old ice inclusions	
PC5		Year-round operation in medium first-year ice which may include old ice inclusions	
PC6		Summer/autumn operation in medium first-year ice which may include old ice inclusions	
PC7		Summer/autumn operation in thin first-year ice which may include old ice inclusions	
PC X(y)		After obtaining one of the polar class from PC7 to PC2, the notation “PC X(y)” may be assigned when one or more hull regions longitudinally divided of a polar class ship are of a higher polar class, where X is the polar class level and y is the longitudinal region of hull, which may be taken as : B: bow region BI: bow intermediate region M: midbody region S: stern region E.g. PC 6; PC 3(BI, M) means that structures of bow intermediate and midbody regions are strengthened to a higher PC3 after the ship obtains PC6	
ARC-M(x)	Higher strength steel for polar ships	When higher strength steels are used for hull structures exposed to weather and sea, this class notation may be assigned, where x indicates the design service temperature	Rules for Heavy Icebreakers

Class notation	Description		Technical requirements
Ice Class B1*	Operation in waters covered by first-year ice①	Operation in severe ice conditions, not requiring ice breaker assistance. Maximum and minimum ice class draughts fore, amidships and aft, and minimum required main engine output to be stated in classification certificate	Ch. 4, Pt. 2 / Ch. 14, Pt. 3 of the Rules②
Ice Class B1		Operation in severe ice conditions and if necessary, with ice breaker assistance. Maximum and minimum ice class draughts fore, amidships and aft, and minimum required main engine output to be stated in classification certificate	
Ice Class B2		Operation in moderate ice conditions and if needed, with ice breaker assistance. Maximum and minimum ice class draughts fore, amidships and aft, and minimum required main engine output to be stated in classification certificate	
Ice Class B3		Operation in light ice conditions and if needed, with ice breaker assistance. Maximum and minimum ice class draughts fore, amidships and aft, and minimum required main engine output to be stated in classification certificate	
Ice Class B		Operation in very light ice conditions and if needed, with ice breaker assistance	
WD (××.×× m)	Operating draft (××.×× m)	Marking the operating draft assigned to floating cranes, dredgers and hopper barges, with the value in the brackets indicating the maximum draft allowed for operations of these working ships, in m	Sec. 13, Ch. 1, Pt. 2 of the Rules
FL	Minimum design fatigue life	Where a ship is designed for a minimum design fatigue life of 25 years or more, the class notation FL may be assigned at 5-year intervals starting from the 25th year, e.g. FL (25), FL (30) *Note: for container ships engaged in unrestricted service and of 150 m and over in length and ore carriers engaged in unrestricted service and of 250 m and over in length, this notation is mandatory, with suffix (XX, YY) added as follows:* *XX - wave environmental conditions of ship operation, WW is taken for the environmental condition based on global wave spectrum and NA is taken for the environmental condition based on North Atlantic wave spectrum;* *YY - fatigue design life, in year; the minimum design fatigue life is 25 years, which may be taken at 5-year intervals starting from the 25th year.* *E.g., FL(NA, 25) means that design life of 25 years under North Atlantic wave environment*	Guidelines for Fatigue Strength of Ship Structure *Notes:* 1. *for container ships engaged in unrestricted service and of 150 m and over in length, in accordance with Chapter 10 of Rules for Structures of Container Ships;* 2. *for ore carriers engaged in unrestricted service and of 250 m and over in length, in accordance with Chapter 10 of Rules for Structures of Ore Carriers*
MCRS	Corrosion resistant steel	Corrosion resistant steel is used as an alternative to protective coating for cargo oil tanks of crude oil tankers in accordance with IMO resolution MSC.289(87)	Relevant requirements of the Guidelines for Survey of Corrosion Resistant Steel of Cargo Oil Tanks in Crude Oil Tankers
Strengthened for Deck Cargoes	Strengthened for deck cargoes	The deck structure of specified deck cargo area is designed to be strengthened. The permissible loads, in ××× t/m^2, in cargo area of strengthened deck are to be indicated in operation documents	The cargo deck plating in deck cargo area to comply with the requirements of 11.3.2 of Sec. 3, Ch. 11, Pt. 2 of the Rules. The cargo deck framing in deck cargo area to comply with the requirements for cargo deck plating as specified in Sec. 4, Ch. 11, Pt. 2 and Sec. 8, Ch. 2, Pt. 2 of the Rules

① Such as Northern Baltic Sea in winter, Bohai Sea in winter and Northern Huanghai Sea in winter.

② Attention is to be paid to relevant special requirements of international industrial organizations and oil companies.

Class notation	Description		Technical requirements
ACC (DST)	Ships operating in low air temperature environments	The basic Anti-Cold Climate notation, applicable for ships intended to operate in non-polar waters in low air temperature environments	Ch. 23, Pt. 8 of the Rules
ACC-POLAR (DST)		The polar Anti-Cold Climate notation, applicable for ships intended to operate in polar waters in low air temperature environments	
H (DST)		The hull Anti-Cold Climate notation, applicable for materials used for hull structures of ships intended to operate in low air temperature environments	
DE-ICE		The DE-ICE notation, applicable for ships operating occasionally in low air temperature environments and in addition, for ships operating in areas and during periods where more severe ice and snow accretion are likely to occur	
DSV-Air	Air diving support system	Ships provided with air diving system may be assigned this notation	Ch. 25, Pt. 8 of the Rules
DSV-Sat	Saturation diving support system	Ships provided with saturation diving system may be assigned this notation	Ch. 25, Pt. 8 of the Rules
SFA	Spectrum-based fatigue strength assessment	This notation is optional and applies to large membrane tank LNG carriers, container ships and ore carriers. Class notation SFA (XX, YY) may be assigned after assessment in accordance with the relevant technical requirements . XX refers to environmental condition (e.g.: NA refers to North Atlantic Ocean, see IACS Rec.34 for scatter diagram), YY refers to design life (year), may be taken as 20, 25, 30, 35 or 40. *Note: for container ships engaged in unrestricted service and of 150 m and over in length and ore carriers engaged in unrestricted service and of 250 m and over in length, the suffix is explained as follows:* *XX - wave environmental conditions of ship operation, WW is taken for the environmental condition based on global wave spectrum and NA is taken for the environmental condition based on North Atlantic wave spectrum;* *YY - fatigue design life, in year; the minimum design fatigue life is 25 years, which may be taken at 5-year intervals starting from the 25th year*	Guidelines for Spectrum-based Fatigue Assessment of Hull Structure *Notes:* *1. for container ships engaged in unrestricted service and of 150 m and over in length, in accordance with Appendix 1, Chapter 10 of Rules for Structures of Container Ships* *2. for ore carriers engaged in unrestricted service and of 250 m and over in length, in accordance with Appendix 1, Chapter 10 of Rules for Structures of Ore Carriers*
i-Ship (Ai, Ri, Nx, Hx, Mx, Ex, Cx, I)	Intelligent ships	"i-Ship" intelligent ship class notation is assigned to ships with functions of intelligent navigation, intelligent hull, intelligent machinery, intelligent energy efficiency management, intelligent cargo management, intelligent integration platform, remote control and autonomous operation. Each function corresponds to a functional notation as follows: Ai– functional notation for autonomous operation; Ri– functional notation for remote control; Nx – functional notation for intelligent navigation; Hx – functional notation for intelligent hull; Mx – functional notation for intelligent machinery; Ex – functional notation for intelligent energy efficiency management; Cx – functional notation for intelligent cargo management; I – functional notation for intelligent integration platform; i – numbers such as 1, 2, 3, indicating the scope and degree of remote control and autonomous operation. Only one corresponding number can be selected according to the specific functions of the ship. Detailed requirements are given in Chapters	Rules for Intelligent Ships, Guidelines for Surveys of Intelligent Energy Efficiency Management of Ships, Guidelines for Surveys of Intelligent Machinery of Ships, Guidelines for Surveys of Intelligent Integration Platform of Ships

Class notation	Description		Technical requirements
		8 to 9 of the Rules for Intelligent Ships; x – additional notation for optional function. One small letter stands for one additional notation for function and a functional notation may have multiple additional notations for function, which are to be separated by comma. Detailed requirements are given in Chapters 2 to 7 of the Rules for Intelligent Ships. If one functional notation has already covered the function of another notation, only one notation is assigned.	
		Note 1: Ships, for which i-Ship (E), i-Ship(Es) and i-Ship (Et) class notations are requested, are also to comply with the relevant requirements of Guidelines for Surveys of Intelligent Energy Efficiency Management of Ships; Note 2: Ships, for which i-Ship (Mx) class notation is requested, are also to comply with the relevant requirements of Guidelines for Surveys of Intelligent Machinery of Ships; Note 3: Ships, for which i-Ship (I) class notation is requested, are also to comply with the relevant requirements of Guidelines for Surveys of Intelligent Integration Platform of Ships	
i-Ship (Dx)	Intelligent dredging	For dredgers engaged in dredging operations which are, upon request, in compliance with the provisions of 10.2, Chapter 10 of the Rules for Intelligent Ships subject to CCS plan approval and survey, this notation may be assigned: D – basic function of intelligent dredging specified in 10.2.1.3, Chapter 10 of the Rules for Intelligent Ships; x – additional functional notation, expressed by the following lowercase letters: a – one-key dredging function as specified in 10.2.1.4(1), Chapter 10 of the Rules for Intelligent Ships can be achieved; m – condition-based maintenance is implemented for dredging equipment; o – the optimization function of dredging operation parameters as specified in 10.2.1.4(3), Chapter 10 of the Rules for Intelligent Ships can be achieved	Rules for Intelligent Ships
i-Ship (SRx)	Intelligent scientific research	For scientific research ships engaged in scientific research tasks which are, upon request, in compliance with the provisions of 10.3, Chapter 10 of the Rules for Intelligent Ships subject to CCS plan approval and survey, this notation may be assigned: SR – basic function of scientific research operation management specified in 10.3.4.1, Chapter 10 of the Rules for Intelligent Ships; x – additional functional notation, expressed by the following lowercase letter: c – the scientific research ship has the monitoring function of scientific research operation specified in 10.3.4.2, Chapter 10 of the Rules for Intelligent Ships	Rules for Intelligent Ships
i-Ship(Tx)	Intelligent towing operation	This notation is applicable to harbor tugs having the function of intelligent towing operation. where: T—representing tugs have the basic function for intelligent towing operation; x—additional functional notation, expressed by the following lowercase letters: m—condition-based maintenance function for towing equipment and system;	Chapter 10 of Rules for Intelligent Ships

Class notation	Description		Technical requirements
		s—towing operation coordination function	
i-Ship(Gx)	Intelligent geotextiles laying	This notation is applicable to geotextiles layers having the function of intelligent geotextiles laying operation. where: G — basic function of intelligent geotextiles laying; x — additional functional notation, expressed by the following lowercase letters: a—the one-click geotextiles laying function; m — condition monitoring and health management for geotextiles laying equipment; e — the function of assisted decision-making on energy efficiency optimization of geotextiles laying operations; o—the optimization function of geotextiles laying operation parameters	Chapter 10 of Rules for Intelligent Ships
Cyber Security (M, P[SL0]/S[SL_X])	Cyber security of ships	This notation may be assigned to ships with satisfactory results of the assessment of cyber security of ships, where: M represents compliance with the requirements of ship cyber risk management; P[SL0] represents compliance with minimum ship cyber resilience requirements; S[SL_X] represents compliance with related cyber security requirements corresponding to [SL1/SL2/SL3/SL4], where SL4 is the highest level. *Note: for SOLAS ships, Cyber Security (P[SL0]) notation is mandatory*	Guidelines for Ship Cyber Security
CBM(X)	Condition-based maintenance of ship equipment	This notation may be assigned if a condition based maintenance plan of ship's machinery installations or systems is developed in accordance with the analysis and assessment result of the operating condition and health condition of machinery installations or systems of a ship, with one or more notations affixed to identify the equipment for which the condition based maintenance is implemented, e.g. CBM(Cargo Pumps) is the condition based maintenance notation of cargo pumps	Guidelines for Surveys of Intelligent Machinery of Ships
CEDI (Ox, Cx, Fx)	Cruising Experience Design Index	Cruise ships assigned with class notation CEDI is to be affixed with one or more Ox, Cx, Fx marks, the meaning of which are as follows: Ox – passenger occupation, including tonnage per passenger, living area per passenger and passenger to crew ratio; Cx – comfort, including vibration, noise and indoor climate; Fx – passenger leisure facilities, including facilities provided in passenger cabin, passenger public space and recreational and leisure spaces; x is divided into grade 3, 4 and 5, matching the ship hardware such as space arrangement, equipment and system provision corresponding to 3 star and 3 star +, 4 star and 4 star +, 5 star and 5 star + used in the rating of cruise ship industry respectively, so as to achieve passenger occupation, comfort and functional needs required by relevant star rating at the design and construction stage of cruise ships	Ch. 5 of Rules for Cruise Ships
SEDI (x)	Sanitation Ensurance Design Index	Cruise ships comply with the requirements of Sanitation Ensurance Design Index may be assigned notation SEDI (x); Requirements in relation to hygiene and health , such as for galley and dining room, food storage, potable water, garbage, solid and medical waste,	Ch. 6 of Rules for Cruise Ships

Class notation	Description		Technical requirements
		medical facilities, indoor environment are put forward; x is divided into grade 3, 4 and 5, matching the ship hardware such as space arrangement, equipment and system provision corresponding to 3 star and 3 star +, 4 star and 4 star +, 5 star and 5 star + used in the rating of cruise ship industry respectively, so as to achieve passenger occupation, comfort and functional needs required by relevant star rating at the design and construction stage of cruise ships	
PVSED	Passenger and vehicle separated embarkation and disembarkation	Ro-ro passenger ships provided with arrangements of passenger and vehicle separated embarkation and disembarkation	Ch. 30, Pt. 8 of the Rules
ESA	Enhanced Shaft Alignment	This applies to bearings which are white-metal lined and oil lubricated, and ships applying for enhanced shaft alignment (ESA) notation	Appendix 1 of Ch. 12, Pt. 3 of the Rules
EPC N(SVS, NPR, HIT, TAS)	Epidemic Prevention and Control of Ships	Ships complying with epidemic prevention and control guarantee functions specified in the Guidelines for Epidemic Prevention and Control of Ships may be assigned the class notations for epidemic prevention and control upon request, and optional functional notations are included in the parenthesis, where: N—ship's Epidemic Prevention and Control level (N= 1 or 2 or 3, 3 being the highest level); SVS—functional notation for Sanitary Ventilation System; NPR— functional notation for Negative Pressure isolation Room; HIT—functional notation for Health Investigation and Thermometry System; TAS—functional notation for Telemedicine Assistant System	Guidelines for Epidemic Prevention and Control of Ships
SGISC(X)	Second generation intact stability criteria	Sea-going ships engaged on international voyages complying with relevant requirements for second generation intact stability criteria given in Section 9, Ch. 1, Pt. 2 of the Rules may be assigned this notation, where x represents one or more notations of each sub-elements specified as follows: PR_N: parametric rolling failure mode; PL_N: pure loss of stability failure mode; EA_N:excessive acceleration failure mode; DS_N: dead ship condition failure mode; SRB_N: surf-riding/broaching failure mode where: N=1, meaning all loading conditions comply with Level 1 vulnerability criteria; N=2, meaning all loading conditions comply with Level 2 vulnerability criteria; N=M, meaning that there are loading conditions which do not meet the vulnerability criteria, and information on the stability of ship in waves has been prepared for the master	Section 9, Ch. 1, Pt. 2 of the Rules
ASMW	Operational guidance for ships in high sea conditions	The likelihood of different modes of navigation safety failures under the combined or separate action of wind and waves is assessed by using methods based on hydrodynamics, to determine sailing conditions that may affect safety and prepare operational guidance for ships in high sea conditions for the master's reference	Sec. 9, Ch. 1, Pt. 2 of the Rules
AQM(PM N)	Air quality management of ship compartment	Indicating the concentration level of particulate matter in the air of the compartment of the ship that has obtained the AQM notation, including the	Sections 2 and 3, Chapter 2 of the Guidelines for Monitoring and

Class notation	Description		Technical requirements
		inhalable particulate matter PM10 and the fine particulate matter PM2.5 monitoring factor	Evaluation of Ship Compartment Air Quality and Biohazard Factors
AQM(HFG N)	Air quality management of ship compartment	Indicating the concentration level of hazardous substances in the air of the compartment of the ship that has obtained the AQM notation. The monitoring factors include formaldehyde, benzene, toluene, xylene, total volatile organic compounds (TVOC), and carbon dioxide	Sections 2 and 3, Chapter 2 of the Guidelines for Monitoring and Evaluation of Ship Compartment Air Quality and Biohazard Factors
AQMS(PM N)	Air quality on-line monitoring system	Indicating the concentration level of particulate matter in the air of the compartment of the ship that has obtained the AQMS notation, including the inhalable particulate matter PM10 and the fine particulate matter PM2.5 monitoring factor, and the ship is provided with air quality on-line monitoring system	Sections 2 and 3, Chapter 2, and Sections 1 and 3, Chapter 4 of the Guidelines for Monitoring and Evaluation of Ship Compartment Air Quality and Biohazard Factors
AQMS(HFG N)	Air quality on-line monitoring system	Indicating the concentration level of hazardous substances in the air of the compartment of the ship that has obtained the AQMS notation. The monitoring factors include formaldehyde, benzene, toluene, xylene, total volatile organic compounds (TVOC), and carbon dioxide, and the ship is provided with air quality on-line monitoring system	Sections 2 and 3, Chapter 2, and Sections 1 and 3, Chapter 4 of the Guidelines for Monitoring and Evaluation of Ship Compartment Air Quality and Biohazard Factors
ABM(BAS N)	Air bioaerosol health management of ship compartment	Indicating the concentration level of bioaerosol in the air of the compartment of the ship that has obtained the ABM notation, monitoring factors include total number of bacterial colony, and the ship is provided with bioaerosol on-line monitoring system of ship compartment	Sections 2 and 3, Chapter 2, and Sections 2 and 3, Chapter 4 of the Guidelines for Monitoring and Evaluation of Ship Compartment Air Quality and Biohazard Factors
DL(XX)	Specific service life	Strength assessment of container ships and ore carriers with specific service life in accordance with the Guidelines for Strength Assessment of Ships with Specific Service Area or Service Route or Service Life. Where XX is design life, in years, to be less than 20, e.g. DL (15)	Guidelines for Strength Assessment of Ships with Specific Service Area or Service Route or Service Life
Data Quality(X)	Ship data quality	Evaluating that the data retained by the shipboard system meets the relevant technical requirements	Sections 2, 3 and 4 of Chapter 3 of Guidelines for Quality Assessment of Ship Data
GFE	Global finite element strength assessment	1.The class notation is mandatory for container ships complying with one of the following conditions: 1) Length L greater than 250 m; 2) Hatch breadth of strength deck greater than 0.89B; 3) Unconventional structural arrangement. The class notation is optional for other container ships. 2.The class notation is mandatory for ore carriers complying with one of the following conditions: 1)Length L greater than 350 m; 2)Unconventional structural arrangement. The class notation is optional for other ore carriers	1. Chapter 8 of Rules for Structures of Container Ships 2. Chapter 8 of Rules for Structures of Ore Carriers
LIQ(X)	Cargo liquefaction	Where an ore carrier is designed to carry cargoes (e.g. iron ore, etc.) with a moisture content exceeding the Transportable Moisture Limit (TML) which may lead to cargo liquefaction during transportation, the assignment of this notation is mandatory.	Appendix 1, Chapter 12 of Rules for Structures of Ore Carriers

Class notation	Description			Technical requirements
		X — corresponding to the condition under which all cargo holds are designed to carry type A cargo, which may be taken as 1 or 2. For ore carriers with some cargo holds designed to carry liquefied cargo, the suffix “Holds a,b,...” is to be added after LIQ(X), which is identified by LIQ(X, Holds a,b,...), e.g. LIQ(1, Holds NO. 1,3, 5)		
Underwater Noise N	Underwater radiated noise for ships relying on hydro-acoustic equipment to perform the essential service function	For ships relying on hydro-acoustic equipment to perform the essential service function, the class notation for underwater radiated noise can be assigned if the measured underwater noise meet the requirements. N means underwater radiated noise level, N=1, 2 or 3, in which 1 represents the highest level of underwater radiated noise		Guidelines for Underwater Radiated Noise of Ships
Specific Communication Network (Px,Rx)	Ship communication networks satisfying specific needs	The specific communication needs such as passenger using the Internet and remote survey are realized through the arrangement of ship communication network equipment on board, based on hosting modes of communication networks such as satellite broadband communication network and 4G or 5G cellular communication network. The specific meanings are as follows: P - network provided for passengers to satisfy the daily communication needs of passengers to use the Internet (Passenger). R - network provided for crew to satisfy the communication needs for ship remote survey (Remote). x - additional notations for hosting modes of ship communication networks. Each small letter indicates one hosting mode. The ship communication network satisfying one specific need may be realized by one or more hosting modes, which may be assigned one or more additional notations where: s - ship communication network realized by satellite broadband communication network. c - ship communication network realized by 4G or 5G cellular communication network		Chapter 33, Pt. 8 of the Rules
COLL	Evaluation of collision resistance capability of ships	This notation may be assigned to ships for which the evaluation of collision resistance capability is carried out to side structures of sea-going ships in accordance with the relevant requirements of “evaluation of collision resistance capability of ships”		Chapter 34, Pt. 8 of the Rules
DGP-F	Fire-fighting of dangerous goods in packaged form	This notation is assigned to domestic navigation container ships carrying dangerous goods in packaged form that meet the Guidelines for Fire Fighting and Stowage of Domestic Container Ships Carrying Dangerous Goods in Packaged Form		Guidelines for Fire Fighting and Stowage of Domestic Container Ship Carrying Dangerous Goods in Packaged Form
ALY	Aluminum alloy materials	This notation is assigned to ships, the main hull of which is made of aluminum alloy materials	The following sea-going ships of 20 meters and above in length and engaged in restricted service: (1) passenger ship; (2) ferry; (3) traffic ship; (4) public affair ship.	Guidelines for Structure of Non-high-speed All-aluminum Alloy Sea-going Ships
			High speed crafts of 20 meters and above in length	Rules for Construction and Classification of Sea-Going High Speed Craft

Class notation	Description			Technical requirements
			Yachts engaged in uncommercial entertainment activities such as touring, leisure and sightseeing	Rules for Construction and Classification of Yachts
FRP	Fiber reinforced plastics	This notation is assigned to ships, the main hull of which is made of fiber reinforced plastics	High speed craft of 20 meters and above in length	Rules for Construction and Classification of Sea-Going High Speed Craft
			Yachts engaged in uncommercial entertainment activities such as touring, leisure and sightseeing	Rules for Construction and Classification of Yachts
EVA	Simplified evacuation analysis	Ships for which the design of escape routes, evacuation arrangements and evacuation performance are evaluated based on simplified evacuation analysis		Guidelines on Evacuation Analysis for Personnel of Passenger Ships
EVA (Adv)	Advanced evacuation analysis	Ships for which the design of escape routes, evacuation arrangements and evacuation performance are evaluated based on advanced evacuation analysis		

Automation Notations **Table F**

Class notation	Description		Technical requirements
AUT-0	Machinery space periodically unattended	Main propulsion machinery remotely controlled from BCS, machinery space including CCS periodically unattended	Ch. 3, Pt. 7 of the Rules
MCC	Central control of machinery spaces	Ships with this notation are to be provided with CCS and LCS. When machinery and electrical equipment are in normal operation, CCS is to be constantly attended by watch-keepers	Sec. 2, Ch. 4, Pt. 7 of the Rules
BRC	Remote control from bridge	Main propulsion machinery remotely controlled from BCS, machinery spaces constantly attended by watch-keepers	Sec. 3, Ch. 4, Pt. 7 of the Rules

Special Equipment and System Notations **Table G**

Class notation	Description		Technical requirements
Equipped with Container Securing Arrangements	Container securing arrangements	Ships other than container ships fitted with container securing arrangements may be assigned this notation	Appendix 1 of Ch. 7, Pt. 2 of the Rules
Emergency Towing Arrangements	Emergency towing arrangements	Tankers provided with emergency towing arrangements may be assigned this notation	Sec. 5, Ch. 3, Pt. 2 of the Rules
Loading Computer	Loading computers	Ships provided with approved loading computers are to be assigned this notation, with one or more of suffixes OA, S, I, G and D being added thereafter. Meanings of the suffixes are as follows: S: Capable of calculating and checking hull strength under various loading conditions; I: Capable of calculating and checking intact stability; G: Capable of calculating and checking stability of grain in bulk; D: Capable of calculating and checking damage stability	Appendices 1 & 2 of Ch. 2, Pt. 2 of the Rules
Equipped with Single Point Mooring	Equipped with single point mooring	Ships equipped with single point mooring connecting installation according to relevant requirements are to be assigned the notation	Mooring Equipment Guidelines of Oil Companies

Class notation	Description		Technical requirements
Connecting Installation	connecting installation		International Marine Forum (OCIMF)
IGS	Inert gas systems	For ships provided with inert gas system. Note: "IGS" has the same meaning as "Inert Gas System"	Ch. 4, Pt. 6 of the Rules
COW	Crude oil washing system	This notation may be added for ships fitted with crude oil washing system	MARPOL Annex I to be complied with, as appropriate
CBT	Clean ballast tank	This notation may be added for ships fitted with clean ballast tanks	MARPOL Annex I to be complied with, as appropriate
SBT	Segregated ballast tank	This notation may be added for ships fitted with segregated ballast tanks. Where segregated ballast tanks are in a protective location, the notation PL is to be added after SBT	MARPOL Annex I to be complied with, as appropriate
Helicopter Facilities	Helicopter facilities	For ships with areas and structures for takeoff and landing of helicopters, and storage, fire protection and oil supply facilities for helicopters, this notation may be added	Sec. 18, Ch. 2, Pt. 2 & Ch. 5, Pt. 6 of the Rules
Electrical Propulsion System	Electrical propulsion systems	For ships fitted with electrical propulsion system, this notation may be added	Ch. 15, Pt. 8 of the Rules For DC power distribution propulsion system, see the Guidelines for Survey of DC Integrated Electrical Systems of Ships
Water Jet Units	Water jet units	For ships fitted with water jet units, this notation may be added	Standard(s) acceptable to CCS, e.g. CB3404-91 "Technical conditions for water jet mixed-flow pump and axial flow pump of ships"
Z-propulsion	Z-propulsion system	For ships fitted with Z-propulsion system, this notation may be added	Ch. 11, Pt. 3 of the Rules
Non-propulsion	Non-propulsion machinery	This notation is assigned to those ships not fitted with propulsion equipment used for main propulsion purposes, and is to be added after the type notation. In case of a type notation indicating that the ship is not self-propelling, e.g. "Barge, Oil Barge, Pontoon Barge, Floating Dock, Hopper Barge, Split Hopper Barge", this notation need not be added	Ch. 11, Pt. 3 of the Rules
Cargo Handling by Conveyer System	Self-unloading systems	For ships fitted with conveyors for cargo handling and capable of self-loading or self-unloading, this notation may be added. In the case of cement carriers fitted with compression operated cargo handling system, this notation may be replaced by the notation Air Slid Conveyer System, as necessary	Rules for Lifting Appliances of Ships and Offshore Installations
Auxiliary Propelling/ Maneuvering Units	Auxiliary propelling/ maneuvering units	For ships fitted with auxiliary propelling / maneuvering units which are intended not for navigation purposes, but only for locally adjusting operation position of the ship or auxiliary propelling during towing, etc., this notation may be added	Ch. 11, Pt. 3 of the Rules
Lifting Appliance	Lifting appliances	Marine lifting appliances. This notation is to be added together with the notation Floating Crane for floating cranes and upon request, for other ships	Rules for Lifting Appliances of Ships and Offshore Installations
PR-N	Redundant propulsion system	Ships, of which the main propulsion machinery and/or the steering gear is provided with redundancy, may be assigned this notation wherein the letter N indicates one of the following cases: 1 – A ship fitted with two or more propulsion machines but only a single propulsor and a single steering system. 2 – A ship fitted with two or more propulsion	Ch. 14, Pt. 8 of the Rules

Class notation	Description		Technical requirements
		machines and also two or more propulsors and two or more steering systems. 1S – A ship fitted with only a single propulsor and a single steering system but having two or more propulsion machines arranged in separate compartments. 2S – A ship fitted with two or more propulsion machines and also two or more propulsors and two or more steering systems, having the propulsion machines, propulsors and associated steering systems arranged in separate compartments	
HMS(x)	Hull monitoring system	This notation may be assigned when monitoring sensors are installed in the hull monitoring system, but also sensors/ components monitoring other parameters are selected, where within the brackets there will be letters specifying the selected sensors/components and multiple letters are separated by a comma ",". The following sensors/ components may be selected for the hull monitoring system: Gn: Sensor monitoring the global hull strain Dn: Sensor monitoring the local hull strain On: Sensor monitoring the propulsion shaft(s) output An: Sensor monitoring the axial acceleration Mn: Device for monitoring of hull rigid body motions (six degrees of freedom) Pn: Sensor monitoring the transient sea pressure acting on the hull (slamming) Sn: Sensor monitoring the liquid motion pressures in tanks (sloshing) Tn: Sensor monitoring the temperature Bn: Device for monitoring the wave Wn: Wind sensor Nn: Navigation sensors Cn: Online link to loading computer that is continuously up-dating the loading condition Ln: Backed up statistics and triggered time series to be sent to CCS periodically Note: n denotes the number of sensors or devices	Ch. 21, Pt. 8 of the Rules
HMS-HSC(x)		This notation may be assigned to the hull monitoring system installed on high speed craft Within the brackets there will be letters specifying the selected sensors/components and multiple letters are separated by a comma ",". The following sensors/ components may be selected for the hull monitoring system: An: Sensor monitoring the axial acceleration Gn: Sensor monitoring the global hull strain Dn: Sensor monitoring the local hull strain Pn: Sensor monitoring the transient sea pressure acting on the hull (slamming) Note: n denotes the number of sensors or devices	
HMS-ICE	Hull monitoring and assistant decision-making system for operations in ice	This notation may be assigned to ships with ice class that are installed with monitoring and decision system according to the requirements of the Guidelines and relevant rules, capable of monitoring stress of structure members in ice belt area during operations in ice and can send a safety alarm when the monitored value and forecasted value approach or exceed safety value, and will provide a suggestion on modification of operation to the Master	Guidelines for Hull Monitoring and Assistant Decision-making System for Operations in Ice
HMS-ICE(×)		This notation may be assigned to ships with ice class provided with hull monitoring and assistant decision-making system for operations in ice which comply with the requirements for monitoring based on non-standard ice operation mode. Turn: the monitoring and decision system that can	

Class notation	Description		Technical requirements
		meet the need for monitoring of structural response in ice belt area during turning of ships in ice; Glancing: the monitoring and decision system that can meet the need for monitoring of hull girder bending and shear during glancing operation of ships in ice; Oblique: the monitoring and decision system that can meet the need for monitoring of structural response in ice belt area during oblique operation of ships in ice; Stern-Ahead: the monitoring and decision system that can meet the need for monitoring of structural response in ice belt area during stern-ahead operation of ships in ice; Shallow-Water: the monitoring and decision system that can meet the need for monitoring of structural response of ship bottom during shallow-water	
ECL	Ergonomic Container Lashing	This notation may be assigned to ships the decks of which are loaded with containers and specially designed for the safety of securing personnel	Ch. 22, Pt. 8 of the Rules
DP-N	Dynamic positioning systems	Vessels with dynamic positioning systems are to be assigned this notation, with N being one of the following: 1 Vessels with dynamic positioning systems can automatically keep their position and heading within specified environmental conditions. In addition, independent centralized manual position control and automatic heading control are to be provided. 2 Vessels with dynamic positioning systems can automatically keep their position and heading in case of a single failure (excluding loss of a cabin or cabins) within specified environmental conditions and operating limits. 3 Vessels with dynamic positioning systems can automatically keep their position and heading in case of a single failure (including total loss of a cabin caused by fire or flooding) within specified environmental conditions and operating limits	Ch. 11, Pt. 8 of the Rules
BDE-1	Bridge design and equipment	The design and working environment of the bridge and equipment provided for each workstation comply with the basic requirements	Ch. 4, Pt. 8 of the Rules
BDE-2		Ships required to be maneuvered at the workstation for docking on the basis of BDE-1	
BDE-3		Ships provided with the Integrated Bridge System (IBS) in addition to complying with the applicable requirements of BDE-2	
CLC	Lashing calculation programme of containers	Ships provided with onboard container lashing calculation programme may be assigned this notation. This notation is optional and suffixes V, W may be added. Meanings of the suffixes are as follows:: V - specified voyage. Ships applying for securing of containers for specified voyage may be assigned the CLC (V) notation; W- specified weather. Ships applying for securing of containers for specified weather may be assigned the CLC (V, W) notation on the basis of CLC (V)	Appendix 1 of Ch. 7, Pt. 2 of the Rules *Note: for container ships engaged in unrestricted service and of 150 m and over in length, in accordance with Chapter 12 of Rules for Structures of Container Ships*
ROVS	Remote operated submersible vehicles	Ships provided with remote operated submersible vehicles may be assigned this notation	Ch. 25, Pt. 8 of the Rules
BioFuel Oil(Bxx, Yn)	Biofuel oil used by the main propulsion system	This notation may be assigned to ships for which biofuel oil is used by the main propulsion system, where: Bxx: indicating the mixing ratio the biofuel oil used being less than or equal to xx, where xx indicates the volume percentage of biofuel in the biofuel mixture. For example, B30 and B100 indicate that the volume	Guidelines for Ships Using Biofuel

Class notation	Description		Technical requirements
		percentage of biofuel in the biofuel mixture is less than or equal to 30% and 100%, respectively. Yn: indicating the type of biofuel, e.g. FAME, FAEE, HVO, SVO etc. Several biofuels may be used at the same time, e.g. BioFuel Oil(B30, FAME; B50, HVO)	
Bow Loading System	Bow loading system	For oil tankers fitted with bow loading system, this notation may be added	Ch. 27, Pt. 8 of the Rules
Bow Loading System*	Bow loading system	For oil tankers fitted with bow loading system, this notation may be added	Sec. 9, Ch. 27, Pt. 8 of the Rules
Semi-submerged Propeller	Semi-submerged propeller	For ships fitted with semi-submerged propellers, this notation may be added	Guidelines for Semi-submerged Propellers
VDMS	Video monitoring system	Ships provided with video monitoring system may be assigned this notation	Ch. 31, Pt. 8 of the Rules
NVE	Night vision equipment	Ships provided with night vision equipment may be assigned this notation	Ch. 31, Pt. 8 of the Rules
EFN-x	Fog navigation enhanced sensing system	Ships provided with fog navigation enhanced sensing system may be assigned this notation, where x is replaced by one of the following: M - manual identification of typical targets; A- intelligent identification of typical targets	Ch. 31, Pt. 8 of the Rules
T-Propulsion	Transverse propulsion system	For ships provided with transverse propulsion arrangement, this notation may be assigned	Ch. 32, Pt. 8 of the Rules
DP-N(CBV/CBNV)	DP systems based on closed bus bars	Ships or offshore installations provided with DP systems are assigned this notation, among which N should be 2 or 3: Abbreviated CBV and CBNV imply: CBV— witnessing of closed bus bars on board; CBNV— witnessing of closed bus bars on board is not necessary. CBV,CBNV could not be assigned simultaneously	Guidelines for DP Systems Based on Closed Bus Bars
LPG Fuel	Using liquefied petroleum gas as fuel	For ships the main propulsion system of which is fueled by liquefied petroleum gas, this notation may be assigned	1. Chapters 1-13 of the Guidelines for Ships Using Liquefied Petroleum Gas as Fuel for ship length ≥20 m 2. Rules for Classification of Sea-going Boats for ship length <20 m
Battery(Power)	Pure Battery-Powered Propulsion	For ships only using pure battery-powered propulsion, this notation may be assigned	1.Rules for Classification of Sea-going Boats for ship length <20 m 2.Rules for Ships Applying Battery as a Power for other ships
Battery(Power-h)	Battery hybrid powered propulsion	For batteries used as partial propulsion power or energy storage source, the notation may be assigned	Rules for Ships Applying Battery as a Power
Power-R	Remote monitoring of battery powered system	For ships capable of sending the parameters of its battery power system, distribution system and electrical propulsion system to the CCS survey and verification platform of battery powered ships, this notation may be assigned	Rules for Ships Applying Battery as a Power
SPV	Solar photovoltaic system	For ships fitted with solar photovoltaic system, this notation may be assigned	1. Ch.2 of Survey Guidelines of Solar Photovoltaic System and Lithium Iron Phosphate Battery System for ship length ≥20 m 2. Rules for Classification of

Class notation	Description		Technical requirements
			Sea-going Boats for ship length <20 m
AMPS	AC shore connection system	The class notation may be assigned to a ship fitted with an AC shore connection system with rated voltages of 15 kV or less for power supply to ships in port. Such systems are capable of transferring load between the shore supply and the ship's electrical power via blackout or temporary parallel running, so as to ensure normal operation of equipment intended to be used when generating sets of the ship are stopped	1. Ch.19, Pt. 8 of Rules for Classification of Sea-going Steel Ships for ship length ≥20 m 2. Rules for Classification of Sea-going Boats for ship length <20 m
EFS	Enhanced fire safety	Container ships and other types of ships carrying containers may be assigned this notation if basic requirements for enhanced fire safety in the Guidelines for Enhanced Fire Safety of Container Ships are satisfied	Guidelines for Enhanced Fire Safety of Container Ships
EFS(X)	Enhanced fire safety	One or more suffixes X may be added to the EFS notation, where X stands for: acc: protection for accommodation, survival craft, embarkation stations and muster stations; fm: provision of deck fixed water monitor systems; fd: provision of temperature monitoring systems for container stowage areas; ws: provision of cargo hold water spraying systems	Guidelines for Enhanced Fire Safety of Container Ships
Rim-driven Thruster	Rim-driven thruster	For ships fitted with rim-driven thrusters complying with the requirements of the Guidelines for Survey of Rim-driven Thruster which are used as the main propulsion, this notation may be assigned	Guidelines for Survey of Rim-driven Thruster
Ammonia Fuel	Using ammonia as fuel	This notation is assigned to ships the main propulsion of which uses ammonia as fuel	Guidelines for Ships Using Ammonia Fuel
AFD Ready 1	Ammonia fuel ready	Principled plan design and approval are carried out to ammonia fuel power system ready	
AFD Ready 2		Detailed plan design and approval are carried out to ammonia fuel power system ready	
AFD Ready 2(X)		Based on satisfying the requirement of AFD Ready 2, equipment or system related to ammonia fuel power system have been fitted on board. The X stands for one or more added suffixes, which refers to: ① The letter S in capital means that relevant hull structure and the supporting structure of ammonia fuel tank have been strengthened; ② The letter T in capital means that ammonia fuel tank and containment system have been fitted; ③ The letter E in capital means that the main propulsion engine using ammonia fuel has been fitted; ④ The letter P in capital means that ammonia fuel piping system has been fitted; ⑤ The letter D in capital means that electrical equipment within relevant hazardous areas of ammonia fuel power system meets the corresponding explosion-proof requirements	
FC-FULL	Pure fuel cell power	A ship is only provided with FC power installations without any other main power, such as any main engine/main generating set/power battery. The FC power installations supply power to the ship's electrical equipment	Guidelines for Ships Using Fuel Cell Power Installations
FC-POWER 1	Fuel cell power	A ship is provided both FC power installations and other main power (any main engine/main generating set/power battery etc.), and the former, as part of the main source of electrical power of the ship, supplies	

Class notation	Description		Technical requirements
		power to the ship's electrical equipment	
FC-POWER 2		A ship is provided both FC power installations and other main power (any main engine/main generating set/power battery etc.), and the former, not as part of the ship's main generator, supplies power to the ship's electrical equipment	
HFC Ready 1	Hydrogen fuel cell ready	Principled HFC power installations ready plan design and approval have been carried out to ensure that the ship complies with basic requirements for using HFC power installations in the future, and equipment and system related to HFC power installations are not fitted on board	
HFC Ready 2		Detailed HFC power installations ready plan design and approval have been carried out to ensure that the intended HFC power installations can satisfy relevant requirements of the Guidelines, and equipment and system related to HFC power installations are not fitted on board	
HFC Ready 2(X)		Based on satisfying the requirement of HFC Ready 2, equipment or system related to HFC power installations have been partially fitted on board, subject to CCS survey and approval. The suffix X refers to: ① The letter S in capital means that relevant hull structure has been strengthened and the supporting members of hydrogen fuel tanks/hydrogen cylinders have been fitted; ② The letter P in capital means that the piping system of hydrogen fuel has been fitted; ③ The letter FC in capital means that the cell module of hydrogen fuel has been fitted; ④ The letter D in capital means that the classification of all the hazardous areas related to HFC power installations has been considered and the electrical equipment within the above areas meets the corresponding explosion-proof requirements	
Methanol/Ethanol Fuel	Fueled by methanol/ethanol	This notation may be assigned to power ships the main propulsion system of which is fueled by methanol/ethanol	Guidelines for Ships Using Methanol/Ethanol Fuel
M/E FR (X_1,… , X_N)	Methanol/ethanol fuel ready	This notation is assigned to ships adopting a ready plan of methanol/ethanol fuel, where the meaning of X_N is as follows: S: the hull structure has been strengthened in accordance with the relevant requirements; T: methanol/ethanol fuel containment system and its supporting structure have been fitted; F: methanol/ethanol fuel bunkering station and bunkering system have been fitted; P: methanol/ethanol fuel pipelines and related systems have been fitted, or the relevant requirements for the design and arrangement of methanol/ethanol fuel pipelines for future modification have been fully considered; M: the main engine fitted during ship construction is a dual-fuel engine; m: the main engine fitted during ship construction may be retrofitted as/replaced with methanol/ethanol engine in the future; A: the auxiliary engine fitted during ship construction is a dual-fuel engine; a: the auxiliary engine fitted during ship construction may be retrofitted as /replaced with methanol/ethanol	

Class notation	Description		Technical requirements
		engine in the future; B: the boiler fitted during ship construction is a dual-fuel boiler; b: the boiler fitted during ship construction may be retrofitted as methanol/ethanol boiler in the future; FC: due consideration has been given to relevant requirements for arrangement and fitting of methanol/ethanol fuel cell system during modification; E: the power distribution system of equipment related to methanol/ethanol fuel power system has been reserved during ship construction; D: hazardous areas have been considered during ship construction; C: due consideration has been given to control, monitoring and safety systems of methanol/ethanol fuel during ship construction	
Methanol Bunkering	Methanol bunkering	This notation may be assigned to ships provided with methanol bunkering system	Guidelines for Methanol Bunkering Ships
DFD	Dual fuel engines	This notation may be assigned to liquefied gas carriers fitted with dual fuel engines in compliance with the requirements of the Guidelines for Design and Installation of Gas Fuel Engine Systems of Liquefied Gas Carriers	Guidelines for Design and Installation of Gas Fuel Engine Systems of Liquefied Gas Carriers
GF	Gas fuel only engine	This notation may be assigned to liquefied gas carriers fitted with gas fuel only engines in compliance with the requirements of the Guidelines for Design and Installation of Gas Fuel Engine Systems of Liquefied Gas Carriers	Guidelines for Design and Installation of Gas Fuel Engine Systems of Liquefied Gas Carriers
Natural Gas Fuel	Using natural gas fuels	The notation may be assigned to the ships of which the main propulsion and/or auxiliary machinery uses natural gas or natural gas and oil fuel as a fuel, except for liquefied gas carriers	Rules for Ships Using Natural Gas Fuels
DFDR	Natural gas fuel ready system	A ship assigned with the class notation of DFDR may has one or more suffix(es) of X_N. The meanings of X_N are as follows: H: the hull structures have been strengthened in accordance with the relevant requirements of natural gas fuel powered ships T: the natural gas fuel containment system (bunkers/fuel tanks) and its supporting members have been installed M: the main engine installed in ship's construction is a dual fuel engine m: main engine installed in ship's construction may be converted to a dual fuel engine in future A: the auxiliary engine installed in ship's construction is a dual fuel engine a: the auxiliary engine installed in ship's construction may be converted to a dual fuel engine in future B: the boiler installed in ship's construction is a dual fuel boiler P: the arrangement in ship's construction has been considered the approaching installation of natural gas fuel supply system and related to, including the arrangement of piping, bunkering station, compressor room, gas valve unit, fire-fighting system, etc. E: the power distribution system has been reserved for the equipment related to natural gas fuel powered system in ship's construction D: the gas dangerous zones have been taken into consideration in ship's construction	Guidelines for Natural Gas Fuel Ready Ships
SEC(EGCS)	SOx emission control (exhaust gas cleaning	Ships installed with the EGC systems for reduction of SOx emission can be assigned with SEC(EGCS) notation	Guidelines for Design and Installation of Exhaust Gas Cleaning

Class notation	Description		Technical requirements
	system)		Systems
EGC Ready (X)	Exhaust gas cleaning systems (EGC) Ready	For EGC Ready (X) class notation, the symbol X stands for the type of the EGC system, including: (1) dry desulfurization system, expressed by the capital letter D; (2) open loop exhaust gas cleaning system, expressed by the capital letter O; (3) closed loop exhaust gas cleaning system, expressed by the capital letter C; (4) open-closed hybrid composite system, expressed by the capital letter H. X is to be replaced by one of the four letters above based on the type of the EGC system intended to be installed	Guidelines for Exhaust Gas Cleaning System Ready
LSDF	Low sulphur distillate fuel	Ships intended to use low sulphur distillate fuel with sulphur content not exceeding 0.10% (m/m) may be assigned this notation if the requirements of the Guidelines for Use of Low Sulphur Distillate Fuels in Ships are complied with	Guidelines for Use of Low Sulphur Distillate Fuels in Ships
NEC (SCRS)	NOx emission control (Selective catalytic reduction system)	This notation may be assigned to ships installed with the SCR systems for reduction of NOx emission may be assigned n	Guidelines for Application of Selective Catalytic Reduction (SCR) System Onboard Ships
NEC (EGRS)	NOx emission control (Exhaust Gas Recirculation system)	This notation may be assigned to ships installed with the EGR systems for reduction of NOx emission	Guidelines for Application of Exhaust Gas Recirculation (Egr) Systems Onboard Ships
SCR Ready (X)	Selective catalytic reduction system (SCR) Ready	In assigning class notation SCR Ready(X), X is to be replaced by U or A, the meaning of which are as follows: U: SCR with reductant using aqueous urea solution; A: SCR with reductant using aqueous ammonia	Guidelines for Selective Catalytic Reduction (SCR) System Ready
Hybrid	Hybrid system	Ships with various sources of energy (excluding sails) which can serve as main propulsion power simultaneously, and which do not use lithium-ion batteries and energy type supercapacitors as propulsion power, this notation may be assigned.	Guidelines for Ships Applying Hybrid System
WAP(RWS)	Rigid Wing Sails	This notation may be assigned to wind assisted propulsion unit complying with the requirements of the Guidelines for Evaluation and Survey of Marine Rigid Wing Sails (excluding Chapter 4)	Guidelines for Evaluation and Survey of Marine Rigid Wing Sails
ALDR	Air lubrication drag reduction system	This notation may be assigned, where air lubrication for drag reduction technology is applied on the ship and the requirements of Chapters 1 and 2 of the Guidelines for Surveys of Air Lubrication System for Drag Reduction of Ships are complied with	Guidelines for Surveys of Air Lubrication System for Drag Reduction of Ships
LPGF Ready 1	LPG fuel ready ships	This notation may be assigned when the relevant equipment is not installed onboard and only design and approval of principal plans of LPG fuel ready ships are carried out	Chapter 14 of the Guidelines for Ships Using Liquefied Petroleum Gas as Fuel
LPGF Ready 2		This notation may be assigned when the relevant equipment is not installed onboard and design and approval of detailed plans of LPG fuel ready ships are carried out	
LPGF Ready 2(X)		This notation may be assigned when some of the relevant equipment and system are already installed onboard in addition to compliance with the requirements for LPGF Ready 2. The meanings of the suffix X are as follows: ① the capital letter S indicates that the relevant hull structure and fuel tank support structure have been reinforced; ② the capital letter T indicates that the LPG fuel tank	

Class notation	Description		Technical requirements
		and its containment system have been installed; ③ the capital letter M indicates that the main propulsion engine using LPG fuel has been installed; ④ the capital letter P indicates that the LPG fuel piping system has been installed; ⑤ the capital letter D indicates that the electrical equipment of the fuel power system in relevant dangerous zones is to be explosion-proof	
Telescope Gangway	Telescope Gangway	This notation may be assigned to ships provided with telescope gangway	Guidelines for Marine Telescope Gangway
Ready(X-i)	System and equipment ready	For system and equipment ready with regard to existing class notations, this notation may be assigned, where "X" indicates class notation for existing system and equipment, and "i" indicates different ready levels	Ch. 35, Pt. 8 of the Rules
OCCS	Onboard carbon capture system	For ships fitted with the system to reduce CO_2 emission, this notation may be assigned	Ch. 36, Pt. 8 of the Rules
OCCS Ready 1	Carbon capture system ready	Design and approval of principle drawings are carried out for OCCS ready ship to ensure that the ship is in compliance with the basic requirements for future installation of OCCS, and that no equipment or systems related to carbon capture systems have actually been installed on board	Guidelines for Onboard Carbon Capture Systems
OCCS Ready 2		Design and approval of detailed drawings are carried out for OCCS ready ship to ensure that the OCCS ready is in compliance with the relevant requirements, and that no equipment or systems related to carbon capture systems have actually been installed on board	
OCCS Ready 2(X)		On the basis of meeting the requirements of OCCS Ready 2, the OCCS related equipment and systems have actually been installed on board the ship. The symbol X represents one or more suffixes of class notation, with the following specific meanings: ① The hull structures and related supporting structures have been strengthened, represented by the capital letter S; ② The absorption tower, desorption tower and absorbent circulation system have been installed, represented by the capital letter A; ③ The CO_2 compression and liquefaction system has been installed, represented by the capital letter L; ④ The CO_2 storage tanks have been installed, represented by the capital letter T	
WAP(ROTOR)	Rotor assisted propulsion system	This notation may be assigned to ships provided with the wind-rotor assisted propulsion system	Guidelines for Survey of Marine Wind-Rotor Assisted Propulsion System
RWA	Reduced anchor weight	This notation may be assigned to ships using high holding power anchor or very high holding power anchor to replace ordinary stockless bow anchor, so as to reduce anchor weight	Sec.2, Ch. 3, Pt. 2 of the Rules
PSD	Rotating duct in front of propellers	This notation may be assigned to ships provided with the energy-saving appendages in front of propellers	Sec.8, Ch. 3, Pt. 2 of the Rules

Special Survey Notations **Table H**

Class notation	Description		Technical requirements
ESP	Enhanced survey programme	This notation is required for oil tankers, oil/bulk carriers, oil/bulk/ore carriers, chemical tankers, bulk carriers, self-unloading bulk carriers engaged on international voyages. This notation is optional by the owner for oil tankers, oil/bulk carriers, oil/bulk/ore carriers, chemical tankers, bulk carriers, self-unloading	Ch. 5 of this PART

Class notation	Description		Technical requirements
		bulk carriers subject to ESP and engaged on non-international voyages, with attention being given to the special requirements of the flag States	
In-Water Survey	In-water survey	For ships suitable for in-water surveys, this notation may be assigned. The notation is not applicable to ships of 15 years of age and over with ESP notation	Ch. 12, Pt. 8 of the Rules
CHS	Continuous hull survey	Where continuous survey system for hull is adopted in lieu of special survey and items required in special survey are to be surveyed in regular rotation with uniform annual share within the five-year class period, this notation may be assigned and applies to ships other than general dry cargo ships, oil tankers, combination carriers, chemical tankers and bulk carriers only	Ch. 5 of this PART
CMS	Continuous machinery survey	Where continuous survey system for machinery is adopted in lieu of special survey and items required in special survey are to be surveyed in regular rotation with uniform annual share within the five-year class period, this notation may be assigned	Ch. 5 of this PART
SCM	Screwshaft condition monitoring	This notation may be assigned to oil-lubricated or water-lubricated propeller shafts fitted with approved shaft seals and complying with Appendix 14 "Guidelines for Screwshaft Condition Monitoring System" of Ch. 5 of this PART	Sec. 12 and Appendix 14 "Guidelines for Screwshaft Condition Monitoring System" of Ch. 5 of this PART
ECM	Diesel engine lube oil condition monitoring	This notation may be assigned to ships having lubricating oil condition monitoring system of diesel engines and complying with Appendix 15 "Guidelines for Lubricating Oil Condition Monitoring System of Diesel Engines" of Ch. 5 of this PART. Lubricating oil analysis is to cover lubricating oil in use for cylinders, pistons, piston rings, piston rods, piston pins, crossheads, crosshead pins, guides, crankshafts and all bearings, connecting rods, piston rod stuffing boxes. Results of the analysis is to be used to determine whether an overhaul is necessary analyzed through lube oil according to and other parameters	Appendix 15 "Guidelines for Lubricating Oil Condition Monitoring System of Diesel Engines" of Ch. 5 of this PART
PMS	Planned maintenance scheme (PMS) for machinery	This notation may be assigned to ships for which CCS-approved PMS is adopted as an alternative to special or continuous (if adopted) survey of machinery and electrical installations	Appendix 16 "Guidelines for Survey of Planned Maintenance Scheme (PMS) for Machinery" of Ch. 5 of this PART①
TOFD (B**+J**)	Time of flight diffraction (TOFD)	When the following welds are tested by TOFD, if the testing percentage complies with the following requirements, the corresponding notations may be assigned upon application by the ship owner. TOFD (B**+J**): B** is the percentage of section butt welds tested by TOFD; J** is the percentage of plate butt welds tested by TOFD. The percentage ranges from 20% to 100%, with 10% as the interval, e.g. TOFD(B40%+J20%), PAUT-BUTT (B40%+J20%)……. Survey extent of container ships: butt welds of longitudinal members of torsion box and hatch coaming (thickness $\geqslant$ 35 mm). Survey extent of ore carriers: butt welds of the main	Guidelines for the Application of Time-of-Flight Diffraction (TOFD) and Phased Array Ultrasonic Testing (PAUT) Techniques

① Newbuildings which are assigned PMS notation are to be subject to surveys as specified in appendix 16, Chapter 5, PART ONE of the Rules.

Class notation	Description		Technical requirements
		deck in the cargo area (thickness ≥ 35 mm). Survey extent of LNG and LPG carriers: full penetration welds of integral tanks or independent tanks, excluding membrane tanks and fillet welds). Ships intended for operation in low-temperature areas (such as icebreakers and polar research ships): full penetration butt welds of primary members of the main hull (thickness ≥ 35 mm). Other ships of 150 m and over in length: butt welds of strength deck, top strake, bilge strake, bottom shell, flat plate keel, inner bottom and longitudinal bulkhead topside tank plating as well as primary members supporting these platings within 0.4L amidships (thickness ≥35 mm), butt welds of trunk decks and continuous hatch coamings that can be included in the calculation of hull girder section modulus as well as primary members supporting these platings(thickness ≥35 mm)	
PAUT-Butt(B**+J**)	Butt welds tested by Phased array ultrasonic testing (PAUT)	When the following welds are tested by PAUT, if the testing percentage complies with the following requirements, the corresponding notations may be assigned upon application by the ship owner. PAUT-Butt(B**+J**): B** is the percentage of section butt welds tested by PAUT; J** is the percentage of plate butt welds tested by PAUT. The percentage ranges from 20% to 100%, with 10% as the interval, e.g. TOFD(B40%+J20%), PAUT-BUTT (B40%+J20%)……. Survey extent of container ships: butt welds of longitudinal members of torsion box and hatch coaming (thickness ≥ 35 mm). Survey extent of ore carriers: butt welds of the main deck in the cargo area (thickness ≥ 35 mm). Survey extent of LNG and LPG carriers: full penetration welds of integral tanks or independent tanks, excluding membrane tanks and fillet welds). Ships intended for operation in low-temperature areas (such as icebreakers and polar research ships): full penetration butt welds of primary members of the main hull (thickness ≥ 35 mm). Other ships of 150 m and over in length: butt welds of strength deck, top strake, bilge strake, bottom shell, flat plate keel, inner bottom and longitudinal bulkhead topside tank plating as well as primary members supporting these platings within 0.4L amidships (thickness ≥35 mm), butt welds of trunk decks and continuous hatch coamings that can be included in the calculation of hull girder section modulus as well as primary members supporting these platings(thickness ≥35 mm)	Guidelines for the Application of Time-of-Flight Diffraction (TOFD) and Phased Array Ultrasonic Testing (PAUT) Techniques
PAUT-Fillet (**)	Fillet welds tested by Phased array ultrasonic testing (PAUT)	For bulk carriers (ore carriers), if the length percentage of the following fillet welds tested by PAUT complies with the requirements, the corresponding notations may be assigned upon application by the ship owner. PAUT-Fillet (**)：** is the percentage of full penetration fillet welds ranging from 20% to 100%, with 10% as the interval, e.g. PAUT-Fillet (20%), PAUT-Fillet (30%)……. Survey extent: full penetration welds between the	Guidelines for the Application of Time-of-Flight Diffraction (TOFD) and Phased Array Ultrasonic Testing (PAUT) Techniques

Class notation	Description		Technical requirements
		hopper tank plating of bulk carriers/longitudinal bulkhead of ore carriers and inner bottom plating; full penetration weld connections between lower stool and the inner bottom plating; full penetration weld connections between the lower stool slope plate and lower stool shelf plate; full penetration weld connections between the lower stool shelf plate and transverse bulkhead	
DDV	Ship Digital Survey	This notation may be assigned if the ship has the conditions to carry out inspection by means of digital survey	Guidelines for Application of Ship Digital Survey

Class Notations for Green Eco-Ships ① **Table I-1**

Class notation	Description		Technical requirements
G-EP	Environmental protection	The "G-EP" class notation may be assigned to sea-going ships engaged on international voyages in compliance with applicable international conventions and codes only	Rules for Green-Eco Ships
G-EP (X)		Where it is necessary to indicate further the level of environmental protection, " X" is used to represent the sub-elements as follows: OILx-- control of discharge of oil pollutants, where x is 1 or 2; EAL-- environmental acceptable lubricants; IBTS-- integrated bilge water treatment system; NLSx-- control of discharge of noxious liquid substances, where x is 1 or 2; SC-- control of discharge of sewage; GWC-- control of discharge of grey water; RC-- control of discharge of garbage; NECx-- control of NOx emission, where x is 1 or 2; SEC-- control of SOx emission; VCS/VCS-T-- VOC emission control; RSCx-- control of refrigeration system; INC-- emission control of incineration operation on board; BC20, BC70-- emission control of black carbon; AFS/AFS +-- anti-fouling systems; GPR/GPR+-- green passport; GPR（EU）/GPR（EU）+ -- green passport (EU)	
G-ECO	Ecological protection	The "G-ECO" class notation may be assigned to sea-going ships engaged on international voyages in compliance with applicable international conventions and codes only	Rules for Green-Eco Ships
G-ECO (X)		Where it is necessary to indicate further the level of ecological protection, " X" is used to represent the sub-elements as follows: CDx-- CO_2 emission design index for newbuildings, where "x" represents the percentage ratio of the ship's Attained EEDI value lower than the reference line value for that ship; CDEx-- CO_2 emission design index for ships in service, where "x" represents the percentage ratio of the ship's Attained EEDI value lower than the reference line value for that ship; COM-- CO_2 emission operation management; BWM（T）-- ballast water treatment; BWM（Es）-- ballast water sequential method; BWM（Ef）-- ballast water flow-through method; BWM（Ed）-- ballast water dilution method;	

① Sea-going ships engaged on international voyages.

Class notation	Description		Technical requirements
		BWM（O）-- other management method of ballast water; BIO-- biofouling management; VIBx-- comfort onboard (vibration), where x is 1 or 2 or 3, and 3 means the highest grade; NOIx-- comfort onboard (compartment noise), where x is 1 or 2 or 3, and 3 means the highest grade; CLx-- comfort onboard (indoor climate), where x is 1 or 2 or 3, and 3 means the highest grade; UW-- underwater noise; RN-- ambient noise.	

Class Notations for Green Eco-Ships [①] **Table I-2**

Class notation	Description		Technical requirements
Gd-EP	Environmental protection	The “Gd-EP” class notation may be assigned to sea-going ships engaged on domestic voyages in compliance with the applicable requirements of the Technical Regulations for Statutory Surveys of Sea-going Ships Engaged on Domestic Voyages of the Maritime Safety Administration of the People's Republic of China only	Rules for Green-Eco Ships
Gd-EP (X)		Where it is necessary to indicate further the level of environmental protection, “X” is used to represent the sub-elements as follows: OILx-- control of discharge of oil pollutants, where x is 1 or 2; EAL-- environmental acceptable lubricants; IBTS-- integrated bilge water treatment system; NLSx-- control of discharge of noxious liquid substances, where x is 1 or 2; SC-- control of discharge of sewage; GWC-- control of discharge of grey water; RC-- control of discharge of garbage; NECx-- control of NOx emission, where x is 1 or 2; SEC-- control of SOx emission; VCS/VCS-T-- VOC emission control; RSCx-- control of refrigeration system; INC-- emission control of incineration operation on board; GBEC-- emission control of diesel engine exhaust pollutant; AFS/AFS +-- anti-fouling systems; GPR-- green passport	
Gd-ECO (X)	Ecological protection	The “Gd-ECO(X)” class notation may be assigned to sea-going ships engaged on domestic voyages in compliance with applicable requirements of the Rules for Green Eco-Ships, where “X” represents the sub-elements as follows: CDx-- CO_2 emission design index, where “x” represents the percentage ratio of the ship’s Attained EEDI value lower than the reference line value (RLV) for that ship; COM-- O_2 emission operation management; VIBx-- comfort onboard (vibration), where x is 1 or 2 or 3, and 3 means the highest grade; NOIx-- comfort onboard (compartment noise), where x is 1 or 2 or 3, and 3 means the highest grade; CLx-- comfort onboard (indoor climate), where x is 1 or 2 or 3, and 3 means the highest grade; UW-- underwater noise; RN-- ambient noise.	Rules for Green-Eco Ships

① Sea-going ships engaged on domestic voyages.

Refrigerated Cargo Installation Notations **Table J**

Class notation	Description		Technical requirements
CRS (×× Hold ××℃, ××℃ Max. Sea Water)	Refrigerated cargo	For ships fitted with refrigerated cargo installations, this notation is to be added after type notation, and minimum temperature(s) to be maintained by the installation at maximum sea water temperature stated and cargo area covered by the minimum temperature(s) are to be stated	Ch. 1 to Ch. 3, Pt. 5 of the Rules
CF	Preservation of fruit	For refrigerated installations for cargo fruits, this notation is to be added	Ch. 1 to Ch. 3, Pt. 5 of the Rules
CRC (×× Holds), AC f/WC	Carriage of refrigerated containers in holds	For container ships capable of carrying refrigerated containers in holds, this notation may be added, where: AC — Air-cooled refrigerated containers; f — Simultaneity factor for refrigerating plant; WC — Water-cooled refrigerated containers	Ch. 4, Pt. 5 of the Rules

Other Notations **Table K**

Class notation	Description		Technical requirements
EOM	Ship's energy efficiency real-time on-line monitoring	Capable of monitoring ship's operation in real time and supporting decision on operational energy efficiency management and optimization by collecting operational parameters of ship's energy-consuming equipment and navigational equipment and synchronizing with shore-based equipment	Sec. 7, Ch. 6 of this PART
HIMS	Hull inspection and maintenance scheme	Periodical inspection and maintenance scheme for hull structure and deck equipment. By implementation of scheme, which is implemented by means of computerized management system, improving the management level of crew and superintendent in terms of inspection and maintenance of hull structure and deck equipment, avoiding any impact on the normal operation of ships due to unplanned repair, improving the hull structural safety management level and achieving scientific management of ships	Guidelines for Hull Inspection and Maintenance Scheme
Crew Accommodation (MLC)	Accommodation of crew members	This notation may be assigned to ships meeting the plan approval and construction requirements for accommodation of crew members on board sea-going ships in CCS Guidelines, in addition to statutory requirements for accommodation of crew members	Guidelines for Implementation of Inspections of Maritime Labour Conditions

APPENDIX 2 DIAGRAMS OF MANDATORY SHIP TYPES FOR SHIPS HAVING ESP NOTATION

1 Preamble

1.1 The regime of enhanced surveys as specified in Sections 6, 7 and 8, Chapter 5 of this PART is applicable to a number of ship types falling within the broad definitions of oil tankers, chemical tankers and bulk carriers.

1.2 To clearly indicate to shipowners and the users of CCS Register of Ships those ships which are subject to an enhanced survey programme, the notation ESP is to be added after the type notation assigned to all such ships, built and/or maintained in accordance with the Rules.

1.3 Survey requirements can be found in:

(1) Section 6, Chapter 5 of this PART for oil tankers;

(2) Section 7, Chapter 5 of this PART for single side skin bulk carriers①;

(3) Section 8, Chapter 5 of this PART for chemical tankers;

(4) Section 7, Chapter 5 of this PART for ore carriers, depending on the structural configuration;

(5) Sections 6 and 7, Chapter 5 of this PART for combination carriers (ore/oil and oil/bulk/ore), depending on the structural configuration.

(6) Section 7, Chapter 5 of this PART for self-unloaders, depending on the structural configuration.

2 Ship Type and Enhanced Survey Programme (ESP) Notations

2.1 Oil tanker

The ship type notation "Oil Tanker", or equivalent, and the notation "ESP" are to be assigned to sea-going self-propelled ships② which are constructed with integral cargo tanks and intended primarily to carry oil in bulk. This type notation is to be assigned to tankers of both single and double hull construction, as well as tankers with alternative structural arrangements, e.g. mid-deck designs. Typical midship sections are given in Figure 2.1.

Note: Oil tankers that do not comply with MARPOL I/19 may be subject to International and/or National Regulations requiring phaseout under MARPOL I/20 and/or MARPOL I/21.

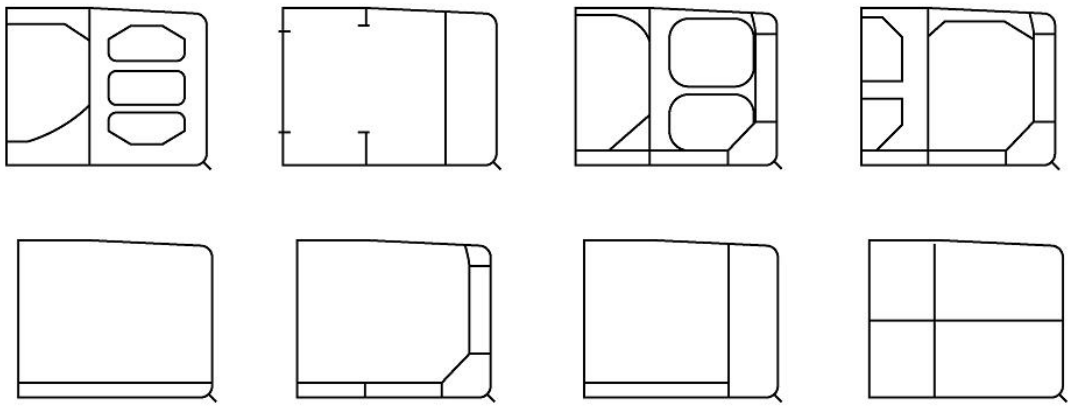


Figure 2.1

2.2 Bulk carrier

The ship type notation "Bulk Carrier", or equivalent, and the notation "ESP" are to be assigned to sea-going self-propelled ships[2] which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in cargo length area and intended primarily to carry dry cargoes in bulk. Typical midship sections are given in Figure 2.2.

---

① For bulk carriers with hybrid cargo hold arrangements, i.e. with some cargo holds of single side skin and others of double side skin, the requirements of Section 7, Chapter 5 of this PART are to apply to cargo holds of single side skin.

② Self-propelled ships are ships with mechanical means of propulsion not requiring assistance from another ship during normal operation.

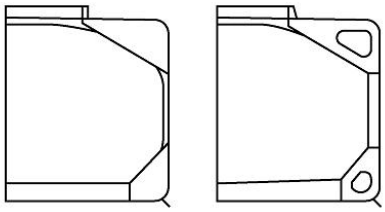


Figure 2.2

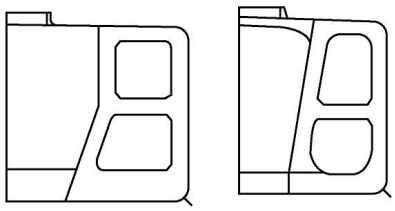


Figure 2.3

2.3 Ore carrier

The ship type notation “Ore Carrier”, or equivalent, and the notation “ESP” are to be assigned to sea-going self-propelled ships① which are constructed generally with single deck, two longitudinal bulkheads and a double bottom throughout the cargo length area and intended primarily to carry ore cargoes in the holds only. Typical midship sections are given in Figure 2.3.

2.4 Combination carrier

(1) “Combination carrier” is a general term applied to ships intended for the carriage of both oil and solid cargoes in bulk; these cargoes are not carried simultaneously, with the exception of oily mixture retained in slop tanks. The ship types defined in (2) and (3) below are to be considered to be combination carriers.

(2) The ship type notation “Ore/Oil Carrier”, or equivalent, and the notation “ESP” are to be assigned to sea-going self-propelled sea-going ships which are constructed generally with single deck, two longitudinal bulkheads and a double bottom throughout the cargo length area and intended primarily to carry ore cargoes in the centre holds or of oil cargoes in centre holds and wing tanks. Typical midship sections are given in Figure 2.4.

Note: Ore/Oil carriers that do not comply with MARPOL I/19 may be subject to International and/or National Regulations requiring phaseout.

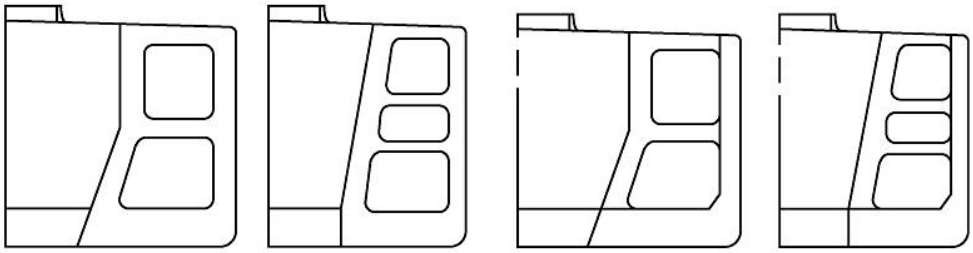


Figure 2.4

(3) The ship type notation “Oil/Bulk/Ore (OBO) carrier”, or equivalent, and the notation “ESP” are to be assigned to sea-going self-propelled ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks, and with single or double side skin construction in the cargo length area, and intended primarily to carry oil or dry cargoes, including ore, in bulk. Typical midship sections are given in Figure 2.5.

Note: Oil/Bulk/Ore carriers that do not comply with MARPOL I/19 may be subject to International and/or National Regulations requiring phaseout.

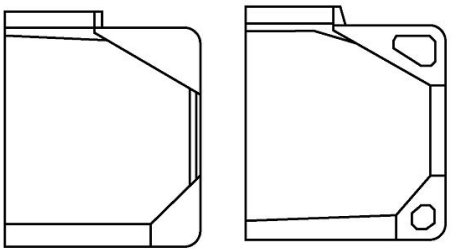


Figure 2.5

2.5 Self-unloaders

The ship type notation “Self-Unloaders", or equivalent, and the notation "ESP" are to be assigned to

① Self-propelled ships are ships with mechanical means of propulsion not requiring assistance from another ship during normal operation.

sea-going self-propelled ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in cargo length area and intended to carry and self-unload dry cargoes in bulk. Typical midship sections are given in Figure 2.6.

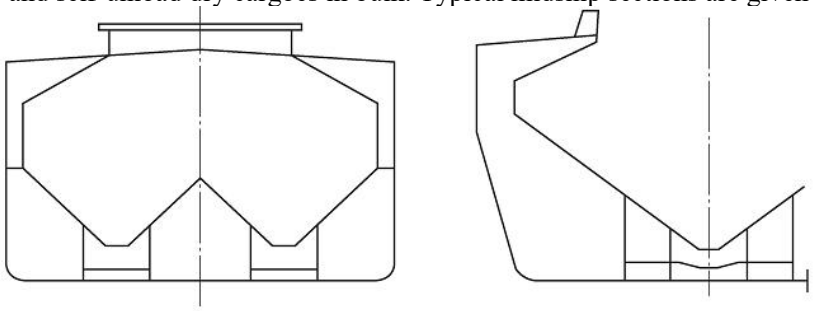


Figure 2.6

2.6 Chemical Tanker

The ship type notation “Chemical Tanker”, or equivalent, and the notation “ESP” are to be assigned to sea-going self-propelled ships which are constructed generally with integral tanks and intended primarily to carry chemicals in bulk. This type notation is to be assigned to tankers of both single or double hull construction, as well as tankers with alternative structural arrangements. Typical midship sections are given in Figure 2.7.

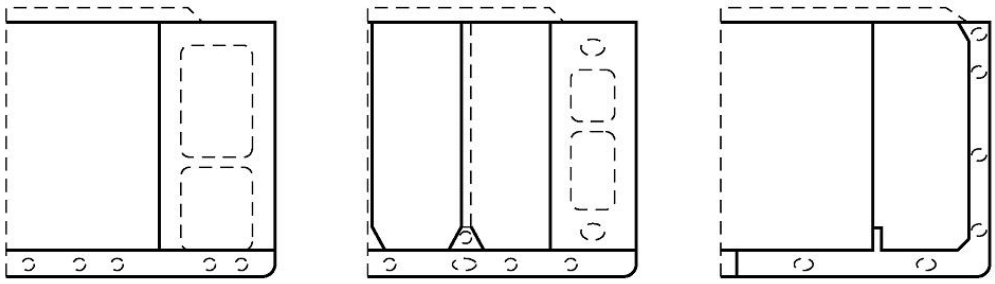


Figure 2.7

CHAPTER 3 INSPECTIONS OF PRODUCTS

Section 1 GENERAL PROVISIONS

3.1.1 General requirements

3.1.1.1 Inspections of products are part of the ship survey, including inspections of products to be classed, delegated inspections of statutory products and entrusted inspections of other products. These inspections are to confirm that the products meet the requirements of the rules for classification or statutory requirements or the requirements of the entrusting party.

3.1.1.2 The products intended for classed ships are to be inspected in accordance with this Chapter and in addition, with relevant Chapters of the Rules and CCS Rules for Materials and Welding.

3.1.1.3 For the products intended for other ships, reference is to be made to provisions of this Chapter.

3.1.1.4 For the products required by the rules, appropriate standards may be accepted as alternative requirements. In any case, however, the equipment, components and systems are to be subject to drawing and document examination, prototype/type test and inspections during manufacturing, testing and functional tests for confirming that they are not less effective than as required by the rules.

3.1.1.5 Where no technical requirements are specified for any products covered by the Rules, they may be designed, manufactured and tested according to applicable standards at the discretion of the manufacturer. The confirmation of technical requirements for such products are in general to include:

(1) drawings and information;

(2) conditions for use on board;

(3) requirements for materials and welding;

(4) test items relating to safety and performance.

3.1.1.6 The manufacturer is to be responsible for compliance with relevant law, regulations, compulsory standards or customers' requirements by the products.

3.1.1.7 Class notations of the product are to be applied by the applicant and assigned by CCS after compliance with CCS relevant provisions is verified by CCS plan approval, approval test and on-site audit.

3.1.2 Definitions

3.1.2.1 For the purpose of products inspections required by the Rules:

(1) **Products inspection** means the process of evaluating the compliance of the products with applicable requirements through drawing examination, prototype/type test, document examination and testing of the final products and/or during their manufacturing, including unit/batch inspection, design approval, type approval and works approval.

(2) **Unit/batch inspection** means the unit-by-unit or batch-by-batch inspection of products by CCS Surveyor for the purpose of issuing a products certificate/equivalent document.

(3) **Design approval (DA)** means the evaluation process whereby CCS confirms that product design meets requirements of CCS rules and/or other acceptable standards through drawing examination and prototype test.

Note: Design approval specified in Chapter 9, PART THREE of the Rules refers to the process of evaluating all drawings, data and calculations related to the diesel engine design. For details, see Chapter 9, PART THREE of the Rules.

(4) **Type approval (TA)** means the evaluation process whereby the manufacturer's ability and condition to produce consistent products in compliance with CCS rules and/or other acceptable standards is confirmed by CCS through drawing examination, type test and on-site audit. Depending on the ability and level of quality assurance of the manufacturer, the type approval is divided into modes A and B.

(5) **Works approval (WA)** means the evaluation process whereby the manufacturer's ability and condition of continuously producing products meeting requirements of CCS rules and/or other acceptable standards are confirmed by CCS through documentation review or drawing examination, type test and on-site audit.

(6) **Type test** means testing of the sample as defined in (9) below including its materials and components by a specified method for confirming compliance with all requirements of technical specifications or designated standard(s).

(7) **Prototype test** means testing of the prototype as defined in (8) below including its materials and components for evaluating the product design.

(8) **Prototype** means a model product manufactured to the design which is to be evaluated for compliance with applicable requirements.

(9) **Sample** means a representative product used for test/inspection. The selected sample is to be, in respect to performance, characteristics and manufacturing quality, capable of representing or covering the products or product series to be inspected.

(10) **Inspection** means the document review, examination and test carried out by the Surveyor for products' compliance with relevant requirements of rules, statutory regulations and standards before commencement and/or during process and/or after completion of production.
(11) **Final inspection** means acceptance inspection and test witnessed by the Surveyor at final stage.
(12) **Applicant** means an organization applying for an inspection of products by CCS. An applicant may be a manufacturer, an agency or a design institute.
(13) **Audit** means a systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve the stated objectives.
(14) **Periodical audit** means an audit for confirming continued compliance with the certificate of type approval or the certificate of works approval.
(15) **Additional audit** means an audit carried out by CCS in accordance with the specific requirements. Specific requirements mean situations as deemed necessary by CCS, such as changes to the design, manufacturing process or testing, major production problems or major product delivery problems and reinstatement of the suspended approval certificate.
(16) **Components** mean parts/members forming a piece of equipment and/or a system.
(17) **Design** means all relevant drawings, documents and calculation reports describing the performance, installation and manufacturing technologies of products.
(18) **Documentation** means all necessary written information regarding design, processes, products or services.
(19) **Manufacturer** means an organization producing and/or assembling final products and fully responsible for such products.
(20) **Document** means a formal document showing compliance of a design, product, service or process with specified requirements.
(21) **Manufacturer's document** means statements or certificates issued by the manufacturer as the result of exercising his inspection duty, showing that the products meet relevant requirements.
(22) **Test report** means a document issued by manufacturer, showing that the completed inspection and test of the samples from the existing products has met the requirements for the products.
(23) **Equivalent document** means certificates, reports, etc. issued not in the name of CCS, but stamped by CCS and endorsed by CCS Surveyor, showing that the products have been satisfactorily inspected according to CCS requirements.
(24) **Class notations** indicate different features of a product in sequence, and will be appended on approval and/or product certificates, which are optional.
(25) **Approval of class notations** means that the manufacturer's ability of continuously producing products meeting requirements of CCS additional requirements are confirmed by CCS through documentation review, approval test and on-site audit, which is optional.
(26) **Alternative Certification Scheme (ACS)** means a certification scheme through which classification society will evaluate manufacturer's quality assurance and quality control arrangement and authorize the manufacturer to replace classification society's surveyor in undertaking and witnessing tests after confirming the compliance of the arrangement with the Rules.
(27) **Principle approval** means the evaluation process of confirming the feasibility of the product and/or technology through the review of the technical plan and technical principle of the product design in advance and the necessary verification test. Principle approval is the approval in principle given at the product development stage, and it is a technical certification service that clients voluntarily request CCS to provide during the development of new products and new technologies.

3.1.3 Requirements for manufacturers

3.1.3.1 Manufacturers of classed products used for construction or repair of the ships classed or intended to be classed with CCS are to apply for inspection of such products by CCS.
3.1.3.2 Unless otherwise provided by the Administration of the flag State, manufacturers of statutory products used for construction or repair of the ships, of which CCS is authorized to carry out statutory surveys, are to apply for inspection of such products by CCS.
3.1.3.3 In addition to 3.1.3.1 and 3.1.3.2, CCS may carry out inspections of products for compliance with the standards provided by the applicant (e.g. rules, or SOLAS Convention, or relevant codes of IMO, or provisions of the Administration or standards provided by the applicant).
3.1.3.4 Manufacturers, who apply for approval and inspection by CCS, are to meet appropriate conditions for production, testing, resources and quality management system in accordance with the relevant requirements of this Chapter.
3.1.3.5 Manufacturers are to exercise an effective control over the quality of raw materials, components

and parts of their products, submit to CCS for information lists of suppliers of raw materials, components and parts having direct influence on the quality of their products, and assist CCS in getting necessary information of suppliers. Where CCS rules and guidelines require that raw materials, components and parts should be certified, the related suppliers and their products are to be approved and/or inspected by CCS.

3.1.3.6 Manufacturers are to carry out product manufacturing according to the requirements of CCS Rules and/or approved drawings or technical documents, carry out inspection/test unit-by-unit or by sampling and apply for CCS inspection based on satisfactory judgment.

3.1.3.7 The manufacturer is to notify CCS promptly when any serious quality problems of production or products are found.

3.1.4 Basic requirements for products inspections

3.1.4.1 The products required by CCS rules are, prior to their use or installation on ships classed with CCS or during their manufacturing, to be inspected according to relevant requirements to confirm compliance with CCS rules, and an appropriate certificate as specified in 3.1.5.2 is to be issued.

3.1.4.2 CCS implements the following 3 modes of products approval (approval process as shown in Figure 3.1.4.2):

(1) design approval;

(2) type approval, as type approval A and type approval B;

(3) works approval.

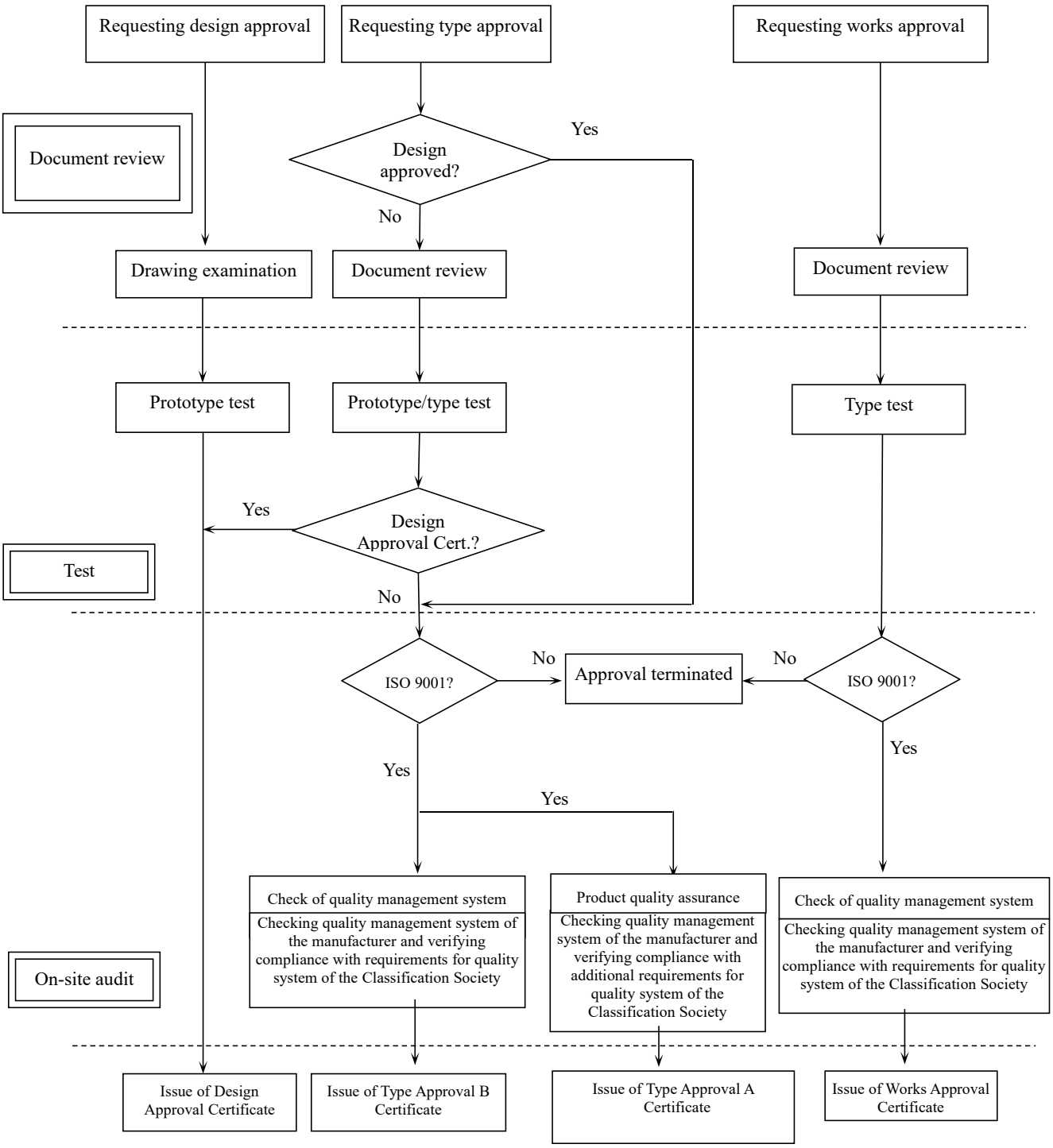


Figure 3.1.4.2

3.1.4.3 The products' manufacturing characteristics and representativeness of inspection samples are basis for distinguishing type approval and works approval. Applicable approval modes are shown in Appendix of this Chapter.

3.1.4.4 In addition to the products to be approved as specified in CCS rules and/or statutory requirements, the manufacturer may apply for approval of one or more types of products for one or more of the following purposes:

(1) providing products of which the type approval is required by CCS rules;

(2) avoiding repeated drawing examination and prototype/type test for the same products;

(3) replacing the Surveyor by the manufacturer in carrying out a part of or complete on-site inspections;

(4) desiring that his products be entered into CCS Lists of Approved Marine Products.

3.1.4.5 Where the products have been approved in one or more modes, the specified unit/batch inspection requirements may be replaced with the following:

(1) reducing the inspection items requiring attendance by the Surveyor;

(2) replacing the Surveyor by the manufacturer in carrying out a part of or complete on-site inspections; verifying by the Surveyor of production and quality control information provided by the manufacturer.

3.1.4.6 The manufacturer is to make preparations for inspection and provide sufficient and safe conditions for inspection so as to ensure that the Surveyor is capable of:

(1) having access to products for carrying out the specified inspection;

(2) witnessing specified tests of products on site;

(3) obtaining documents, records and information necessary for the inspection, including information of suppliers of raw materials, components and parts.

3.1.4.7 Where required by CCS rules and guidelines, the raw materials, components and parts used for products are also to be certified accordingly and/or their manufacturers are to be approved by CCS.

3.1.4.8 The products, for which type approval or works approval is granted, are to be produced at the manufacturer's production facilities stated in the approval certificate, and CCS does not accept any inspection of those approved products which are subcontracted.

3.1.4.9 With approval by CCS, relevant parties carrying out production by OEM or ODM may apply for approval by CCS, sign written agreement relating to product design, manufacture and quality control and submit it to CCS.

3.1.4.10 Where any harmful defect or damage is caused by raw materials or main components and parts to approved products, the manufacturer is to promptly inform CCS of this and take one or more of the following measures:

(1) suspension of the manufacturing of such products, investigation and analysis of the quality and the safety effects of such products installed onboard;

(2) termination of their use for approved products;

(3) re-evaluation of supplier(s);

(4) disqualification of supplier(s).

Where the measure stated in (1) above is considered necessary by CCS, the approval will be suspended.

3.1.4.11 The nameplate, usage identification, usage/operation instructions and quality certificate (including standards used as basis, product performance, quality assurance, liability, etc.) of the products inspected by CCS are to be in a language specified by the ordering party, with at least an English translation for ships engaged on international voyages.

3.1.5 Documents

3.1.5.1 Approval certificates

(1) An appropriate approval of the product by CCS is to be certified as follows:

① Design Approval Certificate (DAC) issued by CCS, showing compliance of the design with CCS rules;

② Type Approval Certificate (TA-BC and TA-AC) issued by CCS, showing that the design complies with CCS rules and that the manufacturer has the ability to continuously produce in batches the products in compliance with rules and/or recognized standards;

③ Works Approval Certificate (WAC) issued by CCS, showing that the manufacturer has the ability to produce the products required by CCS rules;

④ Class Notation Approval Certificate (AAC) issued by CCS, showing that the products meet additional requirements of CCS rules/guidelines.

(2) The Design Approval Certificate, Type Approval Certificate, Works Approval Certificate and Marine Products Certificate are documents of compliance for products at different stage aiming at different requirements, and they cannot replace each other.

3.1.5.2 Products documents

(1) A unit/batch inspection of classed or statutory products is to be documented as follows:

① Marine Products Certificate:

A document issued by the Surveyor to show that:

a. the product complies with rules;

b. required inspection and test have been carried out;

c. the sample is taken from the product to be inspected;

d. the product has been tested in the presence of the Surveyor, or a recognized independent third-party service firm of inspection and testing accepted by CCS, or in a specially agreed

condition.

② Equivalent document[①]:

A document issued by the manufacturer, stamped by CCS and endorsed by the Surveyor to show that:

a. the product complies with rules;
b. required inspection and test have been carried out;
c. the sample is taken from the product to be inspected;
d. the product has been tested in the presence of the Surveyor, or a recognized independent third-party service firm of inspection and testing accepted by CCS, or in a specially agreed condition.

(2) The classed and statutory products of which the type approval and/or works approval is required but the products certificate is not required, are to provide type approval and/or works approval certificates and may be certified as follows:

① Manufacturer's document (W) is issued by the manufacturer to show that:

a. the product is type approved or works approved by CCS;
b. the product complies with rules;
c. required inspection and test have been carried out;
d. the sample is taken from the product to be inspected;
e. the product has been tested and endorsed in the presence of the department's representative authorized by the manufacturer.

(3) An inspection of products other than those specified in rules or statutory requirements is to be documented as follows:

① Inspection certificate of marine products:

A document issued by the Surveyor to show that:

a. the product standards as determined by the applicant have been complied with;
b. the inspection and test has been witnessed by the Surveyor and/or the test report has been reviewed by him;
c. the test sample is taken from the product to be inspected.

② Test certificate of marine products:

A document issued by the Surveyor to show that:

a. the product has been tested in the presence of the Surveyor;
b. the test sample is taken from the product to be inspected.

3.1.5.3 The requirements for certificates of classed and statutory products and lifting appliances are given respectively in Appendices of this Chapter. These appendices are to be used in accordance with 4.2.1.2 of Chapter 4. Products with approval and/or inspection requirements by appendices of this Chapter are not to be issued with inspection certificate and inspection certificate.

3.1.5.4 If deemed necessary, the Surveyor may require to attend the test of the products which may hold a manufacturer's document (W), or examine the control of their manufacturing quality.

3.1.6 Conditions for use of inspection marks

3.1.6.1 The marine products inspected by CCS are to be stamped with an inspection mark on the body of the products and/or at their nameplates. According to the way in which an inspection is carried out, one of the following inspection marks is to be stamped:

Mark A

Mark B

(1) Mark A indicates that the product has been satisfactorily inspected and tested in the presence of the Surveyor;

(2) Mark B indicates that the product has been inspected by the manufacturer according to CCS

---

① The contents of an equivalent document are to comply with the following requirements:

a) the units of measurement are to be consistent with those in rules or international units (i.e. SI units) are to be used;
b) symbols used for properties and characteristics (e.g. tensile strength and impact property of materials) of products are to be consistent with those in CCS rules and if any other symbol is adopted, a definition is to be given;
c) the basis for inspection is to be identified;
d) the identification of products (e.g. cast/batch no.) and that of inspection are to be identified;
e) a manufacturer's statement is to be contained to the effect that "testing has been satisfactorily completed in accordance with CCS rules, or technical specifications for acceptance or relevant standards approved or accepted by CCS".

requirements not in the presence of the Surveyor and that the inspection results have been confirmed by CCS as satisfactory; or that the product has been inspected and tested in the presence of the Surveyor, but such marks are affixed by the authorized manufacturer to satisfactorily inspected products.

3.1.6.2 Mark A is only for use by the Surveyor. The use of mark B is delegated to inspection personnel of the manufacturer according to an approved inspection scheme.

3.1.6.3 The inspection marks are to be affixed by a steel stamp so far as is practicable, generally on a readily accessible non-working face and/or nameplate of the product. If this is impracticable, fake-proof CCS inspection poster or other marking means agreed by CCS may be used. The distribution of the steel stamps or other marks is to be controlled.

3.1.6.4 The style and size of an inspection mark to be used by the manufacturer as delegated by CCS are to be confirmed by CCS for information prior to use.

3.1.6.5 The style of the inspection mark stamped on products is to be reflected conformably on the Marine Products Certificate or equivalent document.

3.1.6.6 Where any product, which has been stamped with an inspection mark, is found unsatisfactory in the subsequent inspection, measures are to be taken to remove the mark.

3.1.7 Conditions for use of approved product logos

3.1.7.1 When a product is eligible for approval in accordance with the relevant requirements of this Chapter, the manufacturer may use CCS logo as an approved product logo, provided that following requirements are complied with:

(1) The logo may only be used on advertising and promotional material and must not be used except in connection with those products or services described in the approval certificate.

(2) Where the logo is used directly on or closely linked to products, it does not imply that such products themselves are found satisfactory by CCS in any unit/batch inspection.

(3) If used with other logos, any misunderstanding must be avoided. CCS may ask that the manufacturer discontinue any use of other logos that are unacceptable to CCS.

(4) Upon the invalidation of CCS approval certificate, the manufacturer must immediately discontinue all use of the logo and to dispose all stocks of material on which the logo appears.

(5) The logo may be scaled uniformly to any size necessary. The manufacturer is not to make any unauthorized change to the letters or graphics of the logo or their combination.

(6) Without authorization by CCS, the manufacturer is not to allow any third party to use the logo in whatever form and for whatever reason.

(7) If CCS has clear evidence for believing that the manufacturer is in contravention of the provisions for using the logo, it will cancel the approval certificate and terminate the approval of other products of the manufacturer.

(8) CCS shall not be responsible and liable for any economic and legal consequences arising from the use by the manufacturer of the logo.

3.1.7.2 The approved product logos① are shown below:

3.1.8 Invalidation, suspension, cancellation and reinstatement of approval certificate

3.1.8.1 The approval certificate will be automatically invalid in one of the following conditions:

(1) any unauthorized alteration has been made to the certificate by its holder;

(2) any convention, law, rule or standard applicable to the existing approved products has been abolished;

(3) any major change has been made to the design (see 3.1.2.1(17)) or documentation (see 3.1.2.1(18)) of products without approval by CCS;

(4) any change has been made to the mode of production without approval by CCS; or

(5) a periodical audit by CCS has not been accepted as required.

3.1.8.2 CCS will suspend the certificate within the period of its validity when CCS identifies that one of the following conditions exists at the manufacturer:

(1) a periodical audit by CCS has not been accepted as required;

(2) any serious nonconformity of the approved products is found during a periodical audit;

---

① Where the use of any logo is permitted by CCS, a sample of such logo will be provided to the manufacturer.

(3) any nonconformity found during a periodical audit has not been rectified as required;
(4) any major change has been made to the quality management system of the manufacturer without notification to CCS;
(5) quality problems of products are caused by ineffective operation of the quality management system of the manufacturer;
(6) any change affecting product performance and safety has been made to approved major raw materials and/or components and parts without approval by CCS;
(7) no remedial action has been promptly taken against quality problems of products or no assistance given to investigation by CCS;
(8) the approved product logos of CCS are not used according to relevant provisions;
(9) relevant fees have not been paid on time;
(10) any other condition identified by CCS for which suspension of the certificate is necessary.

3.1.8.3 CCS will cancel the certificate within the period of its validity when CCS identifies that one of the following conditions exists at the manufacturer:
(1) the condition leading to suspension of the certificate has not been rectified within the specified period, or suspension of the certificate has continued for 6 months;
(2) the products installed or used on board a ship classed with CCS have been produced at the facilities not stated in the certificate (including the approved products being subcontracted or the approved products being produced by another manufacturer under the same brand) without approval by CCS;
(3) the approval certificate and/or the marine products certificate is used not according to CCS requirements, and the ordering party has been intentionally misled to install or use products, which have actually not been inspected by CCS as required, on board a ship classed with CCS;
(4) CCS inspection marks are not used according to CCS requirements;
(5) any CCS marine products certificate or inspection mark has been counterfeited;
(6) there was any fraud, falsification, deliberate concealment of facts or any other illegal conduct on the part of the manufacturer in the process of design, manufacture or survey of marine products;
(7) any serious nonconformity of the approved products is found during a periodical audit and has not been corrected within specified period;
(8) any other condition identified by CCS for which cancellation of the certificate is necessary.

3.1.8.4 Reinstatement of approval certificate
(1) Reinstatement of approval certificate is not allowed after it is invalidated or canceled.
(2) If the approval certificate is suspended, the customer may apply for reinstatement of the certificate if the conditions for reinstatement are satisfied. If the certificate is still within its validity period and it is confirmed by CCS that the reinstatement conditions are satisfied by the customer, the approval qualification can be reinstated, and the certificate will remain valid with its validity period subject to confirmation by CCS. If the customer fails to satisfy the reinstatement conditions within 3 months, the certificate will become invalid, and the customer is to go through formalities for cancellation of approval certificate. If the approval certificate expires during the suspension period, the certificate will automatically become invalid.

3.1.9 Cancellation of marine product certificate/equivalent document

3.1.9.1 Marine product certificate/equivalent document will be automatically cancelled in one of the following conditions:
(1) any unauthorized alteration has been made to the certificate by its holder;
(2) CCS is not informed in a timely manner as required or no remedial action has been taken to quality problems of products or no assistance given to investigation by CCS;
(3) any fraud, falsification, intentional concealing of facts or any other illegal conduct on the part of the manufacturer in obtaining certificate;
(4) relevant fees have not been paid on time;
(5) any other condition identified by CCS for which cancellation of the certificate is necessary;
(6) after the product is furnished with a certificate, any change which is inconsistent with the product design and documents approved by CCS has been made to the product, or the product has been adjusted in accordance with procedures not approved by CCS.

3.1.10 Intellectual property rights and confidential principles

3.1.10.1 The applicant shall promise legal possession of submitted drawings and documents and be responsible for the truthfulness and completeness of application and submitted drawings and documents. CCS will not be liable for any loss, damage or legal responsibilities arising from truthfulness and completeness of submitted documents and property of drawings and documents.

3.1.10.2 CCS is responsible for keeping confidentiality of drawings and technical documents submitted by the applicant. Except for legal litigation, without written authorization of the applicant, disclosure shall not be made to any other person or entity irrelevant to product design, manufacturer and maintenance. The application conditions of information disclosure are shown in 2.12.2 of this PART.

Section 2 UNIT/BATCH INSPECTIONS

3.2.1 Application

3.2.1.1 Unless otherwise provided, the unit/batch inspection procedure of this Section applies to the products with CCS marine product certificate/equivalent document.

3.2.1.2 Appendix 1A of this Chapter is the List of Certification Requirements for Classed Marine Products, as required for the ships classed with CCS.

3.2.1.3 Appendix 1B of this Chapter is the List of Certification Requirements for Statutory Marine Products, as required for the statutory services delegated to CCS.

3.2.1.4 Appendix 1C of this Chapter is the List of Certification Requirements for Lifting Appliances, as required for the issue of certificates relevant to lifting appliances by CCS.

3.2.1.5 Appendix 1D of this Chapter is the List of Certification Requirements for Liquefied Natural Gas Specialized Products, as required for the issue of certificates relevant to liquefied natural gas carriers and ships powered by natural gas as fuel by CCS.

3.2.1.6 Appendix 1E of this Chapter is the List of Certification Requirements for Methanol Fuel System Specialized Products, as required for the issue of certificates relevant to ships powered by methanol as fuel by CCS.

3.2.1.7 Appendix 1F of this Chapter is the List of Certification Requirements for Ammonia Transport and Ammonia Fuel Specialized Products, as required for the issue of certificates related to liquid ammonia carriers and ships powered by ammonia as fuel by CCS.

3.2.1.8 Appendices 2A, 2B and 2C of this Chapter are list of certification requirements for material and components of products of Appendices 1A, 1B and 1C respectively. Except for diesel engines, boilers, pressure vessels and lifting appliances, certification requirements for raw material of general machinery and electrical installations are not shown in Appendices 2A, 2B and 2C.

3.2.2 General requirements

3.2.2.1 Unless specially considered by CCS, the statutory products, classed materials, and essential machinery and electrical equipment as specified in Appendices of this Chapter are to be subject to unit/batch inspection after approval of such products (specific products are given in Appendices of this Chapter). For the products of which the approval is not required in Appendices of this Chapter, CCS will make an appropriate assessment of the production capability and conditions of the manufacturer, when receiving his initial application for unit/batch inspection, to determine whether or not to accept the application.

3.2.2.2 In general, the procedure of unit/batch inspection consists of the following process (see Figure 3.2.2.2):

(1) examination of drawings and technical documents (hereinafter referred to as “drawing approval”), or prototype/type test or measurement, for confirming compliance with CCS rules or other recognized standards;

(2) inspection and test during manufacturing and/or of final products for confirming compliance with CCS rules and/or approved design drawings;

(3) the Marine Products Certificate or an equivalent document is issued to the products complying with relevant requirements.

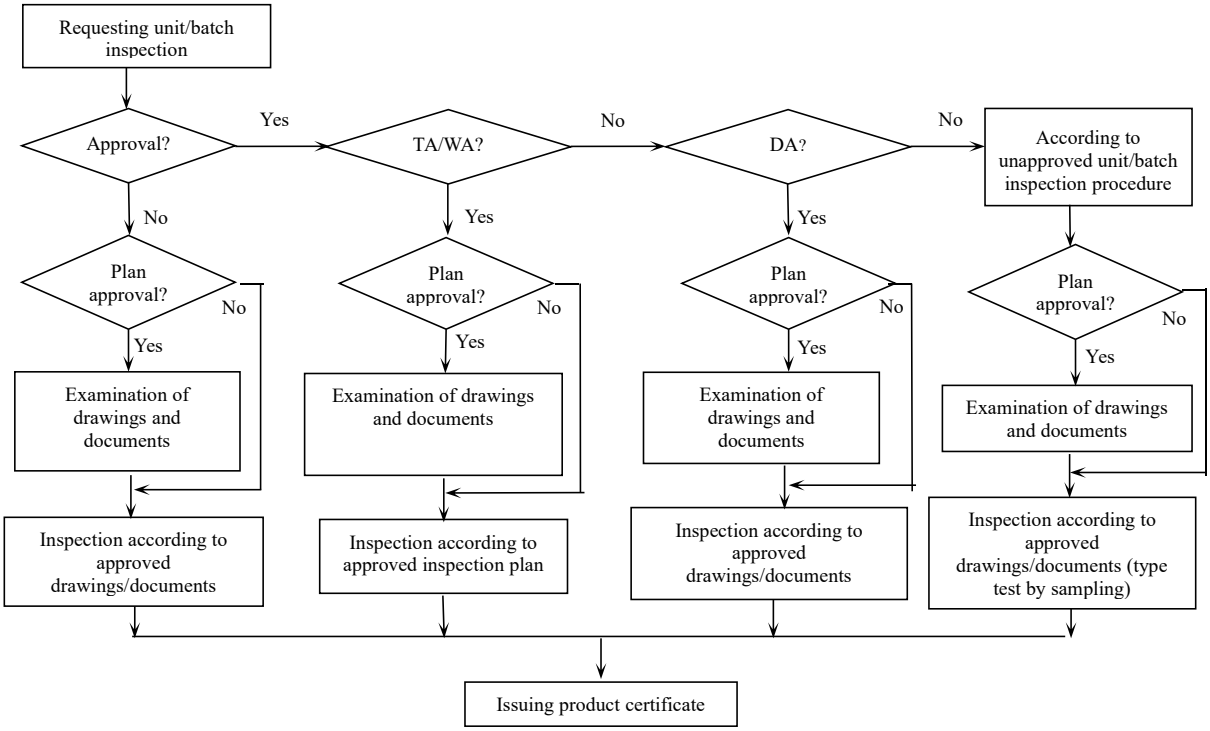


Figure 3.2.2.2

3.2.2.3 For one or more products which have been approved by CCS, the unit/batch inspection attended by the Surveyor may be dealt with according to the approved inspection scheme , and the preparation of product inspection scheme is to comply with following principles:
(1) no repeated type test is needed after design approval, and the Surveyor is to carry out site inspection unit by unit;
(2) no repeated type test is needed after type approval B, test items witnessed by the Surveyor and/or witnessed sampling proportion may be reduced according to the result of on-site audit to the manufacturer;
(3) no repeated type test is needed after type approval A, inspection witnessed by the attending Surveyor may be replaced in full according to the result of on-site audit to the manufacturer, and unit/batch inspection may issue certificate for auditing works documents;
(4) no repeated type test is needed after works approval, test items and/or frequency witnessed by the Surveyor may be reduced according to the result of on-site audit to the manufacturer.
3.2.2.4 For products requiring unit/batch inspection after approval in Appendices of this Chapter, if the applicant has no will for approval, application for unit/batch inspection may be accepted with approval by CCS, requiring that products are to carry out plan approval and inspection according to the requirements of 3.2.2.2.
3.2.2.5 Unit/batch inspections to products which are unnecessary to be approved are to be carried out unit by unit or batch by batch according to drawings and technical documents approved by CCS.
3.2.2.6 Where type approval or equivalent information is available for the products to be inspected, CCS will assess the relevant information provided by the applicant to determine whether a partial or full type test is needed.

3.2.3 Drawing approval

3.2.3.1 For each application for unit/batch inspection, the applicant is to prepare design drawings and/or technical documents and submit them to CCS for examination. For details, see Section 6.

3.2.4 Type test

3.2.4.1 The products, of which type test is required by relevant chapters of CCS rules and/or Appendices of this Chapter, are subject to type test when unit/batch inspection of such products is requested.
3.2.4.2 The type test is to be carried out according to a test programme approved by CCS.
3.2.4.3 The type test sample is to be manufactured according to approved drawings and/or production technology and be the prototype or a product of the same specification and manufacture taken at random from the production line. In the latter case, the sample is to be taken and specifically identified and if

necessary, sealed up in the presence of the Surveyor.
Where preparation of samples is necessary, they are to be prepared, identified and their marks transferred in the presence of the Surveyor. The way of sampling are taken, the technology of preparation and the number of samples are to comply with CCS rules. Prior to the test, the Surveyor is to check the compliance of samples and verify the identification of the samples.
3.2.4.4 The items related to product performance, environment, etc., as specified in CCS rules, the standards applied by or the technical requirements of the manufacturer, are in general to be tested in the presence of the Surveyor.
Type tests are to be arranged in priority in laboratory approved by CCS according to 3.7.5.2 of this Chapter. Where the manufacturer arranges required tests at a laboratory approved by China National Accreditation Board for Laboratories or another foreign laboratory acceptable to CCS, if the laboratory is found by CCS, upon an assessment, to comply with the requirements for testing of marine products, consideration may be given to accepting the results of such tests and if necessary, CCS may require a retest.
3.2.4.5 Some or all of type test items may be tested under test conditions provided by the manufacturer. However, the appropriate test ability under such test conditions are to be confirmed CCS.
3.2.4.6 After completion of the type test, the test organization is to prepare a test report, covering at least the following:
(1) type, specification and identification of the product;
(2) test basis: test method and acceptance condition;
(3) environmental conditions of each test item, if applicable;
(4) date and place of test;
(5) test results.
3.2.4.7 The test report is to be signed by person(s) in charge from the test organization and the Surveyor. Where the Surveyor is not present at the test, he is to confirm the test report.

3.2.5 Material test

3.2.5.1 Materials are to be tested according to CCS rules. In general, the Surveyor is to confirm the document of material test and where required by CCS rules, the Surveyor is to be present at the test.
3.2.5.2 The test and measurement equipment is to be properly calibrated and maintained in a good condition. The calibration records are to be kept and made available to the Surveyor when he needs them.
3.2.5.3 The chemical composition of materials is to be determined and this composition is to be proved by the material supplier through the specified ladle analysis. The laboratory undertaking the analysis is to be provided with adequate test equipment and instrumentation, and the analysis is to be performed by qualified personnel.
3.2.5.4 The chemical analysis by the manufacturer is in general acceptable. However, the Surveyor may require a random check.

3.2.6 Inspections

3.2.6.1 During manufacturing, the manufacturer is to assist the Surveyor in getting access to all locations related to the inspection for confirming:
(1) effective implementation of the production technology;
(2) compliance of manufacturing with the approved drawings and technical requirements;
(3) correct application of materials and welding consumables;
(4) correct sampling and testing.
3.2.6.2 The final inspection and test of the products are to be carried out in the presence of CCS Surveyor and according to the approved design documents actually used and the applicable requirements specified in CCS rules. CCS is responsible only for those inspection and test items requiring attendance by its Surveyors.

3.2.7 Issue of marine product certificate /equivalent document

3.2.7.1 The certification requirements for various products (including components and raw material) are given in Appendices of this Chapter, except as required by the applicant otherwise. An appropriate marine product certificate/equivalent document is to be issued after completion of the unit/batch inspection.
3.2.7.2 Unless otherwise specified, a separate marine product certificate/equivalent document may not be required for the marine products manufactured by the shipyard and covered by the ship survey according to product inspection requirements.
3.2.7.3 For components with type approval requirements in Appendices 2A, 2B and 2C which are manufactured by the manufacturer and only for the products of the manufacturer, if the components are covered by product approval, a separate approval certificate is not to be issued.

3.2.7.4 For components with product certificate requirements in Appendices 2A, 2B and 2C which are manufactured by the manufacturer and only for the products of the manufacturer, inspection is to be carried out according to CCS requirements, and a separate product certificate may not be issued.

Section 3 DESIGN APPROVAL

3.3.1 General requirements

3.3.1.1 The design approval applies in general to the approval of design of marine products in the category of equipment and systems. Specific products to which such approval is applicable are listed in Appendices of this Chapter. For products listed in the Appendices and not applicable to design approval, if they are used for design transfer, CCS may accept applicant's application for design approval. But for use in real ship, the products are to obtain relevant approval certificates according to certification requirements in Appendices of this Chapter.

3.3.1.2 The applicant for design approval is to submit to CCS Application for Design Approval of Products and clearly state the purpose, type, model and main characteristic parameters of the products together with the latest versions of all standards used.

3.3.1.3 The design approval consists of drawing examination and prototype test.

3.3.2 Drawing examination

3.3.2.1 Design approval applicants are to prepare product design drawings and/or technical documents according to relevant requirements of Chapters and PARTS of the rules for CCS examination or for information. For details, see Section 6 of this Chapter.

3.3.3 Prototype test and/or inspection

3.3.3.1 The prototype product, for which design approval is sought, is to be inspected and identified by the Surveyor to confirm that it is manufactured according to approved drawings and that it complies with CCS rules and guidelines, applicable standards or the manufacturer's technical requirements and is fit for its intended purpose on board.

3.3.3.2 If applicable and considered as a necessary process for design approval, the prototype test is to be conducted by the manufacturer in the presence of the Surveyor. The prototype test is to cover product performance tests, environmental tests or other tests, as specified in CCS rules and guidelines, applicable standards or the manufacturer's technical requirements, and the test programme is to be submitted to CCS for approval.

3.3.3.3 The requirements for the prototype test report are to be in accordance with 3.2.4 of this Chapter.

3.3.3.4 If the required tests have been completed or are underway at an independent testing organization accepted by CCS, special consideration will be given to the acceptability of any test results obtained not in the presence of CCS Surveyor. For details, see also 3.2.4.4.

3.3.4 Issue and validity of Design Approval Certificate

3.3.4.1 Where the products have been assessed according to 3.3.2 and 3.3.3 of this Section and found to comply with CCS rules, guidelines and/or applicable standards and/or the manufacturer's technical requirements, a Design Approval Certificate valid for not more than 5 years will be issued by CCS.

3.3.4.2 The renewal of the approval certificate is to be completed within 3 months before the expiry date of the existing certificate, and the new approval certificate is to be valid to a date not exceeding five years from the date of expiry of the existing certificate.

3.3.4.3 The products, of which the design has been approved, and their designer will be entered into CCS Lists of Approved Marine Products.

3.3.5 Renewal audit

3.3.5.1 The renewal audit for the Design Approval Certificate is to be carried out within 3 months before the expiry date of the certificate. The manufacturer is to send a written application to CCS and inform CCS of any change to the product design. CCS is to:

(1) verify the drawings to check any change to the design or specifications of the products to the applicable rules or standards;

(2) re-approve the test programme in case of any change.

3.3.5.2 Where there is no change to the design, the prototype/type test may in general be dispensed with and if necessary, CCS may require a random inspection of all/partial items for retest.

3.3.5.3 Where the applicant is found to remain in compliance with the conditions for design approval

upon check, a new Design Approval Certificate will be issued by CCS.

3.3.6 Change of approved products

3.3.6.1 For products subject to CCS design approval, the original applicant of design approval is to inform CCS of any change to design or applicable standards and receive CCS assessment thereof. CCS is to determine whether a new design approval is needed according to character and degree of design change.

Section 4 TYPE APPROVAL

3.4.1 General requirements

3.4.1.1 This Section specifies general principles and procedures for CCS type approval of products in confirming the manufacturer's ability to produce consistent products in compliance with CCS rules.

3.4.1.2 Upon application by the manufacturer, the products not required by CCS rules may be approved according to the standards/technical requirements agreed between CCS and the manufacturer.

3.4.1.3 The manufacturer is to have a quality management system certificate based upon ISO 9001 or the equivalent standards and issued by an accredited certification body, the certificate is to be kept valid.

3.4.1.4 The manufacturer is to have a quality control system, drawings, rules and standards that cover the product to be certified.

3.4.1.5 The manufacturer applying for type approval of mode A is to have the quality management system or the additional alternative quality control plan which covers all required inspection, testing and certification in compliance with CCS rules. Where associated sub-suppliers or sub-contractors are needed, the quality management system of the sub-supplier or sub-contractor is to be included in the control requirements of the manufacturer, or the sub-supplier or sub-contractor applies separately for type approval of mode A.

3.4.1.6 For manufacturers applying for type approval of mode A, the required inspection and testing are permitted in two versions with regard to traceability:

(1) The manufacture describes the relevant inspection, testing and certification additional to the manufacturer's standard quality control in order to meet the Rules. The components are to be stamped with a special stamp supplied by CCS or identified as required by CCS.

(2) The manufacturer has a standard quality control system which covers all required inspection, testing and certification in compliance with the Rules. The traceability and the required type of product document for components or products are defined in the system.

3.4.1.7 For manufacturers applying for type approval of mode B for Alternative Certification Scheme, the relevant requirements of Section 10 of this Chapter are to be complied with.

3.4.2 Process of type approval

3.4.2.1 The type approval of products consists of following processes:

(1) Document examination, including:

① drawing examination;

② document examination.

(2) prototype/type test;

(3) on-site audit, including:

① check of quality management system;

② audit of the manufacturing process.

3.4.2.2 The applicant for type approval is to submit an application to CCS, stating the requested type approval and providing information on the manufacturer and his production location as well as all other information necessary for the products to be approved.

3.4.2.3 While the process of type approval covers design approval (see Section 3 of this Chapter), a separate application for design approval need not be made in respect to the products for which type approval is sought, unless the manufacturer requests both type approval and issue of the Design Approval Certificate.

3.4.2.4 If the applicant is not the patent party having design approval, it is to identify in writing that authorization from patent party has been obtained with legal source.

3.4.3 Document examination

3.4.3.1 The drawing examination is to be in accordance with Section 6 of this Chapter.

3.4.3.2 The document examination is to be in accordance with 3.5.2, Section 5 of this Chapter.

3.4.3.3 In addition, for manufacturers applying for type approval of mode A, the following documents are to be submitted for examination:
(1) the extent of the required inspection and testing under which conditions the manufacturer may perform all or parts of the required inspection and testing without the presence of a Surveyor, including that of the sub-contracted components;
(2) the additional alternative quality control plan which covers all required inspection, testing and certification in compliance with the Rules, including the procedure of the components to be stamped with a special stamp supplied by CCS or identified as required by CCS;
(3) the standard quality control system which covers all required inspection, testing and certification in compliance with the Rules, including the procedure of the traceability and the required type of product document for components or products;
(4) the existing class approvals of the manufacturer's products as far as required;
(5) quality control plans relevant to the products and relevant components. Such plans are to detail the inspections and tests required by the Rules with an indication that the inspections and tests have been delegated to the manufacturer;
(6) list of nominated personnel for:
① marking/stamping of products;
② tests and inspection (responsible);
③ provision of data and information (e.g. declaration of conformity, test reports etc.);
(7) any other additional documents that CCS may require in order to evaluate the manufacturing processes and the product quality control.

3.4.4 Type test
3.4.4.1 The type test is to be in accordance with 3.2.4, Section 2 of this Chapter.
3.4.4.2 Where the products, for which type approval is requested, have been design approved by CCS,
(1) if samples for prototype test of design approval is manufactured by the applicant, the confirmation of the Design Approval Certificate will suffice, and the requirements of above 3.4.3.1 and 3.4.4.1 need not be followed. However, a final inspection of product samples is to be performed with attendance by CCS Surveyor;
(2) if samples for prototype test of design approval is not manufactured by the applicant, considering the difference of raw material, production equipment and production technology, the applicant is to carry out a new type test unless otherwise agreed by CCS.

3.4.5 On-Site audit
3.4.5.1 Check of quality management system in production location of the manufacturer by the Surveyor is to meet the requirements of Section 9 of this Chapter.
(1) For manufacturers applying for type approval of mode B, check of quality management system is to meet the requirements of 3.9.2.1, Section 9 of this Chapter.
(2) For manufacturers applying for type approval of mode A, check of quality management system is to meet the requirements of 3.9.2.1 and 3.9.2.2, Section 9 of this Chapter.
3.4.5.2 Audit of the manufacturing process
(1) The Surveyor is to carry out audit in such locations as relevant departments, workshops, storage locations and laboratories according to the scope of application for approval, so as to confirm that production equipment, manufacturing technology and test ability meet relevant requirements of CCS.
(2) Representative pieces of the products within the approval scope are to be provided by the manufacturer to the Surveyor for verifying that they are manufactured according to the design documents. The Surveyor is to audit manufacturer's production and inspection records consistency of approved drawings/technology documents.
(3) A quality control plan for the products within the approval scope is to be established by the manufacturer applying for type approval of mode A and submitted to CCS for approval. This quality control plan is to describe the quality assurance and control methods used in the manufacturing process according to the technical requirements or standards of the products, reflecting in particular the inspection and test requirements of CCS rules, guidelines and/or conventions.
3.4.5.3 For purchased materials and components, CCS may, depending on their importance level, require:
(1) an inspection at workshops of the suppliers;
(2) appropriate tests.
3.4.5.4 Any nonconformity found during the audit is to be notified to the manufacturer for remedial actions. Any remedial action for any nonconformity is to be followed up for verification.

3.4.6 Issue and validity of Type Approval Certificate

3.4.6.1 CCS will issue a Type Approval B Certificate valid for not more than 5 years to a manufacturer for whom the drawing examination, type test and on-site audit have been completed according to 3.4.3, 3.4.4 and 3.4.5 respectively and who is found to meet following conditions:

(1) the product design complies with conventions, applicable requirements of CCS rules and/or other applicable standards;

(2) an effective specialized quality management system for marine products is in place for ensuring the quality control level required by the manufacturer.

3.4.6.2 The renewal of the approval certificate is to be completed within 3 months before the expiry date of the existing certificate, and the new approval certificate is to be valid to a date not exceeding five years from the date of expiry of the existing certificate.

3.4.6.3 CCS will issue the Type Approval A Certificate for a period not exceeding 5 years to a manufacturer at his request for whom the drawing examination, type test and on-site audit have been completed according to 3.4.3, 3.4.4 and 3.4.5 respectively and who is found to comply with the following requirements:

(1) the requirements for type approval B are met, product quality assurance meeting requirements of ISO 9001, having an additional CCS-approved procedure for ensuring that inspections and tests will be in accordance with CCS rules and guidelines;

(2) product quality is found upon CCS inspection experience and quality system check to be continually kept stable during the period of holding the Type Approval B Certificate;

(3) the operation of the quality management system for marine product is capable of achieving at least the results of the inspections and tests attended by CCS Surveyor.

3.4.6.4 The products having a Type Approval Certificate and their manufacturers will be entered into CCS Lists of Approved Marine Products.

3.4.7 Periodical audit

3.4.7.1 Within the period of validity of the approval certificate, a manufacturer complying with the following three conditions is to apply for a periodical verification annually to ensure maintenance of the validity of the certificate. The periodical verification is to be carried out within 3 months before or after the anniversary date of the certificate which corresponds to the expiry date:

(1) the product has type approval mode A certificate;

(2) the product has type approval mode B certificate, and marine product certificate/equivalent document is not necessary;

(3) the product has type approval mode B certificate, and the use of the Alternative Certification Scheme as specified in Section 10 of this Chapter is applied for.

3.4.7.2 The periodical audit includes:

(1) check of quality management system is to meet the requirements of 3.9.2.3, Section 9 of this Chapter;

(2) if deemed necessary by CCS, random inspection/test for the approved products may be carried out. The samples for inspections/ tests are to be selected in the presence of the Surveyor, with the type and number of samples being determined by the Surveyor depending on the complexity, production scale and type of the products;

(3) for manufacturers using the Alternative Certification Scheme specified in Section 10 of this Chapter, the process of their product manufacturing, inspection and testing is to be audited to verify it is properly controlled, and the consistency and validity of the approved quality control plan.

3.4.7.3 Where the manufacturer is found to comply with the conditions for maintaining the certificate at the periodical audit, a periodical audit certificate will be issued by CCS.

3.4.8 Renewal audit

3.4.8.1 The renewal audit for the Type Approval Certificate is to be carried out within 3 months before the expiry date of the certificate. The manufacture is to send a written application to CCS and inform CCS of any change to the product design and quality system. CCS is to:

(1) confirm the drawings to check any change to the rules or standards applicable to the design or specifications of the products;

(2) re-approve the type test programme in case of any change;

(3) carry out on-site audit according to 3.4.5;

(4) for manufacturers using the Alternative Certification Scheme specified in Section 10 of this Chapter, audit and verify that the process of their product manufacturing, inspection and testing is to be properly controlled, complying with the conditions for maintaining the Alternative Certification Scheme, and the consistency and validity of the approved quality control plan.

3.4.8.2 Where there is no change to the technical requirements for product approval and design, part or all of the type approval test items may be dispensed with; if necessary, CCS may require all test items.
3.4.8.3 Where the manufacturer is found to remain in compliance with the conditions for type approval upon check, a new Type Approval Certificate will be issued.

3.4.9 Change of approved products

3.4.9.1 The manufacturer is to supervise any change to the products or their manufacturing process, inform CCS of any major change and receive CCS assessment thereof.
3.4.9.2 Where any change is made to the design of the approved products and their components and parts, materials used or manufacturing method and this affects the main characteristics and features of the products or leads to any change of any performance criterion of the products, a new type approval is to be carried out.

3.4.10 Additional audit

3.4.10.1 Additional audits may be required to the manufacturer and/or sub-supplier, sub-contractor at the discretion of CCS.

Section 5 WORKS APPROVAL

3.5.1 General requirements

3.5.1.1 The works approval applies to the products of which the quality assurance is achieved by means of batch production in a continuous process or completely based on production technology and process. The products for which the works approval is required by CCS are indicated in Appendix of this Chapter.
3.5.1.2 The procedure of works approval consists of the following three parts:
(1) document review;
(2) type test;
(3) on-site audit, including:
① quality system check;
② audit of the manufacturing process.
3.5.1.3 The manufacture is to have obtained the quality management system certificate issued on the basis of ISO 9001 or equivalent standard and maintained valid.

3.5.2 Document review

3.5.2.1 The applicant is to submit a signed application for works approval, stating the products and production locations covered by the works approval, together with the following documents and information for examination:
(1) technical characteristics of the products, at least including the purpose, type, model and main characteristic parameters of the products together with the latest versions of all standards used;
(2) drawings and relevant technical documents of products and manufacturing technologies, including technological processes;
(3) type test programme;
(4) lists of suppliers of raw materials, main components and parts, with an indication of their class approval (as far as required by the Rules) and the type of material certification in each case;
(5) quality assurance system documents, including quality manual, and the procedures relevant to the quality control and inspections, their methods, frequency and certification, information on main production, inspection and test equipment;
(6) other valid documents, reports and certificates showing the applicant's ability to manufacture the products and control their quality within the scope of approval.
3.5.2.2 CCS examines the documents and information submitted by the applicant, approves drawings and relevant technical documents of products and manufacturing technologies as well as type test programme and returns them to the applicant.

3.5.3 On-site audit

3.5.3.1 An audit of the quality management system at the manufacturer's production locations by the Surveyor is to meet the requirements of Section 9 of this Chapter.
3.5.3.2 Audit of the manufacturing process
(1) The Surveyor is to carry out audit in such locations as relevant departments, workshops, storage locations and laboratories according to the scope of application for approval, so as to confirm that

production equipment, manufacturing technology and test ability meet relevant requirements of CCS.
(2) Representative products within the approval scope are to be provided by the manufacturer to the Surveyor for verifying that they are manufactured according to the design documents. The Surveyor is to follow up and witness the manufacturing process of representative products (i.e. products for type test or test samples), including witnessing sampling and test to process monitoring and quality verification.
3.5.3.3 For purchased materials and components, CCS may, depending on their importance level, require:
(1) an inspection at workshops of the suppliers;
(2) appropriate tests.
3.5.3.4 Any nonconformity found during the audit is to be notified to the manufacturer for remedial actions. Any remedial action for any nonconformity is to be followed up for verification.

3.5.4 Type test
3.5.4.1 A type test is to be carried out according to 3.2.4, Section 2 of this Chapter.

3.5.5 Issue and validity of Works Approval Certificate
3.5.5.1 CCS will issue a Works Approval Certificate valid for not more than 5 years to a manufacturer for whom the drawing examination, type test and on-site audit have been completed according to 3.5.2 to 3.5.4 respectively.
3.5.5.2 The renewal of the approval certificate is to be completed within 3 months before the expiry date of the existing certificate, and the new approval certificate is to be valid to a date not exceeding five years from the date of expiry of the existing certificate.
3.5.5.3 The products having Works Approval Certificate and their manufacturers will be entered into CCS Lists of Approved Marine Products.

3.5.6 Periodical audit
3.5.6.1 Within the period of validity of the approval certificate, a manufacturer having works approval is to apply for a periodical verification annually to ensure maintenance of the validity of the certificate. The periodical verification is to be carried out within 3 months before or after each anniversary date of the works approval certificate.
The periodical audit includes:
(1) quality system check is to meet the requirements of 3.9.2.3, Section 9 of this Chapter;
(2) if deemed necessary by CCS, random inspection/test for the approved products may be carried out. The samples for inspections/ tests are to be selected in the presence of the Surveyor, with the type and number of samples being determined by the Surveyor depending on the complexity, production scale and type of the products;
(3) for manufacturers using the Alternative Certification Scheme specified in Section 10 of this Chapter, the process of their product manufacturing, inspection and testing is to be audited to verify it is properly controlled, and the consistency and validity of the approved quality control plan.
3.5.6.2 Where the manufacturer is found to comply with the conditions for maintaining the Works Approval Certificate upon the periodical verification, a periodical verification certificate will be issued by CCS.

3.5.7 Renewal audit
3.5.7.1 Where renewal of the Works Approval Certificate is necessary at its expiry, the manufacturer is to send a written application to CCS and inform CCS of any change to the product design and the quality management system within 3 months before the expiry date of the certificate.
3.5.7.2 The document review, on-site audit, approval test and issue of the Works Approval Certificate are to be in accordance with 3.5.2, 3.5.3, 3.5.4 and 3.5.5. For manufacturers using the Alternative Certification Scheme specified in Section 10 of this Chapter, the process of their product manufacturing, inspection and testing is to be audited to verify it is properly controlled, complying with the conditions for maintaining the Alternative Certification Scheme, and the consistency and validity of the approved quality control plan.
3.5.7.3 If there is no change to the technical requirements for product approval and product design, part or all of the test items may be exempted; if necessary, CCS may require all test items.
3.5.7.4 Where the manufacturer is found to remain in compliance with the conditions for works approval upon check, a new Works Approval Certificate will be issued.

3.5.8 Changes to approved products
3.5.8.1 The manufacturer is to supervise any change to the products or their manufacturing process, inform CCS of any major change and receive CCS assessment thereof.

3.5.8.2 After the works approval, the manufacturer is to inform CCS of any significant change to product drawings, technical documents, technological specifications or quality management system. In case of any change affecting product design, main manufacturing materials, key technologies or characteristics and features of products, the associated drawings and technical documents which have been previously approved are to be submitted to CCS for re-approval and if necessary, the items involved in the scope of the changes are to be inspected and tested in the presence of the Surveyor.

3.5.9 Additional audit

3.5.9.1 Additional audits may be required to the manufacturer and/or sub-supplier, sub-contractor at the discretion of CCS.

Section 6 PRODUCT DRAWING EXAMINATION

3.6.1 General requirements

3.6.1.1 Product drawing examination means an examination of design drawings and technical documents for ship associated products.

3.6.1.2 This Section is applicable to examination of drawings for classed ship associated products. In addition, at the request of applicant and with the consent of CCS, CCS may carry out examination to design of relevant products based on information provided by the applicant and according to applicable classification or statutory requirements. Examination is only limited to the scope agreed by CCS and applicant, generally not including requirements for ship system.

3.6.1.3 Product drawing examination is carried out for the purpose of:

(1) confirming product design meets applicable CCS rules and relevant statutory requirements; or

(2) agreeing with applicant on products as basis for verification of compliance of manufactured products with examined drawings.

3.6.1.4 Marine products applying for design approval, type approval, works approval and unit/batch inspection are to be subject to product drawing examination according to the requirements of Appendix of this Chapter.

3.6.1.5 Basis for marine product examination includes CCS rules, international conventions and statutory regulations of flag State government applicable to the product as well as product standards accepted by CCS. For the products clearly specified by the rules, at the request of the applicant, appropriate standards may be accepted as alternative requirements. In any case, alternative standards are not to be inferior to requirements specified by the rules. The drawing examination is primarily to confirm compliance of the design of products with applicable rules and guidelines, or their alternative standards as permitted. Where there are no specially required technical standards in CCS rules, the examination may be based on applicable industrial standards, or in the absence of applicable rules or industrial standards, the manufacturer's standards or product technical requirements or engineering calculation and analysis may also be accepted as the basis for examination. The basis for examination of product drawings will be clearly stated in the product Plan Approval Comments.

3.6.1.6 Examination of product design drawings and technical documents by CCS only includes part of examination basis applicable to the product.

3.6.1.7 The applicant is to submit a formal written application for drawing examination together with the complete drawings and documents, which may be submitted in paper or electronic form (PDF). The applicant is, in the case of paper drawings, generally to submit the application form (to be downloaded on website: http://www.ccs.org.cn) and drawings in triplicate to the plan approval units designated by CCS for examination. Where the drawing examination and inspection are carried out by a same unit, only two copies of drawings need to be submitted. Where the applicant requires more than one copy of drawings to be returned, copies of drawings to be submitted are to be increased accordingly. The application and drawings may be submitted, in the case of electronic form, through registration on website: https://www.ccs-service.net.

3.6.2 Drawing examination

3.6.2.1 Unless otherwise specified by CCS rules, international conventions and statutory regulations of flag State government, following drawings and technical documents related to product design are to be submitted for examination:

(1) design drawings, including general arrangement, drawing of essential parts, main parts or materials list;

(2) documents stating specifications;

(3) documents stating performance and purpose;
(4) necessary engineering calculation and analysis reports;
(5) when necessary, other documents required by CCS.

3.6.2.2 Product drawings and technical documents submitted by the applicant are to comply with following requirements:

(1) Drawings and technical documents are to be submitted in Chinese or English, clearly stating product design, construction, material, dimensions as well as function and performance parameters. If necessary, limitations or provisions for use are to be included.

3.6.2.3 When examination of drawings and technical documents is completed and designed is deemed to comply with the requirements of examination basis, CCS will issue the Plan Approval Comments to applicant.

3.6.2.4 Unless otherwise provided by CCS rules, approval generally means that drawings or documents have been examined and satisfy applicable examination basis requirements. Other drawings or technical documents include but not limited to relevant information for support or assisting examination, which will be kept by CCS for information. Approved conditions and limitation comments may be written on the drawings or stated in the Plan Approval Comments. State of "approval" or "for information" is to be clearly stated in the Plan Approval Comments.

3.6.2.5 One copy of the Plan Approval Comments together with stamped drawings and technical documents is to be kept by the plan approval unit, one copy is to be submitted to the unit carrying out inspection and one copy is to be returned to the applicant. For items applying in the form of electronic document, return is to be in electronic form.

3.6.3 Validity of approval

3.6.3.1 Approved drawings and technical documents are only valid within the scope of manufacturer, construction engineering No. and construction number stated in the Plan Approval Comments.

3.6.3.2 If drawings and technical documents are revised after approval, involving or affecting essential structure, strength, material used, characteristics, features or limitations of main system of product, product and main components, they are to be resubmitted to CCS for approval.

3.6.3.3 Where the entry into force of new rules including their amendments affects product design, main manufacturing materials, key technologies or characteristics and features of products, the approved product drawings and technical documents will be invalid automatically.

3.6.3.4 Where the statutory requirements of the flag State or the international conventions, codes accepted by it and the entry into force of the amendments thereto affect the validity of the approved plans mentioned in 3.6.3.2, the approved statutory plans will be invalid automatically.

Section 7 APPROVAL OF SERVICE FIRM OF INSPECTION AND TESTING

3.7.1 General requirements

3.7.1.1 Approval of service firm of inspection and testing means approval of capability and condition of specific inspection and test items of marine and relevant products carried out by CCS to service firm of testing by such audit methods as document examination, site audit and approval test.

3.7.1.2 This Section is not applicable to approval of service suppliers.

3.7.1.3 Upon CCS audit, if it is confirmed that following provisions are complied with, approval will be given to the firm and a Firm Approval Certificate will be issued:

(1) the firm is to be registered legal entity or organization authorized by legal person, with clear legal status and capability of undertaking legal responsibilities;

(2) complying with relevant provisions of CCS rules, CCS Guidelines on Firm Approval and documents relating to firm approval, and fulfilling relevant liabilities;

(3) complying with provisions of relevant legal regulations.

3.7.1.4 Firm approval procedure is composed of following three parts:

(1) document examination;

(2) on-site audit;

(3) approval test.

3.7.2 Document examination

3.7.2.1 The applicant is to submit a signed application for firm approval, indicating scope of firm

approval, and submit following documents for examination:
(1) firm name, address, brief introduction of service and capability, qualification certificate or system certificate issued by other authorities, history of experience on marine product inspection and testing;
(2) notarial announcement, conduct rules, secrecy promise and other activity information which may present a conflict of interest of marine product manufacturer;
(3) list of inspection and test items and list of inspection standards;
(4) list of main inspection and test instruments, equipment and calibration gauge, including name, type, technical index, manufacturer, inspection period, inspection condition and person in charge of inspection and test instruments, etc.;
(5) post and list of personnel carrying out inspection, calibration and maintenance, training and working experience of relevant personnel within application approval scope and compliance with relevant international, national or industrial approval standards;
(6) organization frame and responsibility;
(7) inspection procedures;
(8) guidelines on operation of inspection and testing equipment;
(9) personnel training procedure;
(10) quality manual or system and procedural documents for implementing effective quality control;
(11) record of customer claims and corrective actions;
(12) formal inspection and test report sample;
(13) firm approval test programme;
(14) other documents as deemed necessary by the Surveyor during approval.
3.7.2.2 CCS carries out examination to documents submitted by the applicant, approves firm approval test programme and returns them to the applicant.

3.7.3 On-site audit

3.7.3.1 Upon document examination and approval of firm approval test programme, the Surveyor carries out on-site audit to technical capability and quality management activities within the scope of application of the applicant according to CCS rules, guidelines and firm approval documents. During on-site audit, all other sites for carrying out one or more key activity and covered by application scope of the applicant are to be audited. On-site audit is to at least include following contents:
(1) checking implementation of management system documents, operational procedure and other documents by inspection firm;
(2) checking and confirming personnel training, experience, educational background, quality and other qualifications of inspection firm;
(3) verifying whether inspection firm facilities and environment are helpful to correct implementation of inspection, test and maintenance;
(4) verifying whether inspection firm uses proper method and procedure to carry out inspection, test and maintenance within approval scope safely and effectively and whether inspection, sampling and storage comply with requirements of relevant provisions;
(5) verifying whether inspection firm is provided with necessary inspection and testing equipment, whether calibration gauge and software comply with required accuracy and requirements of inspection and test rules, and whether periodical calibration and check system are provided;
(6) verifying correctness and traceability of inspection and testing results, inspection and testing quality records and reports of inspection firm as well as whether report preparation, endorsement, audit and issuance comply with relevant provisions;
(7) verifying inspection and testing capability of inspection firm, and verifying correctness, safety and effectiveness of inspection and testing carried out by operator, if necessary, the Surveyor may witness main test items for application.
3.7.3.2 If nonconformities are found during audit, the responsible person of applicant is to be informed to take corrective measures. Corrective measures aiming at nonconformities are to be followed up and verified.

3.7.4 Verification test

3.7.4.1 Verification is to be carried out according to approved firm approval test programme.

3.7.5 Firm approval certificate

3.7.5.1 On completion of document examination, on-site audit and approval test mentioned in 3.7.2 to 3.7.4, CCS will issue a Firm Approval Certificate for service firm of inspection and testing which is valid not more than 5 years.

3.7.5.2 If inspection firm with CCS approval need to provide third party inspection service, the Surveyor may directly accept inspection report, and on-site witness is not necessary.
3.7.5.3 Inspection firm with approval is to collect and summarize relevant testing information required by CCS at regular interval and submit them to CCS.
3.7.5.4 Test data, test reports and other relevant test information are to be submitted to CCS through CCS Product Inspection and Testing Organization Data Acquisition System.
3.7.5.5 The firm with approval certificate for service firm of inspection and testing will be published in CCS website.

3.7.6 Periodical audit

3.7.6.1 Within the period of validity of approval certificate for service firm of inspection and testing, a periodical audit is to be carried out. The scope of periodical audit may be all or partial contents of approval field and approval requirements. The type of periodical audit includes on-site supervision review and information audit, and inspection firm is to provide relevant documents and records (e.g. inspection record, internal quality control result and complaint record). For service firm of inspection and testing in several locations, periodical audit is to cover all locations.
3.7.6.2 Periodical audit is to be completed within 3 months before or after the second anniversary of expiry date of certificate. If service firm of inspection and testing does not submit application for periodical audit to CCS within 3 months after expiry date of periodical audit, CCS will suspend approval certificate according to the provisions of 3.1.8.2. If service firm of inspection and testing does not submit application for periodical audit to CCS within 3 months after suspension of approval certificate, CCS will cancel approval certificate according to the provisions of 3.1.8.3.

3.7.7 Renewal audit

3.7.7.1 Where renewal of the Firm Approval Certificate is necessary at its expiry, the service firm of inspection and testing is to send a written application to CCS within 3 months before the expiry date of the certificate and inform CCS of any change to the approval certificate and the quality system.
3.7.7.2 The document review, on-site audit, approval test and issue of the Firm Approval Certificate are to be in accordance with 3.7.2 to 3.7.5.

3.7.8 Changes to approval certificate

3.7.8.1 Within period of validity of approval certificate for service firm of inspection and testing, if firm name and address are changed or inspection item and scope are added, changes to approval certificate may be applied according to CCS relevant requirements.

3.7.9 Additional audit

3.7.9.1 Additional audits may be required to the service firm of inspection and testing at the discretion of CCS.

Section 8 CLASS NOTATIONS FOR PRODUCTS

3.8.1 General requirements

3.8.1.1 Class notations are certificate identification that CCS confirms that marine products meet additional requirements of CCS by such means as document examination, on-site audit and type test.
3.8.1.2 Audit and test requirements for product class notations are to meet guidelines relating to CCS class notations.
3.8.1.3 For marine products with CCS approval and inspection requirements, the applicant is to complete relevant approval and inspection at first (for requirements, see Appendix of this Chapter).
3.8.1.4 Class notations applicable to marine products include but not limited to in Table 3.8.1.4.

Class Notations for Marine Products **Table 3.8.1.4**

Class notation	Applicable products	Description	Technical requirements to be complied with
Asbestos-free	All marine products	Asbestos-free	Resolution MSC.282(86) − Amendments to the International Convention for the Safety of Life at Sea, 1974, as Amended
Hong Kong Convention	All marine products	To meet requirements of Hongkong Convention on control of harmful	Appendixes 1 and 2 of the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships,

Class notation	Applicable products	Description	Technical requirements to be complied with
		substances	2009, and resolution MEPC.269(68) − 2015 Guidelines for the Development of the Inventory of Hazardous Materials
EU Ship Recycling Regulation	All marine products	To meet requirements of EU Regulation on ship control of harmful substances	EU 1257/2013 Regulation on ship recycling
E-Noise	Machinery	Noise resource products are subject to vibration and noise inspection according to the requirements of CCS guidelines	Resolution MSC.337(91) − Code on Noise Levels on Board Ships and CCS Guidelines for Control and Measurement of Noises for Ships and Marine Products
SLC1, SLC2, SLC3	Marine computer system (including programmable electronic system)	Safe and reliable assessment of the marine software	CCS Guidelines for Safe and Reliable Assessment of the Marine Software

3.8.2 Document examination

3.8.2.1 The applicant is to submit a signed application for works/type approval/product inspection or application for class notation approval, indicating product scope involved by approval, and submit following documents for examination:

(1) approval certificate and/or marine product certificate (if applicable);

(2) drawings and documents indicating requirements for product structure type, production technology, raw material, components and parts (or documents required by CCS for approval and inspection);

(3) approval test programme (if applicable);

(4) other documents required by CCS class notations.

3.8.2.2 CCS examines documents submitted by the applicant, approves approval test programme and returns them to the applicant.

3.8.3 On-site audit

3.8.3.1 On-site audit includes product confirmation and quality system check.

3.8.3.2 Product confirmation is compliance verification whether product structure type, production technology, raw material, components and parts meet documents submitted by the applicant. For products with CCS approval and inspection requirements, it is to confirm whether above contents are consistent with conditions for approval and inspection.

3.8.3.3 Quality system audit is audit verification whether manufacturer's quality system meets ISO 9001 standard according to relevant guidelines on CCS class notations.

3.8.4 Approval test

3.8.4.1 It is carried out according to approved test programme.

3.8.4.2 Test is generally carried out by service firm of inspection and testing approved by CCS.

3.8.5 Class notations and class notation approval certificate

3.8.5.1 After completion of document examination, on-site audit and approval test according to the requirements of 3.8.2 to 3.8.4, CCS will issue the following certificates with class notations:

(1) for marine products with CCS approval and inspection requirements, the obtained class notations will be reflected in column of class notations for approval and/or marine product certificate;

(2) for marine products without CCS approval and inspection requirements, CCS will issue approval certificate for class notations of marine products valid for not more than 5 years.

3.8.6 Class notation approval renewal audit

3.8.6.1 Class notation approval renewal audit is to be carried out 3 months before expiry date of certificate. The manufacturer is to submit written application to CCS, and inform CCS of any change to product design. CCS is to:

(1) reexamine product drawings and technology documents and verify changes to product design, production technology, raw material or components and parts;

(2) carry out product on-site audit according to 3.8.3;

(3) if changes affect validity of approval, approval test is to be carried out according to reexamined test programme.

3.8.6.2 If there is no change to product design, production technology, raw material or components and parts, approval test may be exempted; if necessary, CCS may require a new test.
3.8.6.3 Where the manufacturer is found to remain in compliance with the conditions for class notation approval upon check, a new Class Notation Approval Certificate will be issued.

3.8.7 Changes to class notation approved products

3.8.7.1 The manufacturer is to supervise any change to the products or their manufacturing process, inform CCS of any major change and receive CCS assessment thereof.
3.8.7.2 Where any change is made to the design of the approved products and their components and parts, materials used or manufacturer and this affects the characteristics or performance criterion relating to product and class notations, a new approval is to be carried out.

Section 9 REQUIREMENTS FOR QUALITY SYSTEM CHECK

3.9.1 General requirements

3.9.1.1 Quality system check is a compliance evaluation carried out by CCS during type approval, works approval and class notation approval on whether manufacturer meets the requirements of ISO 9001 quality system.
3.9.1.2 Quality system check is usually applicable to following 4 types of work:
(1) initial, change or renewal of works approval;
(2) initial, change or renewal of type approval;
(3) initial, change or renewal of class notation approval;
(4) periodical audit of works approval and type approval.
3.9.1.3 Requirements for quality system check of class notation approval are shown in Section 8 of this Chapter. This Section is mainly applicable to quality system check of works approval, type approval and their periodical audit.

3.9.2 Contents of quality system check

3.9.2.1 General contents of quality system check of works approval and type approval B:
(1) Personnel: the manufacturer is to have sufficient and qualified inspectors and essential processes operators.
(2) Equipment: the manufacturer is to ensure that production equipment, technology equipment, test equipment and instruments used during production have and keep characteristics and conditions necessary for marine products to meet requirements and/or carry out process monitoring. For inspection, measuring and testing equipment (including measuring equipment and test software), effective control, calibration and maintenance systems are to be established and effective calibration and applicable conditions are to be kept.
(3) Environment: the manufacturer is to confirm and manage working condition necessary for products' compliance with requirements.
(4) Document management: the manufacturer's quality system is to establish review and control requirements for documents, purchasing documents, inspection documents and external documents necessary for production process preparation and operation.
(5) Purchasing link: the manufacturer is to establish evaluation criterion and management requirements for raw material and components and parts supplier complying with requirements of conventions and CCS rules, carry out effective quality control according to management requirements, preparation and maintenance of lists of suppliers of raw materials, main components and parts, and submission to CCS for information.
(6) Production link: the manufacturer is to establish appropriate production technology process, technology procedure and quality control point, to control any subcontract process affecting products' compliance with requirements.
(7) Inspection link: the manufacturer is to establish product inspection procedures complying with conventions, CCS rules or applicable standards and make them operate effectively.
(8) Identification: the manufacturer is to establish perfect identification and marking system, selected samples are to be able to be traced back to corresponding products, and finished products are to be able to be traced back to the source of main material and main components and parts for use.
(9) Control of non-conformities: the manufacturer is to establish non-conformity control procedure which is to meet the requirements of 3.1.4.10 of this Chapter.
3.9.2.2 Additional requirements for type approval A and Alternative Certification Scheme quality system check

(1) The manufacturer is to be familiar with CCS test and inspection requirements for approved marine products.
(2) Marine product test and inspection records are to be kept in complete and clear condition.
(3) The manufacturer is to be able to undertake marine product quality responsibilities.
(4) CCS marine product inspection experience, quality system check and customers' feedback show that product quality is continuously kept stable.
(5) The manufacturer has established documented quality assurance system.
(6) The manufacturer agrees to accept periodical audit on completion of CCS approval.
(7) The inspection, testing and certification of products comply with the submitted additional alternative quality control plan or standard quality control system.
3.9.2.3 Requirements for quality system check of periodical audit
(1) The use of product approval and inspection marks is to comply with the requirements of CCS rules.
(2) The purchasing of raw materials, components and parts of products is to comply with the provisions of quality system documents of the manufacturer.
(3) The supplier of important raw materials of products is to comply with the provisions of list of qualified supplier approved during approval.
(4) The inspection control of purchased important raw materials of products is to comply with the provisions of quality system documents of the manufacturer.
(5) The product produced after approval is to be consistent with product technology, raw materials, components and parts during the type testing.
(6) Final products and/or inspection and test items in the manufacturing are to comply with the provisions of the inspection plan approved during approval.
(7) Nameplate, usage identification, usage/operation instructions and quality certificate of products for ships engaged on international voyages are to include English.
(8) Product quality feedback, analysis and treatment are to comply with the relevant provisions.
(9) For the manufacturer to which Alternative Certification Scheme is issued, the consistency of manufacturing, inspection and testing of products with the quality control plan approved during approval is to be checked.

Section 10 ALTERNATIVE CERTIFICATION SCHEME

3.10.1 General requirements

3.10.1.1 During unit/batch inspection, the surveyor may reduce or exempt test items requiring witness by CCS and allow the manufacturer to carry out inspection and testing as its substitution.
3.10.1.2 The manufacturer using the Alternative Certification Scheme is to be approved by CCS in one or more modes.
3.10.1.3 For manufacturers using the Alternative Certification Scheme, the required inspection and testing are permitted in two versions with regard to traceability:
(1) The manufacture describes the relevant inspection, testing and certification additional to the manufacturer's standard quality control in order to meet the Rules. The components are to be stamped with a special stamp supplied by CCS or identified as required by CCS.
(2) The manufacturer has a standard quality control system which covers all required inspection, testing and certification in compliance with CCS rules. The traceability and the required type of product document for components or products are defined in the system.
3.10.1.4 The manufacturer using the Alternative Certification Scheme is to have the quality management system or the additional alternative quality control plan which covers all inspection, testing and certification in compliance with CCS rules. Where associated sub-suppliers or sub-contractors are needed, the quality management system of the sub-supplier or sub-contractor is to be included in the control requirements of the manufacturer, or a separate application may be made by the sub-supplier or sub-contractor.

3.10.2 Conditions

3.10.2.1 The conditions for the manufacturer to be granted the permission to carry out inspection and testing without the presence of a Surveyor are that:
(1) the manufacturer has a quality control system, current drawings, and Rules and standards that cover the product to be certified;
(2) the manufacturers (and designers, if producing under license) commit themselves to involve CCS when changes to the design, manufacturing process or testing are made as well as when any major production

problems or any major product delivery problems have occurred;
(3) the inspection and testing required by the Rules are either standard procedures in the Quality System and recognized by CCS or specified in detail in the quality control plan and other documents;
(4) if work certificates (W) or test reports (TR) are found not to fulfil the agreed standards, the component may not be accepted;
(5) CCS ascertains the manufacturer's compliance with the ACS requirements by verifying the required product by means of document review and field audit. Follow-up audit, renewal audits and additional audit are conducted by CCS on a regular basis to verify that conditions of the ACS are continuously maintained by the manufacturer;
(6) the agreed ACS may be suspended or cancelled where deemed necessary by CCS;
(7) additional audits may be required to the manufacturer and/or sub-supplier and sub-contractor as deemed necessary by CCS.

3.10.3 Drawing examination

3.10.3.1 The applicant is to submit an application, indicating the extent of the required inspection and testing, and the extent under which conditions the manufacturer may perform all or parts of the required inspection and testing without the presence of a Surveyor, including that of the sub-contracted components, and the following documents are to be submitted for examination:
(1) the additional alternative quality control plan which covers all required inspection, testing and certification in compliance with CCS rules, including the procedure of the components to be stamped with a special stamp supplied by CCS or identified as required by CCS; or the standard quality control system which covers all required inspection, testing and certification in compliance with CCS rules, including the procedure of the traceability and the required type of product document for components or products;
(2) the existing CCS class approvals of the manufacturer's products as far as required;
(3) quality control plans relevant to the products and relevant components. Such quality control plans are to describe the quality assurance, control methods and frequency used in the manufacturing process according to the technical requirements or standards of the products, reflecting in particular the inspection and test requirements of CCS rules, guidelines and/or conventions with an indication of which inspections and tests are delegated to the manufacturer and which are to be done in the presence of a CCS representative;
(4) list of nominated personnel for:
① marking/stamping of products;
② tests and inspection (responsible);
③ provision of data and information (e.g. declaration of conformity, test reports etc.);
(5) any other additional documents that CCS may require in order to evaluate the manufacturing processes and the product quality control.

3.10.4 On-site audit

3.10.4.1 For manufacturers applying for the Alternative Certification Scheme, the check of quality management system is to comply with the requirements of Section 9 of this Chapter.

3.10.5 Issuance and validity of Alternative Certification Scheme

3.10.5.1 CCS will issue the product inspection scheme attached with an Alternative Certification Scheme to a manufacturer at his request for whom the drawing examination and on-site audit have been completed according to 3.10.2 and 3.10.3 and who is found to comply with the following requirements:
(1) the requirements for approval of products in one or more modes are met, product quality assurance meeting requirements of ISO 9001, having an additional or standard CCS-approved procedure for ensuring that inspections and tests will be in accordance with CCS rules and guidelines;
(2) product quality is found upon CCS inspection and quality system check to be continually kept stable during the period of holding the approval certificate for one or more types of products;
(3) the operation of the quality management system for marine product is capable of achieving at least the results of the inspections and tests attended by CCS Surveyor.

Section 11 PRINCIPLE APPROVAL

3.11.1 General requirements

3.11.1.1 Principle approval as a technical certification service provided by CCS for new products and new technologies, is usually applied to :

(1) innovatively designed products that do not meet the requirements for type approval;
(2) innovatively designed complex system products;
(3) products of equivalent design which are different from traditional standard design;
(4) innovative technical principles or plans;
(5) evaluation service for scientific research achievements.

3.11.1.2 Unless otherwise expressly specified by the Rules, CCS does not require principle approval mandatorily. Principle approval is a technical certification service that clients voluntarily request CCS to provide during the development of new products and new technologies. The following services can be provided:
(1) providing customized service programs;
(2) ensuring an acceptable level of safety and reduce uncertainty in the later stage;
(3) meeting the needs of early market expansion;
(4) approving general technical plans;
(5) approving alternative design plans;
(6) avoiding the risk of unqualified system performance.

3.11.1.3 Principle approval is used to demonstrate its technical feasibility at an acceptable level of reliability and cost, as well as its basic safety to people and the environment, i.e. the design complies with recognized rules or is proved to be sufficiently safe through risk assessment. For new technologies in the concept design stage, verification of the technical feasibility alone may be carried out.

3.11.1.4 Principle approval is the approval in principle for new products and new technologies. Where there is a clear requirement for approval of the product in the requirements for certification in the Appendix of this Chapter, other corresponding certificates of approval are to be obtained prior to installation onboard.

3.11.1.5 Principle approval only needs initial approval, which is only applicable to the technical status at the time of approval, and the certificate is valid for a long time.

3.11.1.6 Principle approval may be used as technology certification services for new products or new technologies with different degrees of technical maturity, such as concept design, principle prototype, engineering prototype, and finalized design.

3.11.1.7 For products with different degrees of technical maturity, some provisions of other chapters and sections on marine product inspection may not be applicable.

3.11.1.8 In view of the diversity of target service market and client demand for principle approval, in order to provide accurate service, generally the target to be achieved, the scope and the content of approval can be clearly defined through the pre-contract service.

3.11.1.9 Principle approval may be in the form of technical plan review, target function assessment, simulation test analysis, prototype verification test, rule compliance review, risk assessment, expert review, etc., as shown in Figure 3.11.1.9.

3.11.1.10 For principle approval in the design and development stage, plan approval, test and analysis can be conducted interactively at the same time.

3.11.1.11 Prototype verification test is a comprehensive means for technical feasibility verification. Prototype test is to be carried out unless the technology is start-up or easy to evaluate.

3.11.1.12 When there is a lack of mature and reliable technical rules or standards in principle approval, it is necessary to conduct risk assessment. For start-up technology, when the client has not completed the safety assessment, exemption may be granted according to the client entrustment.

3.11.1.13 For mature or innovative design concepts approved in principle approval, its technical plan, technical principle and alternative design plan can be used as the basis for CCS approval in subsequent plan approval and approval. The following supporting documents may be included:
(1) principle approval certificate;
(2) design plan and drawing documents approved in principle;
(3) the enterprise standard or design rules formed by recognized mature technical principles.

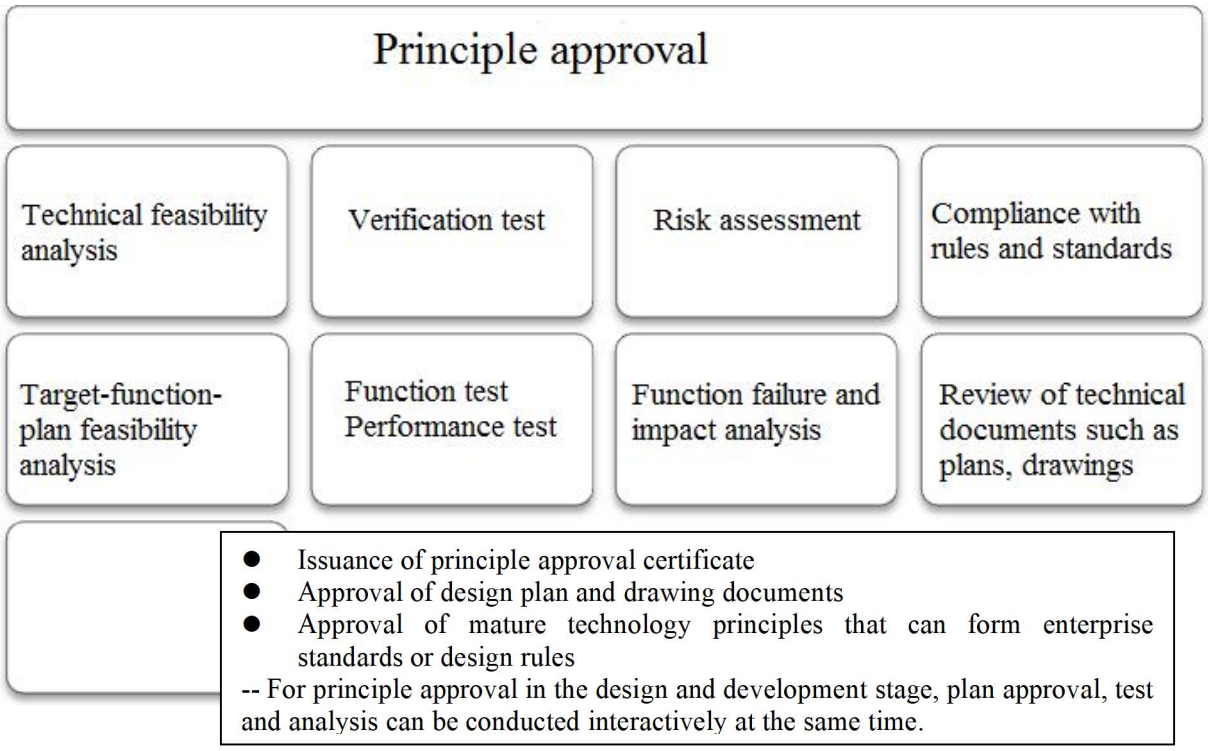


Figure 3.11.1.9 Principle approval

3.11.2 Feasibility review of technical plans

3.11.2.1 Technical feasibility analysis is the basic work of principle approval, which is intended to prove that the product can achieve preset functions. Verification can be carried out by means of basic principle analysis, objective and function analysis, review of recognized standards, prototype test, etc.

3.11.3 Review of technical documents such as plans, drawings

3.11.3.1 The purpose of review of the compliance with rules is to ensure safety, and the safety of the prototype to be tested need be guaranteed.

3.11.3.2 Where there are applicable rules and/or standards as the basis for product approval, the drawings and technical documents provided are to be reviewed according to the development stage of the product, as far as practicable, according to the requirements of CCS for plan approval.

3.11.4 Review of risk assessment reports

3.11.4.1 For products to be tested on board or for prototype test, in order to ensure the safety in the test process, risk assessment is to be conducted when there is no available rules or standards.

3.11.4.2 When the design plan involves alternative design of CCS rules, conventions or regulations, the risk assessment is to be structured and in accordance with the IMO MSC.1/Circ.1455 on Guidelines for Approval of Alternative and Equivalent Designs.

3.11.4.3 Risk analysis of complex systems with significant safety implications may be carried out by a third party.

3.11.5 Prototype verification test

3.11.5.1 Prototype for test is to be manufactured according to the technical stage of product development, which may include laboratory testing machine, principle prototype and engineering prototype.

3.11.5.2 Unless the technology is in the concept design stage or is easy to be confirmed, prototype verification test is normally to be conducted.

3.11.5.3 The prototype is to be inspected and marked by a surveyor to confirm its consistency with the submitted technical plans and drawings, and its compliance with the applicable rules and/or standards for approval, or the technical requirements of the client for the product.

3.11.5.4 The prototype is usually used to verify the core technology in the technical plan. In CCS principle approval, the surveyor is usually only required to participate in the test to prove technology relevance based on client's demand. Verification tests are to take into account CCS rules and guidelines, applicable standards, or the product performance and environment specified in the technical requirements of the client for the product. Test items are to meet the needs of technical verification and are to be submitted to CCS for approval.

3.11.5.5 The test report is to meet the requirements of 3.2.4 of this Chapter.

3.11.5.6 The acceptability of any test results obtained in the absence of a CCS surveyor will be given special consideration if the required test has been or is being carried out by an independent product test organization accepted by CCS. For details, see 3.2.4.4.

3.11.6 Issuance of principle approval certificates and approval of client product specifications

3.11.6.1 If a product is evaluated in accordance with this Section and deemed to comply with CCS rules, guidelines, applicable standards and/or the technical requirements of the client for the product, CCS will issue a certificate of principle approval.

3.11.6.2 Principle approval certificate has no validity period and is only applicable to the technical status at the time of approval.

3.11.6.3 For technical plan and design principle with mature technology approved in the principle approval, if they have been proved to meet the applicable approval basis, the client can form the enterprise standard or product technical specification, which can be used as the design basis for other products after CCS approval.

3.11.7 Changes in approval

3.11.7.1 If a product and/or technology subject to CCS principle approval has been subject to design changes or changes in applicable standards, the approval certificate will cease to be valid. The principle approval does not need changes in approval, and the client can apply for design approval and type approval to CCS after the technology is mature. If the client still requires principle approval, a new one can be applied.

Appendix 1A LIST OF CERTIFICATION REQUIREMENTS FOR CLASSED MARINE PRODUCTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
Material									
1	Metal material								
1.1	Rolled steel	X	–	–	–	–	X	–	Applicable to rolled steel for ships and offshore installations
1.2	Aluminum alloy	X	–	–	–	–	X	–	Applicable to aluminum alloy plate and section (including bar and pipe) for hull as well as aluminum alloy required by plan approval or strength calculation
1.3	Other non-ferrous metal material	X	–	–	–	–	X	–	Such as titanium and titanium alloy, copper and copper alloy, etc.
1.4	Steel wire rope	X	–	–	–	–	X	–	Applicable to towing and mooring ropes for towing ships, steel wire rope for lifting appliances and steel wire rope substituting anchor chain
2	Non-metallic material								Refer to Appendix 1D for the requirements for non-metallic materials for liquefied natural gas cargo tanks and fuel tanks
2.1	Resin	–	X	–	–	–	X	–	
2.2	Reinforcement material	–	X	–	–	–	X	–	
2.3	Fiber rope	X	–	–	–	–	X	–	Towing and mooring ropes for towing ships
2.4	Epoxy casting material for seating	–	X	–	–	–	X	–	For filling seating clearance of main engine, auxiliary engine and deck machinery
2.5	Synthetic (bearing) material	–	X	–	–	–	X	–	Nonmetallic synthetic material for bearings of rudder stock, rudder pin, rudder axle and stern shaft
2.6	Heat-insulating material	–	X	–	–	–	X	–	Applicable to refrigerated ship
2.7	Cargo bearer	–	X	–	–	–	X	–	Applicable to tanker with independent tanks type C
2.8	Cargo hold supporting gaskets	–	X	–	–	–	X	–	Applicable to tanker with independent tanks type C
2.9	Wrapping material of the propeller shaft	–	X	–	–	–	X	–	For ships with water-lubricated screwshaft condition monitoring (SCM) system applying for the class notation SCM
2.10	Structural adhesives	—	X	—	—	—	X	—	
3	Welding consumables								
3.1	Electrode	–	X	–	–	–	X	–	
3.2	Wire	–	X	–	–	–	X	–	
3.3	Flux	–	X	–	–	–	X	–	
4	Corrosion resistant means								
4.1	Shop primer	–	X	–	–	–	X	–	For temporary protection after surface treatment of metal material
4.2	Coating below ship's waterline	–	X	–	–	–	X	–	Including bottom anti-corrosive paint, bottom anti-fouling paint and anodic shielding
4.3	Coating above ship's waterline	–	X	–	–	–	X	–	Including marine anti-corrosive paint, marine waterline paint, hull paint, deck paint, cargo hold paint and internal compartment finish coating
4.4	Ship tank coating	–	X	–	–	–	X	–	Including marine drinking water

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									tank paint, ship ballast tank paint, ship oil tank paint, crude oil tanker cargo oil tank paint and engine room bottom paint
4.5	Sacrificial anode	X	–	–	–	–	–	–	
4.6	Cathodic protection system	X	–	–	–	–	–	X	
Hull									
5	Hull structure equipment	X	–	–	–	–	X	X	
5.1	Stem, stern post, rudder horn, propeller shaft bracket and fore wheel bearing seating	X	–	–	–	–	–	X	Applicable to all forgings and castings integral to hull, and carrying out inspection and certification to roughly machined forgings and castings
5.2	Hatch cover	X	–	–	–	–	–	X	
5.3	Window	X	–	–	–	–	–	X	Watertight window, airtight window, bridge window
5.4	Bow, stern and gangway doors	X	–	–	–	–	–	X	Including control, indication and alarm
5.5	Watertight door	X	–	–	–	–	–	X	Including control, indication and alarm
5.6	Watertight cable transits	—	X	—	X	—	—	X	
5.7	Portable means of access for inspections	X	–	–	–	–	–	X	Applicable to portable means of access for inspections listed according to approved ship structure access manual and kept on board (extension ladder type and cradle type lifting by winch)
5.8	Container securing arrangements	X	–	–	–	–	–	X	Applicable to container ships and non-container ships applying for class notation of container securing arrangements
5.9	Loading computer	–	X	–	X	–	–	X	Applicable to hardware, product inspection is not necessary for the ship provided with two loading computers
6	Outfitting								
6.1	Rudder blade	X	–	–	–	–	–	X	Raw material and products with finish machining are required to be inspected, requirements for raw material are shown in Appendix 2A
6.2	Rudder stock and pintle	X	–	–	–	–	–	X	Raw material and products with finish machining are required to be inspected, requirements for raw material are shown in Appendix 2A
6.3	Rudder bearing and pin bearing	X	–	–	–	–	–	X	Raw material and products with finish machining are required to be inspected, requirements for raw material are shown in Appendix 2A
6.4	Rudder stock connecting bolt	X	–	–	–	–	–	X	Raw material and products with finish machining are required to be inspected, requirements for raw material are shown in Appendix 2A
6.5	Single point mooring arrangement	X	–	–	X	O	–	X	Only spare parts need inspection and certificate
6.6	Emergency towing arrangement	X	–	–	X	O	–	X	Only spare parts need inspection and certificate, applicable to oil tankers, liquefied gas carrier and dangerous chemical carrier more than 20,000 tonnes deadweight

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
6.7	Towing hook	X	–	–	–	–	–	X	Applicable to towing vessels of ship type
6.8	Towing winch	X	–	–	–	–	–	X	Applicable to towing vessels of ship type, and the first product is to be subject to type test
6.9	Seats of high speed craft	–	X	–	X	–	–	X	Applicable to high speed craft
6.10	Accommodation ladder, ramp	X	–	–	–	–	–	X	
7	Anchoring and mooring equipment								
7.1	Anchor chains and fitting	X	–	–	–	–	X	O	Plan approval is only required for unmarked anchor chain fitting
7.2	Anchors and accessory	X	–	–	–	–	X	X	
7.3	Chain stopper	X	–	–	–	–	–	X	
7.4	Cable clenches	X	–	–	–	–	–	X	Applicable to cable clenches with watertight requirements in regulation 22-2 of Load Line Convention
7.5	Windlass	X	–	–	–	–	–	X	The first product is to be subject to type test
7.6	Mooring winch and capstan	X	–	–	–	–	–	X	The first product is to be subject to type test
7.7	Winch or capstan for operation	X	–	–	–	–	–	X	Applicable to working ships, and the first product is to be subject to type test
Machinery (including machinery equipment of refrigerated vessels)									
8	Pumps and piping								Refer to Appendix 1D for the additional requirements for pumps and piping included in liquefied natural gas specialized products
8.1	Bilge pump and bilge injection pump	X	–	–	X	O	–	X	
8.2	Ballast pump	X	–	–	X	O	–	X	
8.3	Liquid cargo pump, stripping pump and tank cleaning pump	X	–	–	X	O	–	X	Oil tanker, tanker carrying liquefied gas in bulk and tanker carrying dangerous chemicals in bulk
8.4	Fuel oil pump	X	–	–	X	O	–	X	Including gas fuel pump
8.5	Fuel oil injection valve cooling pump	X	–	–	X	O	–	X	
8.6	Lubricating oil pump	X	–	–	X	O	–	X	Lubricating oil pump for diesel engine and gearbox
8.7	Fire pump (including emergency fire pump)	X	–	–	X	O	–	X	
8.8	Cooling water pump	X	–	–	X	O	–	X	Cooling water pump for diesel engine
8.9	Boiler feed pump	X	–	–	X	O	–	X	
8.10	Boiler circulating water pump	X	–	–	X	O	–	X	
8.11	Hot oil circulating pump	X	–	–	X	O	–	X	
8.12	Condensate pump	X	–	–	X	O	–	X	Condensate pump for main condenser, gas pump and circulating pump
8.13	Pipes of more than 50 mm in diameter for piping of Classes I and II and fittings (flange, bend and three-way, etc.)	X	–	–	–	–	X	–	
8.14	Pipes of 50 mm in diameter and below for piping of Classes I and II and fittings (flange, bend	–	X	–	–	–	X	–	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	and three-way, etc.)								
8.15	Pipes for piping of Class III and fittings (flange, bend and three-way, etc.)	–	X	–	–	–	X	–	
8.16	Valves of 50 mm in diameter and over for piping of Classes I and II, valves of 300 mm in diameter and over for piping of Class III; sea valve; (operation temperature below -55℃) low temperature valve	X	–	–	X	O	–	X	
8.17	Valves of less than 50 mm in diameter for piping of Classes I and II	–	X	–	X	–	–	X	
8.18	Plastic pipe	–	X	–	–	–	X	–	Applicable to pipes mentioned in Appendix 1, Chapter 2, PART THREE of the Rules, also applicable to the plastic pipes used on the machinery
8.19	Flexible hose assembly, for piping of Classes I and II or more than 50 mm in diameter	X	–	–	X	O	–	X	For fuel oil, lubricating oil, hydraulic and hot oil system, fresh water and sea water cooling system, compressed air system, bilge and ballast system, also applicable to the flexible hoses used on the machinery of the above systems
8.20	Flexible hose assembly: except for above-mentioned	O	X	–	X	–	–	X	For fuel oil, lubricating oil, hydraulic and hot oil system, fresh water and sea water cooling system, compressed air system, bilge and ballast system as well as Class III steam piping system; C/E is necessary for gas pipe; applicable to the flexible hoses used on the machinery of the above systems
8.21	Mechanical pipe joint	–	X	–	X	–	–	X	
8.22	Corrugated expansion joint	–	X	–	X	–	–	X	
8.23	Air pipe closing appliance	X	-	–	X	–	–	X	
8.24	Spark arrester	–	X	–	X	–	–	X	
8.25	Sound damper	–	X	–	X	–	–	X	
8.26	Filter	X	–	–	–	–	–	X	For fuel oil, lubricating oil, sea water, fresh water system
8.27	Fume exhaust valve	–	X	–	X	O	–	X	
9	Boiler and pressure vessel								
9.1	Boiler	X	–	–	–	–	X	X	Including hot oil boiler
9.2	Boiler burner	X	–	X	O	O	–	X	
9.3	Economizer	X	–	X	O	O	–	X	
9.4	Steam generator (over 0.35 MPa)	X	–	X	O	O	–	X	
9.5	Thermal oil and thermal water heating units (for service of propulsion machinery)	X	–	X	O	O	–	X	For heating oil and water for heat conduction
9.6	Safety valve	X	–	–	X	O	–	X	For boiler and air receiver, when kept on board separately
9.7	Boiler liquid meter	–	X	–	X	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
9.8	Classes I and II pressure vessel	X	–	–	–	–	X	X	Air receiver, accumulator, etc.
9.9	Class III pressure vessel	X	–	–	–	–	O	X	Air receiver, accumulator, pressure tank, etc.
9.10	Heat exchanger	X	–	X	O	O	–	X	For heat exchange of fresh water, lubricating oil, hydraulic oil, fuel oil, steam and cooling systems
10	Machinery equipment								
10.1	Steam turbine	X	–	–	X	O	–	X	
10.2	Gas turbine	X	–	–	X	O	–	X	
10.3	Diesel engine	X	–	O	X	O	–	X	Dual fuel diesel engine and gas fuel engine are referred to this requirement
10.4	Air compressor	X	–	X	O	O	–	X	For 1) actuation / emergency actuation; 2) gas control system; 3) air compressor as replacement of spare air charging bottle of fireman's outfit
10.5	Oil separator	X	–	X	O	O	–	X	
10.6	Fuel oil supply unit	X	–	–	–	–	–	X	
10.7	Fan	X	–	X	O	O	–	X	For category A machinery space, cargo pump tank and other hazardous zone
10.8	Refrigerating plant	X	–	–	–	–	–	X	When there is class notation of cargo refrigeration
10.9	Hydraulic power plant	X	–	–	–	–	–	X	
10.10	Cargo compressor	X	–	–	–	–	–	X	Including compressor for gas fuel, for use by LPG carriers; Refer to Appendix 1D for LNG carriers or LNG dual fuel powered ships
10.11	Monitor, foam monitor	X	–	–	X	O	–	X	Applicable to external fire-fighting of fire-fighting ships applying for class notations of Fire Fighting Ship N
10.12	Steering arrangements								In addition to the steering gear, steering arrangements also include heading control system, rudder indicator, simplified operation box, starting box and alarm box for steering arrangements
10.12.1	Steering gear (of or more than 630 kNm)	X	—	—	–	–	–	X	1. The quality system of the steering gear manufacturer is to be satisfactorily audited by CCS; 2. The components that transmit mechanical force to the rudder stock are to be satisfactorily inspected by CCS; 3. The efficiency of the rudder steering mechanism is to be satisfactorily verified by the prototype test; 4. The hydraulic pump set is to be subjected to a load test and satisfactorily inspected by CCS
10.12.2	Steering gear (below 630 kNm)	X	—	—	X	O	—	X	
10.12.3	Heading control system								This product is a statutory product and the requirements for its certification are shown in Appendix 1B 4.12
10.12.4	Rudder indicator								This product is a statutory product and the requirements for its certification are shown in

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									Appendix 1B 4.5
10.12.5	Simplified operation box, starting box and alarm box for steering arrangements								See Appendix 1A, 13.11 for certification and inspection requirements
10.13	Fin stabilizer, vortex absorbed fin	X	–	–	–	–	X		
10.14	Foundation bolts of main engines	X	—	—	—	—	—	—	Applicable to engines with cylinder diameter >300 mm; inspection is to be carried out according to the drawing of arrangement of foundation of main engine provided by the diesel engine manufacturer. The drawing is to include the following: Bolts (Mounting bolts and tightening bolts) Quantity, bolt diameter, bolt material (grade and performance), tightening bolt arrangement, thrust block arrangement
10.15	Hydraulic cylinder	X	–	–	–	–	–	X	
10.16	Hydraulic motor	X	–	–	–	–	–	X	
11	Gear transmission arrangement								
11.1	Gearbox	X	–	–	X	O	–	X	Applicable to gear transmission arrangement of main propulsion machinery for transmitting maximum continuous power of not less than 220 kW and essential auxiliary engine of not less than 110 kW
11.2	Gearbox	X	–	–	–	–	–	X	Applicable to gear transmission arrangement of main propulsion machinery for transmitting maximum continuous power of less than 220 kW and essential auxiliary engine of less than 110 kW
12	Shafting and propeller								
12.1	Thrust shaft	X	–	–	–	–	–	X	Machining inspection, requirements for raw material are shown a in Appendix 2A
12.2	Intermediate shaft and bearing	X	–	–	–	–	–	X	Machining inspection, requirements for raw material are shown a in Appendix 2A
12.3	Stern tube shaft, propeller shaft	X	–	–	–	–	–	X	Machining inspection, requirements for raw material are shown a in Appendix 2A
12.4	Stern tube	X	–	–	–	–	–	X	
12.5	Stern tube sealing device	–	X	–	X	–	–	X	Applicable to oil-lubricated stern shaft and water-lubricated stern shaft
12.6	Stern tube bearing	X	–	–	–	–	X	X	
12.7	Propeller	X	–	–	–	–	X	X	
12.8	Adjustable pitch propeller	X	–	–	–	–	–	X	
12.9	Z propulsion arrangement	X	–	–	–	–	–	X	The first product of the same model is to be subject to type test
12.10	Side thruster	X	–	–	–	–	–	X	The first product of the same model is to be subject to type test
12.11	Water jet propulsion arrangement	X	–	–	–	–	–	X	The first product of the same model is to be subject to type test

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
12.12	Other thrusters	X	–	–	–	–	–	X	The first product of the same model is to be subject to type test
12.13	Elastic coupling	X	–	–	X	O	–	X	
12.14	Non-elastic coupling	X	–	–	–	–	–	X	
12.15	Shafting connecting bolt	X	–	–	–	–	–	X	
12.16	Steel adjustable packing block	–	X	–	X	–	–	X	
12.17	Vibration isolator	–	X	–	X	–	–	X	
12.18	Cycloidal steering oar	X	–	–	–	–	–	X	
Electrical installations and automatic equipment									
13	Electrical installations								
13.1	Generators (50 kVA and over)	X	–	–	X	O	–	X	
13.2	Generators (below 50 kVA)	–	X	–	X	–	–	X	
13.3	Generating sets (50 kVA and over)	X	–	–	–	–	–	X	
13.4	Emergency generating sets	X	–	–	–	–	–	X	
13.5	Motors (50 kW and over)	X	–	–	X	O	–	X	
13.6	Motors (below 50 kW)	–	X	–	X	–	–	X	
13.7	Main switchboard	X	–	–	–	–	–	X	
13.8	Emergency switchboard	X	–	–	–	–	–	X	
13.9	Group starter panel	X	–	–	–	–	–	X	
13.10	Charging and discharging panel	X	–	–	–	–	–	X	
13.11	Electrical control box (associated with essential equipment)	X	–	–	–	–	–	X	For the definition of essential equipment, refer to paragraph 1.1.2.1(1), Chapter 1, PART FOUR of the Rules; for marine propulsion power limitation
13.12	Power, control and communication cables and wires	X	–	–	–	–	X	X	Including optical fiber and network cables in control and communication cables
13.13	Transformers (50 kVA and over)	X	–	–	X	O	–	X	For power and lighting
13.14	Transformers (below 50 kVA)	–	X	–	X	–	–	X	For power and lighting, and single phase transformers rated at 1 kVA or more and 3-phase transformers rated at 5 kVA or more
13.15	Battery	–	X	–	X	–	–	X	For actuation of main and auxiliary engines or spare/emergency power supply
13.16	Power conversion devices (charger, frequency converter, etc.)	X	–	–	X	O	–	X	Charger for charging emergency battery, frequency converter of 50 kW and over
13.17	Uninterrupted Power Supply (UPS) (50 kVA and over)	X	–	–	X	O	–	X	For application, refer to 3.9.1, Chapter 3, PART FOUR of the Rules; for marine propulsion power limitation
13.18	Uninterrupted Power Supply (UPS) (below 50 kVA)	—	X	—	X	O	—	X	For application, refer to 3.9.1, Chapter 3, PART FOUR of the Rules; for marine propulsion power limitation
13.19	Additional emergency illumination equipment	–	X	–	X	O	–	X	For passenger ships with ro-ro cargo spaces or special spaces (refer to 2.2.2.3, Chapter 2, PART FOUR of the Rules)
13.20	Cable management system	X	–	–	–	–	–	X	Applicable to ships applying for class notation of shore power
13.21	Distribution panel for shore power connection	X	–	–	–	–	–	X	
13.22	Control panel for shore	X	–	–	–	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	power switch in								
13.23	Lighting fitting	–	X	–	X	–	–	X	
13.24	Electrical heater	X	–	–	–	–	–	X	For heating combustible medium such as fuel oil and lubricating oil
13.25	Explosion-proof motor	X	–	–	X	O	–	X	
13.26	Explosion-proof lamp	—	X	—	X	—	—	X	
13.27	Other explosion-proof electrical equipment 1	X[1]	X[1]	–	X[1]	–	–	X	Applicable to electrical products for which the certification requirements are specified in the List of Certification Requirements (such as sensor, meter, detector and control box/cabinet, etc.)
13.28	Engine telegraph	–	X	–	X	–	–	X	
13.29	Sound-powered telephone	–	X	–	X	–	–	X	
13.30	Engineer‘s alarm system	X	–	–	X	O	–	X	
13.31	Automatic start device of generators	X	–	–	–	–	–	X	
13.32	Combined visual and audible alarm panel (box)	X	–	–	–	–	–	X	
14	Automatic equipment								
14.1	Propulsion machinery control system	X	–	–	X	O	–	X	
14.2	Engine room monitoring and alarm system	X	–	–	X	O	–	X	
14.3	Level measuring system	X	–	–	X	O	–	X	For level measuring outside cargo tank
14.4	Pressure, temperature, level measuring alarm system	X	–	–	X	O	–	X	Applicable to cargo tank
14.5	Valve remote control system	X	–	–	X	O	–	X	Including manual valve remote control system for emergency maneuvering
14.6	Dynamic positioning control system	X	–	–	X	O	–	X	
14.7	EOM system computer	–	X	–	X	–	–	X	Applicable to hardware, type approval is not necessary for two equipped computers which are standby each other. For ships applying for EOM notation
14.8	Shaft power meter	–	X	–	X	O	–	X	For ships applying for EOM notation; for marine propulsion power limitation
14.9	Flowmeter	–	X	–	X	O	–	X	For ships applying for EOM notation

Symbols:
1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer’s document; X – Applicable; O – Optional.
2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval.
3) X[1]: The certification requirements for such explosion-proof product are consistent with those for the existing non explosion-proof product of the same type.

Appendix 1B① LIST OF CERTIFICATION REQUIREMENTS FOR STATUTORY MARINE PRODUCTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
1	Life-saving appliances								
1.1	Lifebuoy	X	–	–	X	O	–	X	
1.2	Position-indicating lamp for life-saving appliances	–	X	–	X	–	–	X	Including: (a) for lifebuoy; (b) for lifejacket
1.3	Spontaneous distress flare of lifebuoy	–	X	–	X	–	–	X	
1.4	Lifejacket	X	–	–	X	O	–	X	
1.5	Immersion suit, anti-exposure suit	X	–	–	X	O	–	X	
1.6	Thermal protective aid	–	X	–	X	–	–	X	
1.7	Visual signal	–	X	–	X	–	–	X	Including: (a) rocket parachute flare; (b) hand flare; (c) buoyant smoke signal
1.8	Line-throwing appliance	–	X	–	X	–	–	X	
1.9	Life rafts	X	–	–	X	O	–	X	
1.10	Life boats	X	–	–	X	O	–	X	
1.11	Rescue boats	X	–	–	X	O	–	X	
1.12	Lowering apparatus	X	–	–	X	O	–	X	
1.13	Marine evacuation system	X	–	–	X	O	–	X	
1.14	Rescue equipment for person falling into water	X	–	–	X	O	–	X	Effective means for recovering the survival from water surface and transferring them from rescue equipment or life boat to the ship
1.15	Embarkation ladder	X	–	–	–	–	–	X	
1.16	Public address system	X	–	–	X	O	–	X	
1.17	General emergency alarm system	X	–	–	X	O	–	X	
2	Pollution prevention at sea								
2.1	Oil-filtering equipment	X	–	–	X	O	–	X	Oil content of effluent not exceeding 15 ppm
2.2	Oil/water interface detector	X	–	–	X	O	–	X	
2.3	Existing oil-filtering equipment (additional treatment equipment in MEPC.60(33))	X	–	–	X	O	–	X	Oil content of effluent not exceeding 15 ppm
2.4	Oil discharge monitoring and control system	X	–	–	X	O	–	X	For oil tanker
2.5	Sewage treatment plant	X	–	–	X	O	–	X	
2.6	Incinerator	X	–	–	X	O	–	X	
2.7	Nitrogen oxide analyzer (chemical luminescent detector (CLD) type/ heating chemical luminescent detector (HCLD) type)	X	–	–	X	O	–	X	For direct measurement of nitrogen oxide on board ship
2.8	Exhaust cleaning system(scheme A)	X	–	–	X	O	–	X	SOx emission compliance certificate
2.9	Exhaust cleaning system(scheme B)	–	–	–	–	–	–	X	To be implemented in accordance with 2.8 of this Table for ships flying the flag

① If the list is not consistent with the requirements of the flag State Government, the provisions of the flag State Government are to prevail.

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									of China
2.10	Exhaust gas monitoring system	–	X	–	X	O	–	X	For exhaust gas emission monitoring
2.11	Discharge water monitoring system	–	X	–	X	O	–	X	For washwater discharge monitoring
2.12	Equipment reducing NO_x emission on board by other equivalent method	X	–	–	X	O	–	X	
2.13	Equipment limiting SO_x emission by other technology	X	–	–	X	O	–	X	
2.14	Diesel Oxidation Catalyst (DOC)	X	–	–	X	O	–	X	By means of an oxidation reaction, carbon monoxide (CO) and hydrocarbons (HC) (including fugitive methanol) in the exhaust gas are converted into harmless water (H_2O) and carbon dioxide (CO_2). This requirement also applies to equipment using other technologies to reduce emissions of carbon monoxide (CO) and hydrocarbons (HC) (including fugitive methanol)
2.15	NO_x emission of diesel engines of over 130 kW	X	–	–	X	O	–	X	EIAPP certificate
2.16	Ballast water management system	X	–	–	X	O	–	X	
2.17	Crude oil washing machine	X	–	–	X	O	–	X	
2.18	Comminuting and disinfecting system	X	–	–	X	O	–	X	For sewage
3	Fire-resisting material, structure and fire-fighting equipment								
3.1	Deck covering	–	X	–	–	–	X	–	
3.2	Non-combustible material	–	X	–	–	–	X	–	
3.3	Low flame spread material	–	X	–	–	–	X	–	Including: (a) decoration sheet; (b) paint; (c) floor; (d)insulation for cooling piping fittings; (e) adhesives for classes “A”, “B” and “C” division; (f) combustible duct
3.4	Vertical-mounted textile and film	–	X	–	–	–	X	–	Applicable to spaces of passenger ships with requirements for limited fire hazard
3.5	Soft cushion furniture	–	X	–	–	–	X	–	Applicable to spaces of passenger ships with requirements for limited fire hazard
3.6	Bedding	–	X	–	–	–	X	–	Applicable to spaces of passenger ships with requirements for limited fire hazard
3.7	Classes A, B and F fire division	–	X	–	X	–	–	X	
3.8	Class A fire window/side scuttle	X	–	–	X	O	–	X	
3.9	Class A and class B division penetrations	–	X	–	X	–	–	X	Including: 1. (a) cable penetration; (b) penetrations such as pipes,

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									ducts and ports (for penetration piping made of steel 3 mm and over in thickness, not less than 900 mm in length or the equivalent material with no opening, certificate is not required); 2. class B division penetrations made of a steel sleeve, having a thickness of not less than 1.8 mm and a length of not less than 900 mm for pipe diameters of 150 mm or more and not less than 600 mm for pipe diameters of less than 150 mm, certificate is not required
3.10	Fire door	X	–	–	X	O	–	X	
3.11	Fire door control device	X	–	–	X	O	–	X	
3.12	Fire damper	X	–	–	X	O	–	X	
3.13	Flame-retarding material for furniture on high speed craft	–	X	–	–	–	X	–	
3.14	Flame-retarding material for high speed craft	–	X	–	–	–	X	–	Except for furniture
3.15	Fire division of high speed craft	–	X	–	X	–	–	X	
3.16	Fire division penetration of high speed craft	–	X	–	X	–	–	X	Including: (a) cable penetration; (b) penetration such as pipe, duct and port
3.17	Flame arrester	X	–	–	X	O	–	X	
3.18	Pressure vacuum valve	X	–	–	X	O	–	X	Including high speed venting valve and breathing valve
3.19	Bulkhead gearing	X	–	–	–	–	–	X	
3.20	Fixed gas fire-extinguishing arrangement (CO_2)	X	–	–	X	O	–	X	
3.21	Fixed equivalent gas fire-extinguishing arrangement	X	–	–	X	O	–	X	For machinery space and cargo pump tank
3.22	Equivalent gas fire-extinguishing arrangement (aerosol system)	X	–	–	X	O	–	X	For machinery space
3.23	Fixed local water-based fire-extinguishing arrangement	X	–	–	X	O	–	X	For machinery space of category A
3.24	Fixed water-based fire-extinguishing arrangement	X	–	–	X	O	–	X	For ro-ro space and special space
3.25	Fixed high-expansion foam fire-extinguishing arrangement	X	–	–	X	O	–	X	For machinery space and cargo pump tank protection
3.26	Fixed medium-expansion foam fire-extinguishing arrangement	X	–	–	X	O	–	X	For fixed deck system
3.27	Fixed low-expansion foam fire-extinguishing arrangement	X	–	–	X	O	–	X	For machinery space and deck protection
3.28	Foam fire-extinguishing medium	–	X	–	–	–	X	–	
3.29	Chemical dry powder fire-extinguishing arrangement	X	–	–	X	O	–	X	
3.30	Fixed pressure water	X	–	–	X	O	–	X	For a) cabin balcony; b)

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	spray fire-extinguishing arrangement								machinery space and cargo pump tank
3.31	Sprinkler arrangement	X	–	–	X	O	–	X	For accommodation space, service space and control station (including fixed sprinkler arrangement for high speed craft)
3.32	Helicopter deck foam fire-extinguishing arrangement	X	–	–	X	O	–	X	Foam fire-extinguishing arrangement protecting helicopter deck
3.33	Fixed fire-extinguishing arrangement for gallery discharge duct	X	–	–	X	O	–	X	
3.34	Inert gas system	X	–	–	X	O	–	X	
3.35	Portable foam applicator	X	–	–	X	O	–	X	
3.36	Portable fire extinguisher	X	–	–	X	O	–	X	
3.37	Trolley type fire extinguisher	X	–	–	X	O	–	X	
3.38	Water jet/spray nozzle	–	X	–	X	–	–	X	
3.39	Fire hoses	–	X	–	X	–	–	X	
3.40	Fireman's protective clothing (insulation clothing)	–	X	–	X	–	–	X	
3.41	Lifeline	–	X	–	X	–	–	X	
3.42	Self-contained compressed air breathing apparatus	X	–	–	X	O	–	X	
3.43	Compressed air breathing apparatus	X	–	–	X	O	–	X	
3.44	Emergency escape breathing device	X	–	–	X	O	–	X	
3.45	Low location lighting system	–	X	–	X	–	–	X	
3.46	Equivalent low location lighting system	–	X	–	X	–	–	X	
3.47	Electrical safety lamp (explosion-proof electrical safety lamp)	–	X	–	X	–	–	X	For fireman's outfit specified in Chapter 3 of FSS Code
3.48	Portable oxygen concentration measuring device	X	–	–	X	O	–	X	
3.49	Fixed oxygen analyzing and gas detecting equipment	X	–	–	X	O	–	X	Refer to Appendix 1D for LNG carriers or LNG dual fuel powered ships
3.50	Fixed hydrocarbon gas detection system	X	–	–	X	O	–	X	Refer to Appendix 1D for LNG carriers or LNG dual fuel powered ships
3.51	Smoke detection system	X	–	–	X	O	–	X	
3.52	Fixed fire detection and alarm system	X	–	–	X	O	–	X	
3.53	Two-way portable radiotelephone apparatus of an explosion-proof type for fire-fighters	X	–	–	X	O	–	X	
4	Navigational equipment								
4.1	Magnetic compass	X	–	–	X	O	–	X	
4.2	Gyrocompass	X	–	–	X	O	–	X	
4.3	Propulsion indicator	–	X	–	X	–	–	X	
4.4	Side thrust, pitch and operational mode indicator	–	X	–	X	–	–	X	
4.5	Rudder indicator	–	X	–	X	–	–	X	
4.6	Propeller speed indicator	–	X	–	X	–	–	X	
4.7	Pitch indicator	–	X	–	X	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
4.8	Rate-of-turn indicator	–	X	–	X	–	–	X	
4.9	Echo-sounding equipment	X	–	–	X	O	–	X	
4.10	Transmitting heading device (THD)	X	–	–	X	O	–	X	
4.11	Speed and distance measuring equipment (SDME)	X	–	–	X	O	–	X	
4.12	Heading control system (HCS)	X	–	–	X	O	–	X	
4.13	Track control system	X	–	–	X	O	–	X	
4.14	Integrated navigation system (INS)	X	–		X	–	–	X	
4.15	Integrated bridge system (IBS)	–	X	–	X	–	–	X	
4.16	Voyage data recorder (VDR)	X	–	–	X	O	–	X	
4.17	Simplified voyage data recorder (S-VDR)	X	–	–	X	O	–	X	
4.18	Electronic chart display and information system (ECDIS) and backup equipment, raster chart display system (RCDS)	X	–	–	X	O	–	X	
4.19	Electronic chart system (ECS)	X	–	–	X	O	–	X	
4.20	Multi-system electronic positioning equipment	X	–	–	X	O	–	X	
4.21	Global positioning system (GPS) receiver equipment	X	–	–	X	O	–	X	
4.22	Shipborne BEIDOU Satellite navigation system (BDS) receiver equipment	X	–	–	X	O	–	X	
4.23	9 GHz radar search and rescue transponders (SART)	X	–	–	X	O	–	X	
4.24	AIS SART equipment	X	–	–	X	O	–	X	
4.25	Automatic Identification System (AIS)	X	–	–	X	O	–	X	
4.26	Radar equipment	X	–	–	X	O	–	X	
4.27	Radar equipment with chart option	X	–	–	X	O	–	X	
4.28	Radar reflector—passive type	–	X	–	X	–	–	X	
4.29	Radar target intensifier	–	X	–	X	–	–	X	
4.30	Searchlight for high speed craft	–	X	–	X	–	–	X	
4.31	Night-vision unit for high speed craft	X	–	–	X	–	–	X	
4.32	Daylight signaling lamp	X	–	–	X	O	–	X	
4.33	Bridge navigational watch alarm system (BNWAS)	–	X	–	X	–	–	X	
4.34	Sound reception system	X	–	–	X	O	–	X	
4.35	Long-range identification and tracking system (LRIT)	X	–	–	X	O	–	X	
4.36	Ship’s electronic clinometer (navigation bridge)	X	–	–	X	O	–	X	
4.37	Pilot ladder	X	–	–	–	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
4.38	Pilot's accommodation ladder	X	–	–	–	–	–	X	
4.39	Suez Canal searchlight	X	–	–	–	–	–	X	
5	Radio communication equipment								
5.1	VHF radio installations capable of voice communication and digital selective calling (DSC)	X	–	–	X	O	–	X	
5.2	MF radio installations capable of voice communication and digital selective calling (DSC)	X	–	–	X	O	–	X	
5.3	MF DSC watch-keeping receiver	X	–	–	X	O	–	X	
5.4	M/HF DSC watch-keeping receiver	X	–	–	X	O	–	X	
5.5	Narrow-band direct printing telegraph equipment receiving safety information to ship by high frequency	X	–	–	X	O	–	X	
5.6	VHF DSC watch-keeping receiver	X	–	–	X	O	–	X	
5.7	NAVTEX receiver	X	–	–	X	O	–	X	
5.8	Enhanced group call receiver	X	–	–	X	O	–	X	
5.9	406 MHz emergency position-indicating radio beacon (COSPAS-SARSAT)	X	–	–	X	O	–	X	
5.10	BEIDOU emergency position-indicating radio beacon (BD-EPIRB)	X	–	–	X	O	–	X	
5.11	INMARSAT ship earth station	X	–	–	X	O	–	X	
5.12	MF/HF radio installation capable of voice communication narrow band direct-printing telegraph and digital selective calling (DSC)	X	–	–	X	O	–	X	
5.13	Portable survival craft two-way VHF radiotelephone apparatus	X	–	–	X	O	–	X	
5.14	VHF emergency position-indicating radio beacon	X	–	–	X	O	–	X	
5.15	Distress alarm panel	X	–	–	X	O	–	X	
5.16	Ship security alert system	X	–	–	X	O	–	X	
5.17	Aviation two-way VHF radiotelephone apparatus	X	–	–	X	O	–	X	
6	Equipment required by International Regulations for Preventing Collisions at Sea, 1972								
6.1	Navigation light	–	X	–	X	–	–	X	
6.2	Navigation light control panel	X	–	–	X	O	–	X	
6.3	Whistle	X	–	–	X	O	–	X	
6.4	Control panel of whistles	–	X	–	X	–	–	X	
6.5	Audible signal equipment	–	X	–	X	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	(bell and gong)								
7	SOLAS II-1 equipment								
7.1	Water ingress detection alarm system	X	–	–	X	O	–	X	
7.2	Transfer arrangements	X	–	–	–	–	–	X	Embarkation and disembarkation of personnel on board the ships constructed after January 1, 2010, to which SOLAS Chapter II-1, Part A-1 apply
8	SOLAS II-2 equipment								
8.1	Deep-fat cooking equipment	O	X	–	X	O	–	X	
8.2	Fire-extinguishing appliances of deep-fat cooking equipment	O	X	–	X	O	–	X	
8.3	Water fog applicator	—	X	—	X	—	—	X	For container ships
9	SOLAS XI-1 equipment								
9.1	Portable atmosphere testing instrument	X	–	–	X	O	–	X	
10	IBC and IGC Codes								
10.1	Cargo hose	O	X	–	X	O	–	X	Refer to Appendix 1D for LNG carriers or LNG dual fuel powered ships
11	Lights for helideck	–	X	–	X	–	–	X	Used for helideck boundary lights, floodlights, auxiliary floodlights, status lights, windsock lights, and obstruction lights

Symbols:
1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer's document; X – Applicable; O – Optional.
2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval.
Note: Other statutory marine products with certification requirements of the Administration are to be implemented as required by the Administration.

Appendix 1C LIST OF CERTIFICATION REQUIREMENTS FOR LIFTING APPLIANCES

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
1	Derrick system (including derrick type crane)	X	–	–	–	–	–	X	
2	Crane	X	–	–	–	–	–	X	
3	Engine room crane	X	–	–	–	–	–	X	
4	Submersible launching arrangement	X	–	–	–	–	–	X	
5	Lift	X	–	–	–	–	–	X	
5.1	Lift for passenger or crew	X	–	–	–	–	–	X	
5.2	Cargo and vehicle lift and vehicle ramp	X	–	–	–	–	–	X	
6	Telescope gangway	X	–	–	–	–	–	X	

Symbols:
1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer's document; X – Applicable; O – Optional.
2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval.

Appendix 1D LIST OF CERTIFICATION REQUIREMENTS FOR LIQUEFIED NATURAL GAS SPECIALIZED PRODUCTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
Liquefied natural gas carrier cargo containment system (membrane cargo tank)									
1	Materials/Component								
1.1	Adhesive	—	X	—	—	—	X	—	Used for bonding insulation materials and components.
1.2	Glass wool	—	X	—	—	—	X	—	
1.3	Glass cloth	—	X	—	—	—	X	—	
1.4	Load bearing mastic	—	X	—	—	—	X	—	
1.5	Reinforced polyurethane foam	X	—	—	—	—	X	—	
1.6	Perlite	—	X	—	—	—	X	—	
1.7	Insulating material	—	X	—	—	—	X	—	
1.8	Plywood	X	—	—	—	—	X	—	
1.9	Plywood Cleat	X	—	—	—	—	X	X[1]	
1.10	Paint for inner hull protection	—	X	—	—	—	X	—	
1.11	Thermal protection		X	—	—	—	X	—	Used for thermal insulation protection of weld backside
1.12	Stainless steel sheets	X	—	—	—	—	X	—	
1.13	Stainless steel studs, nuts&washers	—	X	—	—	—	X	—	Works approval is only for material approval. If C/E is provided for forged steel parts, approval is not required. C/E doesn't require approval
1.14	Collar studs(forging)	X	—	—	—	—	X	X[1]	Works approval is only for material approval. If C/E is provided for forged steel parts, approval is not required. C/E doesn't require approval
1.15	Self-locked nuts	—	X	—	—	—	X	—	
1.16	Spring washers	—	X	—	—	—	X	—	
1.17	Coupler rods,setting plates	X	—	—	—	—	X	X[1]	
1.18	Coupler base socket(forging)	X	—	—	—	—	X	X[1]	Works approval is only for material approval. If C/E is provided for forged steel parts, approval is not required. C/E doesn't require approval
1.19	Staples	—	X	—	—	—	X	—	Category 1 and 2 staples specified by the patent holder
1.20	Secondary barrier components	X	—	—	—	—	X	X[1]	Three-in-one sheet, including rigid secondary barrier and flexible secondary barrier
1.21	Fe-36% Ni alloy strips	X	—	—	—	—	X	—	
1.22	Aluminium for reinforcement elements	X	—	—	—	—	X	X[1]	
2	Prefabricated elements								

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
2.1	Insulating boxes	X	—	—	X	—	—	X[1]	
2.2	Anchor strips	X	—	—	X	—	—	X[1]	
2.3	Primary barrier components	X	—	—	X	—	—	X[1]	Include flat, corner, corner area and end stainless steel corrugated plates
2.4	Top bridge pads prefabricated elements	X	—	—	X	—	—	X[1]	
2.5	Flat wall panels prefabricated elements	X	—	—	X	—	—	X[1]	
2.6	Corner panels prefabricated elements	X	—	—	X	—	—	X[1]	
2.7	Stainless steel corners	X	—	—	X	—	—	X[1]	
2.8	Single legs prefabricated elements	X	—	—	X	—	—	X[1]	
2.9	Fe-36% Ni alloy tubes and other prefabricated components	X	—	—	—	—	—	X[1]	
Liquefied natural gas carrier cargo containment system (independent cargo Tank type C)									
3.1	Rolled steel	X	—	—	—	—	X	—	
3.2	Forgings	X	—	—	—	—	X	—	
3.3	Pipes, forgings, castings and fittings (bend, three-way, pipe nipple and tapered pipe, etc.) for natural gas piping	X	—	—	—	—	X	—	Applicable to cargo and process piping for design temperature below 0℃
3.4	End plate	X	—	—	—	—	X	X[1]	As purchased parts
3.5	Welding consumables	—	X	—	—	—	X	—	
3.6	Heat-insulating material	—	X	—	—	—	X	—	
3.7	Cargo bearer	—	X	—	—	—	X	—	
3.8	Structural adhesives	—	X	—	—	—	X	—	
3.9	Domes, fluid well	X	—	—	—	—	—	X[1]	As purchased parts
3.10	Electrical penetrations	—	X	—	X	—	—	X	Air-tight electrical penetrations for submerged pump cables
3.11	Safety valve	X	—	—	X	O	—	X	
Cargo and fuel operation system structure									
4.1	Pump tower	X	—	—	—	—	—	X[1]	For membrane cargo tank. If the shipyard has a subcontract agreement with the product factory, the product is inspected by CCS newbuilding surveyor, and C/E may not be required
4.2	Pump tower lower guiding unit (pump tower support)	X	—	—	—	—	—	X[1]	For membrane cargo tank. If the shipyard has a subcontract agreement with the product factory, the product is inspected by CCS newbuilding surveyor, and C/E may not be required
4.3	Gas dome	X	—	—	—	—	—	X[1]	For membrane cargo tank. If the shipyard has a subcontract agreement with the product factory, the product is inspected by CCS newbuilding

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									surveyor, and C/E may not be required
4.4	Vent mast	X	—	—	—	—	—	X[1]	Fire net or safety cover at vent mast
Cargo operation system and cargo as fuel supply system of liquefied natural gas carrier									
5.1	Cryogenic cargo pump	X	—	—	X	O	—	X	
5.2	Cryogenic stripping/spray pump	X	—	—	X	O	—	X	
5.3	Fuel pump	X	—	—	X	O	—	X	
5.4	Cryogenic emergency pump	X	—	—	X	O	—	X	
5.5	Vacuum pump for barrier	X	—	—	X	O	—	X	
5.6	Cryogenic flexible hose assembly	X	—	—	X	O	—	X	For reliquefaction device, nitrogen purging, barrier space cleaning, cargo transfer, etc.
5.7	Cargo pipe insulation and external protection materials	—	X	—	—	—	X	—	
5.8	Cryogenic valve	X	—	—	X	—	—	X	Applicable to valves for working temperature below -55℃
5.9	Cryogenic safety valve	X	—	—	X	—	—	X	
5.10	High velocity valve	X	—	—	X	O	—	X	
5.11	Pipes, forgings, castings and fittings (bend, three-way, pipe nipple and tapered pipe, etc.) for natural gas piping	X	—	—	—	—	X	—	Applicable to fuel and process piping for design temperature below 0℃
5.12	Flowmeter	—	X	—	X	—	—	X	For natural gas and liquefied natural gas pipings
5.13	Cryogenic expansion joint	X	—	—	X	—	—	X	
5.14	Cryogenic flange gasket	—	X	—	—	—	X	—	
5.15	HD compressor	X	—	—	X	—	—	X	
5.16	LD compressor	X	—	—	X	—	—	X	
5.17	BOG compressor	X	—	—	X	—	—	X	For reliquefaction device
5.18	LNG vaporizer	X	—	X	O	O	—	X	
5.19	Forced evaporator	X	—	X	O	O	—	X	
5.20	Warming up heater	X	—	X	O	O	—	X	
5.21	Fuel gas heater	X	—	X	O	O	—	X	
5.22	Inert gas generator	X	—	—	X	O	—	X	
5.23	Nitrogen generator	X	—	—	X	—	—	X	
5.24	Nitrogen buffer tank	X	—	—	—	—	O	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
5.25	Glycol water heater (steam)	X	—	X	O	O	—	X	
5.26	Electrical glycol water heater	X	—	—	—	—	—	X	
5.27	Water sprinkler and cryogenic sprinkler	—	X	—	X	—	—	X	
5.28	Gas combustion unit	X	—	—	—	—	—	X	
5.29	Gas valve unit (Gas valve train)	X	—	O	—	—	—	X	GVU, GVT
5.30	Reliquefaction device	X	—	—	O	—	—	X	Contains cryogenic device
5.31	Double walled pipe for natural gas	X	—	—	—	—	—	X	
5.32	Vacuum insulated double walled pipe	X	—	—	X	—	—	X	
5.33	Integrated gas pressure regulation	X	—	O	—	—	—	X	
5.34	Filter	X	—	—	—	—	—	X	For natural gas and liquefied natural gas pipings
Liquefied natural gas fuel supply and related systems for dual fuel ships									
6	Liquefied natural gas fuel supply system								
6.1	Vaporizer and heater skid	X	—	—	—	—	—	X	Applicable to supply in skid mode
6.2	BOG compressor skid	X	—	—	—	—	—	X	Applicable to supply in skid mode
6.3	Pressure vessel	X	—	—	—	—	X	X	Including gas buffer tank, mist separator and knock-out drum,etc.
6.4	Heat exchanger	X	—	X	O	O	—	X	Including vaporizer, heater and cooler,etc.
6.5	Fuel pump	X	—	—	X	O	—	X	Including submerged pump, deep well pump and booster pump,etc.
6.6	BOG compressor	X	—	—	X	—	—	X	
6.7	Fan	X	—	X	O	O	—	X	For double walled pipe
6.8	Cryogenic pump pool	X	—	—	—	—	—	X	Including pumps and pump pool
6.9	Emergency shut-down valve	X	—	—	X	—	—	X	
6.10	Master gas valve	X	—	—	X	—	—	X	
6.11	Tank master valve	X	—	—	X	—	—	X	
6.12	Gas valve unit (Gas valve train)	X	—	O	—	—	—	X	GVU, GVT
6.13	Integrated gas pressure regulation	X	—	O	—	—	—	X	
6.14	Tank connection space	X	—	—	—	—	—	X	
6.15	Safety valve	X	—	—	X	O	—	X	For natural gas piping and pressure vessel
7	Liquid natural gas bunkering and storage								

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	system								
7.1	Bunkering station skid	X	—	—	—	—	—	X	Applicable to supply in skid mode
7.2	Type C independent tanks	X	—	—	—	—	X	X	See LNG carrier cargo containment system independent cargo tank type C for certification requirements
7.3	Membrane tanks	—	—	—	—	—	—	X	See LNG carrier cargo containment system membrane tanks for certification requirements
7.4	Safety valve	X	—	—	X	O	—	X	For natural gas piping and pressure vessel
7.5	Emergency shut-down valve	X	—	—	X	—	—	X	
7.6	Hydraulic power plant	X	—	—	—	—	—	X	For driving emergency shut-down valve
8	Glycol water heater system								
8.1	Glycol water heater skid	X	—	—	—	—	—	X	Applicable to supply in skid mode
8.2	Glycol water pump	X	—	—	X	O	—	X	
8.3	Glycol water heat exchanger	X	—	X	O	O	—	X	
8.4	Electrical glycol water heater	X	—	—	—	—	—	X	
8.5	Glycol water balancing vessel	X	—	—	—	—	X	X	Applicable to equipment belonging to pressure vessel
9	Nitrogen generator and supply system								
9.1	Nitrogen generator skid	X	—	—	—	—	—	X	Applicable to supply in skid mode
9.2	Nitrogen generator	X	—	—	X	—	—	X	
9.3	Nitrogen tank	X	—	—	—	—	O	X	
9.4	Air compressor	X	—	X	O	O	—	X	
10	Piping, valve and fittings								
10.1	Cryogenic valve	X	—	—	X	—	—	X	Applicable to valves for working temperature below -55℃
10.2	Pipes, forgings, castings and fittings (bend, three-way, pipe nipple and tapered pipe, etc.) for natural gas piping	X	—	—	—	—	X	—	Applicable to fuel and process piping for design temperature below 0℃
10.3	Double walled pipe for natural gas	X	—	—	—	—	—	X	
10.4	Vacuum insulated double walled pipe	X	—	—	X	—	—	X	
10.5	Filter	X	—	—	—	—	—	X	For natural gas and

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									liquefied natural gas pipings
10.6	Flowmeter	—	X	—	X	—	—	X	For natural gas and liquefied natural gas pipings
10.7	Vent mast cap	X	—	—	—	—	—	X	
10.8	Cryogenic flange gasket	—	X	—	—	—	X	—	
10.9	Flexible hose assembly	X	—	—	X	O	—	X	For natural gas and liquefied natural gas pipings
10.10	Expansion joint and corrugated pipe	X	—	—	X	—	—	X	
10.11	Pipe insulation and external protection materials	—	X	—	—	—	X	—	
Electrical installations and automatic equipment									
11.1	Cargo switchboard	X	—	—	—	—	—	X	
11.2	Pressure control and monitoring, alarm system	X	—	—	X	O	—	X	Applicable to inert gas system
11.3	Integrated automatic system	X	—	—	X	O	—	X	Refer to the definition of CCS Rules For Construction and Equipment of ships carrying liquefied gases in bulk, "IAS" for short
11.4	Fuel tank monitoring and control system	X	—	—	X	O	—	X	
11.5	Liquefied natural gas supply electrical control system	X	—	—	X	O	—	X	Including control, alarm and safety system
11.6	Electrical control box	X	—	—	—	—	—	X	Electrical control box of the fan, water glycol pump /electric heater, water glycol emergency pump, Liquefied natural gas pump, compressor, etc
11.7	Fixed gas detection system	X	—	—	X	O	—	X	Applicable to flammable gas detection, toxic gas detection, oxygen levels detection, carbon dioxide gas detection. Including controller and detector
11.8	Ship-Shore/Ship Link-System	X	—	—	—	—	—	X	If the product is included in the Integrated Automatic System (IAS), there is no duplicate requirement to hold the certificate
11.9	Emergency shutdown system(ESD)	X	—	—	—	—	—	X	If the product is included in the Integrated Automatic System (IAS), there is no duplicate requirement to hold the certificate

Symbols:

1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer's document; X – Applicable; — – Not Applicable; O – Optional.
2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval; PA – Plan approval
3) X^1: Inspection is to be carried out according to approved integral product/system (ship, product) drawing.
4) Membrane cargo tanks mean MARK III and NO96 membrane cargo tanks with GTT patented technology.

Appendix 1E LIST OF CERTIFICATION REQUIREMENTS FOR METHANOL FUEL SYSTEM SPECIALIZED PRODUCTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
Independent or portable methanol tank									
1	Independent/portable tank	X	—	—	—	—	X	X	
1.1	Rolled steel	X	—	—	—	—	X	—	
1.2	Forged steel	X	—	—	—	—	X	—	
1.3	Pipes, forgings, castings and fittings (bend, three-way, pipe nipple and tapered pipe, etc.) for methanol piping	X	—	—	—	—	X	—	
1.4	End plate	X	—	—	—	—	X	X[1]	As purchased parts
1.5	Welding consumables	—	X	—	—	—	X	—	
1.6	Fluid well	X	—	—	—	—	—	X[1]	As purchased parts
1.7	Electrical penetrations	—	X	—	X	—	—	X	Air-tight electrical penetrations for submerged pump cables
1.8	Safety valve	X	—	—	X	O	—	X	
Methanol fuel supply and related systems									
2	Methanol main engine fuel supply system								
2.1	Methanol fuel supply unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
2.1.1	Fuel pump	X	—	—	X	O	—	X	Including low pressure pump and high pressure pump etc.
2.1.2	Filter	X	—	—	—	—	—	X	Used for pipes of methanol fuel
2.1.3	Heat exchanger	X	—	X	O	O	—	X	
2.1.4	Electrical control box	X	—	—	—	—	—	X	
2.2	Methanol fuel valve unit	X	—	O	—	—	—	X	
2.2.1	Valve	X	—	—	X	—	—	X	
2.2.2	Filter	X	—	—	—	—	—	X	Used for pipes of methanol fuel
2.2.3	Electrical control box	X	—	—	—	—	—	X	
3	Generator set methanol fuel supply system								
3.1	Methanol low pressure pump unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
3.1.1	Fuel pump	X	—	—	X	O	—	X	Low pressure pump etc.
3.1.2	Heat exchanger	X	—	X	O	O	—	X	
3.1.3	Electrical control box	X	—	—	—	—	—	X	
3.2	Methanol fuel valve unit	X	—	O	—	—	—	X	
3.2.1	Valve	X	—	—	X	—	—	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
3.2.2	Filter	X	—	—	—	—	—	X	Used for pipes of methanol fuel
3.2.3	Pressure vessel	X	—	—	—	—	X	X	Including knock-out drum etc.
3.2.4	Electrical control box	X	—	—	—	—	—	X	
3.3	Methanol fuel pump unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
3.3.1	Fuel pump	X	—	—	X	O	—	X	High pressure pump etc.
3.3.2	Electrical control box	X	—	—	—	—	—	X	
3.4	Seal and control oil pump unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
3.4.1	Oil pump	X	—	—	X	O	—	X	Seal and control oil pump unit etc.
3.4.2	Valve	X	—	—	X	—	—	X	
3.4.3	Filter	X	—	—	—	—	—	X	
4	Methanol boiler fuel supply system								
4.1	Methanol fuel valve unit	X	—	O	—	—	—	X	
4.1.1	Valve	X	—	—	X	—	—	X	
4.1.2	Filter	X	—	—	—	—	—	X	Used for pipes of methanol fuel
4.1.3	Electrical control box	X	—	—	—	—	—	X	
4.1.4	Fuel pump								Used for methanol boiler fuel delivery
5	Methanol bunkering and storage system								
5.1	Bunkering station unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
5.2	Independent/portable tank	X	—	—	—	—	X	X	For certification requirements, refer to independent or portable methanol tank
5.3	Safety valve	X	—	—	X	O	—	X	Used for methanol piping and pressure vessel
5.4	Emergency shut-down valve	X	—	—	X	—	—	X	
5.5	Hydraulic power plant	X	—	—	—	—	—	X	For driving emergency shut-down valve
6	Glycol water system								
6.1	Glycol water system unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
6.2	Glycol water circulation pump	X	—	—	X	O	—	X	
6.3	Heat exchanger	X	—	X	O	O	—	X	
6.4	Glycol water balancing vessel	X	—	—	—	—	X	X	Applicable to equipment belonging to pressure vessel
6.5	Electrical control box	X	—	—	—	—	—	X	
7	Nitrogen generator and supply system								

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
7.1	Nitrogen generator unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
7.2	Nitrogen generator	X	—	—	X	—	—	X	
7.3	Nitrogen tank	X	—	—	—	—	O	X	
7.4	Air compressor	X	—	X	O	O	—	X	
7.5	Electrical control box	X	—	—	—	—	—	X	
8	Piping, valve and fittings								
8.1	Valve	X	—	—	X	—	—	X	Applicable to methanol fuel piping valve
8.2	Pipes, forgings, castings and fittings (bend, three-way, pipe nipple and tapered pipe, etc.) for methanol piping	X	—	—	—	—	X	—	
8.3	Double walled pipe	X	—	—	—	—	—	X	
8.4	Filter	X	—	—	—	—	—	X	Used for pipes of methanol fuel
8.5	Flowmeter	—	X	—	X	—	—	X	Used for pipes of methanol fuel
8.6	Vent mast cap	X	—	—	—	—	—	X	
8.7	Flexible hose assembly	X	—	—	X	O	—	X	Used for pipes of methanol fuel
8.8	Expansion joint and corrugated pipe	X	—	—	X	—	—	X	
8.9	Pressure/vacuum valve	X	—	—	X	—	—	X	Used for ventilation of methanol daily tank
8.10	Fan	X	—	X	O	O	—	X	Used for ventilation of of double walled pipe
Electrical installations and automatic equipment									
9.1	Pressure control and monitoring, alarm system	X	—	—	X	O	—	X	Applicable to inert gas system
9.2	Fuel tank monitoring and control system	X	—	—	X	O	—	X	
9.3	Methanol fuel supply electrical control system	X	—	—	X	O	—	X	Including control, alarm and safety system
9.4	Fixed gas detection system	X	—	—	X	O	—	X	Applicable to flammable gas detection, toxic gas detection, oxygen levels detection, chlorine concentration gas detection, carbon dioxide gas detection. Including controller and detector
9.5	Fixed fire detection and fire alarm system	X	—	—	X	O	—	X	The system shall effectively detect methanol flame
9.6	Ship-Shore/Ship Link-System	X	—	—	—	—	—	X	If the product is included in other system , there is no duplicate requirement to hold the certificate

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
9.7	Emergency shutdown system(ESD)	X	—	—	—	—	—	X	If the product is included in other system , there is no duplicate requirement to hold the certificate

Symbols:

1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer's document; X – Applicable; — – Not Applicable; O – Optional.

2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval; PA – Plan approval

3)X^{1}: Inspection is to be carried out according to approved integral product/system (ship, product) drawing.

Appendix 1F LIST OF CERTIFICATION REQUIREMENTS FOR AMMONIA TRANSPORT AND AMMONIA FUEL SPECIALIZED PRODUCTS

No.	Product name	Document		Approval mode				Document	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
Ammonia carrier cargo containment system (membrane cargo tank)									
1	Materials/Component								
1.1	Adhesive	—	X	—	—	—	X	—	Used for bonding insulation materials and components
1.2	Glass wool	—	X	—	—	—	X	—	
1.3	Glass cloth	—	X	—	—	—	X	—	
1.4	load bearing mastic	—	X	—	—	—	X	—	
1.5	Reinforced polyurethane foam	X	—	—	—	—	X	—	
1.6	Plywood	X	—	—	—	—	X	—	
1.7	Paint for inner hull protection	—	X	—	—	—	X	—	
1.8	Thermal protection		X	—	—	—	X	—	Used for thermal insulation protection of weld backside
1.9	Stainless steel sheets	X	—	—	—	—	X	—	
1.10	Stainless steel studs, nuts& washers	—	X	—	—	—	X	—	Works approval is only for material approval. If C/E is provided for forged steel parts, approval is not required.
1.11	Secondary barrier components	X	—	—	—	—	X	X1	Three-in-one sheet, including rigid secondary barrier and flexible secondary barrier.
1.12	Aluminium for reinforcement elements	X	—	—	—	—	X	X1	
2	Prefabricated elements								
2.1	Anchor strips	X	—	—	X	—	—	X1	
2.2	Primary barrier components	X	—	—	X	—	—	X1	Include flat, corner, corner area and end stainless steel corrugated plates.
2.3	Top bridge pads prefabricated elements	X	—	—	X	—	—	X1	
2.4	Flat wall panels prefabricated elements	X	—	—	X	—	—	X1	
2.5	Corner panels prefabricated elements	X	—	—	X	—	—	X1	
2.6	Stainless steel corners	X	—	—	X	—	—	X1	
2.7	Single legs prefabricated elements	X	—	—	X	—	—	X1	
Ammonia carrier cargo containment system (independent cargo Tank type A)									
3.1	Cargo containment material	X	—	—	—	—	X	—	Such as carbon manganese steel, aluminum alloy, stainless steel etc.
3.2	Welding consumables	—	X	—	—	—	X	—	
3.3	Bearer	—	X	—	—	—	X	—	
3.4	Epoxy resin	—	X	—	—	—	X	—	
3.5	Foam board	X	—	—	—	—	X	—	Such as polyurethane material

No.	Product name	Document		Approval mode				Document	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
3.6	Insulating structure	—	X	—	X	O	—	X1	
3.7	Dome seals	—	X	—	—	—	X	—	
3.8	Rupture discs	—	X	—	X	O	—	X	
3.9	Domes, fluid well	X	—	—	—	—	—	X1	As purchased parts
3.10	Electrical penetrations	—	X	—	X	—	—	X	Airtight electrical penetrations for submersible pump cables
3.11	Safety valve	X	—	—	X	O	—	X	
Ammonia carrier cargo containment system (independent cargo Tank type B)									
4.1	Cargo containment material	X	—	—	—	—	X	—	Such as carbon manganese steel, aluminum alloy, stainless steel etc.
4.2	Welding consumables	—	X	—	—	—	X	—	
4.3	Bearer	—	X	—	—	—	X	—	
4.4	Epoxy resin	—	X	—	—	—	X	—	
4.5	Insulating material	—	X	—	—	—	X	—	
4.6	Foam board	X	—	—	—	—	X	—	Such as polystyrene foam
4.7	platen	X	—	—	—	—	X	X1	
4.8	Adhesive strips	—	X	—	—	—	X	—	
4.9	Insulating structure	—	X	—	X	O	—	X1	
4.10	Dome seals	—	X	—	—	—	X	—	
4.11	Rupture discs	—	X	—	X	O	—	X	
4.12	Domes, fluid well	X	—	—	—	—	—	X1	As purchased parts
4.13	Electrical penetrations	—	X	—	X	—	—	X	Airtight electrical penetrations for submersible pump cables
4.14	Safety valve	X	—	—	X	O	—	X	
Ammonia carrier cargo containment system (independent cargo Tank type C)									
5.1	Rolled steel	X	—	—	—	—	X	—	
5.2	Forgings	X	—	—	—	—	X	—	
5.3	Pipes, forgings, castings and fittings(bend, three-way, pipe nipple and tapered pipe, etc.) for ammonia piping	X	—	—	—	—	X	—	Applicable to cargo and process piping for design temperature below 0℃
5.4	Heads	X	—	—	—	—	X	X1	As purchased parts
5.5	Welding consumables	—	X	—	—	—	X	—	
5.6	Insulating material	—	X	—	—	—	X	—	
5.7	Bearer	—	X	—	—	—	X	—	
5.8	Structural adhesives	—	X	—	—	—	X	—	
5.9	Domes, fluid well	X	—	—	—	—	—	X1	As purchased parts
5.10	Electrical penetrations	—	X	—	X	—	—	X	Airtight electrical penetrations for submersible pump cables
5.11	Safety valve	X	—	—	X	O	—	X	
Cargo and fuel operation system structure									
6.1	Pump tower	X	—	—	—	—	—	X1	For membrane cargo tank. If the shipyard has a subcontract agreement with the product factory, the product is inspected by CCS newbuilding surveyor, and C/E may not be required

No.	Product name	Document		Approval mode				Document	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
6.2	Pump tower lower guiding unit (pump tower support)	X	—	—	—	—	—	X1	For membrane cargo tank. If the shipyard has a subcontract agreement with the product factory, the product is inspected by CCS newbuilding surveyor, and C/E may not be required
6.3	Gas dome	X	—	—	—	—	—	X1	For membrane cargo tank. If the shipyard has a subcontract agreement with the product factory, the product is inspected by CCS newbuilding surveyor, and C/E may not be required
6.4	Vent mast	X	—	—	—	—	—	X1	Fire net or safety cover at vent mast
Cargo operation system and cargo as fuel supply system of ammonia carrier									
7.1	Cargo pump	X	—	—	X	O	—	X	
7.2	Stripping/spray pump	X	—	—	X	O	—	X	
7.3	Fuel pump	X	—	—	X	O	—	X	
7.4	Emergency pump	X	—	—	X	O	—	X	
7.5	Vacuum pump for barrier	X	—	—	X	O	—	X	
7.6	Flexible hose assembly	X	—	—	X	O	—	X	For reliquefaction device, nitrogen purging, Shielding layer space clean, Cargo lightening, etc.
7.7	Cargo pipe insulation and external protection materials	—	X	—	—	—	X	—	
7.8	Valve	X	—	—	X	—	—	X	Applicable to valves for ammonia
7.9	Safety valve	X	—	—	X	—	—	X	
7.10	High velocity valve	X	—	—	X	O	—	X	
7.11	Pipes, forgings, castings and fittings (bend, three-way, pipe nipple and tapered pipe, etc.) for ammonia piping	X	—	—	—	—	X	—	Applicable to cargo and process piping for design temperature below 0℃
7.12	Flowmeter	—	X	—	X	—	—	X	Applicable to valves for ammonia
7.13	Expansion joint	X	—	—	X	—	—	X	
7.14	Flange gasket	—	X	—	—	—	X	—	Applicable to valves for ammonia
7.15	HD compressor	X	—	—	X	—	—	X	
7.16	Ammonia fuel compressor	X	—	—	X	—	—	X	
7.17	BOG compressor	X	—	—	X	—	—	X	For reliquefaction device
7.18	Ammonia evaporator	X	—	X	O	O	—	X	
7.19	Forced evaporator	X	—	X	O	O	—	X	
7.20	Warming up heater	X	—	X	O	O	—	X	

No.	Product name	Document		Approval mode				Document	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
7.21	Ammonia heater	X	—	X	O	O	—	X	
7.22	Ammonia buffer tank	X	—	—	—	—	X	X	
7.23	Ammonia treatment plant	X	—	—	—	—	—	X	
7.24	Inert gas generator	X	—	—	X	O	—	X	
7.25	Nitrogen generator	X	—	—	X	—	—	X	
7.26	Nitrogen buffer tank	X	—	—	—	—	O	X	
7.27	Glycol water heater (steam)	X	—	X	O	O	—	X	
7.28	Electrical glycol water heater	X	—	—	—	—	—	X	
7.29	Water sprinkler and cooling sprinkler	—	X	—	X	—	—	X	
7.30	Gas combustion unit	X	—	—	—	—	—	X	
7.31	Gas valve unit	X	—	O	—	—	—	X	Gas valve unit，Gas valve train
7.32	Reliquefaction device	X	—	—	O	—	—	X	Contains cryogenic device
7.33	Double walled pipe for ammonia	X	—	—	—	—	—	X	
7.34	Vacuum insulated double walled pipe	X	—	—	X	—	—	X	
7.35	Integrated gas pressure regulation	X	—	O	—	—	—	X	
7.36	Filter	X	—	—	—	—	—	X	Applicable to valves for ammonia
Ammonia fuel supply and related systems for dual fuel ships									
8	Ammonia fuel supply system								
8.1	Vaporizer and heater skid	X	—	—	—	—	—	X	Applicable to supply in skid mode
8.2	Ammonia treatment unit	X	—	—	—	—	—	X	
8.3	Ammonia fuel supply system skid	X	—	—	—	—	—	X	Applicable to supply in skid mode
8.4	Pressure vessel	X	—	—	—	—	X	X	Including buffer tank, mist separator and knock-out drum, etc.
8.5	Heat exchanger	X	—	X	O	O	—	X	Including vaporizer, heater and cooler, etc.
8.6	Fuel pump	X	—	—	X	O	—	X	Including submerged pump, deep well pump and booster pump, etc.
8.7	BOG compressor	X	—	—	X	—	—	X	
8.8	Fan	X	—	X	O	O	—	X	For double walled pipe
8.9	Ammonia fuel pump pool	X	—	—	—	—	—	X	Including pumps and pump pool
8.10	Emergency shut-down valve	X	—	—	X	—	—	X	
8.11	Master ammonia	X	—	—	X	—	—	X	

No.	Product name	Document		Approval mode				Document	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	valve								
8.12	Tank master valve	X	—	—	X	—	—	X	
8.13	Gas valve unit	X	—	O	—	—	—	X	Gas valve unit, Gas valve train
8.14	Integrated gas pressure regulation	X	—	O	—	—	—	X	
8.15	Tank connection space	X	—	—	—	—	—	X	
8.16	Safety valve	X	—	—	X	O	—	X	For ammonia piping and pressure vessel
9	Ammonia bunkering and storage system								
9.1	Bunkering station skid	X	—	—	—	—	—	X	Applicable to supply in skid mode
9.2	Type A,B,C independent tanks	X	—	—	—	—	X	X	See ammonia carrier cargo containment system independent cargo Tank type A,B, C for certification requirements
9.3	Membrane tanks	—	—	—	—	—	—	X	See ammonia carrier cargo containment system membrane tanks for certification requirements
9.4	Safety valve	X	—	—	X	O	—	X	For ammonia piping and pressure vessel
9.5	Emergency shut-down valve	X	—	—	X	—	—	X	
9.6	Hydraulic power plant	X	—	—	—	—	—	X	For driving emergency shut-down valve
10	Glycol water heater system								
10.1	Glycol water heater skid	X	—	—	—	—	—	X	Applicable to supply in skid mode
10.2	Glycol water pump	X	—	—	X	O	—	X	
10.3	Glycol water heat exchanger	X	—	X	O	O	—	X	
10.4	Electrical glycol water heater	X	—	—	—	—	—	X	
10.5	Glycol water balancing vessel	X	—	—	—	—	X	X	Applicable to equipment belonging to pressure vessel
11	Nitrogen generator and supply system								
11.1	Nitrogen generator skid	X	—	—	—	—	—	X	Applicable to supply in skid mode
11.2	Nitrogen generator	X	—	—	X	—	—	X	
11.3	Nitrogen tank	X	—	—	—	—	O	X	
11.4	Air compressor	X	—	X	O	O	—	X	
12	Piping, valve and fittings								
12.1	Valve	X	—	—	X	—	—	X	Applicable to valves for ammonia
12.2	Pipes, forgings,	X	—	—	—	—	X	—	Applicable to fuel and

No.	Product name	Document		Approval mode				Document	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	castings and fittings (bend, three-way, pipe nipple and tapered pipe, etc.) for ammonia piping								process piping for design temperature below 0℃
12.3	Double walled pipe for ammonia	X	—	—	—	—	—	X	
12.4	Vacuum insulated double walled pipe	X	—	—	X	—	—	X	
12.5	Filter	X	—	—	—	—	—	X	For ammonia piping
12.6	Flowmeter	—	X	—	X	—	—	X	For ammonia piping
12.7	Vent mast	X	—	—	—	—	—	X	
12.8	Flange gasket	—	X	—	—	—	X	—	For ammonia piping
12.9	Flexible hose assembly	X	—	—	X	O	—	X	For ammonia piping
12.10	Expansion joint and corrugated pipe	X	—	—	X	—	—	X	
12.11	Pipe insulation and external protection materials	—	X	—	—	—	X	—	
12.12	Ammonia Slip Catalyst (ASC)	X	—	—	X	O	—	X	Used for ammonia slip treatment; this requirement also applies to equipment using other technologies to reduce ammonia slip
Electrical installations and automatic equipment									
13.1	Cargo switchboard	X	—	—	—	—	—	X	
13.2	Pressure control and monitoring, alarm system	X	—	—	X	O	—	X	Applicable to inert gas system
13.3	Integrated automatic system	X	—	—	X	O	—	X	Refer to the definition of CCS Rules For Construction and Equipment of ships carrying liquefied gases in bulk, "IAS" for short
13.4	Fuel tank monitoring and control system	X	—	—	X	O	—	X	
13.5	Ammonia fuel supply electrical control system	X	—	—	X	O	—	X	Including control, alarm and safety system
13.6	Electrical control box	X	—	—	—	—	—	X	Electrical control box of the fan, water glycol pump/electric heater, water glycol emergency pump, Ammonia pump, compressor, etc.
13.7	Fixed gas detection system	X	—	—	X	O	—	X	Applicable to flammable gas detection, toxic gas detection, oxygen levels detection, carbon dioxide gas detection. Including controller and detector
13.8	Ship-Shore/Ship Link-System	X	—	—	—	—	—	X	If the product is included in the Integrated

No.	Product name	Document		Approval mode				Document	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									Automatic System (IAS), there is no duplicate requirement to hold the certificate
13.9	Emergency shutdown system	X	—	—	—	—	—	X	If the product is included in the Integrated Automatic System (IAS), there is no duplicate requirement to hold the certificate

Symbols:

1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer's document;
X – Applicable; — – Not Applicable; O – Optional.

2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval;
PA – Plan approval

3) X1: Inspection is to be carried out according to approved integral product/system (ship, product) drawing.

4) Membrane cargo tanks mean MARK III and NO96 membrane cargo tanks with GTT patented technology.

Appendix 2A LIST OF CERTIFICATION REQUIREMENTS FOR CLASSED MARINE PRODUCT PARTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
Material									
1	Metal material								
1.1	Rolled steel								
1.2	Aluminum alloy								
1.3	Other non-ferrous metal material								
1.4	Steel wire rope								
2	Non-metallic material								
2.1	Resin								
2.2	Reinforcement material								
2.3	Fiber rope								
2.4	Epoxy casting material for seating								
2.5	Synthetic (bearing) material								
2.6	Heat-insulating material								
2.7	Cargo bearer								
2.8	Cargo hold supporting gaskets								
2.9	Propeller shaft coating material								
2.10	Structural adhesives								
3	Welding consumables								
3.1	Electrode								
3.2	Wire								
3.3	Flux								
4	Corrosion resistant means								
4.1	Shop primer								
4.2	Coating below ship's waterline								
4.3	Paint above ship's waterline								
4.4	Ship tank coating								
4.5	Sacrificial anode								
4.6	Cathodic protection system								
Hull									
5	Hull structure equipment								
5.1	Stem, stern post, rudder horn and propeller shaft bracket								
5.2	Hatch cover								
.1	Rolled steel	X	–	–	–	–	X	–	
5.3	Window							–	
.1	Window glass	–	X	–	–	–	X	–	
5.4	Bow, stern and gangway doors								
.1	Rolled steel	X	–	–	–	–	X	–	
.2	Hydraulic cylinder	X	–	–	–	–	–	X	
.3	Hydraulic power unit	X	–	–	–	–	–	X	
.4	Electrical control, indication and alarm box/panel	X	–	–	–	–	–	X	
5.5	Watertight door								
.1	Rolled steel	X	–	–	–	–	X	–	
.2	Hydraulic cylinder	X	–	–	–	–	–	X	
.3	Hydraulic power unit	X	–	–	–	–	–	X	
.4	Electrical control, indication and alarm	X	–	–	–	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	box/panel								
5.6	Watertight cable transits								
5.7	Portable means of access for inspections								
5.8	Container securing arrangements								
.1	Forging	–	X	–	–	–	X	–	For details, see Appendix 1, Chapter 7, PART TWO of the Rules
.2	Casting	–	X	–	–	–	X	–	For details, see Appendix 1, Chapter 7, PART TWO of the Rules
5.9	Loading computer								
6	Outfitting								
6.1	Rudder blade								
.1	Casting	X	–	–	–	–	X	X[1]	
.2	Steel plate	X	–	–	–	–	X	–	
6.2	Rudder stock and pintle								
.1	Forging	X	–	–	–	–	X	X[1]	
6.3	Rudder bearing and pin bearing								
.1	Casting	X	–	–	–	–	X	X[1]	
6.4	Rudder stock connecting bolt								
.1	Forging	X	–	–	–	–	X	X[1]	
6.5	Single point mooring arrangement								
.1	Chain stopper, bow fairlead, chafing chain and pedestal roller	X							Material is subject to inspection and certification according to rules requirements
6.6	Emergency towing arrangement								
.1	Towing pennant, chafing chain, fairlead, strong point and roller pedestal	X							Material is subject to inspection and certification according to rules requirements
6.7	Towing hook								
.1	Forging and casting	X	–	–	–	–	X	X[1]	
6.8	Towing winch								
.1	Hydraulic cylinder	X	–	–	–	–	–	X	For brake
.2	Hydraulic power unit	X	–	–	–	–	–	X	
.3	Hydraulic motor	X	–	–	–	–	–	X	
.4	Electrical control box	X	–	–	–	–	–	X	
.5	Motors (50 kW and over)	X	–	–	X	O	–	X	
.6	Motors (below 50 kW)	–	X	–	X	–	–	X	
6.9	Seats of high speed craft								
7	Anchoring and mooring equipment								
7.1	Anchor chains and fitting								
.1	Anchor chain steel bar	X	–	–	–	–	X	–	
.2	Casting/forging	X	–	–	–	–	X	–	
7.2	Anchors and accessory								
.1	Anchor head	X	–	–	–	–	X	X[1]	
.2	Anchor shank and anchor pin	X	–	–	–	–	X	X[1]	
.3	Anchor shackle	X	–	–	–	–	X	X[1]	
.4	Steel plate	X[2]	–	–	–	–	X	–	Applicable to welding anchor
7.3	Chain stopper								
.1	Casting	X[2]	–	–	–	–	X	X[1]	
.2	Forging	X[2]	–	–	–	–	X	X[1]	
.3	Steel plate	X[2]	–	–	–	–	X	–	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
7.4	Cable clenches								
7.5	Windlass								
.1	Motors (50 kW and over)	X	–	–	X	O	–	X	
.2	Motors (below 50 kW)	–	X	–	X	–	–	X	
.3	Electrical control box	X	–	–	–	–	–	X	
.4	Master controller	X	–	–	–	–	–	X	
.5	Hydraulic cylinder	X	–	–	–	–	–	X	For brake
.6	Hydraulic power unit	X	–	–	–	–	–	X	
.7	Hydraulic motor	X	–	–	–	–	–	X	
.8	Cable lifter	X[2]	–	–	–	–	X	X[1]	
.9	Main shaft (forging)	X	–	–	–	–	X	X[1]	
.10	Main shaft (steel bar)	X[2]	–	–	–	–	–	X[1]	
.11	Transmission gearing	X	–	–	X	O	X	X[1]	Applicable to rated power of 100 kW or above
7.6	Mooring winch and capstan								If used as an alternative for windlass, see relevant requirements for windlass
.1	Motors (50 kW and over)	X	–	–	X	O	–	X	
.2	Motors (below 50 kW)	–	X	–	X	–	–	X	
.3	Hydraulic motor	X	–	–	–	–	–	X	
.4	Main shaft (forging)	X	–	–	–	–	X	X[1]	
.5	Main shaft (steel bar)	X[2]	–	–	–	–	–	X[1]	
.6	Hydraulic power unit	X	–	–	–	–	–	X	
7.7	Winch or capstan for operation								
.1	Motors (50 kW and over)	X	–	–	X	O	–	X	
.2	Motors (below 50 kW)	–	X	–	X	–	–	X	
.3	Hydraulic motor	X	–	–	–	–	–	X	
.4	Main shaft (forging)	X	–	–	–	–	X	X[1]	
.5	Main shaft (steel bar)	X[2]	–	–	–	–	–	X[1]	
.6	Hydraulic power unit	X	–	–	–	–	–	X	
Machinery (including machinery equipment of refrigerated vessels)									
8	Pumps and piping								
8.1	Bilge pump and bilge injection pump								
8.2	Ballast pump								
8.3	Liquid cargo pump, stripping pump and tank cleaning pump								
8.4	Fuel oil pump								
8.5	Fuel oil injection valve cooling pump								
8.6	Lubricating oil pump								
8.7	Fire pump (including emergency fire pump)								
8.8	Cooling water pump								
8.9	Boiler feed pump								
8.10	Boiler circulating water pump								
8.11	Hot oil circulating pump								
8.12	Condensate pump								
8.13	Pipes of more than 50 mm in diameter for piping of Classes I and II and fittings (flange, bend and three-way, etc.)								
8.14	Pipes of 50 mm in diameter and below for piping of Classes I and II and fittings (flange, bend and three-way, etc.)								

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
8.15	Pipes for piping of Class III and fittings (flange, bend and three-way, etc.)								
8.16	Valves of 50 mm in diameter and over for piping of Classes I and II, valves of 300 mm in diameter and over for piping of Class III; sea valve								
.1	Valve body	–	X	–	–	–	X	X[1]	
8.17	Valves of less than 50 mm in diameter for piping of Classes I and II								
8.18	Plastic pipe								
8.19	Flexible hose assembly, for piping of Classes I and II or more than 50 mm in diameter								
.1	Pipe end fittings	–	X	–	X	–	–	–	Pipe end fittings which are type tested along with hose assembly may not apply for a separate type approval
8.20	Flexible hose assembly: except for above-mentioned								
.1	Pipe end fittings	–	X	–	X	–	–	–	Pipe end fittings which are type tested along with hose assembly may not apply for a separate type approval
8.21	Mechanical pipe joint								
8.22	Corrugated expansion joint								
8.23	Air pipe closing appliance								
.1	Casting	–	X	–	–	–	X	–	
8.24	Spark arrester								
8.25	Sound damper								
8.26	Filter								
8.27	Fume exhaust valve								
9	Boiler and pressure vessel								
9.1	Boiler body								
.1	Steel plate	X[2]	–	–	–	–	X	–	Not applicable to heat-conducting oil furnace
.2	Steel pipe	X[2]	–	–	–	–	X	–	
.3	End plate	X	–	–	–	–	X	X[1]	Not applicable to heat-conducting oil furnace
9.2	Boiler burner								
.1	Flexible hose assembly	X	–	–	X	O	–	X	
.2	Motors (below 50 kW)	-	X	–	X	–	–	X	
.3	Electrical control box	X	–	–	–	–	–	X	
9.3	Economizer			–					
.1	Steel plate	X[2]	–	–	–	–	X	–	
.2	Steel pipe	X	–	–	–	–	X	–	
9.4	Steam generator (over 0.35 MPa)								
.1	Steel plate	X[2]	–	–	–	–	X	–	
.2	Steel pipe	X	–	–	–	–	X	–	
9.5	Thermal oil and thermal water heating units (for service of propulsion machinery)								
.1	Steel plate	X[2]	–	–	–	–	X	–	
.2	Steel pipe	X	–	–	–	–	X	–	
9.6	Safety valve								

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
9.7	Boiler liquid meter								
9.8	Classes I and II pressure vessel								
.1	Steel plate	X[2]	–	–	–	–	X	–	
.2	Steel pipe	X	–	–	–	–	X	–	
.3	End plate	X	–	–	–	–	X	X[1]	
.4	Safety valve	X	–	–	X	O	–	X	
9.9	Class III pressure vessel								
.1	Steel plate	–	X	–	–	–	X[2]	–	
.2	Steel pipe	–	X	–	–	–	X	–	
9.10	Heat exchanger								
10	Machinery equipment								
10.1	Steam turbine								
.1	Rotor	X	–	–	–	–	–	X	
.2	Impeller	X	–	–	–	–	–	X	
.3	Shaft	X	–	–	–	–	–	X	
.4	Thimble	X	–	–	–	–	–	X	The temperature of main and auxiliary steam turbine and steam turbine of inlet temperature > 250℃
.5	Blade	X	–	–	–	–	–	X	The temperature of main and auxiliary steam turbine and steam turbine of inlet temperature > 250℃
.6	Teeth coupling	X	–	–	–	–	–	X	The temperature of main and auxiliary steam turbine and steam turbine of inlet temperature > 250℃
.7	Cylinder and bolt	X	–	–	–	–	–	X	The temperature of main and auxiliary steam turbine and steam turbine of inlet temperature > 250℃
.8	Diaphragm plate	X	–	–	–	–	–	X	The temperature of main and auxiliary steam turbine and steam turbine of inlet temperature > 250℃
.9	Guide blade	X	–	–	–	–	–	X	The temperature of main and auxiliary steam turbine and steam turbine of inlet temperature > 250℃
.10	Box body	X	–	–	–	–	–	X	The temperature of main and auxiliary steam turbine and steam turbine of inlet temperature > 250℃
.11	Foundation	X	–	–	–	–	–	X	The temperature of main and auxiliary steam turbine and steam turbine of inlet temperature > 250℃
.12	Condenser	X	–	–	–	–	–	X	The temperature of main and auxiliary steam turbine and steam turbine of inlet temperature > 250℃
.13	Electrical control box	X	–	–	–	–	–	X	
10.2	Gas turbine								
.1	Shaft	X	–	–	–	–	–	X	Also applicable to small power
.2	Turbine and blower impeller	X	–	–	–	–	–	X	Also applicable to small power
.3	Blade	X	–	–	–	–	–	X	
.4	Guide blade	X	–	–	–	–	–	X	
.5	Turbine and blower shell	X	–	–	–	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
.6	Combustion chamber	X	–	–	–	–	–	X	
.7	Coupling and bolt	X	–	–	–	–	–	X	
.8	Gear transmission equipment	X	–	–	–	–	–	X	
.9	Heat exchanger	X	–	–	–	–	–	X	
.10	Pipe	X	–	–	–	–	–	X	
.11	Electrical control box	X	–	–	–	–	–	X	
10.3	Diesel engine								
10.3.1	Diesel engine (cylinder diameter > 300 mm or single cylinder power >400 kW)								For dual fuel engines and gas fuel engines, reference is made to this paragraph for implementation
.1	Welding bedplate	X	—	—	—	—	X	X[1]	W to be provided for material properties; W to be provided for NDT
.2	Bearing seat (steel casting)	X	—	—	—	—	X	X[1]	W to be provided for material properties; W to be provided for NDT
.3	Welded frame	X	—	—	—	—	X	X[1]	W to be provided for material properties; W to be provided for NDT
.4	Cylinder block (iron casting)	—	X	—	—	—	—	X[1]	Applicable to engines with power >400kW/cyl; W to include hydraulic tests
.5	Welded cylinder block	X	—	—	—	—	X	X[1]	Applicable to crosshead engines; W to be provided for material properties; W to be provided for NDT
.6	Engine block body (iron casting)	—	X	—	—	—	X	X[1]	Applicable to engines with power >400kW/cyl; W to include mechanical properties (for ductile cast iron) and hydraulic tests
.7	Cylinder liner	—	X	—	—	—	X	X[1]	Applicable to engines with cylinder diameter >300mm ; W to include material properties and hydraulic tests
.8	Cylinder cover(iron casting)	—	X	—	—	—	X	X[1]	Applicable to engines with cylinder diameter >300mm; W to include hydraulic tests
.9	Cylinder cover(steel casting, forging)	X	—	—	—	—	X	X[1]	Applicable to engines with cylinder diameter >300mm; W to be provided for material properties; W to be provided for NDT and hydraulic tests
.10	Piston crown	X	—	—	—	—	X	X[1]	Applicable to engines with cylinder diameter >400mm; W to be provided for material properties; W to be provided for NDT
.11	Crankshaft	X	—	—	—	—	X	X[1]	C/E to be provided for material properties; W to be provided for NDT; W to be provided for scantling inspection (including surface condition)
.12	Crank, Main shaft journal (forging) and shaft journal with flange	X	—	—	—	—	X	X[1]	Applicable to structure-semi-integrated crankshaft; C/E to be provided for material properties; W to be provided for NDT; W to be provided for scantling inspection

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									(including surface condition)
.13	Exhaust valve casing	—	X	—	—	—	—	X[1]	Applicable to crosshead engines; W to include hydraulic test;
.14	Piston rod	X	—	—	—	—	X	X[1]	W Applicable to crosshead engines with cylinder diameter >400mm; C/E to be provided for material properties; W to be provided for NDT
.15	Crosshead	X	—	—	—	—	X	X[1]	Applicable to crosshead engines; C/E to be provided for material properties; W to be provided for NDT
.16	Connecting rod (including bearing cover)	X	—	—	—	—	X	X[1]	C/E to be provided for material properties; W to be provided for NDT; W to be provided for scantling inspection (including surface condition)
.17	Crankshaft connecting bolt (semi-built crankshaft)	X	—	—	—	—	X	X[1]	C/E to be provided for material properties; W to be provided for NDT; W to be provided for scantling inspection (including surface condition)
.18	Main bearing bolt	—	X	—	—	—	X	X[1]	Applicable to engines with cylinder diameter >300mm ; W to include material properties and NDT
.19	Cylinder cover bolt	—	X	—	—	—	X	X[1]	Applicable to engines with cylinder diameter >300mm ; W to include material properties and NDT
.20	Connecting rod upper/ lower bolt	—	X	—	—	—	X	X[1]	Applicable to engines with cylinder diameter >300mm; W to include material properties and NDT
.21	Tie rod	X	—	—	—	—	X	X[1]	Applicable to crosshead engines; W to be provided for material properties; W to be provided for NDT; test report to be provided for scantling inspection (including surface condition)
.22	High pressure fuel injection pump	—	X	—	—	—	—	X	W to include material properties and hydraulic test (manufacturer with cylinder diameter ≤ 300mm may submit hydraulic test report)
.23	High pressure fuel injection valve	—	X	—	—	—	—	X	W to include hydraulic test (manufacturer with cylinder diameter ≤ 300mm may submit hydraulic test report)
.24	High pressure fuel injection pipe (including fuel common rail)	—	X	—	X	—	—	X	W to include material properties and hydraulic test (manufacturer with cylinder diameter ≤ 300mm may submit hydraulic test report)
.25	High pressure servo oil pipe (including common rail pipe)	—	X	—	X	—	—	X	W to include material properties and hydraulic test (manufacturer with cylinder

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									diameter ≤ 300mm may submit hydraulic test report)
.26	Heat exchanger	—	X	X	O	O	—	X	Engine-driven heat exchanger is applicable to engines with cylinder diameter >300mm; including: lubricating oil cooler, fuel oil cooler, sea/fresh water cooler, air cooler; W to include raw material properties and hydraulic test
.27	Accumulator	—	X	—	—	—	—	X[1]	Applicable to the capacity > 0.5 *l*; W to include material properties and hydraulic test
.28	Piping, pump, actuator for hydraulic driven valves	—	X	—	—	—	—	X[1]	Applicable to engines with power > 800kW/cyl; W to include material properties and hydraulic test; pipes to be furnished with WA; pumps to be furnished with TA;
.29	Other engine-driven pump (oil, water, fuel, bilge water) except for .22 and .28	—	X	—	X	O	—	X	Applicable to engines with power > 800kW/cyl; W to include hydraulic test;
.30	Main bearing bush, crosshead bush, crank pin bush	—	X	—	—	—	—	—	Applicable to engines with power > 800kW/cyl; W to include chemical composition, NDT (for contact surfaces between base material and bearing bush) and scantling inspection (including surface condition)
.31	Crankcase explosion relief valves	—	X	—	X	—	—	X	
.32	Oil mist detector	—	X	—	X	—	—	X	
.33	Turbocharger (Class C)	X	—	—	X	O	—	X	
.34	Turbocharger(Class A and Class B)	—	X	—	X	O	—	X	
.35	Speed governor	—	X	—	X	—	—	X	Applicable to electronic governor
.36	Main starting valve	X	—	—	—	—	—	X[1]	
.37	Start air pipe	X[2]	—	—	—	—	X	X[1]	
.38	Flexible hose assembly, for piping of Classes I and II or more than 50 mm in diameter	X	—	—	X	O	—	X	
.39	Flexible hose assembly: except for above-mentioned	—	X	—	X	—	—	X	
.40	Corrugated expansion joint	—	X	—	X	—	—	X	
.41	Engine-driven air bottle	X	—	—	—	—	—	X	
.42	Motors (50 kW and over)	X	—	—	X	O	—	X	
.43	Motors (below 50 kW)	—	X	—	X	—	—	X	
.44	Control and alarm box/cabinet of diesel engine	X[3]	—	—	X	O	—	X	Including safety alarm system
.45	Electric control system	—	X	—	X	O	—	X	Applicable to electric controlled diesel engine

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
.46	Explosion-proof device for the engine intake and exhaust manifolds	–	X	–	X	O	–	X	
10.3.2	Diesel engine (cylinder diameter ≤ 300mm and single cylinder power ≤ 400 kW, rated power ≥ 100kW)								For dual fuel engines and gas fuel engines, reference is made to this paragraph for implementation
.1	Welding bedplate	X	–	–	–	–	X	X[1]	W to be provided for material properties; W to be provided for NDT
.2	Bearing seat (steel casting)	X	–	–	–	–	X	X[1]	W to be provided for material properties; W to be provided for NDT
.3	Welded frame	X	–	–	–	–	X	X[1]	W to be provided for material properties; W to be provided for NDT
.4	Engine block body	–	X	–	–	–	X	X[1]	W to include mechanical properties of the material
.5	Crankshaft	X	–	–	–	–	X	X[1]	C/E to be provided for material properties
.6	Crankshaft connecting bolt (semi-built crankshaft)	X	–	–	–	–	X	X[1]	C/E to be provided for material properties
.7	Connecting rod	X	–	–	–	–	X	X[1]	C/E to be provided for material properties
.8	Cylinder liner	–	X	–	–	–	X	X[1]	W to include material properties
.9	High pressure fuel injection pump	–	X	–	–	–	–	X	W to include material properties and hydraulic test report
.10	High pressure fuel injection valve	–	X	–	–	–	–	X	W to include hydraulic test or hydraulic test report to be provided
.11	High pressure fuel injection pipe (including fuel common rail)	–	X	–	X	–	–	X	W to include material properties and hydraulic test report
.12	High pressure servo oil pipe (including common rail pipe)	–	X	–	X	–	–	X	W to include material properties and hydraulic test report
.13	Accumulator	–	X	–	–	–	–	X[1]	Applicable to the capacity > 0.5 *l*; W to include material properties and hydraulic test
.14	Turbocharger(Class C)	X	–	–	X	O	–	X	
.15	Turbocharger(Class A and Class B)	–	X	–	X	O	–	X	
.16	Speed governor	–	X	–	X	–	–	X	Applicable to electronic governor
.17	Crankcase explosion relief valves	–	X	–	X	–	–	X	
.18	Oil mist detector	–	X	–	X	–	–	X	
.19	Control and alarm box/cabinet of diesel engine	X[3]	–	–	X	O	–	X	Including safety alarm system
.20	Electric control system	–	X	–	X	O	–	X	Applicable to electric controlled diesel engine
.21	Explosion-proof device for the engine intake and exhaust manifolds	–	X	–	X	O	–	X	
10.3.3	Diesel engine (rated power ＜100kW)								For dual fuel engines and gas fuel engines, reference is made to this paragraph for implementation
.1	Crankshaft	X[2]	–	–	–	–	X	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
.2	Connecting rod	X[2]	—	—	—	—	X	X	
.3	Electric control system	—	X	—	X	O	—	X	Or carry out type test according to requirements of CCS
.4	Explosion-proof device for the engine intake and exhaust manifolds	–	X	–	X	O	–	X	
10.3.4	EGR system(if fitted)								EGR system is not separately certified. The certification requirements for pipes and fittings, motors, electric control boxes and valves used in the system are given in the corresponding provisions in Appendix 1A
.1	EGR unit	X	—	—	—	—	—	X	
.2	Pump	X	—	—	X	—	—	X	Power of diesel engine ≥ 2250kW, or cylinder diameter＞300mm
.3	EGR fan	X	—	X	O	O	—	X	Fan power ≥100kW
.4	Electrical control box	X	—	—	—	—	—	X	Electrical control box with motor power≥100kW
.5	Alkali fluid system	X	—	—	X	—	—	X	
.6	Washwater treatment unit	X	—	—	X	—	—	X	
.7	Tank (pressure vessel)	X	—	—	—	—	—	X	EGR residue /NaOH overflow tank, storage tank
.8	15ppm oil meter								to comply with the requirements of MEPC.107(49); certification requirements are as given in the corresponding provisions of Appendix 1B
.9	Discharge water monitoring system								to comply with the requirements of MEPC. 307(73); certification requirements are as given in the corresponding provisions of Appendix 1B
.10	Control, monitoring, alarming and safety system	X	—	X	—	—	—	X	may be approved and certified together with the corresponding system of the engine
10.4	Air compressor								
.1	Air bottle	O	X	–	–	–	X	X	<0.7 MPa & 0.1 ~ 0.25 m^3, WA to be provided for W, ≥ 0.7 MPa or ≥0.25 m^3, C/E to be provided
.2	Gas-oil separator	X[2]	–	–	–	–	–	X[1]	
.3	Flexible hose assembly, for piping of Classes I and II or more than 50 mm in diameter	X	–	–	X	O	–	X	
.4	Flexible hose assembly: except for above-mentioned	–	X	–	X	–	–	X	
.5	Motors (50 kW and over)	X	–	–	X	O	–	X	
.6	Motors (below 50 kW)	–	X	–	X	–	–	X	
.7	Diesel engine	X	–	–	X	O	–	X	
.8	Electrical control box	X	–	–	–	–	–	X	
10.5	Oil separator								
.1	Motors (50 kW and over)	X	–	–	X	O	–	X	
.2	Motors (below 50 kW)	–	X	–	X	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
.3	Electrical control box	X	–	–	–	–	–	X	
10.6	Fuel oil supply unit								
.1	Heat exchanger	X	–	X	O	O	–	X	Including electric heater
.2	Pressure vessel	O	X	–	–	–	X	X	<0.7 MPa & 0.1 ~ 0.25 m^3, WA to be provided for W, ≥ 0.7 MPa or ≥ 0.25 m^3, C/E to be provided
.3	Pump	X	–	–	X	O	–	X	
.4	Motors (50 kW and over)	X	–	–	X	O	–	X	
.5	Motors (below 50 kW)	–	X	–	X	–	–	X	
.6	Electrical control box	X	–	–	–	–	–	X	
10.7	Fan								For category A machinery space and other hazardous zone
.1	Motors (50 kW and over)	X	–	–	X	O	–	X	
.2	Motors (below 50 kW)	–	X	–	X	–	–	X	
10.8	Refrigerating plant								With class notation of cargo refrigeration
.1	Heat exchanger (evaporator, condenser, intercooler)	X	–	–	–	–	–	X	
.2	Pressure vessel	O	X	–	–	–	X	X	<0.7 MPa & 0.1 ~ 0.25 m^3, WA to be provided for W, ≥ 0.7 MPa or ≥ 0.25 m^3, C/E to be provided
.3	Refrigerating compressor	X	–	–	–	–	–	X	
.4	Motors (50 kW and over)	X	–	–	X	O	–	X	
.5	Motors (below 50 kW)	–	X	–	X	–	–	X	
.6	Electrical control box	X	–	–	–	–	–	X	
10.9	Hydraulic power plant								
.1	Flexible hose assembly, for piping of Classes I and II or more than 50 mm in diameter	X	–	–	X	O	–	X	
.2	Flexible hose assembly: except for the above	–	X	–	X	–	–	X	
.3	Accumulator	O	X	–	–	–	X	X	<0.7 MPa & 0.1 ~ 0.25 m^3, WA to be provided for W, ≥ 0.7 MPa or ≥ 0.25 m^3, C/E to be provided
.4	Hydraulic pump	X	–	–	X	O	–	X	Applicable to adjustable pitch propeller, Z propulsion arrangement, water jet propulsion arrangement, gearbox, steering gear and windlass, opening and closing hatch cover, driving cargo pump, etc.
.5	Motors (50 kW and over)	X	–	–	X	O	–	X	
.6	Motors (below 50 kW)	–	X	–	X	–	–	X	
.7	Electrical control box	X	–	–	–	–	–	X	
10.10	Cargo compressor								
.1	Motors (50 kW and over)	X	–	–	X	O	–	X	
.2	Motors (below 50 kW)	–	X	–	X	–	–	X	
.3	Diesel engine	X	–	–	X	O	–	X	
.4	Electrical control box	X	–	–	–	–	–	X	
10.11	Monitor, foam monitor								
10.12	Steering arrangements								Heading control system, rudder indicator, simplified operation box, starting box and alarm box for steering arrangements are to be surveyed in accordance

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									corresponding requirements
10.12.1 & 10.12.2	Steering gear								
.1	Hydraulic cylinder	X	–	–	–	–	–	X	If the cylinder body is casting, C/E is to be provided for material
.2	Rudder tiller	X	–	–	–	–	X	X[1]	Applicable to casting/forging material
.3	Cylinder body, end cover, rotor	X	–	–	–	–	X	X[1]	Applicable to rotating blade type steering gear
.4	Hydraulic power unit	X	–	–	–	–	–	X	
.5	Flexible hose assembly, for piping of Classes I and II or more than 50 mm in diameter	X	–	–	X	O	–	X	
.6	Flexible hose assembly: except for above-mentioned	–	X	–	X	–	–	X	
.7	Electrical control box	X	–	–	–	–	–	X	
10.13	Fin stabilizer, vortex absorbed fin								
.1	Fin	X	–	–	–	–	–	X[1]	C/E to be provided for steel casting and steel plate
.2	Fin shaft	X[2]	–	–	–	–	X	X[1]	
.3	Crosshead	X[2]	–	–	–	–	X	X[1]	
.4	Crosshead body steel casting	X	–	–	–	–	X	X[1]	
.5	Hydraulic cylinder	X	–	–	–	–	–	X	
.6	Hydraulic power unit	X	–	–	–	–	–	X	
.7	Electrical control box	X	–	–	–	–	–	X	
10.14	Foundation bolts of main engines								
10.15	Hydraulic cylinder								
10.16	Hydraulic motor								
11	Gear transmission arrangement								
11.1	Gearbox								
.1	Gear box body	X	–	–	–	–	X	X[1]	C/E to be provided for casting material
.2	Gear	X	–	–	–	–	X	X[1]	C/E to be provided for forging material
.3	Shaft	X	–	–	–	–	X	X[1]	C/E to be provided for forging material
.4	Heat exchanger	X	–	X	O	O	–	X	
.5	Lubricating oil pump	X	–	–	X	O	–	X	
.6	Hydraulic power unit	X	–	–	–	–	–	X	
11.2	Gearbox								
12	Shafting and propeller								
12.1	Thrust shaft								
.1	Forging	X	–	–	–	–	X	X[1]	
12.2	Intermediate shaft and bearing								
.1	Forging and casting	X	–	–	–	–	X	X[1]	
12.3	Stern tube shaft, propeller shaft								
.1	Forging	X	–	–	–	–	X	X[1]	
12.4	Stern tube								
.1	Forging and casting	X	–	–	–	–	X	X[1]	
.2	Steel plate	X[2]	–	–	–	–	X	–	
12.5	Stern tube sealing device								
12.6	Stern tube bearing								
.1	Casting/forging	X	–	–	–	–	X	X[1]	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
12.7	Propeller								
12.8	Adjustable pitch propeller								
.1	Propeller hub	X	–	–	–	–	X	X[1]	
.2	Propeller blade	X	–	–	–	–	X	X[1]	
.3	Propeller blade bolt	X	–	–	–	–	X	X[1]	
.4	Crank disc	X	–	–	–	–	X	X[1]	
.5	Push and pull rod	X	–	–	–	–	X	X[1]	
.6	Actuating hydraulic cylinder	X	–	–	–	–	X	X[1]	
.7	Hydraulic power unit	X	–	–	–	–	-	X	
.8	Electrical control box	X	–	–	–	–	-	X	
.9	Hydraulic oil pipe	X	–	–	–	–	X	X[1]	
12.9	Z propulsion arrangement								
.1	Propeller and blade bolt	X	–	–	–	–	X	X[1]	
.2	Upper/lower box, column, bedplate and well box	X	–	–	–	–	X	X[1]	
.3	Nozzle	X	–	–	–	–	–	X[1]	
.4	Shaft and gear	X	–	–	–	–	X	X[1]	Including power shaft, vertical spindle, propeller shaft, gear shaft and gear
.5	Coupling and connecting bolt	X	–	–	–	–	X	X[1]	Including universal coupling
.6	Hydraulic power unit	X	–	–	–	–	–	X	
.7	Motors (50 kW and over)	X	–	–	X	O	–	X	
.8	Motors (below 50 kW)	–	X	–	X	–	–	X	
.9	Electrical control box	X	–	–	–	–	–	X	
12.10	Side thruster								
.1	Propeller	X	–	–	–	–	X	X[1]	
.2	Nozzle	X	–	–	–	–	–	X[1]	
.3	Motors (50 kW and over)	X	–	–	X	O	–	X	
.4	Motors (below 50 kW)	–	X	–	X	–	–	X	
.5	Electrical control box	X	–	–	–	–	–	X	
.6	Other components and parts								Refer to the requirements of CCS Guidelines M16 Transverse Propulsion Arrangement
12.11	Water jet propulsion arrangement								
.1	Pump case, guide blade, rudder blade, rudder case	X	–	–	–	–	–	X[1]	C/E to be provided for steel plate material
.2	Impeller	X	–	–	–	–	X	X	
.3	Shaft	X	–	–	–	–	X	X[1]	Including pump shaft, rudder stock, rudder bearing and rudder pin
.4	Coupling and connecting bolt	X	–	–	–	–	X	X[1]	
.5	Hydraulic cylinder	X	–	–	–	–	–	X	
.6	Hydraulic power unit	X	–	–	–	–	–	X	
.7	Motors (50 kW and over)	X	–	–	X	O	–	X	
.8	Motors (below 50 kW)	–	X	–	X	–	–	X	
.9	Electrical control box	X	–	–	–	–	–	X	
12.12	Other thrusters								
12.13	Elastic coupling								
12.14	Non-elastic coupling								
12.15	Shafting connecting bolt								
12.16	Steel adjustable packing block								
12.17	Vibration isolator								
12.18	Cycloidal steering oar								
.1	Motors (50 kW and over)	X	–	–	X	O	–	X	
.2	Electrical control box (if	X	–	–	–	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	any)								
.3	Main shaft	X	–	–	–	–	X	X	
.4	Bevel gear shaft	X	–	–	–	–	X	X	
.5	Bevel gear	X	–	–	–	–	X	X	
.6	Gear shaft	X	–	–	–	–	X	X	
.7	Blade	X	–	–	–	–	X	X	
.8	Propeller shaft	X	–	–	–	–	X	X	
Electrical installations and automatic equipment									
13	Electrical installations								
13.1	Generators (50 kVA and over)								
.1	Revolution axis	X[2]	–	–	–	–	X	–	Applicable to generator of which revolution axis driven by main engine is part of propulsion shaft
13.2	Generators (below 50 kVA)								
.1	Revolution axis	X[2]	–	–	–	–	X	–	Applicable to generator of which revolution axis driven by main engine is part of propulsion shaft
13.3	Generating sets (50 kVA and over)								
.1	Diesel engine	X	–	–	X	O	–	X	
.2	Generator	X	–	–	X	O	–	X	
.3	Electrical control box	X	–	–	–	–	–	X	
13.4	Emergency generating sets								
.1	Diesel engine	X	–	–	X	O	–	X	
.2	Generator	X	–	–	X	O	–	X	
.3	Electrical control box	X	–	–	–	–	–	X	
.4	Elastic coupling	–	X	–	X	O	–	X	
13.5	Motors (50 kW and over)								
.1	Revolution axis	X	–	–	–	–	X	X[1]	Applicable to propulsion motor
13.6	Motors (below 50 kW)								
.1	Revolution axis	X	–	–	–	–	X	X[1]	Applicable to propulsion motor
13.7	Main switchboard								
.1	Circuit breaker	–	X	–	X	–	–	X	Applicable to main switch and branch switch
.2	Isolating switch	–	X	–	X	–	–	X	
.3	Generator overload protective device	–	X	–	X	–	–	X	
.4	Automatic parallel operation arrangement of generating sets	–	X	–	X	–	–	X	
.5	Power management system	–	X	–	X	–	–	X	
.6	Electric meter	–	X	–	X	–	–	X	
.7	Insulation monitor	–	X	–	X	–	–	X	
.8	Contactor	–	X	–	X	–	–	X	
.9	Relay	–	X	–	X[4]	–	–	X	
.10	Fuse	–	X	–	X[4]	–	–	X	
.11	Wire cable	–	X	–	–	–	X	X	
13.8	Emergency switchboard								
.1	Circuit breaker	–	X	–	X	–	–	X	Applicable to main switch and branch switch
.2	Electric meter	–	X	–	X	–	–	X	
.3	Insulation monitor	–	X	–	X	–	–	X	
.4	Contactor	–	X	–	X	–	–	X	
.5	Relay	–	X	–	X[4]	–	–	X	
.6	Fuse	–	X	–	X[4]	–	–	X	
.7	Wire cable	–	X	–	–	–	X	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
13.9	Group starter panel								
.1	Circuit breaker	–	X	–	X	–	–	X	Applicable to branch switch
.2	Electric meter	–	X	–	X	–	–	X	
.3	Contactor	–	X	–	X	–	–	X	
.4	Relay	–	X	–	X[4]	–	–	X	
.5	Fuse	–	X	–	X[4]	–	–	X	
.6	Wire cable	–	X	–	–	–	X	X	
13.10	Charging and discharging panel								
.1	Charger	X	–	–	X	O	–	X	
.2	Circuit breaker	–	X	–	X	–	–	X	Applicable to branch switch
.3	Electric meter	–	X	–	X	–	–	X	
.4	Contactor	–	X	–	X	–	–	X	
.5	Relay	–	X	–	X[4]	–	–	X	
.6	Fuse	–	X	–	X[4]	–	–	X	
.7	Insulation monitor	–	X	–	X	–	–	X	
.8	Wire cable	–	X	–	–	–	X	X	
13.11	Electrical control box (associated with essential equipment)								
.1	Circuit breaker	–	X	–	X	–	–	X	Applicable to protection switch
.2	Electric meter	–	X	–	X	–	–	X	
.3	Contactor	–	X	–	X	–	–	X	
.4	Relay	–	X	–	X[4]	–	–	X	
.5	Fuse	–	X	–	X[4]	–	–	X	
.6	Soft starter	–	X	–	X	–	–	X	
.7	Frequency converter	X	–	–	X	–	–	X	Power rated 50kW and above
.8	Master controller	X	–	–	–	–	–	X	
.9	Wire cable	–	X	–	–	–	X	X	
13.12	Power, control and communication cables and wires								
13.13	Transformers (50 kVA and over)								
13.14	Transformers (below 50 kVA)								
13.15	Battery								
13.16	Power conversion devices (charger, frequency converter, etc.)								
13.17	Uninterrupted Power Supply (UPS) (50 kVA and over)								
13.18	Uninterrupted Power Supply (UPS) (below 50 kVA)								
13.19	Additional emergency illumination equipment								
13.20	Cable management system								
.1	Cable winch	X	–	–	–	–	–	X	
.2	Electrical control box	X	–	–	–	–	–	X	
13.21	Distribution panel for shore power connection								
.1	Vacuum circuit breaker	–	X	–	X	–	–	X	
.2	High voltage relay protective device	–	X	–	X	–	–	X	
.3	Electric meter	–	X	–	X	–	–	X	
.4	Insulation monitor	–	X	–	X	–	–	X	
.5	Relay	–	X	–	X[4]	–	–	X	
.6	Fuse	–	X	–	X[4]	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
.7	Wire cable	–	X	–	–	–	X	X	
.8	Contactor	–	X	–	X	–	–	X	
13.22	Control panel for shore power switch in								
.1	Circuit breaker	–	X	–	X	–	–	X	
.2	Electric meter	–	X	–	X	–	–	X	
.3	Relay	–	X	–	X[4]	–	–	X	
.4	Fuse	–	X	–	X[4]	–	–	X	
.5	Wire cable	–	X	–	–	–	X	X	
.6	Contactor	–	X	–	X	–	–	X	
13.23	Lighting fitting								
13.24	Electrical heater								
.1	Control device	X	–	–	–	–	–	X	
13.25	Explosion-proof motor								
13.26	Explosion-proof lamp								
13.27	Other explosion-proof electrical equipment 1								
13.28	Engine telegraph								
.1	Programmable controller	–	X	–	X	–	–	X	
13.29	Sound-powered telephone								
13.30	Engineer‘s alarm system								
.1	Programmable controller	–	X	–	X	–	–	X	
13.31	Automatic start device of generators								
.1	Programmable controller	–	X	–	X	–	–	X	
13.32	Combined visual and audible alarm panel (box)								
.1	Programmable controller	–	X	–	X	–	–	X	
14	Automatic equipment								
14.1	Propulsion machinery control system								
14.2	Engine room monitoring and alarm system								
.1	Computer	–	X	–	X[3]	–	–	X	
.2	Display	–	X	–	X[3]	–	–	X	
.3	Uninterrupted Power Supply (UPS)	–	X	–	X[3]	–	–	X	
.4	Programmable controller	–	X	–	X	–	–	X	
14.3	Level measuring system								
.1	Computer	–	X	–	X[3]	–	–	X	
.2	Display	–	X	–	X[3]	–	–	X	
.3	Uninterrupted Power Supply (UPS)	–	X	–	X[3]	–	–	X	
.4	Sensor	–	X	–	X	–	–	X	
14.4	Pressure, temperature, level measuring alarm system								
.1	Computer	–	X	–	X[3]	–	–	X	
.2	Display	–	X	–	X[3]	–	–	X	
.3	Uninterrupted Power Supply (UPS)	–	X	–	X[3]	–	–	X	
.4	Programmable controller	–	X	–	X	–	–	X	
.5	Sensor	–	X	–	X	–	–	X	
14.5	Valve remote control system								
.1	Computer	–	X	–	X[3]	–	–	X	
.2	Display	–	X	–	X[3]	–	–	X	
.3	Uninterrupted Power Supply (UPS)	–	X	–	X[3]	–	–	X	
.4	Hydraulic power unit	X	–	–	–	–	–	X	
.5	Programmable controller	–	X	–	X	–	–	X	
.6	Valve	O	X	–	X	O	–	X	Refer to 8.16 ~ 8.17 of

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									Appendix 1A
.7	Actuator	O	X	–	X[3]	–	–	X	For emergency maneuvering, or as valve actuator, located in the ballast tank, can not be locally maneuvered
14.6	Dynamic positioning control system								
.1	Computer	–	X	–	X[3]	–	–	X	
.2	Display	–	X	–	X[3]	–	–	X	
.3	Uninterrupted Power Supply (UPS)	–	X	–	X[3]	–	–	X	
.4	Position reference system	–	X	–	X[3]	–	–	X	
.5	Vertical surface reference system	–	X	–	X[3]	–	–	X	
.6	Gyrocompass	–	X	–	X[3]	–	–	X	
.7	Wind velocity and direction gauge	–	X	–	X[3]	–	–	X	
.8	Programmable controller	–	X	–	X	–	–	X	
14.7	EOM system computer	–	X	–	X	–	–	X	Applicable to hardware, type approval is not necessary to two equipped computers which are standby each other. For ships applying for EOM notation
14.8	Shaft power meter	–	X	–	X	O	–	X	For ships applying for EOM notation
14.9	Flowmeter	–	X	–	X	O	–	X	For ships applying for EOM notation

Symbols:
1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer's document; X – Applicable; O – Optional;
2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval; PA – Plan approval;
3) X[1]: Inspection is to be carried out according to approved integral product/system (ship, product) drawing;
4) X[2]: If certification requirements for purchased parts can not be satisfied, inspection is to be carried out according to the requirements of CCS rules;
5) X[3]: If certification requirements for purchased parts can not be satisfied, complete type test is to be carried out with integral product;
6) X[4]: may be accepted subject to special agreement of CCS.

General requirements:
1) Aluminum alloy plate, section, rivet and piston for manufacturing equipment are to meet relevant inspection requirements in Chapter 8, PART ONE of CCS Rules for Materials and Welding.
2) In the Table, if parts with type approval requirements are manufactured by the equipment manufacturer and only for products manufactured by the manufacturer, and product approval process can cover those parts, those parts may be deemed as being approved by CCS. There is no need to issue individual approval certificate for those parts. If parts with product certificate requirements are manufactured by the equipment manufacturer and only for products manufactured by the manufacturer, inspection is to be carried out according to CCS requirements, and there is no need to issue individual product certificate.
3) If parts requiring individual plan approval have been approved in equipment drawing, plan approval need not be carried out again.
4) Material and parts only needing manufacturer's certification are not detailed in the Table, for details, see the Guidelines.
5) WA in the Table means works approval by material manufacturer.

Appendix 2B LIST OF CERTIFICATION REQUIREMENTS FOR STATUTORY MARINE PRODUCT PARTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
1	Life-saving appliances								
1.1	Lifebuoy								
.1	Retroreflective material	–	X	–	X	–	–	X	
1.2	Position-indicating lamp for life-saving appliances								
1.3	Spontaneous distress flare of lifebuoy								
1.4	Lifejacket								
.1	Retroreflective material	–	X	–	X	–	–	X	
1.5	Immersion suit, anti-exposure suit								
.1	Retroreflective material	–	X	–	X	–	–	X	
1.6	Thermal protective aid								
1.7	Visual signal								
1.8	Line-throwing appliance								
1.9	Life rafts								
.1	Main body adhesive cloth	–	X	–	X	–	–	–	Manufactured by life raft plant approved by CCS and with glue-making capability, TA to be provided with W
.2	Raft case	X	–	–	X	O	–	–	
.3	Radar reflector	–	X	–	X	–	–	X	May be replaced by radar responder
.4	Raft light	–	X	–	X	–	–	X	
.5	Thermal protective aid	–	X	–	X	–	–	X	
.6	Life-saving provisions	–	X	–	X	–	–	–	
.7	Manual reverse osmosis sea water desalination device	–	X	–	X	–	–	X	
.8	Free floating equipment (static pressure relief device)	X	–	–	X	O	–	X	
.9	Relieving gear	X	–	–	X	O	–	X	
.10	Retroreflective material	–	X	–	X	–	–	X	
.11	Rocket parachute flare	–	X	–	X	–	–	X	
.12	Hand flare	–	X	–	X	–	–	X	
.13	Buoyant smoke signal	–	X	–	X	–	–	X	
.14	Inflatable life-saving appliance charging system	–	X	–	X	–	–	X	
.15	Charging steel bottle	X	–	–	–	–	X	X	
1.10	Life boats								
.1	Lifeboat engine group	X	–	–	X	O	–	X	
.2	Air bottle	X	–	–	–	–	X	X	
.3	Lifeboat radar reflector	–	X	–	X	–	–	X	May be replaced by radar responder
.4	Searchlight for lifeboat	–	X	–	X	–	–	X	
.5	Compass for lifeboat	–	X	–	X	–	–	X	
.6	Retroreflective material	–	X	–	X	–	–	X	
.7	Battery	–	X	–	X	–	–	X	
.8	Relieving gear	X	-	–	X	O	–	X	
.9	Portable fire-extinguisher	–	X	–	X	–	–	X	
.10	Thermal protective aid	–	X	–	X	–	–	X	
.11	Resin	–	X	–	–	–	X	–	
.12	Fiber-reinforced material for hull structure	–	X	–	–	–	X	–	
.13	Rocket parachute flare	–	X	–	X	–	–	X	
.14	Hand flare	–	X	–	X	–	–	X	
.15	Buoyant smoke signal	–	X	–	X	–	–	X	
.16	Life-saving provisions	–	X	–	X	–	–	–	
.17	Manual reverse osmosis sea water desalination device	–	X	–	X	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
.18	Position-indicating lights for life boats	–	X	–	X	–	–	X	
1.11	Rescue boats								
.1	Rescue boat engine group	X	–	–	X	O	–	X	
.2	Rescue boat radar reflector	–	X	–	X	–	–	X	
.3	Searchlight for rescue boat	–	X	–	X	–	–	X	
.4	Compass for rescue boat	–	X	–	X	–	–	X	
.5	Retroreflective material	–	X	–	X	–	–	X	
.6	Battery	–	X	–	X	–	–	X	
.7	Relieving gear	X	–	–	X	O	–	X	
.8	Portable fire-extinguisher	–	X	–	X	–	–	X	
.9	Thermal protective aid	–	X	–	X	–	–	X	
.10	Resin	–	X	–	–	–	X	–	
.11	Fiber-reinforced material for hull structure	–	X	–	–	–	X	–	
.12	Watertight VHF radio communication equipment	X	–	–	X	O	–	X	
.13	Position-indicating lights for rescue boats	–	X	–	X	–	–	X	
1.12	Lowering apparatus								
.1	Boat davit	X	–	–	X	O	–	X[1]	
.2	Wire rope	X	–	–	–	–	X	–	
.3	Moving parts	X	–	–	–	–	X	X[1]	Refer to paragraph 1.2.1(5), Chapter 1 of Rules for Lifting Appliances of Ships and Offshore Installations
.4	Lifting hook	X	–	–	X	O	–	X[1]	Material is to be purchased from approved factory
.5	Release hook	X	–	–	X	O	–	X[1]	
.6	Winch	X	–	–	X	O	–	X[1]	
.7	Hydraulic cylinder	X	–	–	–	–	–	X[1]	
.8	Hydraulic power unit	X	–	–	–	–	–	X[1]	
.9	Accumulator	X	–	–	–	–	X	X	
.10	Motors (50 kW and over)	X	–	–	X	O	–	X	
.11	Motors (below 50 kW)	–	X	–	X	–	–	X	
.12	Electrical control box	X	–	–	–	–	–	X[1]	The first product is to be subject to type test
1.13	Marine evacuation system								
.1	Main body adhesive cloth	–	X	–	X	–	–	–	Refer to requirements for life raft
.2	Vessel	X	–	–	X	O	–	–	
.3	Free floating equipment (static pressure relief device)	X	–	–	X	O	–	X	
.4	Charging steel bottle	X	–	–	–	–	X	X	
1.14	Rescue equipment for person falling into water								
1.15	Embarkation ladder								
1.16	Public address system								
1.17	General emergency alarm system								
2	Pollution prevention at sea								
2.1	Oil-filtering equipment								
.1	Pump	X	–	–	X	O	–	–	
.2	Motors (below 50 kW)	–	X	–	X	–	–	X	
.3	Electrical control box	X	–	–	–	–	–	X	The first product is to be subject to type test
.4	15 ppm alarm	X	–	–	X	O	–	X	
2.2	Oil/water interface detector								
2.3	Existing oil-filtering equipment (additional treatment equipment in resolution MEPC.60(33)) (oil content of effluent not								

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	exceeding 15 ppm)								
2.4	Oil discharge monitoring and control system								
.1	Electrical control box	X	–	–	–	–	–	X	The first product is to be subject to type test
.2	Oil content meter	X	–	–	X	O	–	X	
2.5	Sewage treatment plant								
.1	Pump (discharge pump, disintegrating pump, circulating pump and air pump)	X	–	–	X	O	–	X	
.2	Motors (below 50 kW)	–	X	–	X	–	–	X	
.4	Electrical control box	X	–	–	–	–	–	X	The first product is to be subject to type test
2.6	Incinerator								
.1	Motors (below 50 kW)	–	X	–	X	–	–	X	
.2	Fan	X	–	–	–	–	–	X	
.3	Electrical control box	X	–	–	–	–	–	X	The first product is to be subject to type test
2.7	Nitrogen oxide analyzer (chemical luminescent detector (CLD) type/ heating chemical luminescent detector (HCLD) type)								
2.8	Exhaust cleaning system(scheme A)								Exhaust pipe, induced-draft fan/blower, pump, valve, piping, motor, electrical control box etc. used for the system are to be certified in accordance with the requirements of appendix 1A. Water treatment system is to be certified by referring to 10.3.4 of Appendix 2A
2.8.1	Scrubber	X	–	–	–	–	–	X	
2.9	Exhaust cleaning system(scheme B)								Exhaust pipe, induced-draft fan/blower, pump, valve, piping, motor, electrical control box etc. used for the system are to be certified in accordance with the requirements of appendix 1A. Water treatment system is to be certified by referring to 10.3.4 of Appendix 2A
2.9.1	Scrubber	X	–	–	–	–	–	X	
2.10	Equipment reducing NO_x emission on board by other equivalent method								
2.10.1	Selective catalysis reducing system (SCR)	X	–	–	X	O	–	X	A system with reductant using urea solution
.1	SCR reactor installation	X	–	–	–	–	–	X[1]	
.2	Electronic control system	X	–	–	X	–	–	X	
.3	Valve	X	–	–	X	O	–	X	Valve of nominal diameter not less than 300 mm
.4	Motors (50 kW and over)	X	–	–	X	O	–	X	
.5	Motors (below 50 kW)	–	X	–	X	O	–	X	
.6	Flexible hose assembly, for piping of Classes I and II or more than 50 mm in nominal diameter	X	–	–	X	O	–	X	
.7	Flexible hose assembly: except for above-mentioned	–	X	–	X	–	–	X	
.8	Plastic pipe	–	X	–	–	–	X	–	Applicable to the pipes

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									mentioned in Appendix 1 of Chapter 2, PART THREE of the Rules
2.11	Equipment limiting SO_x emission by other technology								
2.12	NO_x emission of diesel engines of over 130 kW								
2.13	Ballast water management system								
.1	Ballast pump	X	–	–	X	O	–	X	
.2	Motors (50 kW and over)	X	–	–	X	O	–	X	
.3	Motors (below 50 kW)	–	X	–	X	–	–	X	
.4	Valve	X	–	–	X	O	–	X	Valve of diameter not less than 300 mm
.5	Electrical control box	X	–	–	–	–	–	X	The first product is to be subject to type test
2.14	Crude oil washing machine								
2.15	Comminuting and disinfecting system								
3	Fire-resisting material, structure and fire- fighting equipment								
3.1	Deck covering								
3.2	Non-combustible material								
3.3	Low flame spread material								
3.4	Vertical-mounted textile and film								
3.5	Soft cushion furniture								
3.6	Bedding								
3.7	Classes A, B and F fire division								
3.8	Class A fire window/side scuttle								
.1	Fireproof glass	–	X	–	–	–	X	–	
.2	Non-combustible material	–	X	–	–	–	X	–	
3.9	Class A and class B division penetrations								
3.10	Fire door								
.1	Non-combustible material	–	X	–	–	–	X	–	
.2	Low flame spread material	–	X	–	–	–	X	–	
.3	Door lock	–	X	–	X	–	–	X	
.4	Fireproof glass	–	X	–	–	–	X	–	
3.11	Fire door control device								
.1	Flexible hose assembly	–	X	–	X	–	–	X	
.2	Electrical control box	X	–	–	–	–	–	X	
3.12	Fire damper								
3.13	Flame-retarding material for furniture on high speed craft								
3.14	Flame-retarding material for high speed craft								
3.15	Fire division of high speed craft								
3.16	Fire division penetration of high speed craft								
3.17	Flame arrester								
3.18	Pressure vacuum valve								
3.19	Bulkhead gearing								
3.20	Fixed gas fire- extinguishing arrangement (CO_2)								
.1	Cylinder	X	–	–	–	–	X	X	
.2	Afflux pipe	–	X	–	–	–	X	–	
.3	Bottle head valve, selection valve (release valve)	X	–	–	X	O	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
.4	Flexible hose assembly	–	X	–	X	–	–	X	
3.21	Fixed equivalent gas fire-extinguishing arrangement								
.1	Cylinder	X	–	–	–	–	X	X	
.2	Afflux pipe	–	X	–	–	–	X	–	
.3	Bottle head valve, selection valve (release valve)	X	–	–	X	O	–	X	
.4	Flexible hose assembly	–	X	–	X	–	–	X	Where applicable
3.22	Equivalent gas fire-extinguishing arrangement (aerosol system)								
3.23	Fixed local water-based fire-extinguishing arrangement								
.1	Injector head	X	–	–	X	–	–	X	
.2	Water pump	X	–	–	X	O	–	X	
.3	Motors (below 50 kW)	–	X	–	X	–	–	X	
.4	Electrical control box	X	–	–	–	–	–	X	The first product is to be subject to type test
3.24	Fixed water-based fire-extinguishing arrangement (equivalent to IMO resolution A.123(V))								
.1	Injector head	X	–	–	X	–	–	X	
.2	Water pump	X	–	–	X	O	–	X	
.3	Motors (50 kW and over)	X	–	–	X	O	–	X	
.4	Motors (below 50 kW)	–	X	–	X	–	–	X	
.5	Electrical control box	X	–	–	–	–	–	X	The first product is to be subject to type test
3.25	High-expansion foam fire-extinguishing arrangement								
.1	High-expansion foam fire-extinguishing medium	–	X	–	–	–	X	–	
.2	Foam generator	X	–	–	X	O	–	X	
.3	Proportion mixer	X	–	–	–	–	–	X	
3.26	Fixed medium-expansion foam fire-extinguishing arrangement								
.1	Medium-expansion foam fire-extinguishing medium	–	X	–	–	–	X	–	
.2	Foam storage tank	X	–	–	–	–	X	X	
.3	Proportion mixer	X	–	–	–	–	–	X	
.4	Foam applicator, foam monitor	X	–	–	X	O	–	X	
3.27	Fixed low-expansion foam fire-extinguishing arrangement								
.1	Low-expansion foam fire-extinguishing medium	–	X	–	–	–	X	–	
.2	Foam storage tank	X	–	–	–	–	X	X	
.3	Proportion mixer	X	–	–	–	–	–	X	
.4	Foam applicator, foam monitor	X	–	–	X	O	–	X	
3.28	Foam fire-extinguishing medium								
3.29	Chemical dry powder fire-extinguishing arrangement								
.1	Dry powder applicator/monitor	X	–	–	X	O	–	X	
.2	Dry powder storage tank	X	–	–	–	–	X	X	
3.30	Fixed pressure water spray								

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	fire-extinguishing arrangement								
.1	Injector head	X	–	–	X	O	–	X	
.2	Water pump	X	–	–	X	O	–	X	
.3	Motors (50 kW and over)	X	–	–	X	O	–	X	
.4	Motors (below 50 kW)	–	X	–	X	–	–	X	
.5	Electrical control box	X	–	–	–	–	–	X	The first product is to be subject to type test
3.31	Sprinkler arrangement								
.1	Injector head	–	X	–	X	–	–	X	
.2	Pressure tank	X	–	–	–	–	X	X	
.3	Wet type alarm valve, rain valve	–	X	–	X	–	–	X	
.4	Electrical control box	X	–	–	–	–	–	X	The first product is to be subject to type test
3.32	Helicopter deck foam fire-extinguishing arrangement								
.1	Low-expansion foam fire-extinguishing medium	–	X	–	–	–	X	–	
.2	Foam storage tank	X	–	–	–	–	X	X	
.3	Proportion mixer	X	–	–	–	–	–	X	
.4	Foam monitor	X	–	–	X	O	–	X	
3.33	Fixed fire-extinguishing arrangement for gallery discharge duct								
3.34	Inert gas system								
.1	Blower	X	–	X	O	O	–	X	
.2	Air compressor	X	–	X	O	O	–	X	
.3	Inert gas generator	X	–	–	X	–	–	X	
.4	Scrubber (cleaning device)	X	–	–	–	–	–	X[1]	
.5	Deck water seal	X	–	–	–	–	–	X[1]	
.6	Pressure vessel	X	–	–	–	–	X	X	
.7	Pump	X	–	–	X	O	–	X	
.8	Motors (50 kW and over)	X	–	–	X	O	–	X	
.9	Motors (below 50 kW)	–	X	–	X	–	–	X	
.10	Electrical control box	X	–	–	–	–	–	X	The first product is to be subject to type test
3.35	Portable foam applicator								
.1	Low-expansion foam fire-extinguishing medium	–	X	–	–	–	X	–	
.2	Self-absorbing foam monitor	X	–	–	X	O	–	X	
3.36	Portable fire extinguisher								
.1	Fire-extinguishing medium (foam)	–	X	–	–	–	X	–	
3.37	Trolley type fire extinguisher								
.1	Fire-extinguishing medium (foam)	–	X	–	–	–	X	–	
3.38	Water jet/spray nozzle								
3.39	Fire hoses								
3.40	Fireman's protective clothing (insulation clothing)								
3.41	Lifeline								
3.42	Self-contained compressed air breathing apparatus								
.1	Cylinder	X	–	–	–	–	X	X	
3.43	Compressed air breathing apparatus								
.1	Air compressor	X	–	–	–	–	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
3.44	Emergency escape breathing device								
.1	Cylinder	X	–	–	–	–	X	X	
3.45	Low location lighting system								
3.46	Equivalent low location lighting system								
3.47	Electrical safety lamp (explosion-proof electrical safety lamp)								
3.48	Portable oxygen concentration measuring device								
3.49	Fixed oxygen analyzing and gas detecting equipment								
.1	Controller	X	–	–	X	O	–	X	
.2	Detector	X	–	–	X	O	–	X	
3.50	Fixed hydrocarbon gas detection system								
.1	Controller	X	–	–	X	O	–	X	
.2	Detector	X	–	–	X	O	–	X	
3.51	Smoke detection system								
.1	Controller	X	–	–	X	O	–	X	
.2	Detector	X	–	–	X	O	–	X	
.3	Motors (below 50 kW)	–	X	–	X	–	–	X	
3.52	Fixed fire detection and alarm system								
.1	Controller	X	–	–	X	O	–	X	
.2	Detector	X	–	–	X	O	–	X	
.3	Manual alarm button	X	–	–	X	O	–	X	
.4	Fire alarm repeater	X	–	–	X	O	–	X	
3.53	Two-way portable radiotelephone apparatus of an explosion-proof type for fire-fighters								
4	Navigational equipment								
4.1	Magnetic compass								
4.2	Gyrocompass								
.1	Master compass	X	–	–	X	O	–	X	
.2	Heading repeater	X	–	–	X	O	–	X	
.3	Bearing repeater	X	–	–	X	O	–	X	
4.3	Propulsion indicator								
4.4	Side thrust, pitch and operational mode indicator								
4.5	Rudder indicator								
4.6	Propeller speed indicator								
4.7	Pitch indicator								
4.8	Rate-of-turn indicator								
4.9	Echo-sounding equipment								
4.10	Transmitting heading device (THD)								
4.11	Speed and distance measuring equipment (SDME)								
4.12	Heading control system (HCS)								
4.13	Track control system								
.1	Heading control system (HCS)	X	–	–	X	O	–	X	
.2	Electronic chart display and information system (ECDIS)	X	–	–	X	O	–	X	
4.14	Integrated navigation system (INS)								Parts and components forming the INS, such as

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
									radars, ECDIS, etc. are to be certified according to the relevant requirements in 1B
4.15	Integrated bridge system (IBS)								
4.16	Voyage data recorder (VDR)								
.1	Fixed recording medium	X	–	–	X	O	–	X	
.2	Float-free recording medium	X	—	—	X	O	—	X	
4.17	Simplified voyage data recorder (S-VDR)								
4.18	Electronic chart display and information system (ECDIS) and backup equipment, raster chart display system (RCDS)								
4.19	Electronic chart system (ECS)								
4.20	Multi-system electronic positioning equipment								
4.21	Global positioning system (GPS) receiver equipment								
4.22	Shipborne BEIDOU Satellite navigation system (BDS) receiver equipment								
4.23	9 GHz radar search and rescue transponders (SART)								
4.24	AIS SART equipment								
4.25	Automatic Identification System (AIS)								
4.26	Radar equipment								
4.27	Radar equipment with chart option								
4.28	Radar reflector — passive type								
4.29	Radar target intensifier								
4.30	Searchlight for high speed craft								
4.31	Night-vision unit for high speed craft								
4.32	Daylight signaling lamp								
4.33	Bridge navigational watch alarm system (BNWAS)								
4.34	Sound reception system								
4.35	Long-range identification and tracking system (LRIT)								
4.36	Ship’s electronic clinometer (navigation bridge)								
4.37	Pilot ladder								
4.38	Pilot’s accommodation ladder								
.1	Winch	X	–	–	–	–	–	X	
.2	Wire rope	X	–	–	–	–	X	–	
.3	Electrical control box	X	–	–	–	–	–	X	
4.39	Suez Canal searchlight								
5	Radio communication equipment								
5.1	VHF radio installations capable of voice communication and digital selective calling (DSC)								
5.2	MF radio installations capable of voice								

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	communication and digital selective calling (DSC)								
5.3	MF DSC watch-keeping receiver								
5.4	M/HF DSC watch-keeping receiver								
5.5	Narrow-band direct printing telegraph equipment receiving safety information to ship by high frequency								
5.6	VHF DSC watch-keeping receiver								
5.7	NAVTEX receiver								
5.8	Enhanced group call receiver								
5.9	406 MHz emergency position-indicating radio beacon (COSPAS -SARSAT)								
5.10	BEIDOU emergency position-indicating radio beacon (BD-EPIRB)								
5.11	INMARSAT ship earth station								
5.12	MF/HF radio installation capable of voice communication narrow band direct-printing telegraph and digital selective calling (DSC)								
5.13	Portable survival craft two-way VHF radiotelephone apparatus								
5.14	VHF emergency position-indicating radio beacon								
5.15	Distress alarm panel								
5.16	Ship security alert system								
5.17	Aviation two-way VHF radiotelephone apparatus								
6	Equipment required by International Regulations for Preventing Collisions at Sea, 1972								
6.1	Navigation light								
6.2	Navigation light control panel								
6.3	Whistle								
6.4	Whistle control panel								
6.5	Audible signal equipment (bell and gong)								
7	SOLAS II-1 equipment								
7.1	Water ingress detection alarm system								
.1	Controller	X	–	–	X	O	–	X	
.2	Detector	X	–	–	X	O	–	X	
7.2	Means of embarkation on and disembarkation from ships								
.1	Steel wire rope	X	—	—	—	—	X	—	
8	SOLAS II-2 equipment								
8.1	Deep-fat cooking equipment								
9	SOLAS XI-1 equipment								
9.1	Portable atmosphere testing								

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	instrument								
10	IBC and IGC Codes								
10.1	Cargo hose								
11	Lights for helideck								Used for helideck boundary lights, floodlights, auxiliary floodlights, status lights, windsock lights, and obstruction lights

Symbols:
1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer's document; X – Applicable; O – Optional;
2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval; PA – Plan approval;
3) X^1: Inspection is to be carried out according to approved integral product/system (ship, product) drawing.

General requirements:
1) Aluminum alloy plate, section, rivet and piston for manufacturing equipment are to meet relevant inspection requirements in Chapter 8, PART ONE of CCS Rules for Materials and Welding.
2) In the Table, if parts with type approval requirements are manufactured by the equipment manufacturer and only for products manufactured by the manufacturer, and product approval process can cover those parts, those parts may be deemed as being approved by CCS. There is no need to issue individual approval certificate for those parts. If parts with product certificate requirements are manufactured by the equipment manufacturer and only for products manufactured by the manufacturer, inspection is to be carried out according to CCS requirements, and there is no need to issue individual product certificate.
3) If parts requiring individual plan approval have been approved in equipment drawing, plan approval need not be carried out again.
4) Material and parts only needing manufacturer's certification are not detailed in the Table, for details, see the Guidelines.
5) WA in the Table means works approval by material manufacturer.

Appendix 2C LIST OF CERTIFICATION REQUIREMENTS FOR LIFTING APPLIANCE PARTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
1	Derrick system (including derrick type crane)								
.1	Winch	X[2]	–	–	–	–	–	X[1]	
.2	Detachable parts	X	–	–	–	–	X	X[1]	Refer to paragraph 1.2.1(5), Chapter 1 of CCS Rules for Lifting Appliances of Ships and Offshore Installations Plan approval may not be required for rigging designed in accordance with the standards accepted by CCS
.3	Rigging	X	–	–	–	–	X	X[1]	Plan approval may not be required for rigging designed in accordance with the standards accepted by CCS
.4	Wire rope	X	–	–	–	–	X	–	
.5	Motors (50 kW and over)	X	–	–	X	O	–	X	
.6	Motors (below 50 kW)	–	X	–	X	–	–	X	
.7	Electrical control box	X	–	–	–	–	–	X[1]	
2	Crane								
.1	Steel plate	X	–	–	–	–	X	–	
.2	Steel pipe	X[2]	–	–	–	–	X	–	Applicable to main structure
.3	Casting/forging	X	–	–	–	–	X	X[1]	
.4	Winch	X[2]	–	–	–	–	–	X[1]	
.5	Moving parts	X	–	–	–	–	X	X[1]	Refer to paragraph 1.2.1(5), Chapter 1 of CCS Rules for Lifting Appliances of Ships and Offshore Installations
.6	Rigging	X	–	–	–	–	X	X[1]	Plan approval may not be required for rigging designed in accordance with the standards accepted by CCS
.7	Wire rope	X	–	–	–	–	X	–	
.8	Motors (50 kW and over)	X	–	–	X	O	–	X	
.9	Motors (below 50 kW)	–	X	–	X	–	–	X	
.10	Electrical control box	X	–	–	–	–	–	X[1]	
.11	Luffing cylinder	X	–	–	–	–	–	X[1]	
.12	Hydraulic power unit	X	–	–	–	–	–	X	
.13	Hydraulic motor	X[2]	–	–	–	–	–	X	
.14	Rotating support	X	–	–	–	–	–	X[1]	C/E to be provided for forging material
3	Engine room crane	X	–	–	–	–	–	X	
.1	Manual/electric gourd	X	–	–	–	–	–	X	
.2	Electrical control box	X	–	–	–	–	–	X[1]	
4	Submersible launching arrangement	X	–	–	–	–	–	X	
.1	Winch	X[2]	–	–	–	–	–	X[1]	
.2	Moving parts	X	–	–	–	–	X	X[1]	Refer to paragraph 1.2.1(5), Chapter 1 of CCS Rules for Lifting Appliances of Ships and Offshore Installations
.3	Rigging	X	–	–	–	–	X	X[1]	Plan approval may not be required for rigging designed in accordance with the standards accepted by CCS
.4	Wire rope	X	–	–	–	–	X	–	
.5	Motors (50 kW and	X	–	–	X	O	–	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
	over)								
.6	Motors (below 50 kW)	–	X	–	X	–	–	X	
.7	Electrical control box	X	–	–	–	–	–	X[1]	
5	Lift								
5.1	Lift for passenger or crew								
.1	Safety clamp	–	X	X	–	–	–	X[1]	
.2	Speed-limiting device	–	X	X	–	–	–	X[1]	
.3	Wire rope and rigging	–	X	-	–	–	–	X[1]	
.4	Buffer	–	X	X	–	–	–	X[1]	
.5	Electrical control system	X	–	–	–	–	–	X[1]	The first product is to be subject to type test
.6	Actuating device	–	X	X	–	–	–	X[1]	Including winch and brake
.7	Door lock	–	X	X	–	–	–	X[1]	
.8	Motor	–	X	–	X	–	–	X[1]	
5.2	Cargo and vehicle lift and vehicle ramp								
.1	Electrical control box	X	–	–	–	–	–	X	
.2	Hydraulic cylinder	X	–	–	–	–	–	X	
.3	Hydraulic power unit	X	–	–	–	–	–	X	For certification requirements for motors, refer to Appendix 2A
6	Telescope gangway								
6.1	Main structure								
.1	Aluminium alloy	X	–	–	–	–	X	–	
6.2	Telescopic and amplitude-changing rotary mechanism								
.1	Motors (50 kW and over)	X	–	–	X	O	–	X	
.2	Motors (below 50 kW)	–	X	–	X	–	–	X	
.3	Gear	X	–	–	–	–	X	X[1]	C/E to be provided for forging material
.4	Rack	X	–	–	–	–	–	X	
.5	Guide	X	–	–	–	–	–	X	
.6	Brake	X	–	O	O	–	–	X	
.7	Luffing cylinder	X	–	–	–	–	–	X[1]	
.8	Reduction gearbox	X	–	×	–	–	–	X	
.9	Rotating support	X	–	–	X	O	–	X[1]	C/E to be provided for forging material
.10	Hydraulic motor	X[2]	–	–	–	–	–	X	
6.3	Hydraulic power unit								
.1	Flexible hose assembly, for piping of Classes I and II or more than 50 mm in diameter	X	–	–	X	O	–	X	
.2	Flexible hose assembly: except for above-mentioned	–	X	–	X	–	–	X	
.3	Hydraulic pump	X	–	–	X	O	–	X	
.4	Accumulator	O	X	–	–	–	X	X	<0.7 MPa & 0.1 ~ 0.25 m^3, WA to be provided for W, ≥ 0.7 MPa or ≥ 0.25 m^3, C/E to be provided
.5	Motors (50 kW and over)	X	–	–	X	O	–	X	
.6	Motors (below 50 kW)	–	X	–	X	–	–	X	
.7	Electrical control box	X	–	–	–	–	–	X	
6.4	Winch (where applicable)								
.1	Winch	X	–	–	–	–	–	X	

Symbols:
1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer's document; X – Applicable; O – Optional;

2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval; PA – Plan approval;
3) X^1: Inspection is to be carried out according to approved integral product/system (ship, product) drawing;
4) X^2: If certification requirements for purchased parts can not be satisfied, inspection is to be carried out according to the requirements of CCS rules.

General requirements:

1) Aluminum alloy plate, section, rivet and piston for manufacturing equipment are to meet relevant inspection requirements in Chapter 8, PART ONE of CCS Rules for Materials and Welding.
2) In the Table, if parts with type approval requirements are manufactured by the equipment manufacturer and only for products manufactured by the manufacturer, and product approval process can cover those parts, those parts may be deemed as being approved by CCS. There is no need to issue individual approval certificate for those parts. If parts with product certificate requirements are manufactured by the equipment manufacturer and only for products manufactured by the manufacturer, inspection is to be carried out according to CCS requirements, and there is no need to issue individual product certificate.
3) If parts requiring individual plan approval have been approved in equipment drawing, plan approval need not be carried out again.
4) Material and parts only needing manufacturer's certification are not detailed in the Table, for details, see the Guidelines.
5) WA in the Table means works approval by material manufacturer.

CHAPTER 4 SURVEYS DURING CONSTRUCTION①

Section 1 GENERAL PROVISIONS

4.1.1 Application for survey

4.1.1.1 When applying for surveys by CCS during construction of a ship, the applicant is to submit a written application to the Headquarters or a local unit of CCS, prior to the commencement of construction.

4.1.2 Assessment of shipyard

4.1.2.1 When a shipyard for the first time applies for building a ship to be classed with CCS or a novel ship to be classed with CCS, the Surveyor is to assess the production capacity of the shipyard, covering locations and facilities of production, quality assurance system, competence of building personnel in general and subcontractors, and to assess the fitness and effectiveness of the ship to be built.

4.1.3 Examination prior to commencement of construction

4.1.3.1 Prior to the commencement of construction, the Surveyor is to examine and confirm the preparations of the shipyard for construction and surveys, e.g. plan of preparations for construction, building/welding procedure, qualifications of welders/NDT personnel, list of certification requirements for marine products, welding specifications, NDT diagrams, tightness testing diagrams, list of survey/test items, relevant materials (including steel plates, welding consumables), manufacturing tolerance standards, subcontractors (if applicable) and technical documents required before the commencement of construction, such as drawings. Individual items, which will not affect the commencement of construction, may be examined and confirmed before an appropriate stage of construction at the discretion of the Surveyor.

4.1.4 Check of other test/survey documents

4.1.4.1 The Surveyor is to review or confirm the relevant documents provided by the shipyard in preparations for building the ship, such as documents of installing procedures of machinery, equipment and systems (excluding reasonable alignment of shafting), documents and programmes for on-site inclining test, mooring test and sea trial, etc.

4.1.4.2 The Surveyor is to confirm that the measurement and test equipment used for safety systems, etc., is furnished with valid certificates, and that both the operators of such equipment and company personnel on whose service results the surveys are based have recognized qualification certificates or qualification certificates approved by or acceptable to CCS.

Section 2 SURVEYS AND TESTS

4.2.1 General requirements

4.2.1.1 The Surveyor is to carry out surveys according to approved plans (including comments) and confirm the actions taken by the shipyard to implement the plans, and feed different opinions of the shipyard on the implementation of approved plans and associated comments back to the plan approval department in time.

4.2.1.2 The shipyard is to prepare, as required by the rules, lists of certified products for the ship intended to be built, according to Appendices 1A, 1B, 1C, 1D, 1E and 1F of Chapter 3 of this PART and submit them to the attending Surveyor for confirmation.

4.2.1.3 For ships engaged on international voyages and contracted for construction on or after 1 January 2008, the hull survey during construction is additionally to be in accordance with the requirements in Appendix 1 of this Chapter.

4.2.1.4 New installation of materials containing asbestos is to be prohibited for all ships as from 1 January 2011.

4.2.1.5 For newly constructed dual class ships, the scope of survey is to be in accordance with the bilateral agreement adopted by the two Societies or the trilateral agreement adopted by the two Societies and the shipyard.

---

① The requirements for initial classification surveys of ships under construction are given in 5.14.2 of Section 14 of Chapter 5.

4.2.1.6 Unless otherwise specified, the survey of all watertight cable transits installed on all ships contracted for construction on or after 1 July 2024 is to comply with the requirements of Appendix 3 of this Chapter.

4.2.2 Survey and test items

4.2.2.1 Hull survey and test items

(1) The Surveyor is to confirm that hull structural materials (metals, castings, forgings, welding consumables and nonmetallic materials), mooring and anchoring equipment and systems are furnished with the certificates or documents required by the rules.

(2) The Surveyor is to inspect the hull structure and equipment to ensure that the materials, scantlings, construction, arrangement and installation are in accordance with the approved plans, diagrams, specifications, calculations and other technical documentation and that the workmanship is in all respects satisfactory.

(3) Where any scantling, material or poor material, building work, arrangement, procedure, device or equipment is found to not comply with the approved plans, diagrams, specifications or calculations, the Surveyor is to require rectification thereof.

(4) For the purpose of construction survey, the Surveyor is to control and inspect main stages, inspect scantlings, and inspect welding quality and welding specifications of erection.

(5) Compartment structures are to be inspected to confirm integrity of hull structure. Construction monitoring is to be conducted for critical structural areas.

(6) Compartment bulkheads, including transverse and longitudinal ones, are to be subject to structural test, or leak test or hose test or an alternative test.

(7) Inspection and test of hatches and openings together with their closing means, including operation test of remote controls.

(8) Inspection and test of fire protection, extinction and detection arrangements and their installation.

(9) Inspection and test of steering gear, anchoring and mooring equipment after installation, for which the testing of the main steering gear and rudder stock and that of the auxiliary steering gear are to respectively comply with the requirements of 13.1.5.2 and those of 13.1.5.3 of PART THREE of the Rules.

(10) Determination of rudder centreline, propulsion shafting centerline.

(11) Determination of ship’s main dimensions, load line marks, draft scale and other marks.

(12) Lightweight survey.

(13) Inclining test, including inspection of ship’s condition before testing and assessment after testing, is to be attended.

(14) Inspection and test of items related to class notations, including confirming that the materials, equipment, devices and systems as required by the rules are in accordance with the approved plans, calculations and other technical documentation, that they are furnished with the certificates required by the rules and that the workmanship is in all respects satisfactory.

(15) Mooring tests and sea trials are to be attended.

4.2.2.2 Machinery survey and test items

(1) The Surveyor is to confirm that the machineries, equipment, devices and systems as required by the rules are all furnished with the products certificates or documents required by the rules.

(2) The Surveyor is to inspect the machineries, equipment, devices and systems to ensure that their arrangement, installation and workmanship are in all respects in accordance with the approved plans, diagrams, specifications, calculations and other technical documentation.

(3) Inspection and test of manufacturing and installation of piping, including strength test in workshop and tightness test after installation on board the ship are to be attended.

(4) Inspection and performance test of machineries, equipment, devices and systems after installation, such as main engines, propulsion shafting, propeller, gear boxes, generating sets, boilers, pressure vessels, steering gear, windlasses, air compressors, heat exchangers, sea chests, scupper valves, etc.

(5) Performance test of pump and pipe systems, such as those of fuel oil, lubricating oil, cooling, heating, bilge, ballasting, fire fighting, ventilating, measuring, venting, cargo oil, cleaning, inert gas.

(6) Inspection and performance test of control or remote control systems of main and auxiliary engines and other auxiliary machinery and devices after installation.

(7) Inspection and performance test of remotely controlled means of closing, such as emergency closing means of fuel oil tanks, closing of ventilation systems and openings and after their installation.

(8) Inspection and performance test of equipment, devices and systems required by class notations after installation.

(9) Mooring tests and sea trials are to be attended.

(10) The arrangement of fire pumps and fire mains are to be inspected and separate operation of each fire

pump (including emergency fire pumps) is to be checked for ensuring necessary pressure for fire mains in any place of the ship.
(11) Inspection of fixed fire-extinguishing systems, special arrangement of machinery and boiler spaces, mechanical ventilation and exhaust fans, and operation of remotely controlled stop devices.
4.2.2.3 Survey and test items for electrical installations
(1) The Surveyor is to confirm that the electrical installations and systems as required by the rules are all furnished with the products certificates or documents required by the rules.
(2) The Surveyor is to inspect the electrical installations such as generators, motors, cables, main and emergency switchboards to ensure that their arrangement, installation and workmanship are in all respects in accordance with the approved plans, diagrams, specifications, calculations and other technical documentation.
(3) Inspection and test of the electrical installations such as generators, motors, cables, main and emergency switchboards after installation.
(4) Inspection and test of steering systems including emergency steering system.
(5) Inspection and test of internal communication systems and alarm systems on board.
(6) Inspection and test of the electrical installations after installation within dangerous zones (if any).
(7) Inspection and test of emergency power supply including temporary emergency power supply.
(8) Inspection and test of equipment, devices and systems required by class notations after installation, such as mechanical automatic control systems and remote control systems — control of main and auxiliary engines, other auxiliary machinery and boilers, inspection and performance test of safety and alarm systems and dynamic positioning systems.
(9) Mooring tests and sea trials are to be attended.

4.2.3 The requirements for tests
4.2.3.1 The tightness tests of compartments are to be in accordance with the relevant requirements in Section 3 of this Chapter.
4.2.3.2 Tightness test for machineries, boilers, pressure vessels and piping is to be carried out after installation. The duration of test is in general to be not less than 5 min, with the test pressure as required in PART THREE of the Rules.
4.2.3.3 Inclining test
(1) When construction is finished, each ship is to undergo an inclining test to determine the elements of its stability, and the information thereon is to be provided to the master of the ship, which will enable him to promptly assess with ease the stability of his ship in different service conditions. The conditions and requirements for the inclining test and the assessment of test results are to comply with the relevant provisions of IMO or the requirements of the flag State Administration (if any).
(2) CCS may allow the inclining test of an individual cargo ship to be dispensed with, provided basic stability data are available from the inclining test of a sister ship and it is shown to the satisfaction of the Administration that reliable stability information for the exempted ship can be obtained from such basic data. The ship is to be inclined whenever, in comparison with the data derived from the sister ship, a deviation from the lightship displacement exceeding 1% for ships of 160 m or more in length and 2% for ships of 50 m or less in length and as determined by linear interpolation for intermediate lengths or a deviation from the lightship longitudinal centre of gravity exceeding 0.5% of L is found.
Note: Length of the ship (L) is the length as defined in Reg.3 of the Load Line Convention.

(3) CCS may allow the inclining test of an individual ship or class of ships especially designed for the carriage of liquids or ore in bulk to be dispensed with, subject to agreement by the flag State Administration, when reference to existing data for similar ships clearly indicates that, due to the ship's proportions and arrangements, more than sufficient metacentric height will be available in all probable loading conditions.

Section 3 TESTING PROCEDURES OF WATERTIGHT COMPARTMENTS

4.3.1 General requirements
4.3.1.1 The testing procedures of watertight compartments are to be carried out in accordance with Annex 1 of this Section, the "Procedures for Testing Tanks and Tight Boundaries", which are composed of Part A, Part B and Part C as follows:
Part A — SOLAS Ships (including CSR BC & OT)

Part B — SOLAS Exempt/Equivalent Ships
Part C — Non-SOLAS Ships

4.3.1.2 Testing procedures of watertight compartments for SOLAS Ships (including CSR BC & OT) are to be carried out in accordance with Part A, unless:

(1) the shipyard provides documentary evidence of the shipowner's agreement to a request to the flag Administration for an exemption from the application of SOLAS Reg. II-1/11, or for an equivalency agreeing that the content of Part B is equivalent to SOLAS Reg. II-1/11; and

(2) the above-mentioned exemption/equivalency has been granted by the responsible flag Administration.

4.3.1.3 Testing procedures of watertight compartments are to be carried out in accordance with Part B for those SOLAS ships (including CSR BC & OT) for which:

(1) the shipyard provides documentary evidence of the shipowner's agreement to a request to the flag Administration for an exemption from the application of SOLAS Reg. II-1/11, or for an equivalency agreeing that the content of Part B is equivalent to SOLAS Reg. II-1/11; and

(2) the above-mentioned exemption/equivalency has been granted by the responsible flag Administration.

4.3.1.4 Testing procedures of watertight compartments are to be carried out in accordance with PART C for non-SOLAS ships, see SOLAS Chapter I, Regulation 1 and Regulation 3.

Annex 1
Procedures for Testing Tanks and Tight Boundaries
Part A - SOLAS Ships①

1 General

1.1 These test procedures are to confirm the watertightness of tanks,watertight boundaries and the structural adequacy of tanks which form part of the watertight subdivisions② of ships. These procedures may also be applied to verify the weathertightness of structures and shipboard outfitting. The tightness of all tanks and watertight boundaries of ships during new construction and those relevant to major conversions or major repairs③ is to be confirmed by these test procedures prior to the delivery of the ship.

1.2 Testing procedures of watertight compartments for SOLAS Ships (including CSR BC & OT) are to be carried out in accordance with Part A, unless:

(1) the shipyard provides documentary evidence of the shipowner's agreement to a request to the flag Administration for an exemption from the application of SOLAS Reg. II-1/11, or for an equivalency agreeing that the content of Part B is equivalent to SOLAS Reg. II-1/11; and

(2) the above-mentioned exemption/equivalency has been granted by the responsible flag Administration.

2 Application

2.1 All gravity tanks④ and other boundaries required to be watertight or weathertight are to be tested in accordance with this Procedure and proven to be tight and structurally adequate as follows:

(1) gravity tanks for their tightness and structural adequacy;

(2) watertight boundaries other than tank boundaries for their watertightness; and

(3) weathertight boundaries for their weathertightness.

2.2 The testing of cargo containment systems of liquefied gas carriers is to be in accordance with the testing requirements in 4.21 to 4.26 of the IGC Code and standards deemed appropriate by CCS.

2.3 The testing of structures not listed in Table 1 or Table 2 is to be specially considered.

3 Test Types and Definitions

3.1 The following two types of tests are specified in this requirement:

(1) Structural Test:

A test to verify the structural adequacy of tank construction. This may be a hydrostatic test or, where the situation warrants, a hydropneumatic test.

(2) Leak Test:

A test to verify the tightness of a boundary. Unless a specific test is indicated, this may be a hydrostatic/hydropneumatic test or an air test. A hose test may be considered an acceptable form of leak test

---

① Ships to which the SOLAS Convention is applicable.

② Watertight subdivision means the transverse and longitudinal subdivisions of the ship required to satisfy the subdivision requirements of SOLAS Chapter II-1.

③ Major repair means a repair affecting structural integrity.

④ Gravity tank means a tank that is subject to vapour pressure not greater than 70 kPa.

for certain boundaries, as indicated by Footnote 3 of Table 1.

3.2 The definition of each test type is as follows:

Hydrostatic Test: (Leak and Structural)	A test wherein a space is filled with a liquid to a specified head.
Hydropneumatic Test: (Leak and Structural)	A test combining a hydrostatic test and an air test, wherein a space is partially filled with a liquid and pressurized with air.
Hose Test: (Leak)	A test to verify the tightness of a joint by a jet of water with the joint visible from the opposite side.
Air Test: (Leak)	A test to verify tightness by means of air pressure differential and leak indicating solution. It includes tank air test and joint air tests, such as compressed air fillet weld tests and vacuum box tests.
Compressed Air Fillet Weld Test: (Leak)	An air test of fillet welded tee joints wherein leak indicating solution is applied on fillet welds.
Vacuum Box Test: (Leak)	A box over a joint with leak indicating solution applied on the welds. A vacuum is created inside the box to detect any leaks.
Ultrasonic Test: (Leak)	A test to verify the tightness of the sealing of closing devices such as hatch covers by means of ultrasonic detection techniques.
Penetration Test: (Leak)	A test to verify that no visual dye penetrant indications of potential continuous leakages exist in the boundaries of a compartment by means of low surface tension liquids (i.e. dye penetrant test).

3.3 The 'top of the overflow' is defined as being the top of any overflow system which is used to prevent overfilling of a tank. Such system can be an overflow pipe, airpipe, intermediate tank. For gravity tanks (i.e. sewage, grey water and similar tanks, not filled with pumps) the top of the overflow is to be taken as the highest point of the filling line.

Note: Gauging devices are not considered equivalent to an overflow system with the exception of fuel oil overflow tanks not intended to hold fuel which have been fitted with a level alarm.

Where a tank is fitted with multiple means of preventing overfilling, the decision on which overflow system is to be used to determine the test head is to be based on the highest point to which the liquid may rise in service.

4 Test Procedures

4.1 General

Tests are to be carried out in the presence of a Surveyor at a stage sufficiently close to the completion of work with all hatches, doors, windows, etc. installed and all penetrations including pipe connections fitted, and before any ceiling and cement work is applied over the joints. Specific test requirements are given in 4.4 and Table 1. For the timing of the application of coating and the provision of safe access to joints, see 4.5, 4.6 and Table 3.

4.2 Structural test procedures

4.2.1 Type and time of test

Where a structural test is specified in Table 1 or Table 2, a hydrostatic test in accordance with 4.4.1 will be acceptable. Where practical limitations (strength of building berth, light density of liquid, etc.) prevent the performance of a hydrostatic test, a hydropneumatic test in accordance with 4.4.2 may be accepted instead.

A hydrostatic test or hydropneumatic test for the confirmation of structural adequacy may be carried out while the vessel is afloat, provided the results of a leak test are confirmed to be satisfactory before the vessel is afloat.

Alternative equivalent tank testing procedures may be considered for tanks which are constructed from composite materials such as glass reinforced plastic (GRP) and fibre reinforced plastic (FRP) based on the recommendations of the composite manufacturer.

4.2.2 Testing schedule for new construction or major structural conversion

4.2.2.1 Tanks which are intended to hold liquids, and which form part of the watertight subdivision of the ship①, shall be tested for tightness and structural strength as indicated in Table 1 and Table 2.

4.2.2.2 The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.

4.2.2.3 The watertight boundaries of spaces other than tanks for structural testing may be exempted, provided that the water-tightness of boundaries of exempted spaces is verified by leak tests and inspections. Structural testing may not be exempted and the requirements for structural testing of tanks in 4.2.2.1 to 4.2.2.2 shall apply, for ballast holds, chain lockers and a representative cargo hold if intended for in-port ballasting.

4.2.2.4 Tanks which do not form part of the watertight subdivision of the ship[①], may be exempted from structural testing provided that the water-tightness of boundaries of exempted spaces is verified by leak tests and inspections.

4.3 Leak test procedures

(1) For the leak tests specified in Table 1, tank air tests, compressed air fillet weld tests, vacuum box tests in accordance with 4.4.4 through 4.4.6, or their combination, will be acceptable. Hydrostatic or hydropneumatic tests may also be accepted as leak tests provided that 4.5, 4.6 and 4.7 are complied with. Hose tests will also be acceptable for such locations as specified in Table 1, Footnote 3, in accordance with 4.4.3.

(2) The application of the leak test for each type of welded joint is specified in Table 3.

(3) Air tests of joints may be carried out in the block stage provided that all work on the block that may affect the tightness of a joint is completed before the test. See also 4.5.1 for the application of final coatings and 4.6 for the safe access to joints and the summary in Table 3.

4.4 Test methods

4.4.1 Hydrostatic test

(1) Unless another liquid is approved, hydrostatic tests are to consist of filling the space with fresh water or sea water, whichever is appropriate for testing, to the level specified in Table 1 or Table 2. See also 4.7.

(2) In cases where a tank is designed for cargo densities greater than sea water and testing is with fresh water or sea water, the testing pressure height is to simulate the actual loading for those greater cargo densities as far as practicable, but the test pressure shall not exceed the maximum design internal pressure at the top of tank.

(3) All external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, other related damage and leaks.

4.4.2 Hydropneumatic test

(1) Hydropneumatic tests, where approved, are to be such that the test condition, in conjunction with the approved liquid level and supplemental air pressure, will simulate the actual loading as far as practicable. The requirements and recommendations for tank air tests in 4.4.4 will also apply to hydropneumatic tests. See also 4.7.

(2) All external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, other related damage and leaks.

4.4.3 Hose test

(1) Hose tests are to be carried out with the pressure in the hose nozzle maintained at least at $2 \cdot 10^5$ Pa during the test. The nozzle is to have a minimum inside diameter of 12 mm and be at a perpendicular distance from the joint not exceeding 1.5 m. The water jet is to impinge directly upon the weld.

(2) Where a hose test is not practical because of possible damage to machinery, electrical equipment insulation or outfitting items, it may be replaced by a careful visual examination of welded connections, supported where necessary by means such as a dye penetrant test or ultrasonic leak test or the equivalent.

4.4.4 Tank air test

(1) All boundary welds, erection joints and penetrations, including pipe connections, are to be examined in accordance with approved procedure and under a stabilized pressure differential above atmospheric pressure not less than $0.15 \cdot 10^5$ Pa, with a leak indicating solution such as soapy water/detergent or a proprietary brand applied.

(2) A U-tube with a height sufficient to hold a head of water corresponding to the required test pressure is to be arranged. The cross sectional area of the U-tube is not to be less than that of the pipe supplying air to the tank.

(3) Arrangements involving the use of two calibrated pressure gauges to verify the required test pressure may be accepted taking into account the provisions in F5.1 and F7.4 of IACS Rec. 140, “Recommendation for Safe Precautions during Survey and Testing of Pressurized Systems”.

(4) A double inspection is to be made of tested welds. The first is to be immediately upon applying the leak indication solution; the second is to be after approximately four or five minutes in order to detect those smaller leaks which may take time to appear.

4.4.5 Compressed air fillet weld test

(1) In this air test, compressed air is injected from one end of a fillet welded joint and the pressure verified at the other end of the joint by a pressure gauge. Pressure gauges are to be arranged so that an air pressure

---

① Watertight subdivision means the main transverse and longitudinal subdivisions of the ship required to satisfy the subdivision requirements of SOLAS Chapter II-1.

of at least $0.15 \cdot 10^5$ Pa can be verified at each end of all passages within the portion being tested.
Note: Where a leak test is required for fabrication involving partial penetration welds, a compressed air test is also to be applied in the same manner as to fillet weld where the root face is large, i.e., 6-8 mm.

4.4.6 Vacuum box test

(1) A box (vacuum testing box) with air connections, gauges and an inspection window is placed over the joint with a leak indicating solution applied to the weld cap vicinity. The air within the box is removed by an ejector to create a vacuum of $0.20 \cdot 10^5 – 0.26 \cdot 10^5$ Pa inside the box.

4.4.7 Ultrasonic test

(1) An ultrasonic echo transmitter is to be arranged inside of a compartment and a receiver is to be arranged on the outside. The watertight/weathertight boundaries of the compartment are scanned with the receiver in order to detect an ultrasonic leak indication. A location where sound is detectable by the receiver indicates a leakage in the sealing of the compartment.

4.4.8 Penetration test

(1) A test of butt welds or other weld joints uses the application of a low surface tension liquid at one side of a compartment boundary or structural arrangement. If no liquid is detected on the opposite sides of the boundaries after the expiration of a defined period of time, this indicates tightness of the boundaries. In certain cases, a developer solution may be painted or sprayed on the other side of the weld to aid leak detection.

4.4.9 Other test

(1) Other methods of testing may be considered by CCS upon submission of full particulars prior to the commencement of testing.

4.5 Application of coating

4.5.1 Final coating

(1) For butt joints welded by an automatic process, the final coating may be applied any time before the completion of a leak test of spaces bounded by the joints, provided that the welds have been carefully inspected visually to the satisfaction of the Surveyor.
(2) Surveyors reserve the right to require a leak test prior to the application of final coating over automatic erection butt welds.
(3) For all other joints, the final coating is to be applied after the completion of the leak test of the joint. See also Table 3.

4.5.2 Temporary coating

(1) Any temporary coating which may conceal defects or leaks is to be applied at the time as specified for the final coating (see 4.5.1). This requirement does not apply to shop primer.

4.6 Safe access to joints

For leak tests, safe access to all joints under examination is to be provided. See also Table 3.

4.7 Hydrostatic or hydropneumatic tightness test

In cases where the hydrostatic or hydropneumatic tests are applied instead of a specific leak test, examined boundaries must be dew-free, otherwise small leaks are not visible.

Test Requirements for Tanks and Boundaries **Table 1**

	Tank or boundary to be tested	Test type	Test head or pressure	Remark
1	Double bottom tanks[4]	Leak and structural[1]	The greater of - top of the overflow[10], - to 2.4 m above top of tank[2], or - to bulkhead deck	
2	Double bottom voids[5]	Leak	See 4.4.4 through 4.4.6, as applicable	including pump room double bottom and bunker tank protection double hull required by MARPOL Annex I
3	Double side tanks	Leak and structural[1]	The greater of - top of the overflow[10], - to 2.4 m above top of tank[2], or - to bulkhead deck	
4	Double side voids	Leak	See 4.4.4 through 4.4.6, as applicable	

	Tank or boundary to be tested	Test type	Test head or pressure	Remark
5	Deep tanks other than those listed elsewhere in this table	Leak and structural[1]	The greater of - top of the overflow[10], or - to 2.4 m above top of tank[2]	
6	Cargo oil tanks	Leak and structural[1]	The greater of - top of the overflow[10], - to 2.4m above top of tank[2], or - to top of tank[2] plus the design vapour pressure	
7	Ballast hold of bulk carriers	Leak and structural[1]	Top of cargo hatch coaming	
8	Peak tanks	Leak and structural[1]	The greater of - top of the overflow[10], or - to 2.4 m above top of tank[2]	After peak to be tested after installation of stern tube
9	.1 Fore peak spaces with equipment	Leak	See 4.4.3 through 4.4.6, as applicable	
	.2 Fore peak voids	Leak	See 4.4.4 through 4.4.6, as applicable	
	.3 Aft peak spaces with equipment	Leak	See 4.4.3 through 4.4.6, as applicable	
	.4 Aft peak voids	Leak	See 4.4.4 through 4.4.6, as applicable	After peak to be tested after installation of stern tube
10	Cofferdams	Leak	See 4.4.4 through 4.4.6, as applicable	
11	.1 Watertight bulkheads	Leak[8]	See 4.4.3 through 4.4.6, as applicable[7]	
	.2 Superstructure end bulkheads	Leak	See 4.4.3 through 4.4.6, as applicable	
12	Watertight doors below freeboard or bulkhead deck	Leak[6, 7]	See 4.4.3 through 4.4.6, as applicable	
13	Double plate rudder blades	Leak	See 4.4.4 through 4.4.6, as applicable	
14	Shaft tunnels clear of deep tanks	Leak[3]	See 4.4.3 through 4.4.6, as applicable	
15	Shell doors	Leak[3]	See 4.4.3 through 4.4.6, as applicable	
16	Weathertight hatch covers and closing appliances	Leak[3, 7]	See 4.4.3 through 4.4.6, as applicable	Hatch covers closed by tarpaulins and battens excluded
17	Dual purpose tanks/dry cargo hatch covers	Leak[3, 7]	See 4.4.3 through 4.4.6, as applicable	In addition to structural test in item 6 or 7
18	Chain lockers	Leak and structural[1]	Top of chain pipe	
19	L.O. sump. tanks and other similar tanks/spaces under main engines	Leak[9]	See 4.4.3 through 4.4.6, as applicable	
20	Ballast ducts	Leak and structural[1]	The greater of - ballast pump maximum pressure, or - setting of any pressure relief valve	
21	Fuel Oil Tanks	Leak and structural[1]	The greater of - top of the overflow[10], - to 2.4m above top of tank[2], or - to top of tank[2] plus the design vapour pressure, or - to bulkhead deck	
22	Fuel oil overflow tanks not intended to hold fuel	Leak and structural[1]	The greater of - top of the overflow[10], - to 2.4m above top of tank[2], or - to bulkhead deck	

Notes:
1 Refer to section 4.2.2.
2 The top of a tank is the deck forming the top of the tank, excluding any hatchways.
3 Hose Test may also be considered as a medium of the test. See 3.2.
4 Including tanks arranged in accordance with the provisions of SOLAS regulation II-1/9.4.
5 Including duct keels and dry compartments arranged in accordance with the provisions of SOLAS regulation II-1/11.2 and II-1/9.4 respectively, and/or oil fuel tank protection and pump room bottom protection arranged in accordance with the

provisions of MARPOL Annex I, Chapter 3, Part A regulation 12A and Chapter 4, Part A, regulation 22 respectively.
6 Where water tightness of a watertight door has not been confirmed by prototype test, testing by filling watertight spaces with water is to be carried out. See SOLAS regulation II-1/16.2 and MSC/Circ.1572/Rev.1.
7 As an alternative to the hose testing, other testing methods listed in 4.4.7 through 4.4.9 may be applicable subject to adequacy of such testing methods being verified. See SOLAS regulation II-1/11.1. For watertight bulkheads (item 11.1) alternatives to the hose testing may only be used where a hose test is not practicable.
8 A "Leak and structural test", see 4.2.2 is to be carried out for a representative cargo hold if intended for in-port ballasting. The filling level requirement for testing cargo holds intended for in-port ballasting is to be the maximum loading that will occur in-port as indicated in the loading manual.
9 Where L.O. sump tanks and other similar spaces under main engines intended to hold liquid form part of the watertight subdivision of the ship, they are to be tested as per the requirements of Item 5, Deep tanks other than those listed elsewhere in this table.
10 Refer to section 3.3.

Additional Test Requirements for Special Service Ships/Tanks **Table 2**

	Type of Ship/Tank	Structures to be tested	Type of Test	Test Head or Pressure	Remark
1	Liquefied gas carriers	Integral tanks	Leak and structural	Refer to Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk	
		Hull structure supporting membrane or semi-membrane tanks	Refer to Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk	Refer to Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk	
		Independent tanks type A	Refer to Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk	Refer to Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk	
		Independent tanks type B	Refer to Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk	Refer to Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk	
		Independent tanks type C	Refer to Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk	Refer to Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk	
2	Edible liquid tanks	Independent tanks	Leak and structural[1]	The greater of - top of the overflow[3], or - to 0.9 m above top of tank[2]	
3	Chemical carriers	Integral or independent cargo tanks	Leak and structural[1]	The greater of - to 2.4 m above top of tank[2], or - to top of tank[2] plus the design vapour pressure	Where a cargo tank is designed for the carriage of cargoes with specific gravities larger than 1.0, see section 4.4.1

Notes:
1 Refer to section 4.2.2.
2 Top of tank is deck forming the top of the tank excluding any hatchways.
3 Refer to section 3.3.

Application of Leak Test, Coating and Provision of Safe Access for Type of Welded Joints
Table 3

Type of welded joints		Leak test	Coating[1]		Safe Access[2]	
			Before leak test	After leak test but before structural test	Leak test	Structural test
Butt	Automatic	Not required	Allowed[3]	N/A	Not required	Not required
	Manual or Semi-automatic[4]	Required	Not allowed	Allowed	Required	Not required
Fillet	Boundary including	Required	Not allowed	Allowed	Required	Not required

	penetrations					

Notes:
1 Coating refers to internal (tank/hold coating), where applied, and external (shell/deck) painting. It does not refer to shop primer.
2 Temporary means of access for verification of the leak test.
3 The condition applies provided that the welds have been carefully inspected visually to the satisfaction of the Surveyor.
4 Flux Core Arc Welding (FCAW) semiautomatic butt welds need not be tested provided that careful visual inspections show continuous uniform weld profile shape, free from repairs, and the results of NDE testing show no significant defects.

Part B - SOLAS Exempt/Equivalent Ships

1 General

1.1 These test procedures are to confirm the watertightness of tanks, watertight boundaries and the structural adequacy of tanks which form part of the watertight subdivisions① of ships. These procedures may also be applied to verify the weathertightness of structures and shipboard outfitting. The tightness of all tanks and watertight boundaries of ships during new construction and those relevant to major conversions or major repairs② is to be confirmed by these test procedures prior to the delivery of the ship.

1.2 Testing procedures of watertight compartments are to be carried out in accordance with Part B for those SOLAS ships (including CSR BC & OT) for which:

(1) the shipyard provides documentary evidence of the shipowner's agreement to a request to the flag Administration for an exemption from the application of SOLAS Reg. II-1/11, or for an equivalency agreeing that the content of Part B is equivalent to SOLAS Reg. II-1/11; and

(2) the above-mentioned exemption/equivalency has been granted by the responsible flag Administration.

2 Application

2.1 Testing procedures are to be carried out in accordance with the requirements of Part A in association with the following alternative procedures for 4.2.2 "Testing schedule for new construction or major structural conversion" of Part A .

2.2 The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.

2.3 Structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test. The acceptance of leak testing using an air test instead of a structural test does not apply to cargo space boundaries adjacent to other compartments in tankers and combination carriers or to the boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships.

2.4 Additional tanks may require structural testing if found necessary after the structural testing of the first tank.

2.5 For tanks which are less than 2 m^3 in volume, structural testing may be replaced by leak testing.

2.6 Where the structural adequacy of the tanks and spaces of a vessel were verified by the structural testing required by either PART A or PART B 2.3, subsequent vessels in the series (i.e. sister ships built from the same plans at the same shipyard) may be exempted from structural testing of tanks, provided that:

(1) water-tightness of boundaries of all tanks and spaces are verified by leak tests and thorough inspections are carried out;

(2) structural testing is carried out for at least one tank or space of each type among all tanks/spaces of each sister vessel;

(3) additional tanks and spaces may require structural testing if found necessary after the structural testing of the first tank or if deemed necessary by the attending Surveyor.

For cargo space boundaries adjacent to other compartments in tankers and combination carriers or boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships, structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test.

2.7 Sister ships built (i.e. keel laid) two years or more after the delivery of the last ship of the series, may be tested in accordance with Part B 2.6 at the discretion of CCS, provided that:

---

① Watertight subdivision means the main transverse and longitudinal subdivisions of the ship required to satisfy the subdivision requirements of SOLAS Chapter II-1.

② Major repair means a repair affecting structural integrity.

(1) general workmanship has been maintained (i.e. there has been no discontinuity of shipbuilding or significant changes in the construction methodology or technology at the yard, shipyard personnel are appropriately qualified and demonstrate an adequate level of workmanship as determined by CCS); and
(2) an NDT plan is implemented and evaluated by CCS for the tanks not subject to structural tests. Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. The work is to be carried out in accordance with the Rules and under survey by CCS.

Part C - Non-SOLAS Ships

1 General

1.1 These test procedures are to confirm the watertightness of tanks, watertight boundaries and the structural adequacy of tanks which form part of the watertight subdivisions① of ships. These procedures may also be applied to verify the weathertightness of structures and shipboard outfitting. The tightness of all tanks and watertight boundaries of ships during new construction and those relevant to major conversions or major repairs② is to be confirmed by these test procedures prior to the delivery of the ship.
1.2 Testing procedures of watertight compartments are to be carried out in accordance with PART C for non-SOLAS ships, see SOLAS Chapter I, Regulation 1 and Regulation 3.

2 Application

2.1 Testing procedures are to be carried out in accordance with the requirements of PART A in association with the following alternative procedures for 4.2.2 of PART A "Testing Schedule for New Construction or Major Structural Conversion".
2.2 The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.
2.3 The requirements given in Table 1 of Part A to structurally test tanks to 2.4 metres above the top of the tank do not apply. Instead, the minimum test pressure for structural testing is to be taken as 0.3D + 0.76 metres above the top of the tank where the top of the tank is the deck forming the top of the tank, excluding any hatchways and D is the depth of the ship. The minimum test pressure need not be taken greater than 2.4 metres above the top of the tank.
2.4 Structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test. The acceptance of leak testing using an air test instead of a structural test does not apply to cargo space boundaries adjacent to other compartments in tankers and combination carriers or the boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships.
2.5 Additional tanks may require structural testing if found necessary after the structural testing of the first tank.
2.6 For tanks which are less than 2 m^3 in volume, structural testing may be replaced by leak testing.
2.7 Where the structural adequacy of the tanks and spaces of a vessel were verified by the structural testing required by either PART A or PART C section 2.4, subsequent vessels in the series (i.e. sister ships built from the same plans at the same shipyard) may be exempted from structural testing of tanks, provided that:
(1) water-tightness of boundaries of all tanks and spaces are verified by leak tests and thorough inspections are carried out;
(2) structural testing is carried out for at least one tank or space among all tanks/spaces of each sister vessel;
(3) additional tanks and spaces may require structural testing if found necessary after the structural testing of the first tank or if deemed necessary by the attending Surveyor.
For cargo space boundaries adjacent to other compartments in tankers and combination carriers or boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships, structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test.
For cargo space boundaries adjacent to other compartments in tankers and combination carriers or

① Watertight subdivision means the main transverse and longitudinal subdivisions of the ship.
② Major repair means a repair affecting structural integrity.

boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships, structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test.

2.8 Sister ships built (i.e. keel laid) two years or more after the delivery of the last ship of the series, may be tested in accordance with PART C 2.7 at the discretion of CCS, provided that:

(1) general workmanship has been maintained (i.e. there has been no discontinuity of shipbuilding or significant changes in the construction methodology or technology at the yard, shipyard personnel are appropriately qualified and demonstrate an adequate level of workmanship as determined by CCS); and

(2) an NDT plan is implemented and evaluated by CCS for the tanks not subject to structural tests. Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. The work is to be carried out in accordance with the Rules and under survey of CCS.

Section 4 DOCUMENTATION

4.4.1 Reports

4.4.1.1 The shipyard is to submit relevant inspection, testing, measuring reports and records to the Surveyor and the owner.

4.4.1.2 The Surveyor is to attend the inspection and testing of the specified items, review the relevant inspection, testing, measuring reports and records submitted by the shipyard, and then issue various survey reports, records, data and relevant certificates for the ship's hull and equipment, machinery, electrical installations in the forms specified by the Headquarters of CCS and report this to the Headquarters.

4.4.1.3 The shipyard is to submit the as-built construction drawings referred to in 4.4.2.1 of this Section to the Surveyor.

4.4.2 Documents and information

4.4.2.1 At least one set of the following as-built construction drawings is to be maintained on board the ship and by the shore-based management:

(1) Main plans

① General arrangement;

② Capacity plan;

③ Hydrostatic curves;

④ Loading Manual, where required.

(2) Hull structural plans

① Midship section;

② Scantling plan;

③ Decks;

④ Shell expansion;

⑤ Transverse bulkheads;

⑥ Rudder and rudder stock;

⑦ Cargo hatch covers, when applicable.

(3) Bilge ballast and cargo piping diagrams.

4.4.2.2 The following as-built construction documents and information are to be maintained on board the ship and by the owner and/or the shore-based management:

(1) Technical information of the ship:

① Stability information, calculations, and relevant diagrams and tables;

② Specifications, operation manual, equipment instructions and other guidelines.

(2) Certificates of the ship and its equipment including installations and systems, classification certificates, survey reports and records, and other specific certificates.

4.4.2.3 In general, the date of completion for construction surveys is to be recorded as that for construction. The other important dates for the ship, e.g. the signing date of construction contract, the date of commencement of construction, the date of the keel laid, the date of launching and the date of delivery are also to be recorded.

4.4.2.4 Upon request by the owner, certain special purpose ships are to be additionally provided with the

certificates, information, reports and other technical documents required by an industry organization.
4.4.2.5 The documents and information stated in 4.4.2.1, 4.4.2.2, 4.4.2.3 (if any) above and subsequent documents and information related to them are to be kept by all parties concerned, e.g. the ship, owner or manager of the ship, for the lifetime of the ship.
4.4.2.6 CCS is to, at least during the period in which the ship is classed with CCS, maintain the drawings and documentation referred to in 4.4.2.1, 4.4.2.2(1)①, 4.4.2.2(2) and 4.4.2.4 that are related to the classification management of the ship.

Section 5 ASSIGNING CLASS FOR A NEW BUILDING PROJECT WHEN THE DESIGN IS ALREADY APPROVED BY AN INITIAL SOCIETY①

4.5.1 General requirements

4.5.1.1 This Section is applicable to assigning class for a newbuilding project by Memorandum of Understanding (MoU) adopted between CCS, a Shipyard and, if applicable, a Ship Owner covering the acceptance by CCS of a design based on the prior approval by an Initial Society for a new building.

4.5.2 Assigning class for a new building project based on the Rules and the Memorandum of Understanding between CCS, the Shipyard and, if applicable, a Owner

4.5.2.1 Whenever CCS is requested by an Owner/Shipyard to class a vessel(s) for new construction project when the design is already approved by an Initial Society, the following procedures are to be applied.
(1) CCS may accept to class a new building project vessel when the design is already approved by an Initial Society for new building and all comments are confirmed as dealt with by the Initial Society approving the design.
(2) CCS may accept to class a new building project vessel in accordance with the Memorandum of Understanding (MoU) adopted by CCS and the shipyard, subject to the requirements in (3), (4) and (5) being fulfilled. This MoU is to clearly define requirements for submission of plans as required by 4.5.3 below, harmonizing and resolution of plans already approved by an Initial Society for new building project and comments to be dealt with.
(3) CCS is to perform review and approval of plans based on the Rules. As a minimum scope, the approval of the plans listed in 4.5.3 below is required by CCS to verify compliance with the Rules. CCS is to record the written documentary evidence of the above-mentioned plans which were approved as complying with the Rules or with other requirements confirmed acceptable in accordance with the Rules.
(4) CCS is to perform the survey during fabrication, construction and testing of the vessel based on the Rules.
(5) Certification of materials and components of manufacturers is to be carried out by CCS in accordance with the Rules.

4.5.3 Plans to be submitted by the Shipyard to CCS

4.5.3.1 This paragraph contains the list of plans to be submitted by the Shipyard to CCS. The list of plans varies from ship to ship, but are to include at least the following.
4.5.3.2 Main plans
(1) General Arrangement;
(2) Capacity Plan;
(3) Hydrostatic Curves;
(4) Loading Manual, where required;
(5) Damage Stability calculation, where required.
4.5.3.3 Steel plans
(1) Midship Section;
(2) Scantling Plan;
(3) Decks;
(4) Shell Expansion;

---

① Initial Society is the Society which has previously approved the design using their own Rules and which can provide satisfactory evidence of continued compliance with QSCS.

(5) Transverse Bulkheads
(6) Rudder and Rudder Stock;
(7) Hatch Covers;
(8) For CSR vessels, plans showing, for each structural element, both as-built and renewal thicknesses and any thickness for “voluntary addition”;
(9) Plan of tank testing.
4.5.3.4 Machinery and Electrical plans
(1) Machinery Arrangement;
(2) Intermediate, Thrust- and Screw Shafts;
(3) Propeller;
(4) Couplings and shaft alignment calculation;
(5) Main Engines, Propulsion Gears and Clutch Systems (or Manufacturer make, model and rating information);
(6) For Steam Turbine Vessels, Main Boilers, Superheaters and Economisers (or Manufacturer make, model and rating information) and Steam Piping;
(7) Bilge and Ballast Piping Diagram;
(8) Wiring Diagram;
(9) Steering Gear Systems Piping and Arrangements and Steering Gear Manufacturer make and model information;
(10) Diagram of the air, sounding and overflow systems;
(11) Diagram of cooling systems (sea water and fresh water);
(12) Diagram of fuel oil system;
(13) Diagram of the lubricating oil system;
(14) Diagram of the hydraulic systems intended for essential services or located in machinery spaces;
(15) Diagrams of sea water and / or freshwater piping systems;
(16) Electrical power balance (main and emergency supply);
(17) General specification for the automation of the ship;
(18) Detailed specification of the essential service systems;
(19) List of components used in the automation circuits, and references (Manufacturer, type, etc.);
(20) General diagram showing the monitoring and/or control positions for the various installations, with an indication of the means of access and the means of communication between the positions as well as with the engineers;
(21) Diagrams of the supply circuits of automation systems, identifying the power source;
(22) List of monitored parameters for alarm/monitoring and safety systems;
(23) Diagram of compressed air system.
4.5.3.5 Torsional vibration calculations.
4.5.3.6 For vessels with ice class notation, plans for flexible couplings and/or torque limiting shafting devices in the propulsion line shafting (or manufacturer make, model and rating information) are also to be provided.
4.5.3.7 For oil tankers, the following plans are also to be provided:
(1) Pumping arrangement at the forward and after ends and drainage of cofferdams and pump rooms.
4.5.3.8 For ships assigned with unattended machinery space notation, the following plans are also to be provided:
(1) Instrument and Alarm List;
(2) Fixed Fire Detection and Alarm System;
(3) List of Automatic Safety Functions (e.g. slowdowns, shutdowns, etc.);
(4) Function Testing Plan.
4.5.3.9 Document(s) of Approval of Alternative Design and Arrangements, if any.
4.5.3.10 Other plans as required by the Rules are also to be provided depending on the type of ship.

Section 6 ASSIGNING DUAL CLASS FOR A NEW BUILDING

4.6.1 General requirements

4.6.1.1 Each Society acts on behalf of the other Society in accordance with the trilateral agreement adopted by the two Societies and the shipyard. This agreement is to clearly define modalities such as submission of plans, rules to be applied, harmonizing and resolution of plan approval comments between societies.

4.6.2 Plan submission and survey

4.6.2.1 Plans and documents related to classification requirements are to be submitted to each Society by the shipyard.

4.6.2.2 One set of plans and documents fully approved by the First Society shall be provided to the Second Society and each Society is to perform review and approval of plans based on its own classification Rules. As a minimum scope, the approval of the plans listed in 4.5.3, Section 5, Chapter 4 of this PART is required by the Second Society to verify compliance with its applicable classification Rules. The Second Society is to record written documentary evidence of the above-mentioned plans which were approved as complying with the Second Society's own Rules or with other requirements confirmed acceptable in accordance with its own Rules.

4.6.2.3 Each Society is to perform the survey during fabrication, construction and testing of the vessel based on its own classification Rules and in accordance with the work agreed by the two Societies and described in the trilateral agreement, and/or the bilateral agreement adopted by the two Societies, if any.

Appendix 1 HULL SURVEY FOR NEW CONSTRUCTION

1. Scope

1.1 The scope of this Appendix includes the following main aspects:

(1) examination of the parts of the ship covered by CCS rules and by applicable statutory regulations for hull construction, to obtain appropriate evidence that they have been built in compliance with the classification rules and regulations, taking account of the relevant approved drawings;

(2) appraisal of the manufacturing, construction, control and qualification procedures, including welding consumables, weld procedures, weld connections and assemblies, with indication of relevant approval tests;

(3) witnessing inspections and tests as required in the classification rules used for ship construction including materials, welding and assembling, specifying the items to be examined and/or tested and how (e.g. by structural, hydropneumatic, hose or leak testing, non-destructive examination, verification of geometry) and by whom.

1.2 Appraisal of material and equipment used for ship construction and their inspection at works is not included in this Appendix. Details of requirements for hull and machinery steel forgings and castings and for normal and higher strength hull structural steel are given in CCS Rules for Materials and Welding. Acceptance of these items is verified through the survey process carried out at the manufacturer's works and the issuing of the appropriate certificates.

1.3 In addition to the above, for tankers and bulk carriers subject to SOLAS Reg. II-1/3-10 (Goal-based ship construction standards for bulk carriers and oil tankers) (hereinafter referred to as "GBS ships[①]"), see also Annex 2 to this Appendix.

2. Definitions[②]

2.1 For the purpose of this Appendix, the relevant terms are defined as follows:

(1) Hull structure: the following parts and/or structural members are covered:

① hull envelope including all internal and external structures;

② superstructures, deckhouses and casings;

③ welded foundations, e.g. main engine seatings;

④ hatch coamings, bulwarks;

⑤ all penetrations fitted or welded into bulkheads, decks and shell;

⑥ the fittings of all connections to decks, bulkheads and shell, such as air pipes and ship side valves – all ILLC 1966, as amended, items;

⑦ welded attachments to shell and decks, e.g. crane pedestals, bitts and bollards, but only as regards their interaction on the hull structure.

(2) Documents: reference to documents also includes electronic transmission or storage.

(3) Survey methods: survey methods which the Surveyor is directly involved in are patrol, review, witness, defined respectively as follows:

① Patrol: the act of checking on an independent and unscheduled basis that the applicable processes, activities and associated documentation of the shipbuilding functions identified in Table 1 continue to conform with classification and statutory requirements;

② Review: the act of examining documents in order to determine traceability, identification and to confirm that processes continue to conform with classification and statutory requirement;

③ Witness: the attendance at scheduled inspections in accordance with the agreed Inspection and Test Plans to the extent necessary to check compliance with the survey requirements.

3. Application

3.1 This Appendix covers the survey of all new construction of steel ships intended for classification and for international voyages.

3.2 This Appendix covers all statutory items, relevant to the hull structure and coating, i.e. Load Line and SOLAS Safety Construction.

3.3 This Appendix does not cover the manufacture of equipment, fittings and appendages regardless whether they are made inside or outside of the shipyard, examples being as follows. Evidence of acceptance is to be provided by accompanying documentation from class Surveyor at manufacturer and

---

① The requirements for GBS ships in this PART are to be implemented from 1 July 2016.

② Terminology for hull terms and hull survey terms can be found in IACS Recommendation No.82.

verified at the shipyard:
(1) hatch covers;
(2) doors and ramps integral with the shell and bulkheads;
(3) rudders and rudder stock;
(4) all forgings and castings integral to the hull.
3.4 This Appendix applies to the installation into the ship, welding and testing of:
(1) the items listed in 3.3 above;
(2) equipment forming part of the watertight and weathertight integrity of the ship.
3.5 This Appendix applies to the hull structures constructed and coating applied at any of the following:
(1) shipbuilder's facilities;
(2) sub-contractors at the shipbuilder's facilities;
(3) sub-contractors at their own facilities or at other remote locations.

4. Qualification and monitoring of personnel

4.1 CCS Surveyors are to, through patrol, review and witness as defined in 2.1(3) of this Appendix, verify that the ships are built using approved plans in accordance with the relevant rules and statutory requirements. The Surveyors are to be qualified to be able to carry out the tasks.
4.2 CCS is to establish and implement relevant management procedures to ensure that the activities of the Surveyors are monitored.

5. Survey of the hull structure

5.1 Table 1 provides a list of surveyable items for the hull structure and coating covered by this Appendix, including:
(1) description of the shipbuilding functions;
(2) classification and statutory survey requirements;
(3) survey method required for classification;
(4) relevant classification rules, IACS and statutory requirement references;
(5) documentation to be available for the Surveyor during construction:
① the shipbuilder is to provide the Surveyors access to documentation required by classification, this includes documentation retained by the shipbuilder or other third parties;
② the following documents are to be submitted to CCS for approval or examination for the specific new construction:
a. plans and supporting documents;
b. examination and testing plans;
c. NDE plans;
d. welding consumable details;
e. welding procedure specifications;
f. welding plan or details;
g. welders' qualification records;
h. NDE operators' qualification records;
(6) documents to be inserted into the ship construction file. Refer to paragraph 10 for details;
(7) a list of specific activities which are relevant to the shipbuilding functions. This list is not exhaustive and can be modified to reflect the construction facilities or specific ship type.
5.2 Evidence is also to be made available, as required, by the shipbuilder, to the surveyor whilst the construction process proceeds to prove that the material and equipment supplied to the ship has been built or manufactured under survey by CCS relevant to the classification rules and statutory requirements.

6. Review of the construction facility

6.1 CCS is to, by means of review, familiarize itself with the yard's production facilities, management processes, and safety for consideration in complying with the requirements of Table 1 prior to any steelwork or construction taking place in the following circumstances:
(1) where CCS has none or no recent experience of the construction facilities – typically after a one year lapse, or when significant new infrastructure has been added;
(2) where there has been a significant management or personnel re-structuring having an impact on the ship construction process; or
(3) where the shipbuilder contracts to construct a ship of a different type or substantially different in design.
6.2 Review of the construction facility may be referred to Annex 1 "Shipyard Review Record".

7. Newbuilding survey planning

7.1 Prior to commencement of surveys for any newbuilding project, CCS is to discuss with the shipbuilder at a kickoff meeting the items listed in Table 1. The purpose of the meeting is to agree how the list of specific activities shown in Table 1 is to be addressed. If a surveyor has been nominated for a specific newbuilding project, then the surveyor is to attend the kickoff meeting. The meeting is to:

(1) take into account the shipbuilders' construction facilities and ship type;

(2) include the list of proposed subcontractors;

(3) the builder is is to agree to:

① undertake ad hoc investigations during construction as may be requested by CCS where areas of concern arise and keep CCS advised of the progress of any investigation;

② whenever an investigation is undertaken, in principle, suspend relevant construction activities if warranted by the severity of the problem;

(4) make a record of the meeting.

7.2 Attention is to be given to specific published Administration requirements and interpretations of statutory requirements.

7.3 The shipyard is to advise CCS of any changes to the activities agreed at the kickoff meeting and these are to be documented in the survey plan, e.g.:

(1) if the shipbuilder chooses to use or change sub-contractors, or;

(2) if the shipbuilder chooses to incorporate any modifications necessitated by changes in production or inspection methods, rules and regulations, structural modifications, or;

(3) in the event where increased inspection requirements are deemed necessary as a result of a substantial nonconformance or otherwise.

7.4 Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kickoff meeting. Structural fabrication is to be carried out in accordance with IACS Rec.47[①], or a Recognized Fabrication Standard (RFS) which has been accepted by CCS prior to the commencement of fabrication/construction. The work is to be carried out in accordance with the Rules and under survey by CCS.

CCS may accept an RFS as an alternative to IACS Rec.47 provided that 7.4.1 or 7.4.2 is complied with as applicable.

7.4.1 Where a RFS is well established and has well documented history (3 or more years prior to the new vessel contract) of successful application to similar designs as the new vessel and that history is for the same Shipyard as the new vessel. Then the Shipyard is to create a summary document referencing the RFS to be used in construction and highlighting any limitations to usage of the selected RFS. This summary document is to be included with the "record of kick-off meeting" for the vessel.

The summary document is also to be included in the SCF, (for Tankers and Bulk Carriers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10 per Annex 2 of Appendix 1 in this chapter, Table A Tier II Item 11), as applicable.

7.4.2 Where a RFS is new or revised or otherwise not as per 7.4.1 the following steps are to be carried out:

(1) The tolerances and fabrications standards of the RFS are to be compared with those of Recommendation 47. Any that are less stringent than those of Recommendation 47 are to be identified.

(2) The tolerances and fabrication standards of the RFS identified in 7.4.2(1) are to be assessed to determine the acceptability for use and/or any restrictions for usage for the subject (or proposed) design. Details of how the acceptability for use and/or restrictions are to be recorded.

(3) A summary document including the outcomes of 7.4.2(1) and 7.4.2(2) is to be compiled. This document is to also include a reference to the RFS, details of the tolerance and fabrication standards not analysed as part of 7.4.2(2) and any limitations to the usage of the RFS.

The summary document is to be included with the "record of the kick-off meeting" of the vessel. The summary document is also to be included in the SCF, (for Tankers and Bulk Carriers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10 per Annex 2 of Appendix 1 in this chapter, Table A Tier II Item 11), as applicable.

7.5 The kickoff meeting may be attended by other parties (owner, Administrations, etc.) subject to agreement by the shipbuilder.

7.6 In the event of series ship[②] production, the requirement for a kickoff meeting in paragraph 7.1 may be waived for the second and subsequent ships provided that no changes to the specific activities agreed in the kickoff meeting for the first ship are introduced. If any changes are introduced, these are to be agreed in

---

① For detailed requirements of IACS Rec.47, see Appendix 2 of this Chapter.

② Series Ship Production: vessels in the series subsequent to the first one (prototype), i.e. sister ships built in the same shipyard.

a new dedicated meeting and documented in a record of such meeting.

8. Examination and test plan for newbuilding activities

8.1 The shipbuilder is to provide plans of the items which are intended to be examined and tested. These plans need not be submitted for approval and examination at the time of the kickoff meeting. They are to include:

(1) proposals for the examination of completed steelwork – generally referred to as the block plan and are to include details of joining blocks together at the pre-erection and erection stages or at other relevant stages;

(2) proposals for fit up examinations where necessary;

(3) proposals for testing of the structure (leak and hydrostatic) as well as for all watertight and weathertight closing appliances;

(4) proposals for non-destructive examination;

(5) any other proposals specific to the ship type or to the statutory requirements.

8.2 The plans and any modifications to them are to be submitted to the Surveyors in sufficient time to allow review before the relevant survey activity commences.

8.3 In addition to the above, for GBS ships, see also Annex 2 to this Appendix.

9. Proof of the consistency of surveys

9.1 CCS is to be able to provide evidence, e.g. through records, check lists, inspection and test records, etc. that its surveyors have complied with the requirements of the newbuilding survey planning and duly participated in the relevant activities shown in the shipbuilder's examination and test plans.

9.2 In addition, CCS is to maintain records of deficiencies found during the patrolling activities required in Table 1 and described in paragraph 2.1(3). Records are to include the date when deficiency was found, description of the deficiency and the date the deficiency was cleared.

10. Ship construction file

10.1 The purposes of this paragraph are applicable to all ships except GBS ships for which the paragraph 3 of Annex 2 to this Appendix is to be applied. The shipbuilder is to deliver documents for the ship construction file. In the event that items have been provided by another party such as the shipowner and where separate arrangements have been made for document delivery which excludes the shipbuilder, that party has the responsibility. The Ship Construction File is to be reviewed for content in accordance with the requirements of paragraph 10.2.

10.2 It is recognised that the purpose of documents held in the Ship Construction File on board the ship, is to facilitate inspection (survey) and repair and maintenance, and, therefore, is to include in addition to documents listed in Table 1, but not be limited to:

(1) as-built structural drawings including scantling details, material details, and, as applicable, wastage allowances, location of butts and seams, cross section details and locations of all partial and full penetration welds, areas identified for close attention and rudders (see Sections 5, 6, 7, 8 and 16 of Chapter 5 of this PART);

(2) manuals required for classification and statutory requirements, e.g. loading and stability, bow doors and inner doors and side shell doors and stern doors – operations and maintenance manuals (Sections 4 and 5, Chapter 9 of PART TWO of the Rules);

(3) ship structure access manual, as applicable;

(4) copies of certificates of forgings and castings welded into the hull (Chapters 5 and 6 of PART ONE of CCS Rules for Materials and Welding);

(5) details of equipment forming part of the watertight and weather tight integrity of the ship;

① A Cable Transit Seal Systems Register, to be prepared by the shipbuilder for watertight cable transits. The Register can be in either a hard copy or digitized media. For an example of a register see "Annex 3 of this Appendix - Recommendatory Sample - Cable Transit Seal Systems Register". It is to include a marking / identification system, documentation referencing manufacturer manual(s) for each type of cable transit installed, the Type Approval certification for each type of transit system, applicable installation drawings, and a recording of each installed transit documenting the as built condition after final inspection in the shipyard. This is to include sections to record any inspection, modification, repair and maintenance.

(6) tank testing plan including details of the test requirements (Section 3 of this Chapter);

(7) corrosion protection specifications (Sections 6, Chapter 1 of PART TWO of the Rules);

(8) details for the in-water survey, if applicable, information for divers, clearances measurements instructions, tank and compartment boundaries (Chapter 12 of PART EIGHT of the Rules);

(9) docking plan and details of all penetrations normally examined at dry-docking;

(10) coating technical documents (for ships implementing “Guidelines for Implementation of IMO Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in All Types of Ships and Double-Side Skin Spaces of Bulk Carriers” and/or ships having PSPC notation.

Items for Hull Survey **Table 1**

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS① requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
	Shipbuilding quality control function								
1	Welding								
1.1	Welding consumables	Works approval of the manufacturer by CCS	Review approval status and patrol, verify storage, handling and treatment in accordance with manufacturer's requirements	UR W17		Consumable specification and approval status	Not required	Identify consumables against approved list	
								Verify temporary and permanent storage facilities	e.g. kept dry, covered, where applicable heated
								Verify traceability	e.g. random batch number checking
1.2	Welder qualification	Qualified welders	Review of welder certification and patrol	IACS Rec.47		Shipyard's records with individual's identification	Not required	Verify welder qualification standard, e.g. class or recognised standard approval	
								Verify welder approved for weld position	
								Verify validity of qualification certificate	
1.3	Welding – mechanical properties (welding procedures)	All weld joint configurations, positions and materials to be covered by weld procedures approved by CCS	Review and patrol	UR W28		Approved weld procedure specification and welding plan relevant to the ship project or process	Not required	Verify procedures are available at relevant workstations	
		CCS witnesses all new weld procedure	Witness					Verify weld procedures records	

① IACS Recommendations indicated in this Table are not mandatory requirements, IACS UI are given in CCS Guidelines for Implementation of Statutory Surveys (Ships Engaged on International Voyages).

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS© requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
		qualification tests carried out in the shipyard whenever CCS is surveying in the shipyard						have been approved and cover all weld processes and positions in accordance with Rules or recognised standards and are available for the Surveyor's reference	
1.3a	Welding equipment	Correctly calibrated and maintained	Patrol and review			Shipbuilder's maintenance and calibration records	Not required	Verify condition of machinery and equipment	
								Verify machines are calibrated by appropriate staff	
								Verify calibration carried out in accordance with manufacturer's recommendations	
								Verify calibration in accordance with maintenance schedule	
1.3b	Welding environment	Satisfactory environment	Patrol	IACS Rec.47			Not required	Verify welding areas clean, dry, well lit	
								Confirm relevant measures taken for any pre or post heat treatment, drying of surfaces prior to welding	
								Confirm shielding gases, fluxes protected	
1.3c	Welding supervision	Sufficient number of skilled supervisors	Review and patrol	UR W33, IACS Rec.47				Verify supervision is effective	
1.4	Welding – surface	Substantially free from significant	Visual examination, surface detection	UR W33, IACS Rec.47		Shipbuilder's and recognised standards	Not required	Identify workstations where NDE is carried	

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS© requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
	discontinuities	indications, satisfactory profile and size	techniques, review of documents and patrol of operator			and Rules as applicable, welding and NDE plans, NDE report		out, e.g. panel line butt welds, castings into hull structure	
								Verify NDE carried out in accordance with approved plans where applicable	
								Verify suitability of NDE methods	
								Verify operators suitably qualified particularly where sub-contractors have been employed	
								Verify NDE is carried out according to the acceptable process	
								Review NDE records	
1.5	Welding – embedded discontinuities	NDE is to be carried out by qualified operators capable of ensuring that welds are substantially free from significant indications	Radiography and ultrasonic testing, review of documents and patrol of operator, examination of films	UR W33, IACS Rec.47		Shipbuilder's and recognised standards and Rules as applicable, welding and NDE plans, NDE reports, operator qualifications	Not required	Identify workstations where NDE is carried out, e.g. panel line butt welds, castings into hull structure	
								Verify NDE carried out in accordance with approved plans where applicable	
								Verify suitability of NDE methods	
								Verify operators suitably qualified particularly where sub-contractors have been employed	
								Verify that records have been completed and in accordance with recoginsed standards, e.g. IQI and sensitivity	

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS© requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
								recorded	
								Verify that reports and radiographs have been evaluated correctly by the shipbuilder. Systematic review of radiographs carried out by the Surveyor	
								Verify equipment calibration satisfactory and in accordance with manufacturer's and recognised standards requirements	
								Verify NDE is carried out according to the acceptable process	
2	Steel preparation and fit-up								
2.1	Surface preparation, marking and cutting	Traceability and acceptability of material, check of steel plates & profiles, materials type, scantling identification, testing marks	Patrol	IACS Rec.47		Material certificates, shipbuilder's marking/cutting production documents at the workstation – documents retained at the facility	Not required	Verify stockyard storage satisfactory	
								Verify material traceability, e.g. stamping identification against material certification, archiving of records	
								Verify transfer marking after treatment line	
								Verify standard of shot-blasting and priming	
								Verify suitability of primer	
								Verify that steel grades can be identified	

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS© requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
								Verify machinery adjusted to maintain within IACS or manufacturer's recommendations	
								Verify accuracy of marking and cutting	
								Verify storage of piece parts	
2.2	Straightening	Approval of straightening methods/procedures against deformation	Patrol and review	IACS Rec.47		Recognised standards, approved procedures	Not required	Verify that straightening processes are approved for the grade and type of steel, e.g. TMCP, z plate	
								Verify that plates and sections are within recognised tolerances	
2.3	Forming	Maintain material properties. Acceptance of forming method against unproper deformations	Patrol	IACS Rec.47		Shipbuilder's procedure for hot forming	Not required	Verify that temperature control is exercised by the operator	
								Verify that suitable methods of temperature control are available when forming special steels and materials	
								Verify that forming processes are acceptable	
2.4	Conformity with alignment/fit-up/gap criteria	Check alignment/fit-up/gap against reference standards	Patrol	IACS Rec.47		Shipbuilder's and recognised standards and Rules as applicable	Not required	Verify the processes to ensure satisfactory fit-up and alignment at all workstations	
								Verify that edge preparations are reinstated where lost during fitting	

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS© requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
								operations	
								Verify remedial procedures are in place to compensate for wide gaps and alignment deviations	
2.5	Conformity for critical areas, when defined, with alignment/fit-up or weld configuration	Check alignment/fit-up/gap against approved drawings	Witness and review	IACS Rec.47		Shipbuilder's and recognised standards and Rules as applicable, approved plan or standard, builder's records	Approved plans of critical areas if applicable	Verify that the information relevant to the latest approved drawings is available at the workstations	
								Verify the processes to ensure satisfactory fit-up and alignment at all workstations	
								Verify that edge preparations are reinstated where lost during fitting operations	
								Verify remedial procedures are in place to compensate for wide gaps and alignment deviations	
3	Steelwork process, e.g. sub-assembly, block, grand and mega block assembly, pre-erection and erection, closing plates	Compliance with approved drawings, visual examination of welding and material, check alignment and deformations	Patrol of the process and witness of the completed item	IACS Rec.47		Approved plans, shipbuilder's inspection records, shipbuilder's and recognised standards and Rules as applicable, construction plan (steelwork subdivision)		Verify that the information relevant to the latest approved drawings is available at the workstations	
								Verify that correct weld sizes have been adopted	
								Verify operation of the welding processes at the different work stages is satisfactory	
								Verify that piece parts are identifiable	

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS© requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
								Verify that fit-ups are within recognised tolerances	
								Verify that correct welding requirements specified in No.1 of this Table have been adopted	
								Verify processes for closing plates etc. are acceptable	
								Confirm that hull structure is in accordance with the approved plan	
4	Remedial work and alteration	Welding, check against deformation, alignment	Review records and witness	IACS Rec.47		Permanent record of shipyard surveyable items		Verify that records have been maintained of significant deviations from the approved plans, for situations such as mis-cut openings, re-routing outfit items	
								Verify that all deviations brought to the attention of the Surveyor by the shipbuilder are acceptable	
5	Tightness testing, including leak and hose testing, hydropneumatic testing	Absence of leaks	Review and witness of the test	UR S14	Reg. II-1/11 of SOLAS, as amended	Approved tank testing plan, shipbuilder's inspection records	Approved tank testing plan	Confirm that tank testing is carried out in accordance with the approved plan	
								Confirm the methods used to carry out leak testing	
								Confirm that correct test pressures maintained for leak,	

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS© requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
								hose and hydro and hydropneumatic testing is satisfactory	
								Verify that adequate records of the tank testing have been maintained	
6	Structural testing	Structural adequacy of the design	Review and witness of the test	UR S14	Reg. II-1/11 of SOLAS, as amended	Approved tank testing plan, shipbuilder's inspection records	Approved tank testing plan	Confirm that tank testing is carried out in accordance with the approved plan	
								Confirm that correct test pressure maintained for testing is satisfactory	
								Verify that adequate records of the tank testing have been maintained	
7	Corrosion protection systems, e.g. coatings, cathodic protection, impressed current except for coating system subject to PSPC	Salt water ballast tanks with boundaries formed by the hull envelope, and also bulk carrier hold internal surfaces, coamings and hatch covers are to have an efficient protective coating. The safety of cathodic systems to be dealt with separately	Review and report on builder's & manufacturer's documentation	UR Z8 & Z9 , UI SC122, UR F1	Reg. II-1/3-2 of SOLAS, as amended	Manufacturer's and builder's specifications	Corrosion protection specifications	Verify that applied coatings are approved and review records of application	
								Verify that adequate records have been maintained and copied to the ship construction file	

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS© requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
	Application of antifouling systems		Review		AFS Convention	Painting specification	Paint specification and Mfg Declaration	Verify that adequate records have been maintained and copied to the ship construction file	
7.1	Application of protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers subject to PSPC	Monitor implementation of the coating inspection requirements	Patrolling and review	UI SC223	Reg. II-1/3-2 of SOLAS, as amended	Signed and verified tripartite Agreement	Coating Technical File	Verify that applied coatings are approved and review records of application in accordance with Chapter 7 of Annex to MSC.215(82)	
8	Installation, welding and testing of the following:								
8.1	Hatch covers	Tightness and securing	Witness	UR S14 and IACS Rec. 14	Reg. 13, 14, 15 and 16 of ILLC ’66	Approved tank testing plan, shipbuilder’s inspection records	Details required, structural drawings	Confirm leak test of hatch covers	
								Confirm operation and securing test	
8.2	Doors and ramps integral with the shell and bulkheads	Tightness and securing	Witness	UR S14	Reg. II-1/18 of SOLAS as amended, Reg. 12 and 21 of ILLC ’66	Approved tank testing plan, shipbuilder’s inspection records	Details required	Confirm leak test	
								Confirm operation and securing test	
								Confirm safety device operation	
								Ensure correct maintenance logs/manuals supplied with the ship construction file	
8.3	Rudders	Fitting	Witness	UR S14		Approved plan, shipbuilder’s	Details required,	Confirm alignment and mounting and	

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS© requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
						inspection records	structural drawings	fitting up to the connection to the tiller	
								Confirm function test	
								Verify fitting of pintles and all securing bolts	
								Verify all fit-up records including all clearances maintained and placed into the ship construction file	
8.4	Forgings and castings	Compliance with approved drawings, visual examination of welding and material, check alignment and deformations	Patrol of the process and witness of the completed item	UR W7 & W8		Approved plans, shipbuilder's inspection records, shipbuilder's and recognised standards and Rules as applicable, construction plan (steelwork subdivision)	Copies of certificates of forgings and castings	Verify castings and forgings against material certificate	
								Verify that correct welding and fit-up requirements specified in Nos. 1, 2.4 and 2.5 of this Table have been adopted	
								Verify that material certificates are included in the ship construction file	
	Appendages							Verify that correct welding and fit-up requirements specified in reference 1, 2.4 and 2.5 of this Table have been adopted	
8.5	Equipment forming the watertight and weathertight integrity of the ship, e.g. overboard discharges, air	Tightness and securing	Witness		Reg. II-1/16 & 16-1 of SOLAS, as amended; Reg. 17, 18, 19, 20, 22, 23 of ILLC '66	Approved tank testing plan, shipbuilder's inspection records	Details required	Verify that correct welding and fit-up requirements specified in Nos. 1, 2.4 and 2.5 of this Table have been adopted	
								Verify compliance with Load Line	

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS© requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
	pipes, ventilators							Convention 1966 as amended - i.e. all fittings in accordance with the record of freeboard assignment	
				UR P3				Verify closing devices, e.g. air pipes, vents etc are of approved type	
								Verify material certificates for overboard discharges where applicable	
								Verify record of freeboard assignment and all material certificates included in the ship construction file	
	Freeboard marks and draft marks	Within allowable tolerances and in accordance with the freeboard assignment	Witness	UI-LL4	Reg. 4, 5, 6, 7 and 8 of ILLC'66		Details required	Verify freeboard marks in accordance with load line assignment	
								Verify draft marks in accordance with the agreed tolerances specified by the builder unless more onerous flag State requirements	
	Principal dimensions	Within allowable tolerances	Review and witness	IACS Rec. 47			Details required	Verify principal dimensions in accordance with recognised standard	
								Verify dimensions included in the ship construction file	
	Safety Construction certification	No outstanding imperfections or defects	Witness		Reg. I/7 or Reg. I/10 of SOLAS, as amended (as			Verify that Administration requirements have	

No.	Shipbuilding function	Survey requirements for classification	Survey method required for classification	IACS© requirements	Statutory requirements and relevant reference	Documentation available to Surveyor during construction	Ship construction file	Specific activities	Proposals for the project
					appropriate).			been incorporated into the hull structure	
8.6	Watertight cable transit seal systems	Compliance with approved drawings, visual examination of fitting, check alignment and securing	Patrol of the process and witness of the completed item		Reg. II-1/13 and 13-1 of SOLAS as amended	Shipbuilder's inspection records, manufacturer's specification	Cable Transit Seal Systems Register	Verify that correct welding and fit up requirements, including as specified in reference 1, 2.4 and 2.5 of this table have been adopted	
								Verify watertight cable transit seal systems are type approved	
								Verify the format and content of the Register	

Shipbuilder’s name	
Project	
Project duration	
Kick-off meeting date	
Representing builder	
CCS Surveyor	

Annex 1 Shipyard Review Record

Name of shipyard	Date

1 Details of any management systems

Obtained approval	Certified by	Expiry date	Remarks (scope, etc.)
ISO 9001			
ISO 14001			
ISO 45001			
Other:			

2 Construction facilities: (Documents such as a brochure of shipyard can be attached in lieu of completing this section)

2.1 Building berth (B) or dock (D) * In case of berth, depth is not applicable.

B/D	Name	Length (m)	Width (m)	Depth*(m)	Building capacity (Gross tonnage)	Crane (ton × no.)

2.2 Outfitting quays

Name	Length (m)	Width (m)	Depth (m)	Berthing capacity (Gross tonnage)	Crane (ton × no.)

2.3 Main fabrication and erection facilities

(1) Marking and cutting of steel plates (including internal members) – Marking method (Manual, Photo × __, EPM × __, NC × __others _____) – NC cutting machine (Gas × __, Plasma × __, Laser × __) Control procedure of NC (On-line, other) – Cutting equipment (Edge planer × __, Roll-shear × __)
(2) Marking and cutting of section bar – Marking method (Manual, NC) – Marking of reference curved line (Manual, NC) – Cutting method (Manual, NC) – In case of NC (Gas × __, Plasma × __)
(3) One-side automatic welding machine (Yes, No) – Type of welding machine (Flux Backing × __, Flux and Copper Backing × __other _____) – Existence of special surface plate for plate welding (Yes, No)
(4) Fillet welding machine (Gravity, Automatic) Percentage of automatization except gravity: about __% – Line welder (No, Yes: submerged arc × __heads, CO_2 × __heads) – Small automatic fillet welding machine (No, Yes: Name: _____ × __) – Welding robot (No, Yes: Portal × __, Rectangular × __, Articulated × __)
(5) Painting equipment – Plate shot blasting/primer coating machine (No, Yes: Max. Width __ m, Length __ m) – Section bar shot blasting/primer coating machine (No, Yes: Max. Length __ m) – Special coating factory (No, Yes: __m × __ m × __ sections)
(6) Vertical automatic welding machine (No, Yes: EG × __, SEG × __, ES × __) EG: Electrogas SEG: Simplified Electrogas ES: Electroslag
(7) Other main fabrication facilities

3 Shipyard control of qualified welders

(1) Normal steel

		Certification	Traceability	Supervision	Maintenance of qualification
Shipyard workers	Confirm system in place	Yes/No	Yes/No	Yes/No	Yes/No
Subcontracted workers	Confirm system in place	Yes/No	Yes/No	Yes/No	Yes/No

4 Feature of construction procedure

(1) Subcontract of hull blocks (weight) – Sub members (No, Yes: Ratio of subcontracted works __ %, No., of subcontractors __) – Blocks (No, Yes: Ratio of subcontracted works __ %, No., of subcontractors __)
(2) Method of plate block assembly – Method fitting and welding longitudinals and transverse webs on jointed panels – Method welding longitudinals on jointed panels prior to fitting and welding transverse webs – Method fitting and welding a frame consists of longitudinals and transverse webs on jointed panels – Method jointing panels with pre-assembled longitudinals by welding prior to fitting and welding transverse webs – Other (please specify in (5) below)
(3) Pre-erection outfitting carried out Grand block/mega block adopted Method of erection at building berth/dock – Max. weight of loading block: tons – Construction method in building dock/berth/land construction etc. (1 ship, 1.5 ships: Semi-tandem, dual entrance) – Block loading process (single starting block, multi starting blocks, inserting block : No, Yes)
(4) Final dock (No, Yes: In-house, Other place of the same company, Use other company)
(5) Other feature of construction procedure

5 Quality control system (refer to Quality Manual, if available):

Item and description	Result	Remark
(1) Existence of the organization chart including the departments of design, purchasing, manufacturing and quality assurance – Are the function, responsibility and competence of the organization clear?		
(2) Quality control organization – Existence of quality control organization – Number of employees in this organization – Existence of procedures or plans related to tests and inspections	__ persons, including the chief	
(3) Pre-inspection system of shipyard – Is pre-inspection carried out prior to class inspection? – Are pre-inspectors assigned? (check the list.) – Number of pre-inspectors (related to hull only) – Are inspection results marked on the object and/or recorded in the checklist?	__ persons	
(4) Records of inspections and tests – Are records made and kept properly? – Does the responsible person verify the records? – Can the adoption of necessary corrective actions against nonconformity happened be checked?		
(5) Condition at the time of the surveys in the presence of class surveyors – Is the schedule of the surveys changed often? – Are pre-inspection, shipyard inspection and repairs completed beforehand? – Are the sufficient preparations for surveys such as scaffoldings, lighting, cleaning made?		
Note: Above-mentioned (3) and (4) include the acceptance inspection of subcontracted items.		

6 Measures for safety and health

Item and description	Result	Remark
(1) Are conditions of scaffolding, nets, safety belt, lighting and ventilation good?		
(2) Does sufficient attention paid for radiographic examination and operation of cherry picker?		
Note:		

7 Control system of non-destructive examination (NDE)

Item and description	Result	Remark
(1) Number of NDE supervisors in shipyard (including persons responsible for judging results)	_____ persons	
(2) Dependence on subcontracted NDE work – Number of shipyard employees – Number of sub-contractors	 _____ persons _____ persons	
(3) NDE sub-contractor company's name and official technical qualifications	Name _____ (approved by) _____ Name _____ (approved by) _____	
(4) Grade and number of NDE employees with official technical qualifications in shipyard Specialized in radiography Specialized in ultrasonic Specialized in surface detection	 __ Grade __ persons __ Grade __ persons __ Grade __ persons	
(5) If non-destructive examinations are subcontracted, the grade and number of officially qualified persons Specialized in radiography Specialized in ultrasonic Specialized in surface detection	 __ Grade __ persons __ Grade __ persons __ Grade __ persons	
(6) Non-destructive examination equipment (in-house) – Number of radiographic equipment – Number of ultrasonic equipment	 _____ _____	
Note: Even if all works are subcontracted, it is recommendable to attach the qualified person(s) who can verify the works.		

8 Quality control on production line

Item and description	Result	Remark
8.1 Preventive measures for misuse of materials		
(1) Job title of supervisor and person in charge of collating ordered steel and received steel, and checking of mill sheet	Title of supervisor: _____ Title of person in charge: _____	
(2) Are means for checking the material grade in hand prescribed for high-grade steels?		
(3) Are regulations prescribed for checking the material grade for high-tensile steel and steel for low-temperature applications? Are there regulations for inscribing high tensile steel on the surface of the high tensile steel and special indication for steel for low temperature applications?		
(4) Are procedures for re-using of remaining cut-off mild steel?		
(5) Are there procedures for re-using of remaining cut-off high-tensile steel?		
(6) In the case of (4) and (5) above, can a collation be made with the mill sheet?		
(7) Section of controlling the lists of remaining cut-off steel	Name of section: _____	
Notes: – In the case of high tensile steel, are means identifying different grades? – In the case of (3) and (4) above, are the materials approved by other classes controlled similarly?		
8.2 Shot blasting/Primer coating		
(1) Existence of surface preparation standards		
(2) Existence of coating thickness control standards – Existence of thickness measurement records		
Note: The standard is to include the description related traceability after shot blasting and primer coating.		
8.3 Marking and cutting (Assembly work)		
(1) Existence of standards for accuracy and periodical inspection of tape measures, tapes, stencils, etc.		
(2) Existence of standards for accuracy of cut dimensions and edge preparation		
(3) Existence of standards for finish of cutting face		
(4) What is the frequency and extent of maintenance and inspection carried out for ensuring accuracy of NC cutter and/or flame planer?		

Item and description	Result	Remark
(5) In case of NC, are the disks, tapes etc., maintained in good condition?		
(6) What are the measures adopted and guidance given to make the worker fully conversant with cutting work standards for maintaining accuracy?		
Note: – In the case of (2) and (3) above, check items are to include confirmation of edge preparations free from piercing hole. – NC for section bars is also to be in accordance with the above.		
8.4 Bending and strain free		
(1) Existence of standards for maximum heating temperatures during water cooling and at the time of bending and distortion removal of steel by quick heating and cooling		
(2) Existence of regulations for plate thickness and bending radius for flange processing		
(3) What are the measures adopted and guidance given to make the worker fully conversant with maintaining quality and accuracy during the bending process?		
Note:		
8.5 Control of welding procedure		
(1) Are all welding procedures applied to the ships approved by the classification society or other IACS members?		
Note:		
8.6 Treatment of serious nonconformities		
(1) Are repair plans submitted to the classification society when serious nonconformities happened?		
(2) Were the NDE (RT/UT) plans submitted at appropriate timing?		
(3) Was the extent of tests extended considering the results of the test?		
Note:		
8.7 Hydrostatic and watertight tests		
(1) Is the test plan submitted to the classification society?		
(2) Are vacuum tests applied to?		
(3) Are local air injection tests during sub-assembly works applied to?		
(4) If (2) or (3) above is applied to, are the test procedures approved by the classification society?		
Note:		

Annex 2 Requirements for Tankers and Bulk Carriers subject to SOLAS Reg. II-1/3-10 (Goal-based ship construction standards for bulk carriers and oil tankers)

1. Examination and test plan for newbuilding activities

1.1 The shipbuilder is to provide plans of the items which are intended to be examined and tested in accordance with CCS Rules in a document known as the Survey Plan, taking into account the ship type and design. This Survey Plan shall be reviewed at the time of the kick off meeting, and must include:

1.1.1 a set of requirements, including specifying the extent and scope of the construction survey(s) and identifying areas that need special attention during the survey(s), to ensure compliance of construction with mandatory ship construction standards including:

(1) types of surveys (visual, non-destructive examination, etc.) depending on location, materials, welding, casting, coatings, etc.;

(2) establishment of a construction survey schedule for all assembly stages from the kick-off meeting, through all major construction phases, up to delivery;

(3) inspection/survey plan, including provisions for critical areas identified during design approval;

(4) inspection criteria for acceptance;

(5) Interaction with shipyard, including notification and documentation of survey results;

(6) correction procedures to remedy construction defects;

(7) list of items that would require scheduling or formal surveys;

(8) determination and documentation of areas that need special attention throughout ship's life, including criteria used in making the determination;

1.1.2 a description of the requirements for all types of testing during survey, including test criteria.

2. Design Transparency

2.1 For ships subject to compliance with IMO Res. MSC.287(87), IMO Res. MSC.290(87), IMO Res. MSC.454(100) and IMO MSC.1/Circ.1343, readily available documentation is to include the main goal-based parameters and all relevant design parameters that may limit the operation of the ship.

3. Ship Construction File (SCF)

3.1 A Ship Construction File (SCF) with specific information on how the functional requirements of the Goal-based Ship Construction Standards for Bulk Carriers and Oil Tankers have been applied in the ship design and construction is to be provided upon delivery of a new ship, and kept on board the ship and/or ashore and updated as appropriate throughout the ship's service. The contents of the Ship Construction File are to conform to the requirements below.

3.1.1 The following design specific information is to be included in the Ship Construction File (SCF):

(1) areas requiring special attention throughout the ship's life, including critical structural areas;

(2) all design parameters limiting the operation of a ship;

(3) any alternatives to the rules, including structural details and equivalency calculations;

(4) "As built" drawings and information which are verified to incorporate all alterations approved by CCS or flag State during the construction process including scantling details, material details, location of butts and seams, cross section details and locations of all partial and full penetration welds;

(5) net (renewal) scantlings for all the structural constituent parts, as built scantlings and voluntary addition thicknesses;

(6) minimum hull girder section modulus along the length of the ship which has to be maintained throughout the ship's life, including cross section details such as the value of the area of the deck zone and bottom zone, the renewal value for the neutral axis zone;

(7) a listing of materials used for the construction of the hull structure, and provisions for documenting changes to any of the above during the ship's service life;

(8) copies of certificates of forgings and castings welded into the hull (UR W7 and UR W8);

(9) details of equipment forming part of the watertight and weather tight integrity of the ship;

① A Cable Transit Seal Systems Register, to be prepared by the shipbuilder for watertight cable transits. The Register can be in either a hard copy or digitized media. For an example of a register see "Annex 3 of this Appendix - Recommendatory Sample - Cable Transit Seal Systems Register". It is to include a marking / identification system, documentation referencing manufacturer manual(s) for each type of cable transit installed, the Type Approval certification for each type of transit system, applicable installation drawings, and a recording of each installed transit documenting the as built condition after final inspection in the shipyard. This is to include sections to record any inspection, modification, repair and maintenance.

(10) tank testing plan including details of the test requirements (UR S14);

(11) details for the in-water survey, when applicable, information for divers, clearances measurements instructions etc., tank and compartment boundaries;
(12) docking plan and details of all penetrations normally examined at drydocking;
(13) Coating Technical File, for ships subject to compliance with the IMO Performance Standard for Protective Coatings (PSPC).

3.1.2 Refer to Table A of this Annex for details of information to be further included. This information has to be kept on board the ship and/or ashore and updated as appropriate throughout the ship's life in order to facilitate safe operation, maintenance, survey, repair and emergency measures.

3.1.3 It is to be noted that parts of the content of the SCF may be subject to various degrees of restricted access and that such documentation may be appropriately kept ashore.

3.1.4 The SCF has to include the list of documents constituting the SCF and all information listed in Table A of this Annex, which is required for a ship's safe operation, maintenance, survey, repair and in emergency situations. Details of specific information that is not considered to be critical to safety might be included directly or by reference to other documents.

3.1.5 When developing an SCF, all of the columns in Table A of this Annex have to be reviewed to ensure that all necessary information has been provided.

3.1.6 It may be possible to provide information listed in the annex under more than one Tier II① functional requirement as a single item within the SCF, for example, the Coating Technical File required by the PSPC②is relevant for both "Coating life" and "Survey during construction".

3.1.7 The SCF has to remain with the ship and, in addition, be available to CCS and flag State throughout the ship's life. Where information not considered necessary to be on board is stored ashore, procedures to access this information should be specified in the onboard SCF. The intellectual property provisions within the SCF should be duly complied with.

3.1.8 The SCF should be updated throughout the ship's life at any major event, including, but not limited to, substantial repair and conversion, or any modification to the ship structure.

3.2 The SCF is to be reviewed③, at the time of new building, in accordance with the requirements of paragraphs 3.1.1 and 3.1.2 and the normal storage location is to be distinguished.

3.2.1 For the SCF stored on board ship, the surveyor is to verify that the information is placed on board the ship, upon completion of ship construction.

3.2.2 For the SCF stored on shore archive, the surveyor is to verify that the information is stored on shore archive by examining the list of information included on shore archive, upon completion of ship construction.

4. Determination of number of Surveyor(s)

CCS will assign adequate number of suitable qualified surveyor(s) for new building projects according to the construction progress of each ship to meet appropriate coverage of the examination and testing activities as agreed in the Survey Plan.

List of Information to be Included in the Ship Construction File (SCF) **Table A**

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location
DESIGN					
1	Design life	• assumed design life in years	• statement or note on midship section	• SCF-specific	on board ship
				• midship section plan	on board ship

① Tier II items means the functional requirements included in the International Goal-based Ship Construction Standards for Bulk Carriers and Oil Tankers (GBS), adopted by IMO Res. MSC 287(87).

② Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers, adopted by IMO Res. MSC 215(82), as amended and Performance standard for protective coatings for cargo oil tanks of crude oil tankers, adopted by IMO Res. MSC 288(87), as amended.

③ "Review" means the examination of the SCF that is carried out by the surveyor, at the end of the newbuilding process, in order to confirm that drawings and documents required under the paragraph 3 of the annex, plus the possible additional drawings/documents provided by the shipyard, as per the Ship Constructional File (SCF) list of drawings/documents are present in the copies of the SCF stored on board and in the ashore archive.
The "review" is not to be intended as an assessment of the drawings/documents in order to verify their compliances with the applicable Rules/Regulations.

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location
2	Environmental conditions	• assumed environmental conditions	• statement referencing data source or Rule (specific rule and data) or; • in accordance with Rule (date and revision)	• SCF-specific	on board ship
3	Structural strength				
3.1	General design	• applied Rule (date and revision)	• applied design method alternative to Rule and subject structure(s)	• SCF-specific	on board ship
		• applied alternative to Rule		• capacity plan	on board ship
3.2	Deformation and failure modes	• calculating conditions and results;	• allowable loading pattern	• loading manual	on board ship
		• assumed loading conditions	• maximum allowable hull girder bending moment and shear force	• trim and stability booklet	on board ship
3.3	Ultimate strength	• operational restrictions due to structural strength	• maximum allowable cargo density or storage factor	• loading instrument instruction manual	on board ship
				• operation and maintenance manuals	on board ship
3.4	Safety margins	• strength calculation results	• bulky output of strength calculation	• strength calculation	on shore archive
			• plan showing highly stressed areas (e.g. critical structural areas) prone to yielding and/or buckling	• areas prone to yielding and/or buckling	on board ship
		• gross hull girder section modulus			
		• minimum hull girder section modulus along the length of the ship to be maintained throughout the ship's life, including cross section details such as the value of the area of the deck zone and bottom zone, the renewal value for the neutral axis zone		• general arrangement plan	on board ship
		• gross scantlings of structural constituent parts	• structural drawing	• key construction plans	on board ship
		• net scantlings of structural constituent parts, as built scantlings and voluntary addition thicknesses	• rudder and stern frame		
			• structural details of typical members	• rudder and rudder stock plans	on board ship
				• structural details	on board ship
				• yard plans	on shore archive
				• dangerous area plan	on board ship

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location
		• hull form			
			• hull form information indicated in key construction plans	• lines plan	on shore archive
			• hull form data stored within an onboard computer necessary for trim and stability and longitudinal strength calculations	or	
				Equivalent	on board ship
4	Fatigue life	• applied Rule (date and revision)	• applied design method alternative to Rule and subject structures	• SCF-specific	on board ship
		• applied alternative to Rule			
		• calculating conditions and results;	• assumed loading conditions and rates	• structural details	on board ship
		• assumed loading conditions			
		• fatigue life calculation results	• bulky output of fatigue life calculation	• fatigue life calculation	on shore archive
			• plan showing areas (e.g. critical structural areas) prone to fatigue	• areas prone to fatigue	on board ship
5	Residual strength	• applied Rule (date and revision)		• SCF-specific	on board ship
6	Protection against corrosion				
6.1	Coating life	• coated areas and target coating life and other measures for corrosion protection in holds, cargo and ballast tanks, other structure-integrated deep tanks and void spaces	• plans showing areas (e.g. critical structural areas) prone to excessive corrosion	• SCF-specific	on board ship
6.2	Corrosion addition			• Coating Technical File required by PSPC (Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers, adopted by IMO resolution MSC.215(82), as amended and Performance standard for protective coatings for cargo oil tanks of crude oil tankers, adopted by IMO Resolution MSC.288(87), as amended)	on board ship
		• specification for coating and other measures for corrosion protection in holds, cargo and ballast tanks, other structure-integrated deep tanks and void spaces		• areas prone to excessive corrosion	on board ship
		• gross scantlings of structural constituent parts		• key construction plans	on board ship
		• net scantlings of structural constituent			

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location
		parts, as built scantlings and voluntary addition thicknesses			
7	Structural redundancy	• applied Rule (date and revision)		• SCF-specific	on board ship
8	Watertight and weathertight integrity	• applied Rule (date and revision)		• SCF-specific	on board ship
		• key factors for watertight and weathertight integrity	• details of equipment forming part of the watertight and weathertight integrity	• structural details of hatch covers, doors and other closings integral with the shell and bulkheads	on board ship
9	Human element considerations	• list of ergonomic design principles applied to ship structure design to enhance safety during operations, inspections and maintenance of ship		• SCF-specific	on board ship
10	Design transparency	• applied Rule (date and revision) • applicable industry standards for design transparency and IP protection		• intellectual property provisions	on board ship
		• reference to part of SCF information kept ashore		• summary, location and access procedure for part of SCF information on shore	on board ship
CONSTRUCTION					
11	Construction quality procedures	• applied construction quality standard	• recognized national or international construction quality standard	• SCF-specific	on board ship
12	Survey during construction	• survey regime applied during construction (to include all owner and class scheduled inspections during construction)	• applied Rules (date and revision) • copies of certificates of forgings and castings welded into the hull	• SCF-specific • tank testing plan	on board ship on board ship
		• information on non-destructive examination		• non-destructive testing plan	on board ship
				• Coating Technical File required by PSPC	on board ship
IN-SERVICE CONSIDERATIONS					
13	Survey and maintenance	• maintenance plans specific to the structure of the ship where higher attention is called for	• plan showing highly stressed areas (e.g. critical structural areas) prone to yielding, buckling, fatigue and/or excessive corrosion	• SCF-specific • operation and maintenance manuals (e.g. hatch covers and doors)	on board ship on board ship
		• preparations for survey	• arrangement and details of all penetrations normally examined at dry-docking	• docking plan	on board ship
		• gross hull girder section modulus	• detailed information for dry-docking	• dangerous area plan	on board ship

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location
		• minimum hull girder section modulus along the length of the ship to be maintained throughout the ship's life, including cross section details such as the value of the area of the deck zone and bottom zone, the renewal value for the neutral axis zone	• details for in-water survey	• Ship Structure Access Manual	on board ship
				• Means of access to other structure-integrated deep tanks	on board ship
				• Coating Technical File required by PSPC	on board ship
		• gross scantlings of structural constituent parts		• key construction plans	on board ship
		• net scantlings of structural constituent parts, as built scantlings and voluntary addition thicknesses		• rudder and rudder stock	on board ship
				• structural details	on board ship
				• yard plans	on shore archive
			• hull form information indicated in key construction plans	• lines plan	on shore archive
		• hull form		or equivalent	on board ship
14	Structural accessibility	• means of access to holds, cargo and ballast tanks and other structure-integrated deep tanks	• plans showing arrangement and details of means of access	• Ship Structure Access Manual	on board ship
				• means of access to other structure-integrated deep tanks	on board ship
RECYCLING CONSIDERATIONS					
15	Recycling	• identification of all materials that were used in construction and may need special handling due to environmental and safety concerns	• list of materials used for the construction of the hull structure	• SCF-specific	on board ship

Notes:
1. "SCF-specific" means documents to be developed especially to meet the requirements of these GBS guidelines (MSC.1/Circ.1343).
2. "Key construction plans" means plans such as midship section, main O.T. and W.T. transverse bulkheads, construction profiles/plans, shell expansions, forward and aft sections in cargo tank (or hold) region, engine-room construction, forward construction and stern construction drawings.
3. "Yard plans" means a full set of structural drawings, which include scantling information of all structural members.
4. "Hull form" means a graphical or numerical representation of the geometry of the hull. Examples would include the graphical description provided by a lines plan and the numerical description provided by the hull form data stored within an onboard computer.

5. “Lines plan” means a special drawing which is dedicated to show the entire hull form of a ship.
6. “Equivalent (to Lines plan)” means a set of information of hull form to be indicated in key construction plans for SCF purposes. Sufficient information should be included in the drawings to provide the geometric definition to facilitate the repair of any part of the hull structure.
7. “Normal storage location” means a standard location where each SCF information item should be stored. However, those items listed as being on board in the table above should be on board as a minimum to ensure that they are transferred with the ship on a change of owner.
8. “Shore archive” is to be operated in accordance with applicable international standards.

Annex 3 Recommendatory Sample - Cable Transit Seal System Register

Name of Ship:	
IMO No.:	
Place:	
Date:	
Inspected by:	

Transits

Total Openings

TRANSIT			Inspected side		BRAND	FRAME		Type Approved	CONDITION(G,F, P)	INSPECTED	REPAIRED	MODIFIED	MAINTAINED	NOTES	Checked by	DATE
Drawing number	ID	Location	F	B		Type	Opening number									

Appendix 2 SHIPBUILDING AND REPAIR QUALITY STANDARD

1 Shipbuilding and Remedial Quality Standards for New Construction

1.1 Scope

It is intended that these standards provide guidance where established and recognized shipbuilding or national standards accepted by CCS do not exist.

1.1.1 This standard provides guidance on shipbuilding quality standards for the hull structure during new construction and the remedial standard where the quality standard is not met. The applicability of the standard is in each case to be agreed upon by CCS.

1.1.1.1 Whereas the standard generally applies to:

(1) conventional merchant ship types;

(2) parts of hull covered by CCS rules;

(3) hull structures constructed from normal and higher strength hull structural steel.

1.1.1.2 The standard does generally not apply to the new construction of:

(1) special types of ships as e.g. gas tankers;

(2) structures fabricated from stainless steel or other, special types or grades of steel.

1.1.2 In this standard, both a “Standard” range and a “Limit” range are listed. The “Standard” range represents the target range expected to be met in regular work under normal circumstances. The “Limit” range represents the maximum allowable deviation from the “Standard” range. Work beyond the “Standard” range but within the “Limit” range is acceptable. In cases where no ‘limit’ value is specified, the value beyond the ‘standard’ range may be accepted subject to the consideration of CCS.

1.1.3 The standard covers typical construction methods and gives guidance on quality standards for the most important aspects of such construction. Unless explicitly stated elsewhere in the standard, the level of workmanship reflected herein will in principle be acceptable for primary and secondary structure of conventional designs. A more stringent standard may however be required for critical and highly stressed areas of the hull, and this is to be agreed with CCS in each case. In assessing the criticality of hull structure and structural components, reference is made to References l.1, 1.2, 1.3, 1.11, 1.13,1.14, 1.15, 1.16, 1.19 and 1.21 to this Section.

1.1.4 Details relevant to structures or fabrication procedures not covered by this standard are to be approved by CCS on the basis of procedure qualifications and/or recognized national standards.

1.1.5 For use of this standard, fabrication fit-ups, deflections and similar quality attributes are intended to be uniformly distributed about the nominal values. The shipyard is to take corrective action to improve work processes that produce measurements where a skew distribution is evident. Relying upon remedial steps that truncate a skewed distribution of the quality attribute is unacceptable.

1.2 General requirements for new construction

1.2.1 In general, the work is to be carried out in accordance with CCS rules and under the supervision of the CCS Surveyor.

1.2.2 Welding operations are to be carried out in accordance with work instructions accepted by CCS.

1.2.3 Welding of hull structures is to be carried out by qualified welders, according to approved and qualified welding procedures and with welding consumables approved by CCS, see Section 1.3. Welding operations are to be carried out under proper supervision by the shipbuilder. The working conditions for welding are to be monitored by CCS in accordance with URZ23 (Reference 1.12 to this Section).

1.3 Qualification of personnel and procedures

1.3.1 Qualification of welders

1.3.1.1 Welders are to be qualified in accordance with UR W32 (Reference 1.18) or other recognized standard accepted by CCS. Recognition of other standards is subject to submission to CCS for evaluation. Subcontractors are to keep records of welders qualification and, when required, furnish valid approval test certificates.

1.3.1.2 Welding operators using fully mechanized or fully automatic processes need generally not pass approval testing provided that the production welds made by the operators are of the required quality. However, operators are to receive adequate training in setting or programming and operating the equipment. Records of training and operation experience shall be maintained on individual operator’s files and records, and be made available to CCS for inspection when requested.

1.3.2 Qualification of welding procedures

1.3.2.1 Welding procedures are to be qualified in accordance with URW28 (Reference 1.10 to this Section) or other recognized standard accepted by CCS.

1.3.3 Qualification of NDT operators

1.3.3.1 Personnel performing non-destructive testing for the purpose of assessing quality of welds in connection with new construction covered by this standard, are to be qualified in accordance with CCS rules or to a recognized international or national qualification scheme. Records of operators and their current certificates are to be kept and made available to the Surveyor for inspection.

In case of non-destructive examination carried out by an independent firm from the shipbuilder, such firm has to comply with UR W35 (Reference 1.20).

1.4 Materials

1.4.1 Materials for Structural Members

1.4.1.1 All materials, including weld consumables, to be used for the structural members are to be approved by CCS as per the approved construction drawings and meet the respective IACS Unified Requirements (References l.4, 1.5, 1.6, 1.7, 1.8, 1.9 and 1.17 to this Section). Additional recommendations are contained in the following paragraphs.

1.4.1.2 All materials used should be manufactured at a works approved by CCS for the type and grade supplied.

1.4.2 Surface Conditions

1.4.2.1 Definitions

(1) Minor Imperfections: Pitting, rolled-in scale, indentations, roll marks, scratches and grooves.

(2) Defects: Cracks, shells, sand patches, sharp edged seams and minor imperfections exceeding the limits of Table 1.

(3) Depth of Imperfections or defects: The depth is to be measured from the surface of the product.

1.4.2.2 Acceptance without remedies

(1) Minor imperfections, in accordance with the nominal thickness (t) of the product and the limits described in Table 1, are permissible and may be left as they are.

Limits for depth of minor imperfection, for acceptance without remedies Table 1

Imperfection surface area Ratio (%)	15 ~ 20%	5 ~ 15%	0 ~ 5%
$t < 20$ mm	0.2 mm	0.4 mm	0.5 mm
20 mm $\le t <$ 50 mm	0.2 mm	0.6 mm	0.7 mm
50 mm $\le t$	0.2 mm	0.7 mm	0.9 mm

(2) Imperfection surface area Ratio (%) is obtained as influenced area / area under consideration (i.e. plate surface area) × 100%.

(3) For isolated surface discontinuities, influenced area is obtained by drawing a continuous line which follows the circumference of the discontinuity at a distance of 20 mm (Figure 1).

(4) For surface discontinuities appearing in a cluster, influenced area is obtained by drawing a continuous line which follows the circumference of the cluster at a distance of 20 mm (Figure 2).

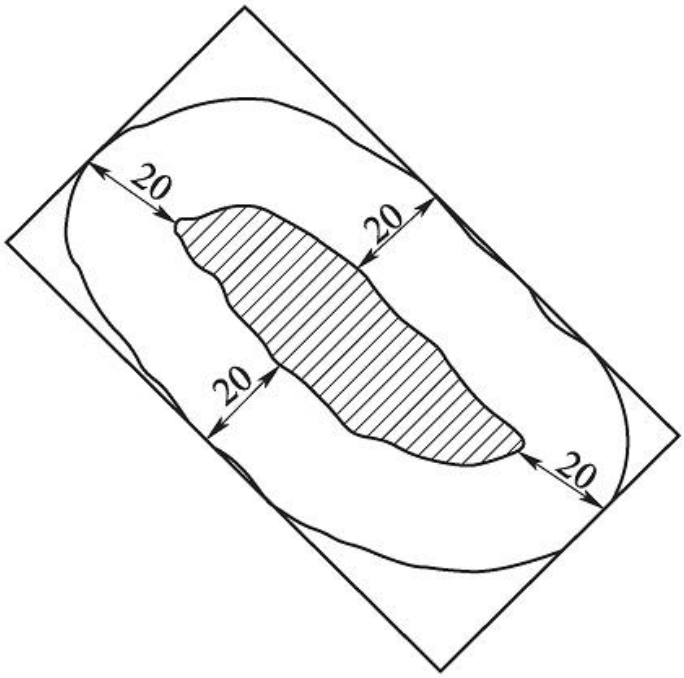


Figure 1 - Determination of the area influenced by an isolated discontinuity (EN 10163-1:2004)

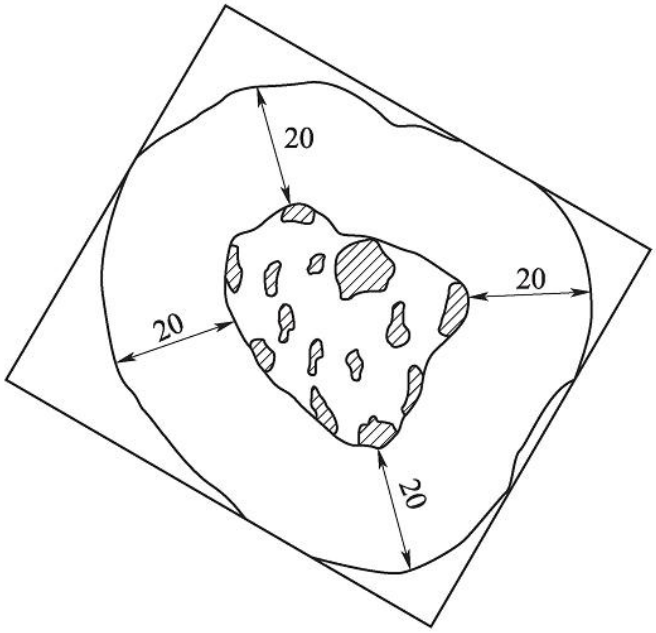


Figure 2 - Determination of the area influenced by clustered discontinuities (EN 10163-1:2004)

1.4.2.3 Remedial of Defects

(1) Defects are to be remedied by grinding and/or welding in accordance with IACS UR W11 (Reference 1.6 to this Section).

1.4.2.4 Further Defects

(1) Lamination

① Investigation to be carried out at the steelmill into the cause and extent of the detected laminations. Severe lamination is to be remedied by local insert plates. The minimum breadth or length of the plate to be replaced is to be:
(a) 1600 mm for shell and strength deck plating in way of cruciform or T-joints;
(b) 800 mm for shell, strength deck plating and other primary members;
(c) 300 mm for other structural members.

② Local limited lamination may be remedied by chipping and/or grinding followed by welding in

accordance with sketch a). In case where the local limited lamination is near the plate surface, the remedial may be carried out as shown in sketch b). For limitations see paragraph 1.4.2.2.

a) b)

(2) Weld Spatters

Loose weld spatters are to be removed by grinding or other measures to clean metal surface (see Table 1.9.13), as required by the paint system, on:

① shell plating;
② deck plating on exposed decks;
③ in tanks for chemical cargoes;
④ in tanks for fresh water and for drinking water;
⑤ in tanks for lubricating oil, hydraulic oil, including service tanks.

1.5 Gas Cutting

The roughness of the cut edges is to meet the following requirements:

1.5.1 Free Edges:

	Standard	**Limit**
Strength Members	150 μm	300 μm
Others	500 μm	1000 μm

1.5.2 Welding Edges:

	Standard	**Limit**
Strength Members	400 μm	800 μm
Others	800 μm	1500 μm

1.6 Fabrication and fairness

1.6.1 Flanged longitudinals and flanged brackets (see Table 1.6.1);
1.6.2 Built-up sections (see Table 1.6.2);
1.6.3 Corrugated bulkheads (see Table 1.6.3);
1.6.4 Pillars, brackets and stiffeners (see Table 1.6.4);
1.6.5 Maximum heating temperature on surface for line heating (see Table 1.6.5);
1.6.6 Block assembly (see Table 1.6.6);
1.6.7 Special sub-assembly (see Table 1.6.7);
1.6.8 Shape (see Table 1.6.8 and 1.6.9);
1.6.9 Fairness of plating between frames (see Table 1.6.10);
1.6.10 Fairness of plating with frames (see Table 1.6.11);
1.6.11 Preheating for welding hull steels at low temperature (see Table 1.6.12).

1.7 Alignment

1.7.1 The quality standards for alignment of hull structural components during new construction are shown in Tables 1.7.1, 1.7.2 and 1.7.3. CCS may require a closer construction tolerance in areas requiring special attention, as follows:
(1) Regions exposed to high stress concentrations;
(2) Fatigue prone areas;
(3) Detail design block erection joints;
(4) High tensile steel regions.

1.8 Welding Joint Details

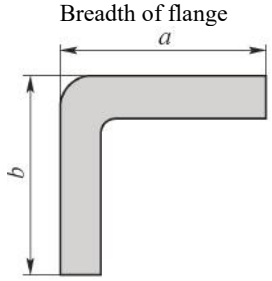
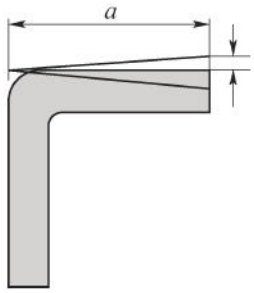
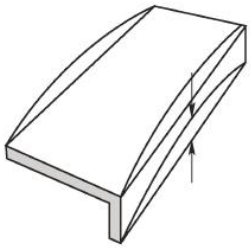
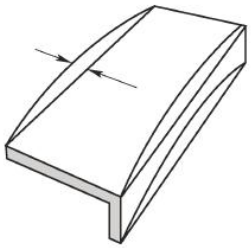
Edge preparation is to be qualified in accordance with URW28 (Reference 1.10 to this Section) or other recognized standard accepted by CCS.
Some typical edge preparations are shown in Tables 1.8.1, 1.8.2, 1.8.3, 1.8.4 and 1.8.6 for reference.
1.8.1 Typical butt weld plate edge preparation (manual and semi-automatic welding) for reference − see Tables 1.8.1 and 1.8.2.
1.8.2 Typical fillet weld plate edge preparation (manual and semi-automatic welding) for reference − see

Tables 1.8.3 and 1.8.4.
1.8.3 Butt and fillet weld profile (manual and semi-automatic welding) − see Table 1.8.5.
1.8.4 Typical butt weld plate edge preparation (Automatic welding) for reference − see Table 1.8.6.
1.8.5 Distance between welds − see Table 1.8.7.

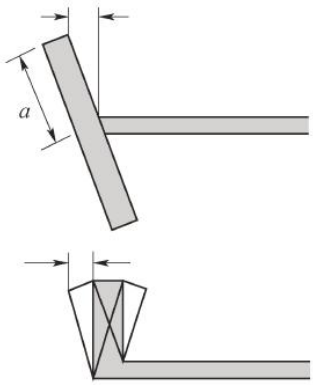
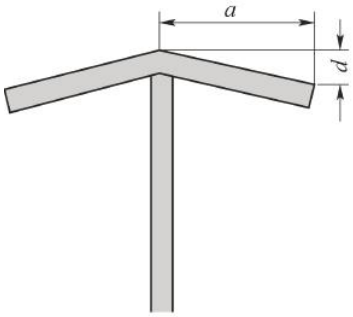
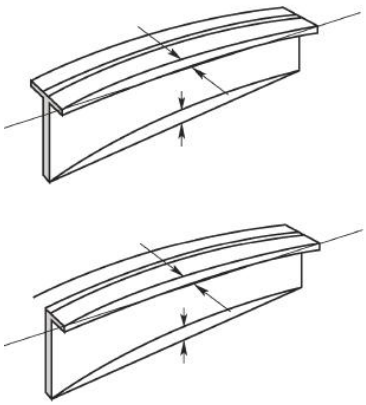
1.9 Remedial

All the major remedial work is subject to reporting by shipbuilder to CCS for approval in accordance with their work instruction for new building.
Some typical remedial works are shown in Tables 1.9.1 to 1.9.13.
1.9.1 Typical misalignment remedial − see Tables 1.9.1 to 1.9.3.
1.9.2 Typical butt weld plate edge preparation remedial (manual and semi-automatic welding) − see Tables 1.9.4 and 1.9.5.
1.9.3 Typical fillet weld plate edge preparation remedial (manual and semi-automatic welding) − see Tables 1.9.6 to 1.9.8.
1.9.4 Typical fillet and butt weld profile remedial (manual and semi-automatic welding) − see Table 1.9.9.
1.9.5 Distance between welds remedial - see Table 1.9.10.
1.9.6 Erroneous hole remedial − see Table 1.9.11.
1.9.7 Remedial by insert plate − see Table 1.9.12.
1.9.8 Weld surface remedial − see Table 1.9.13.
1.9.9 Weld remedial (short bead) − see Table 1.9.14.

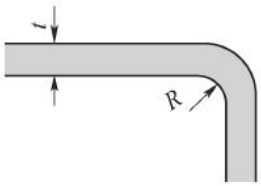
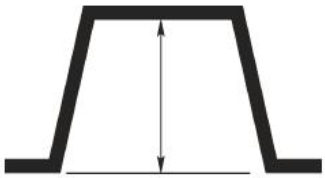
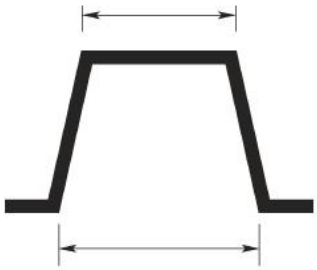
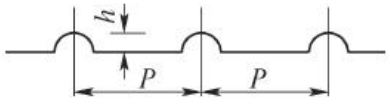
Flanged Longitudinals and Flanged Brackets **Table 1.6.1**

Detail	Standard	Limit	Remark
Breadth of flange  compared to correct size	± 3 mm	± 5 mm	
Angle between flange and web  compared to template	± 3 mm	± 5 mm	per 100 mm of *a*
Straightness in plane of flange and web  	± 10 mm	± 25 mm	per 10 m

Built Up Sections **Table 1.6.2**

Detail	Standard	Limit	Remark
Frames and longitudinal 	± 1.5 mm	± 3 mm	per 100 mm of *a*
Distortion of face plate 	$d \leq 3 + a/100$ mm	$d \leq 5 + a/100$ mm	
Distortion in plane of web and flange of built up longitudinal frame, transverse frame, girder and transverse web 	± 10 mm	± 25 mm	per 10 m in length

Corrugated Bulkheads **Table 1.6.3**

Detail	Standard	Limit	Remark
Mechanical bending 	$R \geq 3t$ mm $R \geq 4.5t$ mm for CSR ships [Note 1]	$2t$ mm [Note 2]	Material to be suitable for cold flanging (forming) and welding in way of radius
Depth of corrugation 	± 3 mm	± 6 mm	
Breadth of corrugation 	± 3 mm	± 6 mm	
Pitch and depth of swedged corrugated bulkhead compared with correct value 	h : ± 2.5 mm Where it is not aligned with other bulkheads P : ± 6 mm Where it is aligned with other bulkheads P : ± 2 mm	h : ± 5 mm Where it is not aligned with other bulkheads P : ± 9 mm Where it is aligned with other bulkheads P : ± 3 mm	

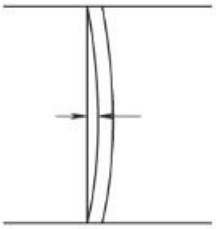
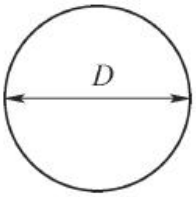
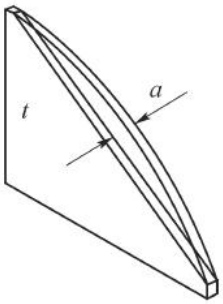
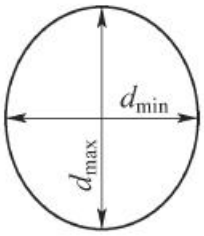
Notes:

1. For CSR Bulk Carriers built under PART TEN of the Rules (2012 version) and its 2013 and 2014 amendments, the standard is $R \geq 2t$ mm.
2. For CSR ships, the allowable inside bending radius of cold formed plating may be reduced provided the following requirements are complied with.
   When the inside bending radius is reduced below 4.5 times the as-built plate thickness, supporting data is to be provided. The bending radius is in no case to be less than 2 times the as-built plate thickness. As a minimum, the following additional requirements are to be complied with:
   a) For all bent plates:
      - 100% visual inspection of the bent area is to be carried out.
      - Random checks by magnetic particle testing are to be carried out.

   b) In addition to a), for corrugated bulkheads subject to lateral liquid pressure:
      - The steel is to be of Grade D/DH or higher.

   The material is impact tested in the strain-aged condition and satisfies the requirements stated herein. The deformation is to be equal to the maximum deformation to be applied during production, calculated by the formula $t_{as\text{-}built}/(2r_{bdg} + t_{as\text{-}built})$, where $t_{as\text{-}built}$ is the as-built thickness of the plate material and r_{bdg} is the bending radius. One sample is to be plastically strained at the calculated deformation or 5%, whichever is greater and then artificially aged at 250℃ for one hour then subject to Charpy V-notch testing. The average impact energy after strain ageing is to meet the impact requirements specified for the grade of steel used.

Pillars, Brackets and Stiffeners **Table 1.6.4**

Detail	Standard	Limit	Remark
Pillar (between decks) 	4 mm	6 mm	
Cylindrical structure diameter (pillars, masts, posts, etc.) 	± *D*/200 mm max. + 5 mm	± *D*/150 mm max. 7.5 mm	
Tripping bracket and small stiffener, distortion at the part of free edge 	$a \leq t/2$ mm	t	
Ovality of cylindrical structure 		$d_{max} - d_{min} \leq 0.02 \times d_{max}$	

Maximum Heating Temperature on Surface for Line Heating **Table 1.6.5**

Item		Standard	Limit	Remark
Conventional Process AH32-EH32 & AH36-EH36	Water cooling just after heating	Under 650℃		
	Air cooling after heating	Under 900℃		
TMCP type AH36-EH36 (C_{eq}. > 0.38%)	Air cooling and subsequent water cooling after heating	Under 900 ℃ (starting temperature of water cooling to be under 500℃)		
TMCP type AH32-DH32 & AH36-DH36 (C_{eq}. ≤ 0.38%)	Water cooling just after heating or air cooling	Under 1000℃		
TMCP type EH32 & EH36 (C_{eq}. ≤ 0.38%)	Water cooling just after heating or air cooling	Under 900℃		
Note: $C_{eq} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr}+\mathrm{Mo}+\mathrm{V}}{5} + \frac{\mathrm{Ni}+\mathrm{Cu}}{15}(\%)$				

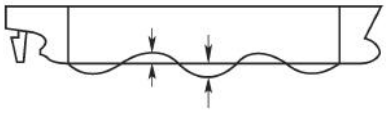
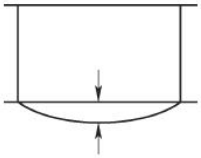
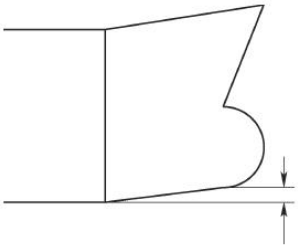
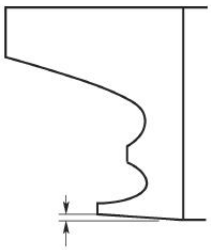
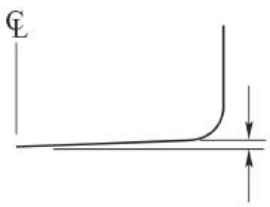
Block Assembly **Table 1.6.6**

Item	Standard	Limit	Remark
Flat Plate Assembly Length and Breadth Distortion Squareness Deviation of interior members from plate	 ± 4 mm ± 10 mm ± 5 mm 5 mm	 ± 6 mm ±20 mm ±10 mm 10 mm	
Curved plate assembly Length and Breadth Distortion Squareness Deviation of interior members from plate	 ± 4 mm ± 10 mm ± 10 mm 5 mm	 ± 8 mm ± 20 mm ± 15 mm 10 mm	measured along the girth
Flat cubic assembly Length and Breadth Distortion Squareness Deviation of interior members from plate Twist Deviation between upper and lower plate	 ± 4 mm ± 10 mm ± 5 mm 5 mm ± 10 mm ± 5 mm	 ± 6 mm ± 20 mm ± 10 mm 10 mm ± 20 mm ± 10 mm	
Curved cubic assembly Length and Breadth Distortion Squareness Deviation of interior members from plate Twist Deviation between upper and lower plate	 ± 4 mm ± 10 mm ± 10 mm ± 5 mm ± 15 mm ± 7 mm	 ± 8 mm ± 20 mm ± 15 mm ± 10 mm ± 25 mm ± 15 mm	measured along with girth

Special Sub-Assembly **Table 1.6.7**

Item	Standard	Limit	Remark
Distance between upper/lower gudgeon	± 5 mm	± 10 mm	
Distance between aft edge of boss and aft peak bulkhead	± 5 mm	± 10 mm	
Twist of sub-assembly of stern frame	5 mm	10 mm	
Deviation of rudder from shaft center line	4 mm	8 mm	
Twist of rudder plate	6 mm	10 mm	
Flatness of top plate of main engine bed	5 mm	10 mm	
Breadth and length of top plate of main engine bed	± 4 mm	± 6 mm	
Note: Dimensions and tolerances have to fulfill engine and equipment manufacturers' requirements, if any.			

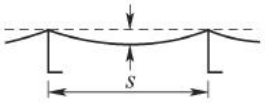
Shape **Table 1.6.8**

Detail	Standard	Limit	Remark
Deformation for the whole length 	± 50 mm		per 100 m against the line of keel sighting
Deformation for the distance between two adjacent bulkheads 	± 15 mm		
Cocking-up of fore body 	± 30 mm		The deviation is to be measured from the design line
Cocking-up of aft-body 	± 20 mm		
Rise of floor amidships 	± 15 mm		The deviation is to be measured from the design line

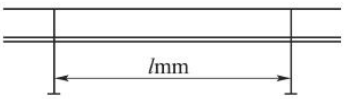
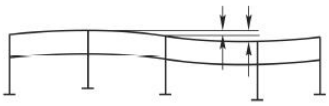
Shape **Table 1.6.9**

Item	Standard	Limit	Remark
Length between perpendiculars	±*L*/1000 mm where *L* is in mm		Applied to ships of 100 m length and above. For the convenience of the measurement the point where the keel is connected to the curve of the stem may be substituted for the fore perpendicular in the measurement of the length
Moulded breadth at midship	±*B*/1000 mm where *B* is in mm		Applied to ships of 15 m breadth and above, measured on the upper deck
Moulded depth at midship	±*D*/1000 mm where *D* is in mm		Applied to ships of 10 m depth and above, measured up to the upper deck

Fairness of Plating Between Frames **Table 1.6.10**

Item		Standard	Limit	Remark
Shell plate	Parallel part (side & bottom shell)	4 mm	8 mm	
	Fore and aft part	5 mm		
Tank top plate		4 mm		
Bulkhead	Longl. Bulkhead Trans. Bulkhead Swash Bulkhead	6 mm		
Strength deck	Parallel part	4 mm	8 mm	
	Fore and aft part Covered part	6 mm 7 mm	9 mm 9 mm	
Second deck	Bare part	6 mm	8 mm	
	Covered part	7 mm	9 mm	
Forecastle deck poop deck	Bare part	4 mm	8 mm	
	Covered part	6 mm	9 mm	
Super structure deck	Bare part	4 mm	6 mm	
	Covered part	7 mm	9 mm	
House wall	Outside wall	4 mm	6 mm	
	Inside wall	6 mm	8 mm	
	Covered part	7 mm	9 mm	
Interior member (web of girder, etc.)		5 mm	7 mm	
Floor and girder in double bottom		5 mm	8 mm	

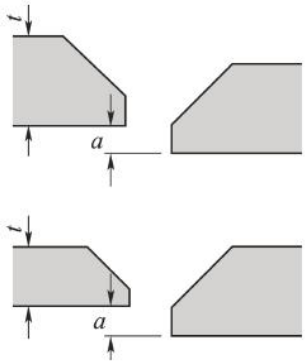
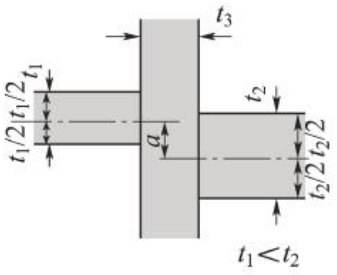
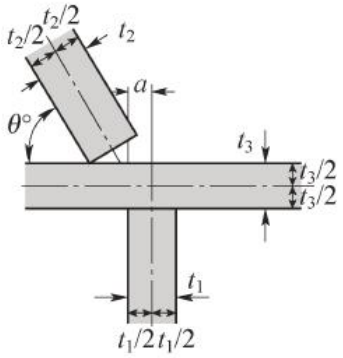
Fairness of Plating with Frames **Table 1.6.11**

Item		Standard	Limit	Remark
Shell plate	Parallel part	± 2 *l* /1000 mm	± 3 *l* /1000 mm	*l* = span of frame (mm) To be measured between on trans. space (min. *l* = 3000 mm)
	Fore and aft part	± 3 *l* /1000 mm	± 4 *l* /1000 mm	
Strength deck (excluding cross deck) and top plate of double bottom	–	± 3 *l* /1000 mm	± 4 *l* /1000 mm	
Bulkhead	–		± 5 *l* /1000 mm	
Accommodation above the strength deck and others	–	± 5 *l* /1000 mm	± 6 *l* /1000 mm	
 *l* = span of frame (minimum *l* = 3000 mm)  To be measured between one trans. space				

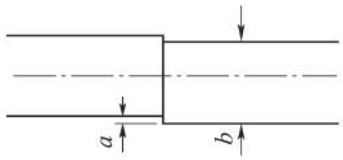
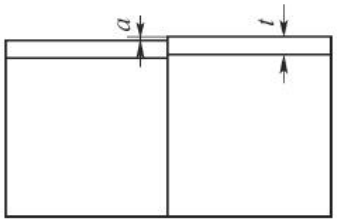
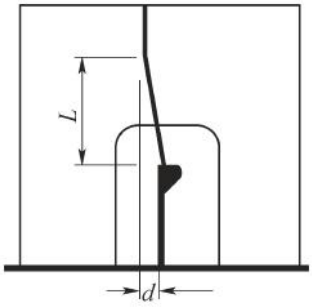
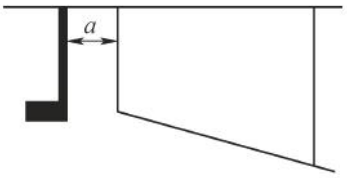
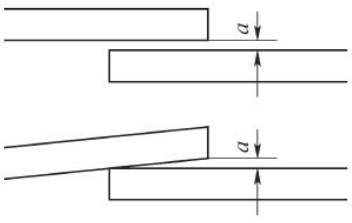
Preheating for welding hull steels at low temperature **Table 1.6.12**

Item		Standard		Limit	Remark
		Base metal temperature needed preheating	Minimum preheating temperature		
Normal strength steels	A, B, D, E	Below -5℃	20℃ [1)]		
Higher strength steels (TMCP type)	AH32 – EH32 AH36 – EH36	Below 0℃			
Higher strength steels (Conventional type)		Below 0℃			
Note: 1) This level of preheat is to be applied unless the approved welding procedure specifies a higher level.					

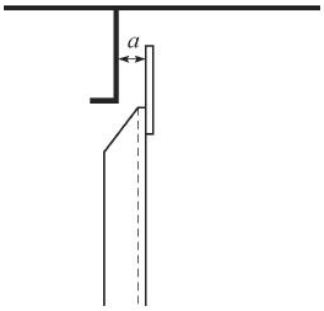
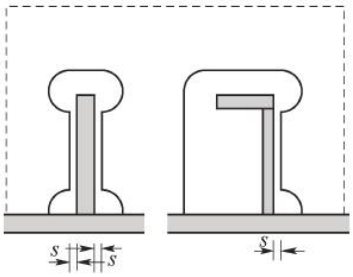
Alignment **Table 1.7.1**

Detail	Standard	Limit	Remark
Alignment of butt welds 		$a \le 0.15t$ strength member $a \le 0.2t$ other but maximum 4.0 mm	t is the lesser plate thickness
Alignment of fillet welds 		Strength member and higher stress member: $a \le t_1/3$ Other: $a \le t_1/2$	Alternatively, heel line can be used to check the alignment. Where t_3 is less than t_1, then t_3 should be substituted for t_1 in the standard
Alignment of fillet welds 		Strength member and higher stress member: $a \le t_1/3$ Other: $a \le t_1/2$	Alternatively, heel line can be used to check the alignment. Where t_3 is less than t_1, then t_3 should be substitute for t_1 in the standard

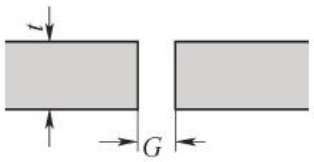
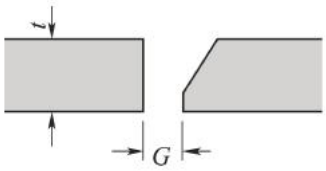
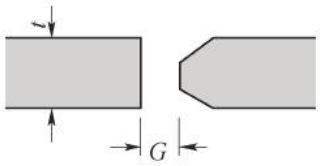
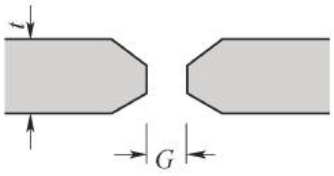
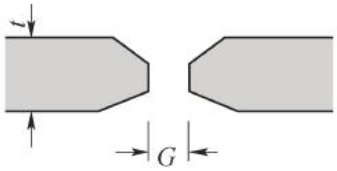
Alignment **Table 1.7.2**

Detail	Standard	Limit	Remark
Alignment of flange of T-longitudinal  *b* (mm)	Strength member $a \le 0.04b$ (mm)	a = 8.0 mm	
Alignment of height of T-bar, L-angle bar or bulb  	Strength member: $a \le 0.15t$ Other: $a \le 0.20t$	a = 3.0 mm	
Alignment of panel stiffener  	$d \le L/50$		
Gap between bracket/intercostal and stiffener  	$a \le 2.0$ mm	a = 3.0 mm	
Alignment of lap welds  	$a \le 2.0$ mm	a = 3.0 mm	

Alignment **Table 1.7.3**

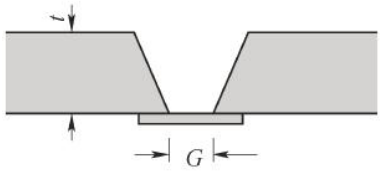
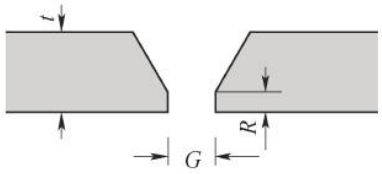
Detail	Standard	Limit	Remark
Gap between beam and frame 	$a \leq 2.0$ mm	$a = 5.0$ mm	
Gap around stiffener cut-out 	$s \leq 2.0$ mm	$s = 3.0$ mm	

Typical Butt Weld Plate Edge Preparation
(Manual Welding and Semi-Automatic Welding) for Reference **Table 1.8.1**

Detail	Standard	Limit	Remark
Square butt $t \le 5$ mm 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Single bevel butt $t > 5$ mm 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Double bevel butt $t > 19$ mm 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Double Vee butt, uniform bevels 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Double Vee butt, non-uniform bevel 	$G \le 3$ mm	$G = 5$ mm	see Note 1

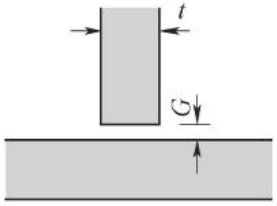
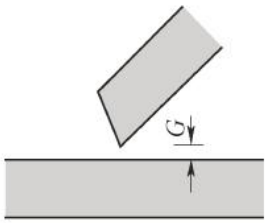
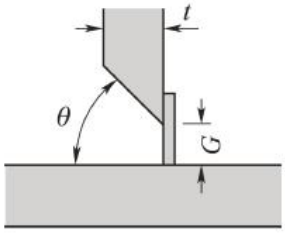
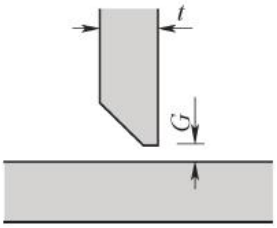
Note 1:
Different plate edge preparation may be accepted or approved by CCS in accordance with UR W28 (Reference 1.10 to this Section) or other recognized standard accepted by CCS.
For welding procedures other than manual welding, see paragraph 1.3.2 Qualification of weld procedures.

Typical Butt Weld Plate Edge Preparation
(Manual Welding and Semi-Automatic Welding) for Reference **Table 1.8.2**

Detail	Standard	Limit	Remark
Single Vee butt, one side welding with backing strip (temporary or permanent) 	G = 3 to 9 mm	G = 16 mm	see Note 1
Single Vee butt 	$G \leq 3$ mm	G = 5 mm	see Note 1

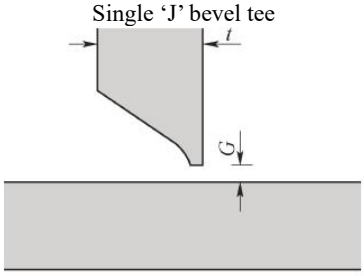
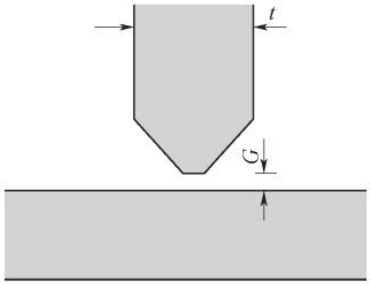
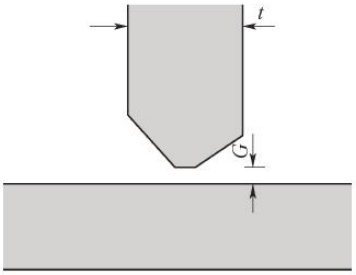
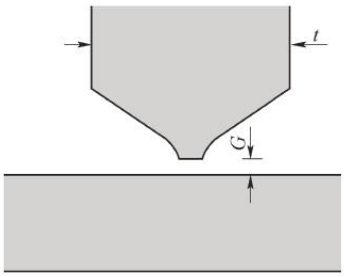
Note 1:
Different plate edge preparation may be accepted or approved by CCS in accordance with UR W28 (Reference 1.10 to this Section) or other recognized standard accepted by CCS.
For welding procedures other than manual welding, see paragraph 1.3.2 Qualification of welding procedures.

Typical Fillet Weld Plate Edge Preparation
(Manual Welding and Semi-Automatic Welding) for Reference **Table 1.8.3**

Detail	Standard	Limit	Remark
Tee Fillet 	$G \leq 2$ mm	$G = 3$ mm	see Note 1
Inclined fillet 	$G \leq 2$ mm	$G = 3$ mm	see Note 1
Single bevel tee with permanent backing 	$G \leq 4$ to 6 mm $\theta° = 30°$ to $45°$	$G = 16$ mm	Not normally for strength member see also Note 1
Single bevel tee 	$G \leq 3$ mm		see Note 1

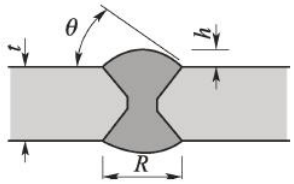
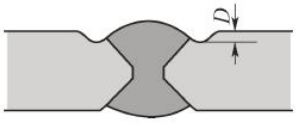
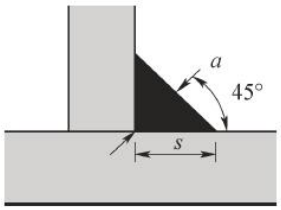
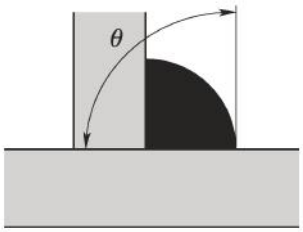
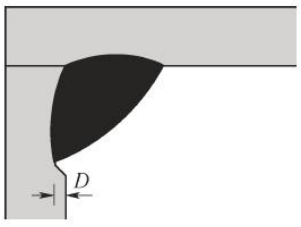
Note 1:
Different plate edge preparation may be accepted or approved by CCS in accordance with UR W28 (Reference 1.10 to this Section) or other recognized standard accepted by CCS.
For welding procedures other than manual welding, see paragraph 1.3.2 Qualification of welding procedures.

Typical Fillet Weld Plate Edge Preparation
(Manual Welding and Semi-Automatic Welding) for Reference **Table 1.8.4**

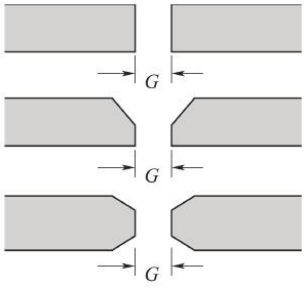
Detail	Standard	Limit	Remark
Single 'J' bevel tee 	G = 2.5 to 4 mm		see Note 1
Double bevel tee symmetrical t > 19 mm 	$G \leq 3$ mm		see Note 1
Double bevel tee asymmetrical t > 19 mm 	$G \leq 3$ mm		see Note 1
Double 'J' bevel tee symmetrical 	G = 2.5 to 4 mm		see Note 1

Note 1:
Different plate edge preparation may be accepted or approved by CCS in accordance with UR W28 (Reference 1.10 to this Section) or other recognized standard accepted by CCS.
For welding procedures other than manual welding, see paragraph 1.3.2 Qualification of welding procedures.

Butt And Fillet Weld Profile
(Manual Welding and Semi-Automatic Welding) **Table 1.8.5**

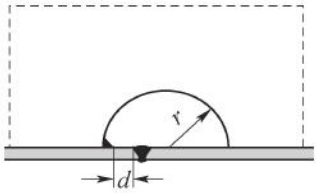
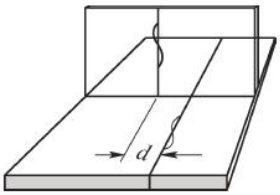
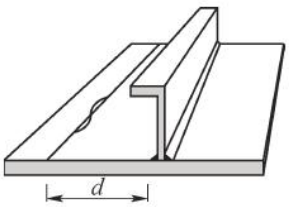
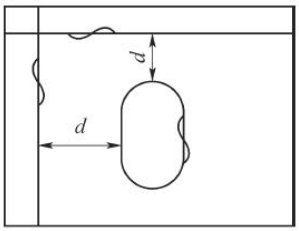
Detail	Standard	Limit	Remark
Butt weld toe angle 	$\theta \leq 60°$ $h \leq 6$ mm	$\theta \leq 90°$	
Butt weld undercut 		$D \leq 0.5$ mm for strength member $D \leq 0.8$ mm for other	
Fillet weld leg length  s = leg length; a = throat thickness		$s \geq 0.9s_d$ $a \geq 0.9a_d$ over short weld lengths	s_d = design s a_d = design a
Fillet weld toe angle 		$\theta \leq 90°$	In areas of stress concentration and fatigue, CCS may require a lesser angle
Fillet weld undercut 		$D \leq 0.8$ mm	

Typical Butt Weld Plate Edge Preparation (Automatic welding) for Reference **Table 1.8.6**

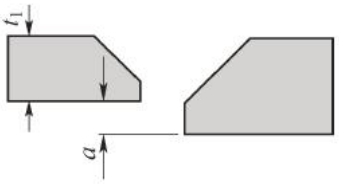
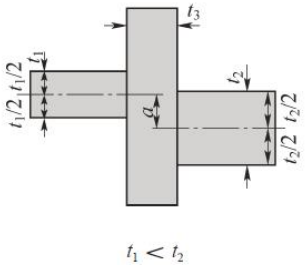
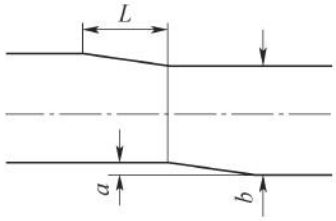
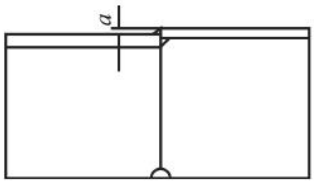
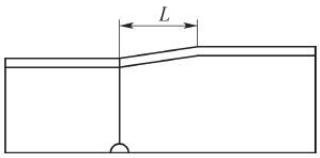
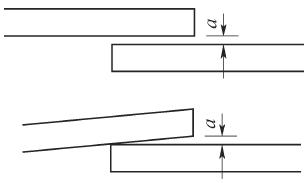
Detail	Standard	Limit	Remark
Submerged Arc Welding (SAW) 	$0 \le G \le 0.8$ mm	$G = 2$ mm	See Note 1

Note 1:
Different plate edge preparation may be accepted or approved by CCS in accordance with UR W28 (Reference 1.10 to this Section) or other recognized standard accepted by CCS.
For welding procedures other than manual welding, see paragraph 1.3.2 Qualification of welding procedures.

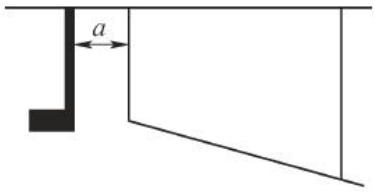
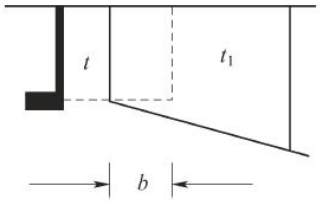
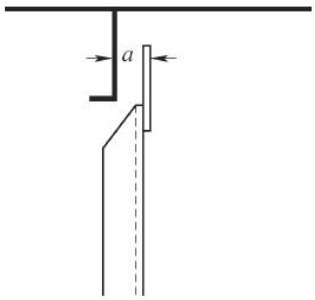
Distance Between Welds **Table 1.8.7**

Detail	Standard	Limit	Remark
Scallops over weld seams 		for strength member $d \ge 5$ mm for other $d \ge 0$ mm	The "*d*" is to be measured from the toe of the fillet weld to the toe of the butt weld
Distance between two butt welds 		$d \ge 0$ mm	
Distance between butt weld and fillet weld 		for strength member: $d \ge 10$ mm for other: $d \ge 0$ mm	The "*d*" is to be measured from the toe of the fillet weld to the toe of the butt weld
Distance between butt welds 	for cut-outs $d \ge 30$ mm		
	for margin plates d ≥ 300 mm	150 mm	

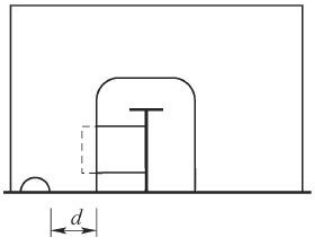
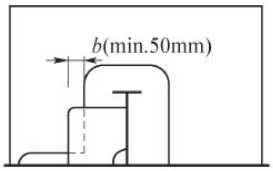
Typical Misalignment Remedial **Table 1.9.1**

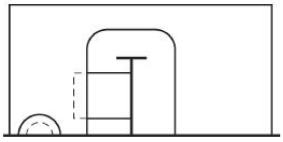
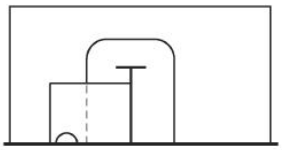
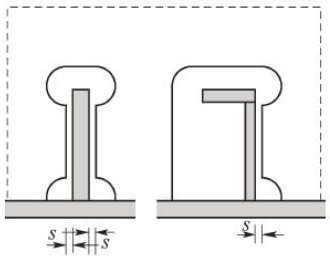
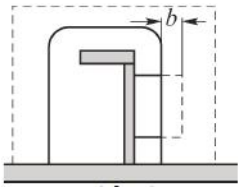
Detail	Remedial Standard	Remark
Alignment of butt joints 	Strength member $a > 0.15t_1$ or $a > 4$ mm release and adjust Other $a > 0.2t_1$ or $a > 4$ mm release and adjust	t_1 is lesser plate thickness
Alignment of fillet welds  $t_1 < t_2$	Strength member and higher stress member $t_1/3 < a \leq t_1/2$ − generally increase weld throat by 10% $a > t_1/2$ −release and adjust over a minimum of $50a$ Other $a > t_1/2$ −release and adjust over a minimum of $30a$	Alternatively, heel line can be used to check the alignment Where t_3 is less than t_1 then t_3 should be substituted for t_1 in standard
Alignment of flange of T-longitudinal 	When $0.04b < a \leq 0.08b$, max 8 mm: grind corners to smooth taper over a minimum distance $L = 3a$ When $a > 0.08$b or 8 mm: release and adjust over a minimum distance $L = 50a$	
Alignment of height of T-bar, L-angle bar or bulb 	When 3 mm $< a \leq 6$ mm: build up by welding When $a > 6$ mm: release and adjust over minimum $L = 50a$ for strength member and $L = 30a$ for other 	
Alignment of lap welds 	3 mm $< a \leq 5$ mm: weld leg length to be increased by the same amount as increase in gap in excess of 3 mm $a > 5$ mm: members to be re-aligned	

Typical Misalignment Remedial **Table 1.9.2**

Detail	Remedial Standard	Remark
Gap between bracket/intercostal and stiffener 	When 3 mm < a ≤ 5 mm: weld leg length to be increased by increase in gap in excess of 3 mm	
	When 5 mm < a ≤ 10 mm: chamfer 30° to 40° and build up by welding with backing	
	When a > 10 mm: increase gap to about 50 mm and fit collar plate  $t \geqslant t_1$ $b = (2t + 25)$ mm, min. 50 mm	
Gap between beam and frame 	3 mm < a ≤ 5 mm: weld leg length to be increased by the same amount as increase in gap in excess of 3 mm a > 5 mm release and adjust	

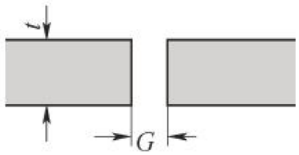
Misalignment Remedial **Table 1.9.3**

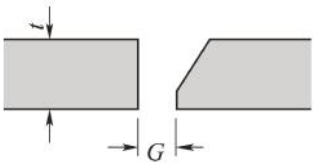
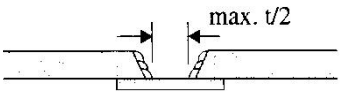
<table>
<tr><th>Detail</th><th>Remedial standard</th><th>Remark</th></tr>
<tr><td>Position of scallop
 
</td><td>When d < 75 mm
web plate to be cut between scallop and slot, and collar plate to be fitted
 

Or fit small collar over scallop
 
Or fit collar plate over scallop
  </td><td></td></tr>
<tr><td rowspan="3">Gap around stiffener cut-out
 
</td><td>When 3 mm < s ≤ 5 mm
weld leg length to be increased by the same amount as increase in gap in excess of 2 mm</td><td rowspan="3"></td></tr>
<tr><td>When 5 mm < s ≤ 10 mm
nib to be chamfered and built up by welding</td></tr>
<tr><td>When s > 10 mm
cut off nib and fit collar plate of same height as nib
 

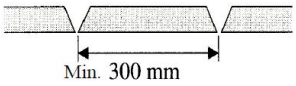
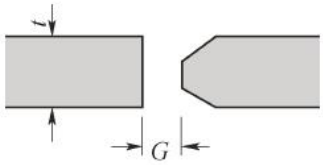
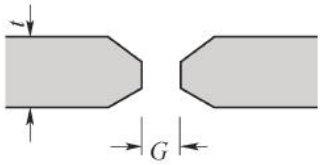
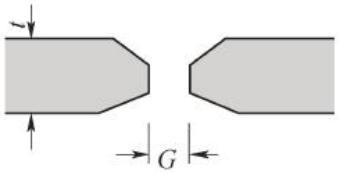
20 mm ≤ b ≤ 50 mm</td></tr>
</table>

Typical Butt Weld Plate Edge Preparation Remedial
(Manual Welding and Semi-Automatic Welding) **Table 1.9.4**

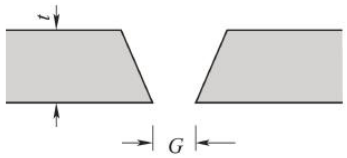
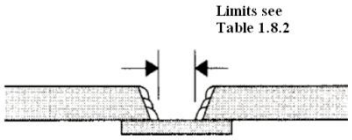
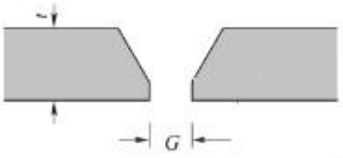
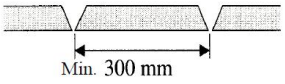
<table>
<tr><th>Detail</th><th>Remedial standard</th><th>Remark</th></tr>
<tr><td>Square butt (no beveling)
 
</td><td>When $G \leq 10$ mm
chamfer to 45° and build up by welding

When $G > 10$ mm, build up with backing strip; remove, back gouge and seal weld;
or, insert plate, min. width 300 mm</td><td></td></tr>
<tr><td>Single bevel butt
 
</td><td rowspan="4">When 5 mm $< G \leq$ 1.5t (maximum 25 mm), build up gap with welding on one or both edges to maximum of 0.5t, using backing strip, if necessary
Where a backing strip is used, the backing strip is to be removed, the weld back gouged, and a sealing weld made
 

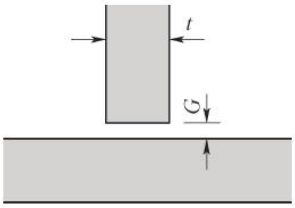
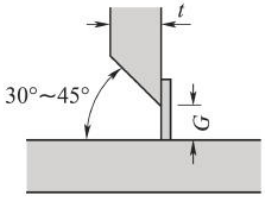
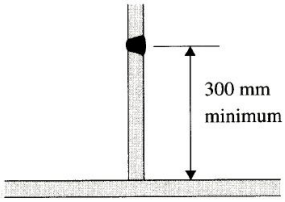
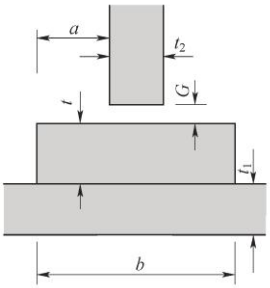
Different welding arrangement by using backing material approved by CCS may be accepted on the basis of an appropriate welding procedure specification

When $G >$ 25 mm or 1.5t, whichever is smaller, use insert plate, of minimum width 300 mm
 
</td><td rowspan="4"></td></tr>
<tr><td>Double bevel butt
 
</td></tr>
<tr><td>Double Vee butt, uniform bevels
 
</td></tr>
<tr><td>Double Vee butt, non-uniform bevel
 
</td></tr>
</table>

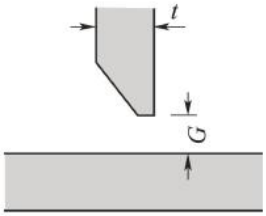
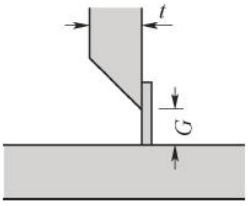
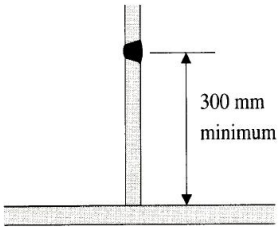
Typical Butt Weld Plate Edge Preparation Remedial
(Manual Welding and Semi-Automatic Welding) **Table 1.9.5**

Detail	Remedial Standard	Remark
Single Vee butt, one side welding  	When 5 mm < G ≤ 1.5t mm (maximum 25 mm), build up gap with welding on one or both edges, to "Limit" gap size preferably to "Standard" gap size as described in Table 1.8.2 Where a backing strip is used, the backing strip is to be removed, the weld back gouged, and a sealing weld made Different welding arrangement by using backing material approved by CCS may be accepted on the basis of an appropriate welding procedure specification  	
Single Vee butt  	When G > 25 mm or 1.5t, whichever is smaller, use insert plate of minimum width 300 mm  	

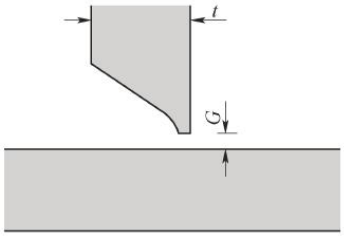
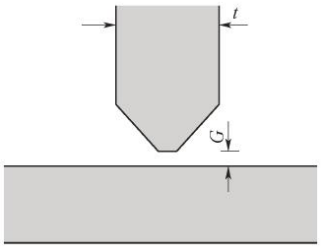
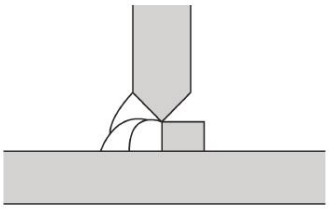
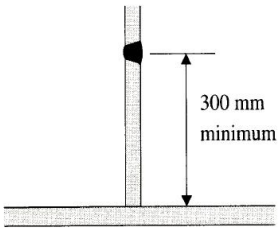
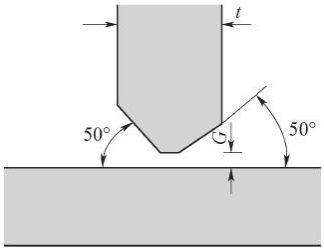
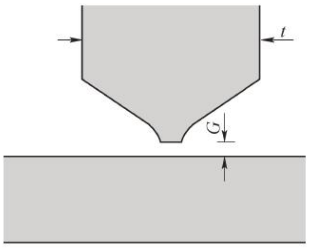
Typical Fillet Weld Plate Edge Preparation Remedial
(Manual Welding and Semi-Automatic Welding) **Table 1.9.6**

Detail	Remedial standard	Remark
Tee Fillet 	3 mm < G ≤ 5 mm – leg length increased to Rule leg + (G-2)	
	5 mm < G ≤ 16 mm or G ≤ 1.5t - chamfer by 30° to 45°, build up with welding, on one side, with backing strip if necessary, grind and weld. 	
	G > 16 mm or G > 1.5t use insert plate of minimum width 300 mm 	
Liner treatment 	$t_2 \le t \le t_1$ $G \le 2$ mm a = 5 mm + fillet leg length	Not to be used in cargo area or areas of tensile stress through the thickness of the liner

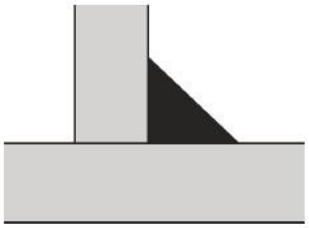
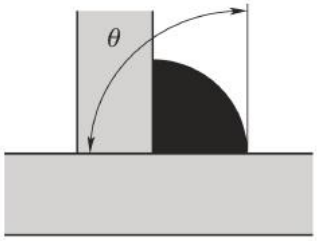
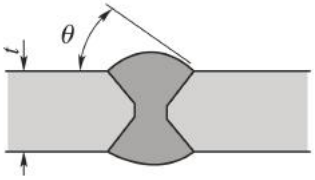
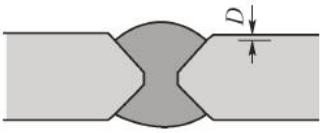
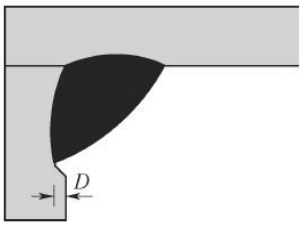
Typical Fillet Weld Plate Edge Preparation Remedial
(Manual Welding and Semi-Automatic Welding) **Table 1.9.7**

Detail	Remedial standard	Remark
Single bevel tee 	3 mm < G ≤ 5 mm build up weld	
	5 mm < G ≤ 16 mm - build up with welding, with backing strip if necessary, remove backing strip if used, back gouge and back weld 	
	G > 16 mm new plate to be inserted of minimum width 300 mm 	

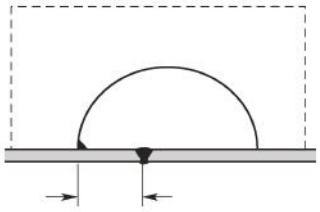
Typical Fillet Weld Plate Edge Preparation Remedial
(Manual Welding and Semi-Automatic Welding) **Table 1.9.8**

Detail	Remedial standard	Remark
Single 'J' bevel tee 	As single bevel tee	
Double bevel tee symmetrical 	When 5 mm < $G \leq$ 16 mm build up with welding using ceramic or other approved backing bar, remove, back gouge and back weld.  When G > 16 mm-insert plate of minimum height 300 mm to be fitted. 	
Double bevel tee asymmetrical 		
Double 'J' bevel symmetrical 		

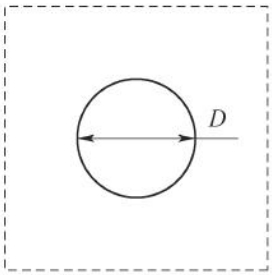
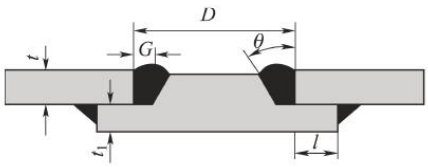
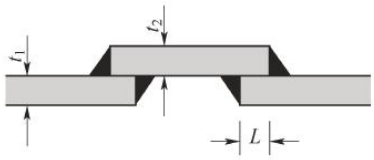
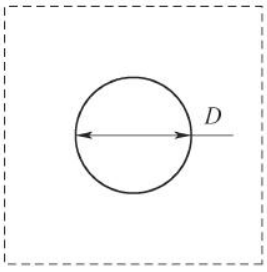
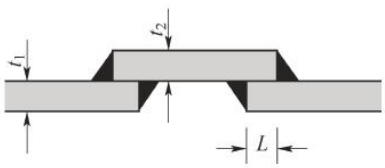
Typical Fillet and Butt Weld Profile Remedial
(Manual Welding and Semi-Automatic Welding) **Table 1.9.9**

Detail	Remedial standard	Remark
Fillet weld leg length 	Increase leg or throat by welding over	Minimum short bead to be referred to Table 1.9.14
Fillet weld toe angle 	θ> 90° grinding, and welding, where necessary, to make $\theta \leq 90°$	
Butt weld toe angle 	θ> 90° grinding, and welding, where necessary, to make $\theta \leq 90°$	
Butt weld undercut 	For strength member, where $0.5 < D \leq 1$ mm, and for other, where $0.8 < D \leq 1$ mm, undercut to be ground smooth (localized only) or to be filled by welding Where $D > 1$ mm undercut to be filled by welding	
Fillet weld undercut 	Where $0.8 < D \leq 1$ mm undercut to be ground smooth (localized only) or to be filled by welding Where $D > 1$ mm undercut to be filled by welding	

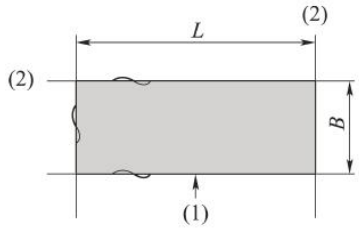
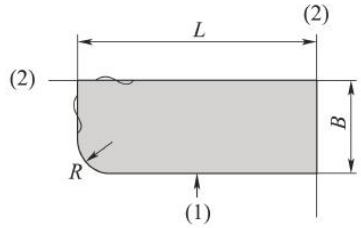
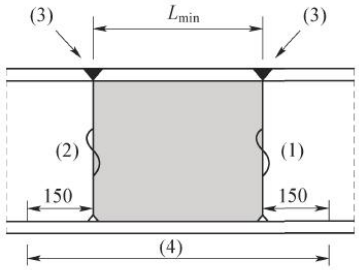
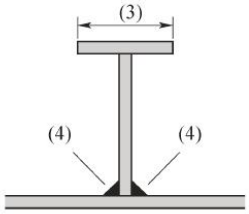
Distance Between Welds Remedial **Table 1.9.10**

Detail	Remedial standard	Remark
Scallops over weld seams 	Hole to be cut and ground smooth to obtain distance	

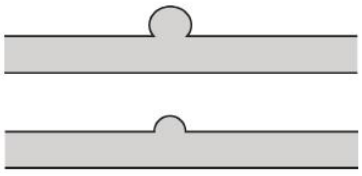
Erroneous Hole Remedial **Table 1.9.11**

Detail	Remedial standard	Remark
Holes made erroneously $D < 200$ mm 	Strength member open hole to minimum 75 mm dia., fit and weld spigot piece  $\theta = 30^\circ - 40^\circ$ $G = 4 - 6$ mm $1/2t = t_1 = t$ $l = 50$ mm Or open hole to over 300 mm and fit insert plate	Fillet weld to be made after butt weld The fitting of spigot pieces in areas of high stress concentration or fatigue is to be approved by CCS.
	Other open hole to over 300 mm and fit insert plate or fit lap plate  $t_1 = t_2$ $L = 50$ mm, min	
Holes made erroneously $D \geq 200$ mm 	Strength member open hole and fit insert plate	
	Other open hole to over 300 mm and fit insert plate or fit lap plate  $t_1 = t_2$ $L = 50$ mm, min	

Remedial by Insert Plate **Table 1.9.12**

Detail	Remedial standard	Remark
Remedial by insert plate   	L = 300 mm minimum B = 300 mm minimum $R = 5t$ mm 100 mm minimum (1) seam with insert piece is to be welded first (2) original seam is to be released and welded over for a minimum of 100 mm.	
Remedial of built section by insert plate   	$L_{min} \geq 300$ mm Welding sequence (1) → (2) → (3) → (4) Web butt weld scallop to be filled during final pass (4)	

Weld Surface Remedial **Table 1.9.13**

Detail	Remedial standard	Remark
Weld spatter 	1. Remove spatter observed before blasting with scraper or chipping hammer, etc. 2. For spatter observed after blasting: a) remove with a chipping hammer, scraper, etc. b) for spatter not easily removed with a chipping hammer, scraper, etc., grind the sharp angle of spatter to make it obtuse	In principle, no grinding is applied to weld surface
Arc strike (HT steel, Cast steel, Grade E of mild steel, TMCP type HT steel, Low temp steel)	Remove the hardened zone by grinding or other measures such as overlapped weld bead etc.	Minimum short bead to be referred to Table 1.9.14

Welding Remedial by Short Bead **Table 1.9.14**

Detail	Remedial standard	Remark
Short bead for remedying scar (scratch)	a) HT steel, Cast steel, TMCP type HT steel (C_{eq} > 0.36%) and Low temp steel (C_{eq} > 0.36%) Length of short bead ≥ 50 mm b) Grade E of mild steel Length of short bead ≥ 30 mm c) TMCP type HT steel (C_{eq} ≤ 0.36%) and Low temp steel (C_{eq} ≤ 0.36%) Length of short bead ≥ 10 mm	Preheating is necessary at 100 ± 25℃
Remedying weld bead	a) HT steel, Cast steel, TMCP type HT steel (C_{eq} > 0.36%) and Low temp steel (C_{eq} > 0.36%) Length of short bead ≥ 50 mm b) Grade E of mild steel Length of short bead ≥ 30 mm c) TMCP type HT steel (C_{eq} ≤ 0.36%) and Low temp steel (C_{eq} ≤ 0.36%) Length of short bead ≥ 30 mm	

Notes:
1. When short bead is made erroneously, remove the bead by grinding.
2. $C_{eq} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr} + \mathrm{Mo} + \mathrm{V}}{5} + \frac{\mathrm{Ni} + \mathrm{Cu}}{15}(\%)$

References:

1.1 IACS Recommendation No.76 “Bulk Carriers - Guidelines for Surveys, Assessment and Repair of Hull Structure”
1.2 TSCF “Guidelines for the inspection and maintenance of double hull tanker structures”
1.3 TSCF “Guidance manual for the inspection and condition assessment of tanker structures”
1.4 IACS UR W7 “Hull and machinery steel forgings”
1.5 IACS UR W8 “Hull and machinery steel castings”
1.6 IACS UR W11 “Normal and higher strength hull structural steel”
1.7 IACS UR W13 “Thickness tolerances of steel plates and wide flats”
1.8 IACS UR W14 “Steel plates and wide flats with specified minimum through thickness properties (“Z” quality)”
1.9 IACS UR W17 “Approval of consumables for welding normal and higher strength hull structural steels”
1.10 IACS UR W28 “Welding procedure qualification tests of steels for hull construction and marine structures”
1.11 IACS UR Z10.1 “Hull surveys of oil tankers”, Z10.2 “Hull surveys of bulk carriers”, Z10.3 “Hull surveys of chemical tankers”, Z10.4 “Hull surveys of double hull oil tankers” and Z10.5 “Hull surveys of double skin bulk carriers” Annex I
1.12 IACS UR Z23 “Hull survey for new construction”
1.13 IACS Recommendation No.20 “Non-destructive testing of ship hull steel welds”
1.14 IACS Recommendation No.96 “Double Hull Oil Tankers - Guidelines for Surveys, Assessment and Repair of Hull Structures”
1.15 IACS Recommendation No.55 “General Dry Cargo Ships - Guidelines For Surveys, Assessment and Repair of Hull Structures”
1.16 IACS Recommendation No.84 “Container Ships - Guidelines for Surveys, Assessment and Repair of Hull Structures”
1.17 IACS UR W31 “YP 47 Steels and Brittle Crack Arrest Steels”
1.18 IACS UR W32 “Qualification scheme for welders of hull structural steels”
1.19 IACS UR W34 “Advanced non-destructive testing of materials and welds”

1.20 IACS UR W35 “Requirements for NDT Suppliers”
1.21 IACS UR S33 “Requirements for Use of Extremely Thick Steel Plates in Container Ships”

Standards
1 EN 10163-1:2004 Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections – Part 1: General requirements

2 Repair Quality Standard for Existing Ships

2.1 Scope

2.1.1 This standard provides guidance on quality of repair of hull structures. The standard covers permanent repairs of existing ships.

2.1.1.1 Whereas the standard generally applies to:

(1) conventional ship types;

(2) parts of hull covered by the rules of CCS;

(3) hull structures constructed from normal and higher strength hull structural steel, the applicability of the standard is in each case to be agreed upon by CCS.

2.1.1.2 The standard does generally not apply to repair of

(1) special types of ships as e.g. gas tankers;

(2) structures fabricated from stainless steel or other, special types or grades of steel.

2.1.2 The standard covers typical repair methods and gives guidance on quality standard on the most important aspects of such repairs. Unless explicitly stated elsewhere in the standard, the level of workmanship reflected herein will in principle be acceptable for primary and secondary structure of conventional design. A more stringent standard may however be required for critical and highly stressed areas of the hull, and is to be agreed with CCS in each case. In assessing the criticality of hull structure and structural components, reference is made to References 2.l, 2.2, 2.3, 2.6, 2.8, 2.9, 2.10 and 2.11 to this Section.

2.1.3 Restoration of structure to the original standard may not constitute durable repairs of damages originating from insufficient strength or inadequate detail design. In such cases strengthening or improvements beyond the original design may be required. Such improvements are not covered by this standard, however it is referred to References 2.l, 2.2, 2.3, 2.6, 2.8, 2.9, 2.10 and 2.11 to this Section.

2.1.4 IACS UR W33 (Reference 2.8) scope is for new construction only, however, for the purpose of NDT applicability within this Appendix, UR W33 may be used as reference for NDT methods and acceptance standards.

2.2 General requirements for repairs and repairers

2.2.1 In general, when hull structure covered by classification is to be subjected to repairs, the work is to be carried out under the supervision of the Surveyor to CCS. Such repairs are to be agreed prior to commencement of the work.

2.2.2 Repairs are to be carried out by workshops, repair yards or personnel who have demonstrated their capability to carry out hull repairs of adequate quality in accordance with CCS requirements and this standard.

2.2.3 Repairs are to be carried out under working conditions that facilitate sound repairs. Provisions are to be made for proper accessibility, staging, lighting and ventilation. Welding operations are to be carried out under shelter from rain, snow and wind.

2.2.4 Welding of hull structures is to be carried out by qualified welders, according to approved and qualified welding procedures and with welding consumables approved by CCS, see Section 2.3. Welding operations are to be carried out under proper supervision of the repair yard.

2.2.5 Where repairs to hull which affect or may affect classification are intended to be carried out during a voyage, complete repair procedure including the extent and sequence of repair is to be submitted to and agreed upon by the Surveyor to CCS reasonably in advance of the repairs. See Reference 2.7 to this Section.

2.3 Qualification of personnel

2.3.1 Qualification of welders

2.3.1.1 Welders are to be qualified in accordance with IACS UR W32 (Reference 2.13) or to a recognised national or international standard, e.g. ISO 9606-1:2012/COR2:2013, ASME BPVC, Section IX:2019, ANSI/AWS D1.1:2020. Recognition of other standards is subject to submission to CCS for evaluation. Repair yards and workshops are to keep records of welders qualification and, when required, furnish valid approval test certificates.

2.3.1.2 Welding operators using fully mechanised of fully automatic processes need generally not pass approval testing, provided that production welds made by the operators are of the required quality. However, operators are to receive adequate training in setting or programming and operating the equipment. Records of training and production test results shall be maintained on individual operator’s files and records, and be made available to CCS for inspection when requested.

2.3.2 Qualification of welding procedures

2.3.2.1 Welding procedures are to be qualified in accordance with IACS UR W28 (Reference 2.12) or a recognised national or international standard, e.g. EN ISO 15607:2019, ISO 15614-1:2017, ASME BPVC, Section IX:2019, ANSI/AWS D1.1:2020. Recognition of other standards is subject to submission to CCS for evaluation. The welding procedure should be supported by a welding procedure qualification record. The specification is to include the welding process, types of electrodes, weld shape, edge preparation, welding techniques and positions.

2.3.3 Qualification of NDT operators

2.3.3.1 Personnel performing non-destructive testing for the purpose of assessing quality of welds in connection with repairs covered by this standard, are to be qualified in accordance with CCS rules or to a recognised international or national qualification scheme. Records of operators and their current certificates are to be kept and made available to the Surveyor for inspection.

2.4 Materials

2.4.1 General requirements for materials

2.4.1.1 The requirements for materials used in repairs are in general the same as the requirements for materials specified in CCS rules for new constructions, (see Reference 2.4 to this Section).

2.4.1.2 Replacement material is in general to be of the same grade as the original approved material. Alternatively, material grades complying with recognised national or international standards may be accepted by CCS provided such standards give equivalence to the requirements of the original grade or are agreed by CCS. For assessment of equivalency between steel grades, the general requirements and guidelines in Section 2.4.2 apply.

2.4.1.3 Higher tensile steel is not to be replaced by steel of a lesser strength unless specially approved by CCS.

2.4.1.4 Normal and higher strength hull structural steels are to be manufactured at works approved by CCS for the type and grade being supplied.

2.4.1.5 Materials used in repairs are to be certified by CCS applying the procedures and requirements in the rules for new constructions. In special cases, and normally limited to small quantities, materials may be accepted on the basis of alternative procedures for verification of the material's properties. Such procedures are subject to agreement by CCS in each separate case.

2.4.2 Equivalency of material grades

2.4.2.1 Assessment of equivalency between material grades should at least include the following aspects:

(1) heat treatment/delivery condition;

(2) chemical composition;

(3) mechanical properties;

(4) tolerances.

2.4.2.2 When assessing the equivalence between grades of normal or higher strength hull structural steels up to and including grade E40 in thickness limited to 50 mm, the general requirements in Table 2.4.1 apply.

2.4.2.3 Guidance on selection of steel grades to certain recognised standards equivalent to hull structural steel grades specified in CCS rules is given in Table 2.4.2.

Minimum extent and requirements to assessment of equivalency between normal or higher strength hull structural steel grades **Table 2.4.1**

Items to be considered	Requirements	Comments
Chemical composition	− C; equal or lower − P and S; equal or lower − Mn; approximately the same but not exceeding 1.6% − Fine grain elements; in same amount − Detoxidation practice	The sum of the elements, e.g. Cu, Ni, Cr and Mo should not exceed 0.8%
Mechanical properties	− Tensile strength; equal or higher	Actual yield strength should not exceed CCS Rule minimum requirements by more than 80 N/mm^2
	− Yield strength; equal or higher	
	− Elongation; equal or higher	
	− Impact energy; equal or higher at same or lower temperature, where applicable	
Condition of supply	− Same or better	Heat treatment in increasing order: − as rolled (AR) − controlled rolled (CR) − normalised (N) − thermo-mechanically rolled (TM)[1)] − quenched and tempered (QT)[1)]

		[1)] TM- and QT-steels are not suitable for hot forming
Tolerances	− Same or stricter	Permissible under thickness tolerances: − plates: 0.3 mm − sections: according to recognised standards

Guidance on steel grades comparable to the normal and high strength hull structural steel grades given in CCS rules **Table 2.4.2**

Steel grades according to CCS rules (Reference 2.4 to this Section)							Comparable steel grades (1)		
Grade	Yield stress R_{eH} (N/mm^2)	Tensile strenth R_m (N/mm^2)	Elongation A_5 min. (%)	Average impact energy for t≤50mm			EN 10025:1990 (2) ISO 4950-2:1995	EN 10025 series:2004	A131	G3106
				Test temp. (℃)	(J,min.) L	(J,min.) T				
A B D E	235	400-520	22	+20 0 -20 -40	- 27 27 27	- 20 20 20	Fe 360B Fe 360C Fe 360D -	S235JR S235J0 S235J2 S275NL,S275ML	A B D E	SM400B SM400B,SM400C - -
A27 D27 E27	265	400-530	22	0 -20 -40	27	20	Fe 430C Fe 430D -	S275J0 S275J2,S275N,S275M S275NL,S275ML	- - -	- - -
A32 D32 E32	315	440-570	22	0 -20 -40	31	22	- - -	- - -	AH32 DH32 EH32	SM490B,SM490C -
A36 D36 E36	355	490-630	21	0 -20 -40	34	24	Fe 510C Fe 510D,E355D D E355E	S355 J0 S355J2,S355N,S355M S355NLS355ML	AH36 DH36 EH36	SM520B,SM520C -
A40 D40 E40	390	510-660	20	0 -20 -40	39	26	E390CC E390DD E390E	S420N,S420M S420N,S420M S420NL,S420 ML	AH40 DH40 EH40	SM570 - -

Notes:
(1) In selecting comparable steels from this table, attention should be given to the requirements of Table 2.4.1 and the dimension requirements of the product with respect to CCS rules. Some steel grades as per national or international standard are defined with specified yield and tensile strength properties which depend on thickness. For thicknesses with tensile properties specified lower than those of CCS Rules, case-by-case consideration is to be given with regards to design requirements.
(2) EN 10025:1990 is superseded by EN10025 series: 2019 (e.g. EN 10025-2:2019, EN 10025-3:2019, EN 10025-4:2019).

2.5 General requirements to welding

2.5.1 Correlation of welding consumables with hull structural steels

2.5.1.1 For the different hull structural steel grades welding consumables are to be selected in accordance with IACS UR W17 (see Reference 2.5 to this Section).

2.5.2 General requirements to preheating and drying out

2.5.2.1 The need for preheating is to be determined based on the chemical composition of the materials, welding process and procedure and degree of joint restraint.

2.5.2.2 A minimum preheat of 50℃ is to be applied when ambient temperature is below 0℃. Dryness of the welding zone is in all cases to be ensured.

2.5.2.3 Guidance on recommended minimum preheating temperature for higher strength steel is given in Table 2.5.1. For automatic welding processes utilising higher heat input e.g. submerged arc welding, the temperatures may be reduced by 50℃. For re-welding or repair of welds, the stipulated values are to be increased by 25℃.

Preheating temperature **Table 2.5.1**

Carbon equivalent 1)	Recommended minimum preheat temperature (℃)		
	t_{comb} ≤ 50 mm 2)	50 mm < t_{comb} ≤ 70 mm 2)	t_{comb} > 70 mm 2)
C_{eq} ≤ 0.39			50
C_{eq} ≤ 0.41			75
C_{eq} ≤ 0.43		50	100
C_{eq} ≤ 0.45	50	100	125
C_{eq} ≤ 0.47	100	125	150
C_{eq} ≤ 0.50	125	150	175

Notes:

1) $C_{eq} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr} + \mathrm{Mo} + \mathrm{V}}{5} + \frac{\mathrm{Ni} + \mathrm{Cu}}{15}(\%)$

2) Combined thickness $t_{comb} = t_1+t_2+t_3+t_4$, see Figure 2.5.2.

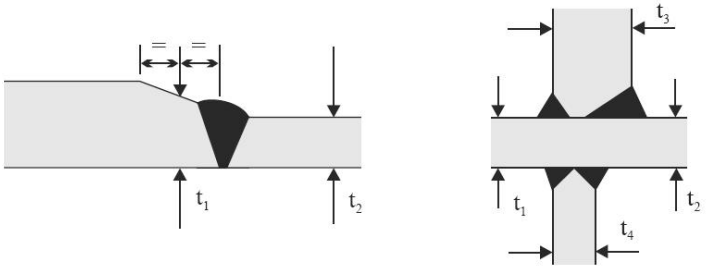


Figure 2.5.2 Combined thickness

2.5.3 Dry welding on hull plating below the waterline of vessels afloat

2.5.3.1 Welding on hull plating below the waterline of vessels afloat is acceptable only on normal and higher strength steels with specified yield strength not exceeding 355 MPa and only for local repairs. Welding involving other high strength steels or more extensive repairs against water backing is subject to special consideration and approval by CCS of the welding procedure.

2.5.3.2 Low-hydrogen electrodes or welding processes are to be used when welding on hull plating against water backing. Coated low-hydrogen electrodes used for manual metal arc welding should be properly conditioned to ensure a minimum of moisture content.

2.5.3.3 In order to ensure dryness and to reduce the cooling rate, the structure is to be preheated by a torch or similar prior to welding, to a temperature of minimum 5℃ or as specified in the welding procedure.

2.6 Repair quality standard

2.6.1 Welding, general requirements

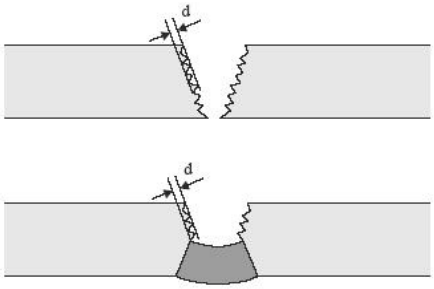


Figure 2.6.1 Groove roughness

Table 2.6.1

Item	Standard	Limit	Remark
Material Grade	Same as original or higher		See Section 2.4
Welding Consumables	IACS UR W17 (Reference 2.5 to this Section)	Approval according to equivalent international standard	
Groove / Roughness	See note and Figure 2.6.1	d < 1.5 mm	Grind smooth
Pre-Heating	See Table 2.5.1	Steel temperature not lower than 5℃	
Welding with water on the outside	See Section 2.5.3	Acceptable for normal and high strength steels	− Moisture to be removed by a heating torch
Alignment	As for new construction		
Weld Finish	IACS UR W33 (Reference 2.8 to this Section)		
NDT	IACS UR W33 (Reference 2.8 to this Section)	At random with extent to be agreed with attending surveyors	

Note: Slag, grease, loose mill scale, rust and paint, other than primer, to be removed.

2.6.2 Renewal of plates

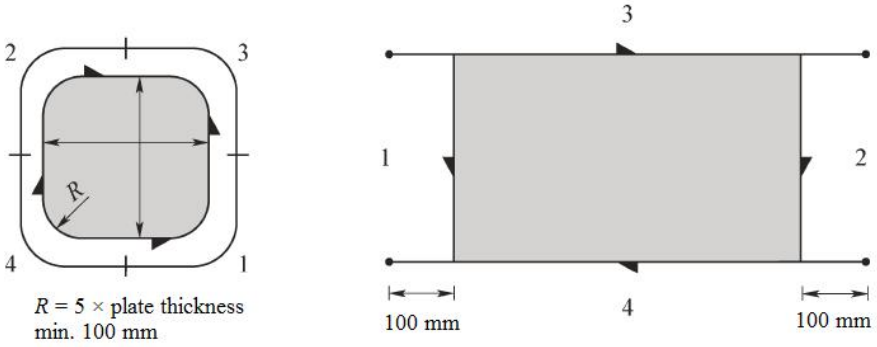


Figure 2.6.2 Welding sequence for inserts

Table 2.6.2

Item	Standard	Limit	Remark
Size Insert	Min 300 × 300 mm R = 5 × thickness Circular inserts: *Dmin* = 200 mm	Min 200 × 200 mm Min R = 100 mm	
Material Grade	Same as original or higher		See Section 2.4
Edge Preparation	As for new construction		In case of non-compliance increase the amount of NDT
Welding Sequence	See Figure 2.6.2, welding sequence: 1 → 2 → 3 → 4		For primary members sequence 1 and 2 transverse to the main stress direction
Alignment	As for new construction		
Weld Finish	IACS UR W33 (Reference 2.8 to this Section)		
NDT	IACS UR W33 (Reference 2.8 to this Section)		

2.6.3 Doublers on plating

Local doublers are normally only allowed as temporary repairs, except as original compensation for openings, within the main hull structure.

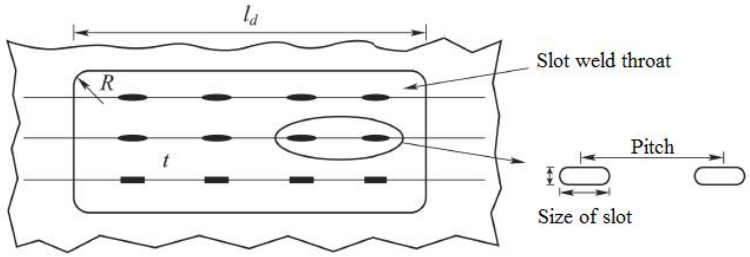


Figure 2.6.3 Doublers on plates

Table 2.6.3

Item	Standard	Limit	Remark
Existing Plating		General:： $t \geq 5$ mm	For areas where existing plating is less than 5 mm plating a permanent repair by insert is to be carried out
Extent / Size	Rounded off corners.	Min 300 × 300 mm $R \geq 50$ mm	
Thickness of Doubler (t_d)	$t_d \leq t_p$ (t_p = original thickness of existing plating)	$t_d > t_p/3$	
Material Grade	Same as original plate		See Section 2.4
Edge Preparation	As for [newbuilding] new construction		Doublers welded on primary strength members: (L_e: leg length) when $t > L_e + 5$ mm, the edge to be tapered (1:4)
Welding	As for [newbuilding]		Welding sequence similar to insert

Item	Standard	Limit	Remark
	new construction		plates
Weld Size (throat thicknesss))	Circumferential and in slots: $0.6 \times t_d$		
Slot Welding	Normal size of slot: (80-100) × 2 t_d Distance from doubler edge and between slots: $d \leq 15\ t_d$	Max pitch between slots 200 mm d_{max} = 500 mm	For doubler extended over several supporting elements, see Figure 2.6.3
NDT	IACS UR W33 (Reference 2.8 to this Section)		

2.6.4 Renewal of internals/stiffeners

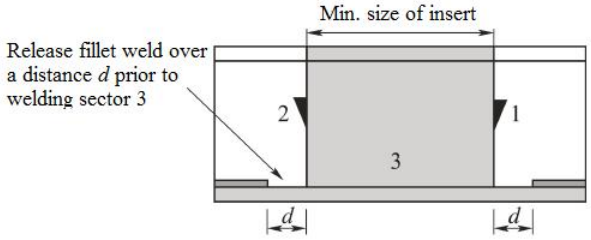


Figure 2.6.4 Welding sequence for inserts of stiffeners

Table 2.6.4

Item	Standard	Limit	Remark
Size Insert	Min. 300 mm	Min 200 mm	
Marterial Grade	Same as original or higher		See Section 2.4
Edge Preparation	As for new construction. Fillet weld stiffener web / plate to be released over min. d = 150 mm		
Welding Sequence	See Figure 2.6.4 Welding sequence is 1→2→3		
Alignment	As for new construction		
Weld Finish	IACS UR W33 (Reference 2.8 to this Section)		
NDT	IACS UR W33 (Reference 2.8 to this Section)		

2.6.5 Renewal of internals/stiffeners – transitions inverted angle/bulb profile

The application of the transition is allowed for secondary structural elements.

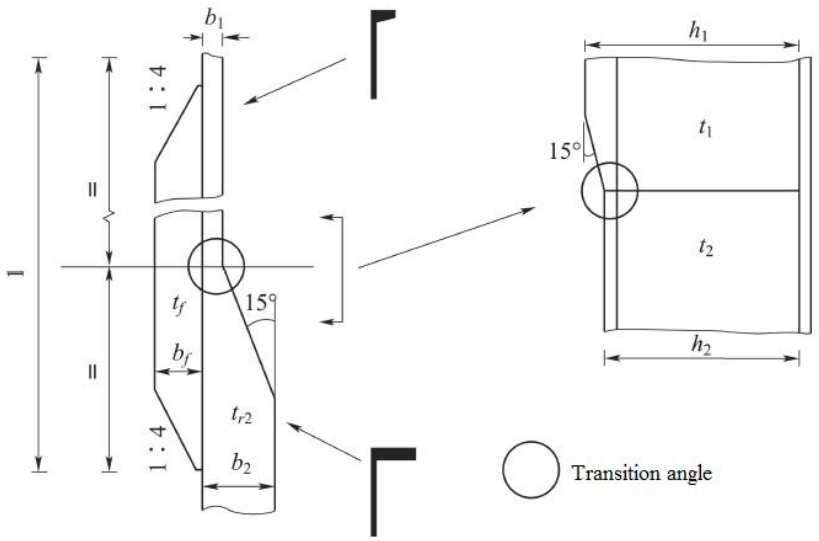


Figure 2.6.5 Transition between inverted angle and bulb profile

Table 2.6.5

Item	Standard	Limit	Remark
$(h_1 - h_2)$	$\leq 0.25 \times b_1$		
$\lvert t_1 - t_2 \rvert$	2 mm		Without tapering transition
Transition Angle	15 degrees		At any arbitrary section
Flanges	$t_f = t_{f2}$ $b_f = b_{f2}$		
Length of Flatbar	$4 \times h_1$		
Material			See Section 2.4

2.6.6 Application of Doubling Straps

2.6.6.1 In certain instances, doubling straps are used as a means to strengthen and reinforce primary structure. Where this has been agreed and approved, particular attention should be paid to:

(1) the end termination points of the straps, so that toe support is such that no isolated hard point occurs;

(2) in the case of application of symmetrical or asymmetrical-ended straps, the corners at the end of the tapering should be properly rounded;

(3) any butts between lengths of doubling straps, so that there is adequate separation of the butt weld from the primary structure below during welding, and so that a high quality root run under controlled circumstances is completed prior to completing the remainder of the weld. Ultrasonic testing should be carried out on completion to verify full penetration.

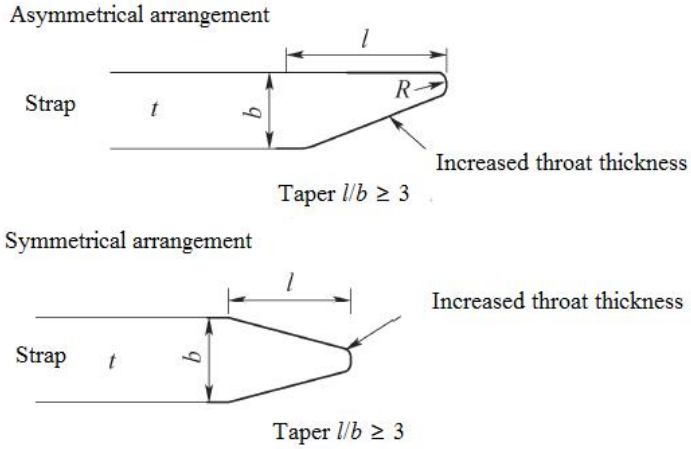


Figure 2.6.6 Application of Doubling Straps

Table 2.6.6

Item	Standard	Limit	Remark
Tapering	$l/b>3$		Special consideration to be drawn to design of strap terminations in fatigue sensitive areas
Radius	$0.1 \times b$	Min 30 mm	
Material			See paragraph 2.4 General requirement to materials
Weld Size			Depending on number and function of straps. Throat thickness to be increased 15 % toward ends
Welding	Welding sequence from middle towards the free ends		See sketch. For welding of lengths > 1000 mm step welding to be applied

2.6.7 Welding of pitting corrosion

Note:

Shallow pits may be filled by applying coating or pit filler. Pits can be defined as shallow when their depth is less than 1/3 of the original plate thickness.

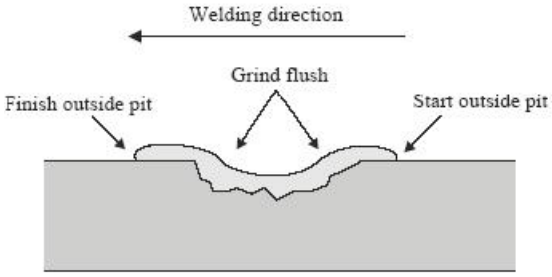


Figure 2.6.7 Welding of pits

Table 2.6.7

Item	Standard	Limit	Remark
Extent / Depth	Pits / grooves are to be welded flush with the original surface.	If deep pits or grooves are clustered together or remaining thickness is less than 6 mm, the plates should be renewed.	See also IACS UR W11 (Reference 2.4 to this Section)
Cleaning	Heavy rust to be removed		
Pre-Heating	See Table 2.5.1	Required when ambient temperature < 5℃	Always use propane torch or similar to remove any moisture
Welding Sequence	Reverse direction for each layer		See also IACS UR W11 (Reference 2.4 to this Section)
Weld Finish	IACS UR W33 (Reference 2.8 to this Section)		
NDT	IACS UR W33 (Reference 2.8 to this Section)	Min 10% extent	Preferably MPI

Reference is made to TSCF Guidelines, Ref. 2.2 & 2.3.

2.6.8 Welding repairs for cracks

In the event that a crack is considered weldable, either as a temporary or permanent repair, the following techniques should be adopted as far as practicable. Run-on and run-off plates should be adopted at all free edges.

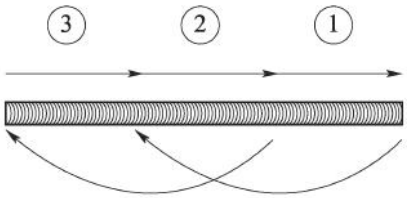


Figure 2.6.8.a Step back technique

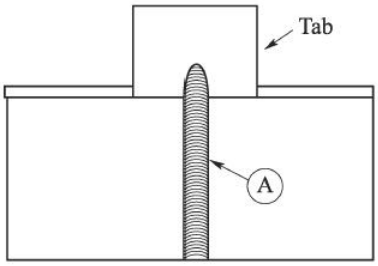


Figure 2.6.8.b End crack termination

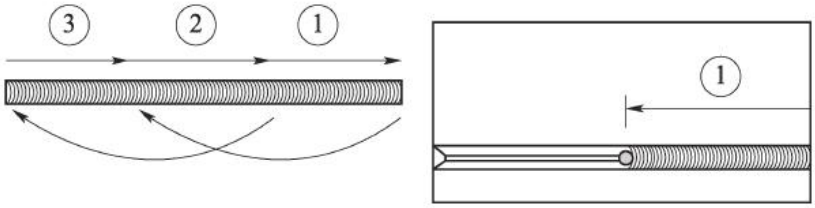


Figure 2.6.8.c Welding sequence for cracks with length less than 300 mm

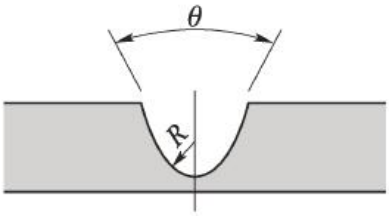


Figure 2.6.8.d Groove preparation (U-groove left and V-groove right)

Table 2.6.8

Item	Standard	Limit	Remark
Groove Preparation	$\theta = 45^{o} \sim 60^{o}$ $r = 5$ mm		For through plate cracks as for newbuilding. See also Figure 2.6.8.d
Termination	Termination to have slope 1:3		For cracks ending on edges weld to be terminated on a tab. See Figure 2.6.8.b
Extent	On plate max 400 mm length. Vee out 50 mm past end of crack	On plate max 500 mm. Linear crack, not branched	
Welding Sequence	See Figure 2.6.8.c for sequence and direction	For cracks longer than 300 mm step-back technique should be used Figure 2.6.8.a	Always use low hydrogen welding consumables
Weld Finish	IACS UR W33 (Reference 2.8 to this Section)		
NDT	IACS UR W33 (Reference 2.8 to this Section)	100 % MP or PE of groove	100% surface crack detection + UE or RE for butt joints

References:

2.1 IACS Recommendation No.76 “Bulk Carriers - Guidelines for Surveys, Assessment and Repair of Hull Structure”

2.2 TSCF “Guidelines for the inspection and maintenance of double hull tanker structures”

2.3 TSCF “Guidance manual for the inspection and condition assessment of tanker structures”

2.4 IACS UR W 11 “Normal and higher strength hull structural steels”

2.5 IACS UR W 17 “Approval of consumables for welding normal and higher strength hull structural steels”

2.6 IACS UR Z 10.1 “Hull surveys of oil tankers”, UR Z 10.2 “Hull surveys of bulk carriers”, UR Z10.3 “Hull surveys of chemical tankers”, UR Z10.4 “Hull surveys of double hull oil tankers” and UR Z10.5 “Hull surveys of double skin bulk carriers” Annex I 2.7 IACS UR Z 13 “Voyage repairs and maintenance”

2.8 IACS UR W33 “Non-destructive testing of ship hull steel welds”

2.9 IACS Recommendation No.96 “Double Hull Oil Tankers - Guidelines for Surveys, Assessment and Repair of Hull Structures”

2.10 IACS Recommendation No.55 “General Dry Cargo Ships - Guidelines For Surveys, Assessment and Repair of Hull Structures”

2.11 IACS Recommendation No.84 “Container Ships - Guidelines for Surveys, Assessment and Repair of Hull Structures”

2.12 IACS UR W28 “Welding procedure qualification tests of steels for hull construction and marine structures”
2.13 IACS UR W32 “Qualification scheme for welders of hull structural steels”

Standards:
1 ANSI/AWS D1.1:2020 Structural Welding Code – Steel
2 ASME BPVC, Section IX:2019 Boiler and Pressure Vessel Code, Section IX: Welding and Brazing Qualifications
3 ASTM A 131:2019 Standard Specification for Structural Steel for Ships
4 EN 10025-2:2019 Hot Rolled Products of Structural Steels - Part 2: Technical Delivery Conditions For Non-alloy Structural Steels
5 EN 10025-3:2019 Hot Rolled Products of Structural Steels - Part 3: Technical Delivery Conditions For Normalized/normalized Rolled Weldable Fine Grain Structural Steels
6 EN 10025-4:2019 Hot Rolled Products of Structural Steels - Part 4: Technical Delivery Conditions for Thermomechanical Rolled Weldable Fine Grain Structural Steels
7 EN ISO 15607:2019 Specification and Qualification of Welding Procedures For Metallic Materials - General Rules
8 GB 712:2011 Ship and ocean engineering structural steel
9 ISO 4950-2:1995/Amd 1:2003High yield strength flat steel products — Part 2: Products supplied in the normalized or controlled rolled condition — Amendment 1
10 ISO 9606 -1:2012/COR2:2013Qualification testing of welders — Fusion welding — Part 1: Steels — Technical Corrigendum 2
11 ISO 15614-1:2017Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys
12 JIS G 3106:2015 /Amd 1:2017 Rolled steels for welded structure (Amendment 1)

Appendix 3 SURVEYS OF WATERTIGHT CABLE TRANSITS

1 Application

1.1 These requirements apply to all vessels contracted for construction on or after 1st July 2021 and are in addition to the requirements of appendix 1 of this Chapter.

1.2 Watertight cable transits are to be installed and maintained in accordance with the manufacturer's requirements and in accordance with the requirements of the relevant Type Approval certification.

2 Cable Transit Seal Systems Register

2.1 A Cable Transit Seal Systems Register (Register) is to be provided by the shipbuilder for all watertight cable transits fitted to the vessel. For an example of a register see Annex 3 to Appendix 1 of this Chapter– "Recommendatory Sample - Cable Transit Seal Systems Register". The Register can be in either a hard copy or digitized media. It is to include:

(1) A marking/identification system,

(2) Documentation referencing manufacturer manual(s) for each type of cable transit installed,

(3) The Type Approval certification for each type of transit system,

(4) Applicable installation drawings,

(5) A recording of each installed transit documenting the as built condition after final inspection in the shipyard.

(6) Sections to record any inspection, modification, repair and maintenance.

2.2 The Register shall be reviewed by the attending Surveyor to confirm it contains a list of the watertight cable transits, applicable cable transit information and sections to maintain in-service maintenance and survey records.

2.3 For manned vessels the Register is to be held onboard of the vessel. For unmanned vessels, if a suitable storage location does not exist onboard, the Register may be held ashore. The Register is to be readily available for the attending surveyor.

3 Installation and Maintenance of Watertight Cable Transits

3.1 It is to be confirmed that cable transits have been installed, and where disrupted have been reinstated, in accordance with the manufacturer's requirements and in accordance with the requirements of Type Approval.

3.2 It is to be confirmed where specified, appropriate specialized tools have been used.

CHAPTER 5 SURVEYS AFTER CONSTRUCTION

Section 1 GENERAL PROVISIONS

5.1.1 General requirements

5.1.1.1 For the purpose of maintaining the validity of certificates, ships which have been classed with CCS are to be subject to the surveys as specified in Section 2 of this Chapter (where applicable). CCS may permit, as appropriate, remote inspection technique① to be used to facilitate the required external and internal examinations, including close-up surveys and gauging. Such surveys may be extended by CCS Surveyors at their professional judgement, and the owner is to provide appropriate survey conditions and make arrangements accordingly and has the obligation to pay the expenses related to extending the surveys.

5.1.1.2 If any damage or defect affecting the validity of certificates is found at any of the surveys, the Surveyor is to inform the owner or his representative of the recommendations in time when he deems necessary. When such recommendations are not dealt with, the Surveyor is to report this to the Headquarters of CCS immediately.

5.1.1.3 It is the responsibility of the owner to apply to CCS for all surveys necessary for the maintenance of the validity of certificates and to make preparations and take safety precautions for surveys in accordance with the requirements of the Rules.

5.1.1.4 Unless provided otherwise in this Chapter, surveys after construction of ships engaged on non-international voyages and in restricted service are to comply with the relevant provisions of PART TEN of the Rules.

5.1.2 Reclassification

5.1.2.1 When reclassification is desired for a ship for which the class previously assigned by CCS has been canceled, CCS will carry out a survey appropriate to the age of the ship and the circumstances of the case. If, at such a survey, the ship is found or placed in a good and efficient condition in accordance with CCS rules, CCS will reinstate the original class or assign such other class as may be deemed necessary. The date of any reclassification will be recorded in the Register of Ships or its supplement.

5.1.3 Damage and repair surveys

5.1.3.1 Any damage to hull, equipment or machinery (including electrical installations), which could invalidate the conditions for which a class has been assigned, is to be reported to CCS without delay. CCS will appoint the Surveyor(s) boarding a ship in time to carry out damage surveys at a suitable port where the ship arrives on its voyage. And the scope of the survey is to be that considered by the Surveyor(s) necessary for ascertaining the extent and cause of the damage.

5.1.3.2 All repairs to hull, equipment or machinery (including electrical installations) involving the ship's class are to be made under the supervision of the Surveyor(s). If repairs are effected at a place where services of a CCS Surveyor are not available, CCS is to be informed in time by the owner/company.

5.1.4 Alteration or modification surveys

5.1.4.1 Plans and particulars of any proposed alternations or modifications to the approved scantlings or arrangements of hull, equipment or machinery (including electrical installations) are to be submitted to CCS for approval. Such alterations or modifications and related items are in general to comply with the provisions of the present rules of CCS or at least the requirements of previously applicable rules.

5.1.4.2 Alterations or modifications of a major character, if any, are to comply with the provisions of Section 15 of this Chapter.

5.1.5 Definitions

5.1.5.1 For the purpose of this Chapter, the following definitions apply to all ships:

(1) A **ballast tank** is a tank which is used primarily for the carriage of salt water ballast.

(2) **Space**s are independent compartments, including holds, tanks, cofferdams and void spaces bounding cargo holds, decks and the outer hull.

(3) A **transverse section** includes all longitudinal members such as plating, longitudinals and girders at the deck, side, bottom, inner bottom, and longitudinal bulkhead (where applicable, hopper side plating and bottom plating of top wing tanks). For transversely framed vessels, a transverse section includes adjacent

---

① Refer to IACS Rec. 42 "Guidelines for Use of Remote Inspection Techniques for surveys".

frames and their end connections in way of transverse sections.
(4) **Representative spaces** are those which are expected to reflect the conditions of other spaces of similar type and service and with similar corrosion protection systems. When selecting representative spaces, account is to be taken of the service and repair history on board and identifiable critical and/or suspect areas.
(5) **Suspect areas** are locations showing substantial corrosion and/or are considered by the Surveyor to be prone to rapid wastage.
(6) **Substantial corrosion** is an extent of corrosion such that assessment of corrosion pattern indicates a wastage in excess of 75% of allowable margins, but within acceptable limits. For CSR ships, substantial corrosion is an extent of corrosion such that the assessment of the corrosion pattern indicates a gauged (or measured) thickness between t_{ren} + 0.5 mm and t_{ren}.
(7) A **corrosion prevention system** is normally considered a full hard protective coating. For the purpose of this Chapter, a full hard protective coating is usually to be epoxy coating or equivalent. Other coating systems, which are neither soft nor semi-hard coatings①, may be considered acceptable as alternatives provided that they are applied and maintained in compliance with the manufacturer's specifications.
(8) A **prompt and thorough repair** is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, therein removing the need for the imposition of any associated condition of classification.
(9) **Air pipe heads installed on the exposed decks** are those extending above the freeboard deck or superstructure decks.
(10) **Wind and water strakes** are the strakes of a ship's side shell plating between the ballast and deepest load waterlines. Due to the ship's trim, the strakes may vary over the length of the ship.
(11) An **overall survey** is a survey intended to report on the overall condition of the hull structure and determine the extent of additional close-up surveys.
(12) A **close-up survey** is a survey where the details of structural components are within the close visual inspection range of the surveyor, i.e. normally within reach of hand.
(13) **Special consideration** or **specially considered** (in connection with close-up surveys and thickness measurements) means sufficient close-up inspection and thickness measurements are to be taken to confirm the actual average condition of the structure under the coating.
(14) **Cargo length area** is that part of the ship which includes all cargo holds and adjacent areas including fuel tanks, cofferdams, ballast tanks and void spaces.
(15) **Coating condition**② is defined as follows:

GOOD: Condition with only minor spot rusting;
FAIR: Condition with local breakdown at edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for POOR condition;
POOR: Condition with general breakdown of coating over 20% or more of areas or hard scale at 10% or more of areas under consideration.

(16) **Extensive corrosion** is an extent of corrosion consisting of hard and/or loose scale, including pitting, over 70% or more of the area under consideration, accompanied by evidence of thickness diminution.
(17) **Renewal thickness (t_{ren})** is the minimum allowable thickness, in mm, below which renewal of structural members is to be carried out.
(18) **Pitting corrosion** is defined as scattered corrosion spots/areas with local material reductions which are greater than the general corrosion in the surrounding area. Pitting intensity is defined in Figure 5.1.5.1(18).
(19) **Edge corrosion** is defined as local corrosion at the free edges of plates, stiffeners, primary support members and around openings. An example of edge corrosion is shown in Figure 5.1.5.1(19).
(20) **Grooving corrosion** is typically local material loss adjacent to weld joints along abutting stiffeners and at stiffener or plate butts or seams. An example of groove corrosion is shown in Figure 5.1.5.1(20).
(21) **Remote Inspection Technique (RIT)** is a means of survey that enables examination of any part of the structure without the need for direct physical access of the surveyor (refer to IACS Rec.42).

---

① As for the requirements regarding semi-hard coatings, these coatings, if already applied, will not be accepted from the next special or intermediate survey commenced on or after 1 July 2010, whichever comes first, with respect to waiving the annual internal examination of the ballast tanks.
② For oil tankers and chemical tankers, reference is made to IACS Recommendation No.87 - Guidelines for Coating Maintenance & Repairs for Ballast Tanks and Combined Cargo/Ballast Tanks on Oil Tankers.

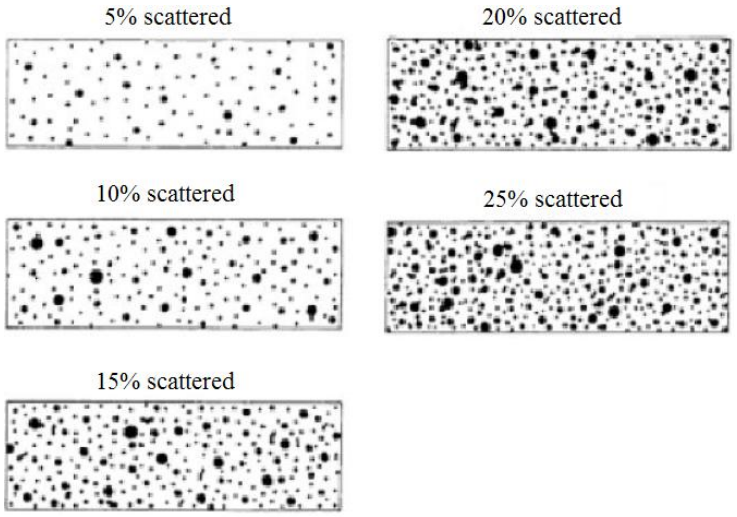


Figure 5.1.5.1(18) Pitting Intensity Diagrams

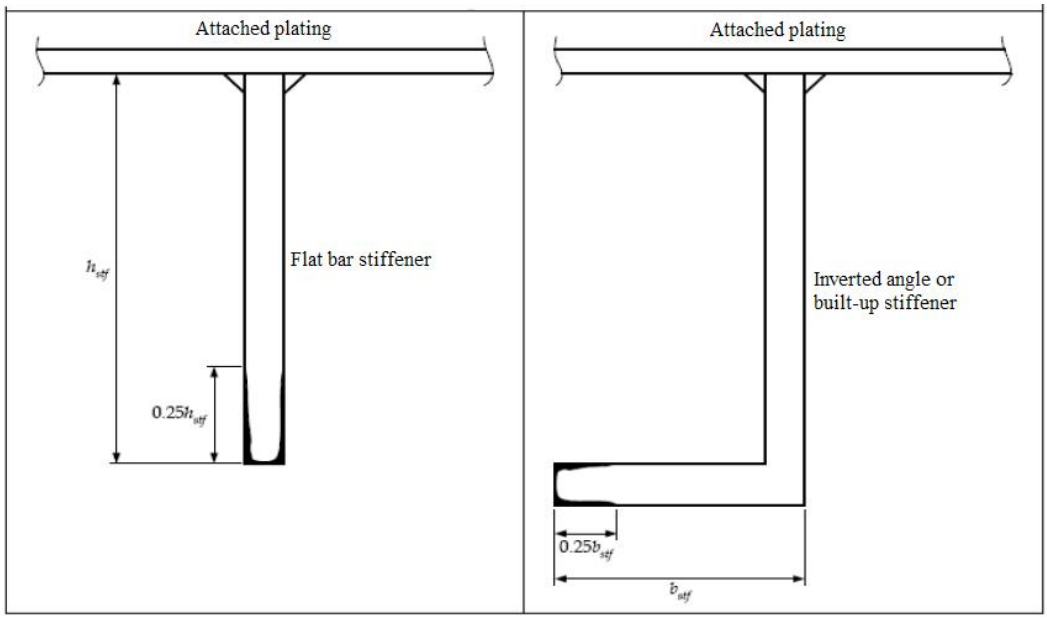


Figure 5.1.5.1(19) Edge Corrosion

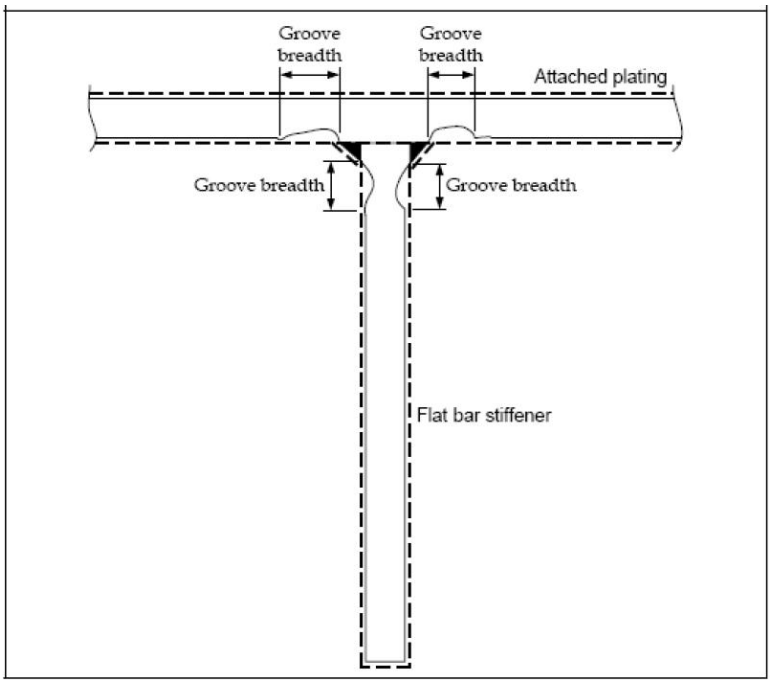


Figure 5.1.5.1(20) Grooving Corrosion

5.1.5.2 The following definitions are added for oil tankers in addition to those in 5.1.5.1 of this Chapter:
(1) A **ballast tank** is a tank which is used primarily for the carriage of salt water ballast.
A **combined cargo/ballast tank** is a tank which is used for the carriage of cargo or ballast water as a routine part of the ship's operation and will be treated as a ballast tank. Cargo tanks in which water ballast might be carried only in exceptional cases per MARPOL I/18.3 are to be treated as cargo tanks.
(2) **Cargo area** is that part of the ship that contains cargo tanks, slop tanks and cargo/ballast pump-rooms, cofferdams, ballast tanks and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above mentioned spaces.
(3) An **oil tanker** is a ship which is constructed primarily to carry oil in bulk in cargo tanks forming an integral part of the ship's hull, including ship types such as combination carriers (Ore/Oil ships etc.) but excluding ships carrying oil in independent tanks not part of the ship's hull such as asphalt carriers.
(4) A **double hull oil tanker** is a ship which is constructed primarily for the carriage of oil in bulk, which has the cargo tanks forming an integral part of the ship's hull and is protected by a double hull which extends for the entire length of the cargo area, consisting of double sides and double bottom spaces for the carriage of water ballast or void spaces.
5.1.5.3 The following definitions are added for bulk carriers in addition to those in 5.1.5.1 of this Chapter:
(1) An **existing bulk carrier** is generally a bulk carrier which has been constructed in compliance with plans approved in accordance with the rules effective before entry into force of the Rules.
(2) A **double skin bulk carrier** is a ship which is constructed generally with single deck, double bottom, topside tanks and hopper side tanks in cargo spaces, and is intended primarily to carry dry cargo in bulk, including such types as ore carriers and combination carriers,[①] in which all cargo holds are bounded by a double-side skin (regardless of the width of the wing space). Common Structural Rules[②] does not apply to ore and combination carriers.
(3) **Ballast tank:**
① A **ballast tank of a bulk carrier** is a tank which is used primarily for salt water ballast, or, where applicable, a space which is used for both cargo and salt ballast will be treated as a ballast tank when substantial corrosion has been found in that space.
② A **ballast tank of a double skin bulk carrier** is a tank which is used primarily for salt water ballast, or, where applicable, a space which is used for both cargo and salt ballast will be treated as a ballast

① For combination carriers and combination carriers with longitudinal bulkheads, additional requirements are specified in Section 6 of this Chapter.
② PART TEN of the Rules (2012 version) and its 2013 and 2014 amendments or PART NINE of the Rules (2015 version) and its subsequent versions (including amendments).

tank when substantial corrosion has been found in that space. A double side tank is to be considered as a separate tank even if it is in connection to either the topside tank or the hopper side tank.

5.1.6 Preparations for survey

5.1.6.1 Conditions for survey

(1) The owner is to provide the necessary facilities for a safe execution of the survey. For self-propelled ships having the notation ESP, the following are to be complied with:

① in order to enable the attending Surveyors to carry out the survey, provisions for proper and safe access are to be agreed between the owner and CCS in accordance with the relevant requirements of IACS PR37;

② details of the means of access are to be provided in the Survey Planning Questionnaire given in Appendix 11B of this Chapter;

③ in cases where the provisions of safety and required access are judged by the attending Surveyors not to be adequate, the survey of the spaces involved is not to proceed.

(2) Tanks and spaces are to be safe for access. Tanks and spaces are to be gas free and properly ventilated. Prior to entering a tank, void or enclosed space, it is to be verified that the atmosphere in that space is free from hazardous gas and contains sufficient oxygen.

(3) In preparation for survey and thickness measurements and to allow for a thorough examination, all spaces are to be cleaned including removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues etc. to reveal corrosion, deformation, fractures, damages, or other structural deterioration, as well as the condition of the coating. However, those areas of structure whose renewal has already been decided by the owner need only be cleaned and descaled to the extent necessary to determine the limits of the renewed areas.

(4) Sufficient illumination is to be provided to reveal corrosion, deformation, fractures, damages or other structural deterioration, as well as the condition of the coating.

(5) Where soft or semi-hard coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft or semi-hard coating is to be removed.

(6) Casings, ceilings or linings, and loose insulation, where fitted, are to be removed, as required by the Surveyor, for examination of plating and framing. Compositions on plating are to be examined and sounded, but need not be disturbed if found adhering satisfactorily to the plating.

(7) In refrigerated cargo spaces the condition of the coating behind the insulation is to be examined at representative locations. The examination may be limited to verification that the protective coating remains effective and that there are no visible structural defects. Where POOR coating condition is found, the examination is to be extended as deemed necessary by the Surveyor. If indents, scratches, etc., are detected during surveys of shell plating from the outside, insulations in way are to be removed as required by the Surveyor, for further examination of the plating and adjacent frames.

5.1.6.2 Access to structures

(1) For survey including overall survey of all ships, means are to be provided to enable the Surveyor to examine the hull structure in a safe and practical way.

(2) For survey of all ships in cargo holds and ballast tanks, and for close-up survey of general cargo ships, oil tankers, chemical tankers, and the hull structure, other than cargo hold shell frames, of bulk carriers, one or more of the following means for access, acceptable to the Surveyor, is to be provided:

① permanent staging and passages through structures;

② temporary staging and passages through structures;

③ hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms;

④ boats or rafts;

⑤ portable ladders;

⑥ other equivalent means.

(3) For close-up surveys of the cargo hold shell frames of bulk carriers less than 100,000 DWT, one or more of the following means for access, acceptable to the Surveyor, is to be provided:

① means referred to in (2)① to ③ and ⑥ above;

② portable ladder restricted to not more than 5 m in length may be accepted for surveys of lower section of a shell frame including bracket;

③ hydraulic arm vehicles such as conventional cherry pickers;

④ boats or rafts, provided the structural capacity of the hold is sufficient to withstand static loads at all

levels of water.

(4) Close-up surveys of the cargo hold shell frames of bulk carriers of 100,000 DWT and above:

① For annual surveys, intermediate survey under 10 years of age and special survey No.1, one or more of the means for access referred to in (3) above (except the portable ladder), acceptable to the surveyor, may be provided.

② For subsequent intermediate surveys and special surveys, one or more of the following means for access, acceptable to the Surveyor, is to be provided:

a. either permanent or temporary staging and passage through structures for close-up survey of the upper part of hold frames;

b. hydraulic arm vehicles such as conventional cherry pickers for surveys of lower and middle parts of shell frames as alternative to staging;

c. means referred to in (2)③, ④ and ⑥ above. Boats or rafts, provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water.

③ Notwithstanding the requirement in (4)① for exclusion of portable ladder, the use of a portable ladder fitted with a mechanical device to secure the upper end of the ladder is acceptable for the following:

a. "close-up examination of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approx. lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating of the forward cargo hold" at annual survey, as required in 5.7.2.4(1)①b;

b. "close-up examination of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approx. lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating of one other selected cargo hold (other than forward cargo hold)" at annual survey, as required in 5.7.2.4(2)①b;

④ The use of hydraulic arm vehicles or aerial lifts ("Cherry picker") may be accepted by the attending surveyor for the close-up survey of the upper part of side shell frames or other structures in all cases where the maximum working height is not more than 17 m.

(5) For Surveys conducted by use of a remote inspection technique, one or more of the following means for access, acceptable to the Surveyor, is to be provided:

① unmanned robot arm;

② Remotely Operated Vehicles (ROV);

③ Unmanned Aerial Vehicles / Drones;

④ other means acceptable to CCS.

5.1.6.3 Equipment for survey

(1) Thickness measurement is normally to be carried out by means of ultrasonic test equipment. The accuracy of the equipment is to be proven to the Surveyor as required. Thickness measurements are to be carried out by a firm approved by CCS in accordance with Appendix 10 of this Chapter, except that in respect of measurements of non-ESP ships less than 500 gross tonnage and all fishing vessels, the firm need not be so approved.

(2) One or more of the following fracture detection procedures may be required if deemed necessary by the Surveyor:

① radiographic equipment;

② ultrasonic equipment;

③ magnetic particle equipment;

④ dye penetrant.

(3) For self-propelled ships having the notation ESP, the following are to be complied with:

① explosimeter, oxygen-meter, breathing apparatus, lifelines, riding belts with rope and hook and whistles together with instructions and guidance on their use are to be made available during the survey. A safety checklist is to be provided;

② adequate and safe lighting is to be provided for the safe and efficient conduct of the survey;

③ adequate protective clothing is to be made available and used (e.g. safety helmet, gloves, safety shoes, etc.) during the survey.

5.1.6.4 Survey at sea or at anchorage[①]

(1) Survey at sea or at anchorage may be accepted provided the Surveyor is given the necessary assistance from the personnel onboard. Necessary precautions and procedures for carrying out the survey are to be in

① Reference is made to IACS Recommendation No.39 − Safe Use Of Rafts Or Boats For Survey.

accordance with 5.1.6.1, 5.1.6.2 and 5.1.6.3 above.
(2) A communication system is to be arranged between the survey party in the tank and the responsible officer on deck. This system must also include the personnel in charge of ballast pump handling if boats or rafts are used.
(3) When boats or rafts are used, appropriate life jackets are to be available for all participants. A safety checklist is to be provided.
(4) Surveys of tanks or applicable holds by means of boats or rafts may only be undertaken with the agreement of the Surveyor, who is to take into account the safety arrangements provided, including weather forecasting and ship response under foreseeable conditions and provided the expected rise of water within the tank does not exceed 0.25 m.
(5) Self-propelled ships having the notation ESP (hereinafter referred to as ESP ships) are to comply with, in addition to 5.1.6.4(1) to (4), the following requirements:

① Rafts or boats alone may be allowed for inspection of the under deck areas for tanks or spaces, if the depth of the webs is 1.5 m or less.

② If the depth of the webs is more than 1.5 m, rafts or boats alone may be allowed only:

a. when the coating of the under deck structure is in GOOD condition and there is no evidence of wastage; or

b. if a permanent means of access is provided in each bay① to allow safe entry and exit. This means:

(a) access direct from the deck via a vertical ladder and a small platform fitted approximately 2 m below the deck in each bay; or

(b) access to deck from a longitudinal permanent platform having ladders to deck in each end of the tank. The platform is, for the full length of the tank, be arranged in level with, or above, the maximum water level needed for rafting of under deck structure. For this purpose, the ullage corresponding to the maximum water level is to be assumed not more than 3 m from the deck plate measured at the midspan of deck transverses and in the middle length of the tank, e.g. in respect to oil tankers (including double hull oil tankers) and chemical tankers, see Figure 5.1.6.4(5)②.

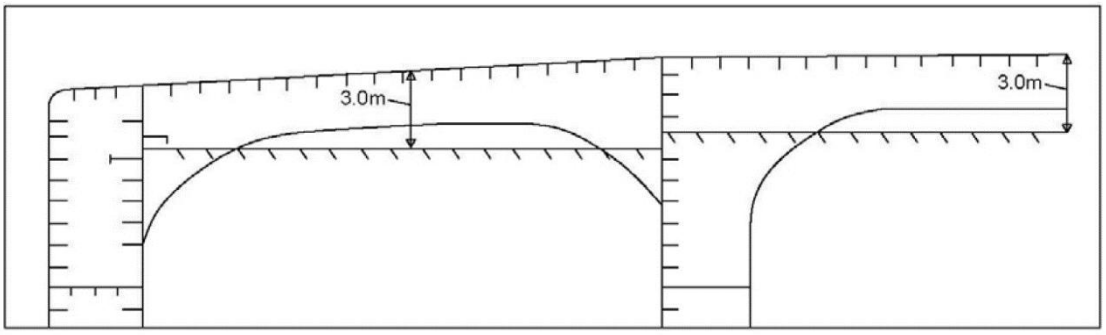


Figure 5.1.6.4(5)② Maximum Water Level in a Tank

If neither of the above conditions are met, then staging or an "other equivalent means" is to be provided for the survey of the under deck areas.

③ The use of rafts or boats alone in ① and ② above does not preclude the use of boats or rafts tomove about within a tank during a survey.

④ When rafts or boats will be used for close-up survey, the following conditions are to be observed:

a. the boat or raft is to be tethered to the access ladder and an additional person is to be stationed down the access ladder with a clear view of the boat or raft;

b. the surface of water in the tank or hold is to be calm (under all foreseeable conditions the expected rise of water within the tank or hold is not to exceed 0.25 m) and the water level stationary. On no account is the level of the water to be rising while the boat or raft is in use;

c. the tank, hold or space must contain clean ballast water only. Even a thin sheen of oil on the water is not acceptable;

d. at no time is the water level to be allowed to be within 1 m of the deepest underdeck web face

① Bay is the area between adjacent transverse frames or transverse bulkheads.

flat so that the survey team is not isolated from a direct escape route to the tank hatch. Filling to levels above the deck transverses is only to be contemplated if a deck access manhole is fitted and open in the bay being examined, so that an escape route for the survey party is available at all times. Other effective means of escape to the deck may be considered;

e. if the tanks (or spaces) are connected by a common venting system, or inert gas system, the tank in which the boat or raft is to be used is to be isolated to prevent a transfer of gas from other tanks (or spaces) (for close-up survey of oil tankers and chemical tankers);

f. only rough duty, inflatable rafts or boats, having satisfactory residual buoyancy and stability even if one chamber is ruptured, are to be used.

5.1.6.5 Survey programme

(1) A specific survey programme is to be worked out by the owner in cooperation with CCS in advance of the special survey for ESP ships or the intermediate survey for ESP ships of 10 years of age or over. The survey programme at intermediate survey may consist of the survey programme at the previous special survey supplemented by the executive hull summary of that special survey and later relevant survey reports. The survey Programme is to be worked out taking into account any amendments to the survey requirements implemented after the last special survey carried out. The survey programme is to be in a written format based on the information in Appendix 11A of this Chapter. The survey is not to commence until the survey programme has been agreed. Prior to the development of the survey programme, the survey planning questionnaire is to be completed by the owner based on the information set out in Appendix 11B of this Chapter, and forwarded to CCS.

(2) In developing the survey programme, the following documentation is to be collected and consulted with a view to reasonably selecting tanks, areas, and structural elements to be examined:

① For bulk carriers:

a. survey status and basic ship information;

b. documentation on board, as described in 5.1.7.2 and 5.1.7.3;

c. main structural plans (scantling drawings), including information regarding use of high-tensile steels (HTS);

d. relevant previous survey and inspection reports from both CCS and the owner;

e. information regarding the use of the ship's holds and tanks, typical cargoes and other relevant data;

f. information regarding corrosion protection level of the newbuilding;

g. information regarding the relevant maintenance level during operation;

② For oil tankers and chemical tankers:

a. survey status and basic ship information;

b. documentation on board, as described in 5.1.7.2 and 5.1.7.3;

c. main structural plans (scantling drawings) of cargo and ballast tanks, including information regarding use of high tensile steels (HTS) (for chemical tankers, also including information regarding use of clad steel and stainless steel);

d. Executive Hull Summary;

e. relevant previous damage and repair history;

f. relevant previous survey and inspection reports from both CCS and the owner;

g. details of the inert gas plant and tank cleaning procedures;

h. information and other relevant data regarding conversion or modification of the ship's cargo and ballast tanks since the time of construction;

i. description and history of the coating and corrosion protection system, if any;

j. inspections by the owner's personnel during the last 3 years with reference to structural deterioration in general, leakages in tank boundaries and piping and condition of the coating and corrosion protection system, if any. Guidance for reporting is shown in Appendix 12 of this Chapter;

k. information regarding the relevant maintenance level during operation including port State control reports of inspection containing hull related deficiencies, Safety Management System non-conformities relating to hull maintenance, including the associated corrective action(s);

l. any other information that will help identify suspect areas and critical structural areas;

m. cargo and ballast history for the last 3 years, including carriage of cargo under heated conditions (only for oil tankers);

n. information regarding the use of the ship's tanks, typical cargoes and other relevant data (only for chemical tankers).

(3) The submitted survey programme is to account for and comply, as a minimum, with the requirements for close-up survey, thickness measurement and tank testing (also including pipe testing for chemical

tankers), respectively, and is to include relevant information including at least:

① basic ship information and particulars;

② main structural plans (scantling drawings), including information regarding use of high tensile steels (HTS) (for chemical tankers, also including information regarding use of clad steel and stainless steel);

③ plan of tanks;

④ list of tanks with information on use, protection and condition of coating;

⑤ conditions for survey (e.g. information regarding tank cleaning, gas freeing, ventilation, lighting, etc.);

⑥ provisions and methods for access to structures;

⑦ equipment for surveys;

⑧ nomination of tanks and areas for close-up survey;

⑨ nominations of areas and sections for thickness measurement;

⑩ nomination of tanks for tank testing (for chemical tankers, and the pipes that are to undergo pipe testing);

⑪ identification of the thickness measurement company (for oil tankers and chemical tankers);

⑫ damage experience related to the ship in question;

⑬ critical structural areas and suspect areas, where relevant (for oil tankers and chemical tankers).

(4) The maximum acceptable structural corrosion diminution levels applicable to the ship are given in Appendix 1 of this Chapter.

(5) In preparing the survey programme, reference may be made to Appendix 12 of this Chapter, Guidelines for Technical Assessment in Conjunction with Planning for Enhanced Surveys and owner's Report.

5.1.6.6 Survey planning meeting for ESP ships

(1) The establishment of proper preparation and the close cooperation between the attending Surveyor(s) and the owner's representatives onboard prior to and during the survey are an essential part in the safe and efficient conduct of the survey. During the survey on board safety meetings are to be held regularly.

(2) Prior to commencement of any part of the special and intermediate survey, a survey planning meeting is to be held between the attending Surveyor(s), the owner's representative in attendance, the thickness measurement company operator (as applicable) and the master of the ship or an appropriately qualified representative appointed by the Company for the purpose to ascertain that all the arrangements envisaged in the survey programme are in place, so as to ensure the safe and efficient conduct of the survey work to be carried out.

(3) The following is an indicative list of items that are to be addressed in the meeting:

① schedule of the ship (i.e. the voyage, docking and undocking manoeuvres, periods alongside, cargo and ballast operations, etc.);

② provisions and arrangements for thickness measurements (i.e. access, cleaning/de-scaling, illumination, ventilation, personal safety);

③ extent of the thickness measurements;

④ acceptance criteria (refer to the list of minimum thicknesses contained in Appendix 11A "Survey Programme" of this Chapter);

⑤ extent of close-up survey and thickness measurement considering the coating condition and suspect areas/areas of substantial corrosion;

⑥ execution of thickness measurements;

⑦ taking representative readings in general and where uneven corrosion/pitting is found;

⑧ mapping of areas of substantial corrosion; and

⑨ communication between attending Surveyor(s), the thickness measurement company operator(s) and owner's representative(s) concerning findings.

5.1.6.7 Rescue and emergency response equipment

(1) If breathing apparatus and/or other equipment is used as "rescue and emergency response equipment", then it is recommended that the equipment should be suitable for the configuration of the space being surveyed.

5.1.7 Documentation on board

5.1.7.1 General requirements

(1) For ESP ships, the owner is to supply and maintain on board documentation as specified in 5.1.7.2 and 5.1.7.3, which is to be readily available for the Surveyor.

(2) The documentation is to be kept on board for the lifetime of the ship.
(3) For tankers and bulk carriers subject to SOLAS Reg. II-1/3-10, the Owner is to arrange the updating of the Ship Construction File (SCF) throughout the ship's life whenever a modification of the documentation included in the SCF has taken place. Documented procedures for updating the SCF are to be included within the Safety Management System.

5.1.7.2 Survey report file[①]

(1) A survey report file is to be a part of the documentation on board consisting of:

① reports of structural surveys;

② executive hull summary;

③ thickness measurement reports.

5.1.7.3 Supporting documents

(1) The following additional documentation is to be available on board:

① survey programme as required by 5.1.6.5 until such time as the special survey or intermediate survey, as applicable, has been completed;

② main structural plans of cargo/cargo oil and ballast tanks (for CSR ships these plans are to include for each structural element both the as-built and renewal thickness. Any thickness for voluntary addition is also to be clearly indicated on the plans. The midship section plan to be supplied on board the ship is to include the minimum allowable hull girder sectional properties for the hold/ tank transverse section in all cargo holds/tanks);

③ previous repair history;

④ cargo and ballast history;

⑤ inspection by ship's personnel with reference to:

a. structural deterioration in general;

b. leakages in bulkheads and piping;

c. condition of coating or corrosion protection, if any;

d. a guidance for reporting is shown in paragraph 2, Appendix 12 of this Chapter;

⑥ extent of use of inert gas plant and tank cleaning procedures (for oil tankers and chemical tankers);

⑦ any other information that will help identify suspect areas and/or critical structural areas requiring inspection;

⑧ Cable Transit Seal Systems Register, the owner is to maintain the Register to record any disruption (repair, modification or opening out and closing) to a cable transit or to record the installation of a new cable transit.

(2) For tankers and bulk carriers subject to SOLAS Reg. II-1/3-10, the Ship Construction File (SCF), limited to the items to be retained onboard, is to be available on board.

5.1.7.4 Review of documentation on board

(1) Prior to survey, the Surveyor is to examine the completeness of the documentation on board, and its contents as a basis for the survey.

(2) For tankers and bulk carriers subject to SOLAS Reg. II-1/3-10, on completion of the survey, the surveyor is to verify that the update of the Ship Construction File (SCF) has been done whenever a modification of the documentation included in the SCF has taken place.

① For the SCF stored on board ship, the surveyor is to examine the information on board ship. In cases where any major event, including, but not limited to, substantial repair and conversion, or any modification to the ship structures, the surveyor is to also verify that the updated information is kept on board the ship. If the updating of the SCF onboard is not completed at the time of survey, the Surveyor records it and requires confirmation at the next periodical survey.

② For the SCF stored on shore archive, the surveyor is to examine the list of information included on shore archive. In cases where any major event, including, but not limited to, substantial repair and conversion, or any modification to the ship structures, the surveyor is to also verify that the updated information is stored on shore archive by examining the list of information included on shore archive or kept on board the ship. In addition, the surveyor is to confirm that the service contract with of the Archive Center is valid. If the updating of the SCF Supplement ashore is not completed at the time of survey, the Surveyor records it and requires confirmation at the next periodical survey.

(3) For tankers and bulk carriers subject to SOLAS Reg. II-1/3-10, on completion of the survey, the

① Survey report files are available from the Headquarters of CCS and the owner.

surveyor is to verify any addition and/or renewal of materials used for the construction of the hull structure are documented within the Ship Construction File list of materials.

5.1.8 Reporting and evaluation of survey

5.1.8.1 The data and information on the structural condition of the ship collected during the survey is to be evaluated for acceptability and continued structural integrity of the ship.

(1) For CSR bulk carriers, the ship's longitudinal strength is to be evaluated by using the thickness of structural members measured, renewed and reinforced, as appropriate, during the special surveys carried out after the ship reached 15 years of age (or during the special survey no. 3, if this is carried out before the ship reaches 15 years of age) in accordance with the criteria for longitudinal strength of the ship's hull girder for CSR bulk carriers specified in Common Structural Rules[①].

(2) The final result of evaluation of the ship's longitudinal strength required in (1), after renewal or reinforcement work of structural members, if carried out as a result of initial evaluation, is to be reported as a part of the Executive Hull Summary.

5.1.8.2 Principles for survey reporting are given in Appendix 11 of this Chapter.

5.1.8.3 When a survey is split between different survey units of CCS, a report is to be completed by the survey unit implementing the commencement or intermediate stage of the enhanced survey. A list of items examined and/or tested (pressure testing, thickness measurements, etc.) and an indication of whether the item has been credited, are to be made available to the next survey unit and/or attending Surveyor(s), prior to continuing or completing the survey.

5.1.8.4 An executive hull summary (see Appendix 11 of this Chapter) is to be summarized and developed by the survey unit completing the enhanced survey, and upon verification and endorsement by CCS authorized person, the executive hull summary is to be issued to the owner and placed on board the ship for reference at future surveys.

5.1.9 Procedures for thickness measurements

5.1.9.1 General requirements

(1) Except for 5.1.9.3, this paragraph applies to all ships.

(2) The required thickness measurements, if not carried out by CCS itself, are to be witnessed by an attending Surveyor of CCS.

(3) The thickness measurement company is to be part of the survey planning meeting prior to the commencement of the survey. The following are to be agreed during the meeting:

① reporting of thickness measurements on regular basis;

② prompt notification to the Surveyor in case of findings such as:

a. excessive and/or extensive corrosion or pitting/grooving of any significance;
b. structural defects like buckling, fractures and deformed structures;
c. detached and/or holed structure; and
d. corrosion of welds.

(4) Thickness measurements of structures in areas where close-up surveys are required are to be carried out simultaneously with close-up surveys.

(5) In all cases the extent of the thickness measurements is to be sufficient as to represent the actual average condition.

5.1.9.2 Thickness measurement

(1) The thickness measurements are to be carried out by a qualified company certified by CCS according to Appendix 10 of this Chapter.

5.1.9.3 Number and locations of measurements

(1) Application

This subparagraph only applies to CSR ships. For non-CSR ships, the requirements for number and locations of measurements are to be in accordance the applicable requirements of this Chapter depending on ship's age and structural elements concerned.

(2) Number of measurements

Considering the extent of thickness measurements according to the different structural elements of the ship and surveys (special, intermediate and annual), the locations of the points to be measured are given for the most important items of the structure.

(3) Locations of measurements

Tables 5.1.9.3(3)a to c provide explanations and/or interpretations for the application of those requirements

---

① Chapter 13, PART TEN of the Rules (2012 version) and its 2013 and 2014 amendments or Chapter 13, PART 9-1 of the Rules (2015 version) and its subsequent versions (including amendments).

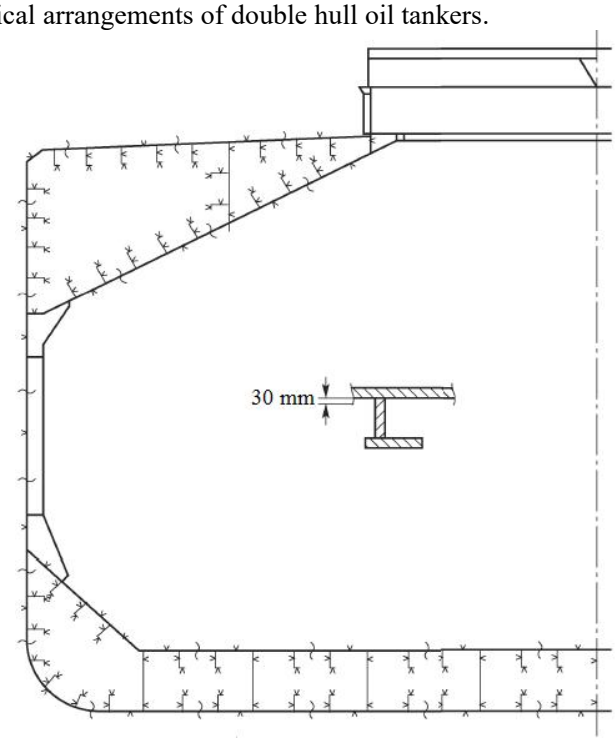
indicated in CSR rules, which refer to both systematic thickness measurements related to the calculation of global hull girder strength and specific measurements connected to close-up surveys.

Interpretations of Rule Requirements for the Locations and Number of Points to Be Measured for CSR Bulk Carriers (Single Skin) Table 5.1.9.3(3)a

Item	Interpretation	Figure reference
Selected plates on deck, tank top, bottom, double bottom and wind-and-water area	"Selected" means at least a single point on one out of three plates, to be chosen on representative areas of average corrosion	
All deck, tank top and bottom plates and wind-and-water strakes	At least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion	
Transverse section	A transverse section includes all longitudinal members such as plating, longitudinals and girders at the deck, side, bottom; inner bottom and hopper side plating, longitudinal bulkhead and bottom plating in top wing tanks	Figure 5.1.9.3(3)a
All cargo hold hatch covers and coamings	Including plates and stiffeners	Locations of points are given in Figure 5.1.9.3(3)b
Transverse section of deck plating outside line of cargo hatch openings	Two single points on each deck plate (to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion) between the ship sides and hatch coamings in the transverse section concerned	
All deck plating and underdeck structure inside line of hatch openings between cargo hold hatches	"All deck plating" means at least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion. "Under deck structure": at each short longitudinal girder: three points for web plating (fwd/middle/aft), single point for face plate, one point for web plating and one point for face plating of transverse beam in way. At each end of transverse beams, one point for web plating and one point for face plating	Extent of areas is shown in Sheet 14 of paragraph 13.2B, Appendix 13 of this Chapter; Location of points are given in Figure 5.1.9.3(3)f
Selected side shell frames in cargo holds	Including side shell frames, upper and lower end attachments and adjacent shell plating. 25% of frames: one out of four frames should preferably be chosen throughout the cargo hold length on each side. 50% of frames: one out of two frames should preferably be chosen throughout the cargo hold length on each side. "Selected frames" means at least 3 frames on each side of cargo holds	Extent of areas is shown in Sheet 14 of paragraph 13.2B, Appendix 13 of this Chapter; Locations of points are given in Figure 5.1.9.3(3)c
Transverse bulkheads in cargo holds	Including bulkhead plating, stiffeners and girders, and including internal structure of upper and lower stools, where fitted. Two selected bulkheads: one is to be the bulkhead between the two foremost cargo holds and the second may be chosen in other positions	Areas of measurements are shown in Sheet 14 of paragraph 13.2B, Appendix 13 of this Chapter; Locations of points are given in Figure 5.1.9.3(3)d
One transverse bulkhead in each cargo hold	This means that the close-up survey and related thickness measurements are to be performed on one side of the bulkhead; the side is to be chosen based on the outcome of the overall survey of both sides. In the event of doubt, the Surveyor may also require (possibly partial) close-up survey on the other side	Areas of measurements are shown in Sheet 14 of paragraph 13.2B, Appendix 13 of this Chapter; Locations of points are given in Figure 5.1.9.3(3)d
Transverse bulkheads in one topside, hopper and double bottom ballast tank	Including bulkhead and stiffening systems. The ballast tank is to be chosen based on the history of ballasting among those prone to have the most severe conditions	Locations of points are given in Figure 5.1.9.3(3)e
Transverse webs in ballast tanks	Including web plating, face plates, stiffeners and associated plating and longitudinals. One of the representative tanks of each type (i.e. topside or hopper or side tank) is to be chosen in the forward part	Areas of measurements are shown in Sheet 14 of paragraph 13.2B, Appendix 13 of this Chapter; Locations of points are given in

Item	Interpretation	Figure reference
		Figure 5.1.9.3(3)c

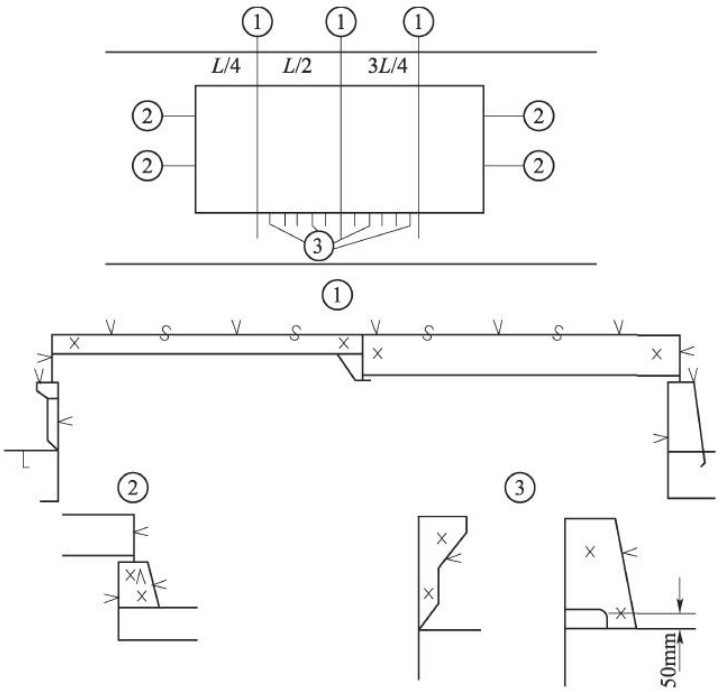
For facilitating the explanations and/or interpretations given in Tables 5.1.9.3(3)a to c, Figures 5.1.9.3(3)a to f are provided to show typical arrangements of single side skin bulk carriers, and Figures 5.1.9.3(3)g to l are provided to show typical arrangements of double side skin bulk carriers and Figures 5.1.9.3(3)m to p are provided to show typical arrangements of double hull oil tankers.



Single side bulk carrier

Note: Measurements are to be taken on both port and starboard sides of the selected transverse section.

Figure 5.1.9.3(3)a Transverse Section of a Single Skin Bulk Carrier

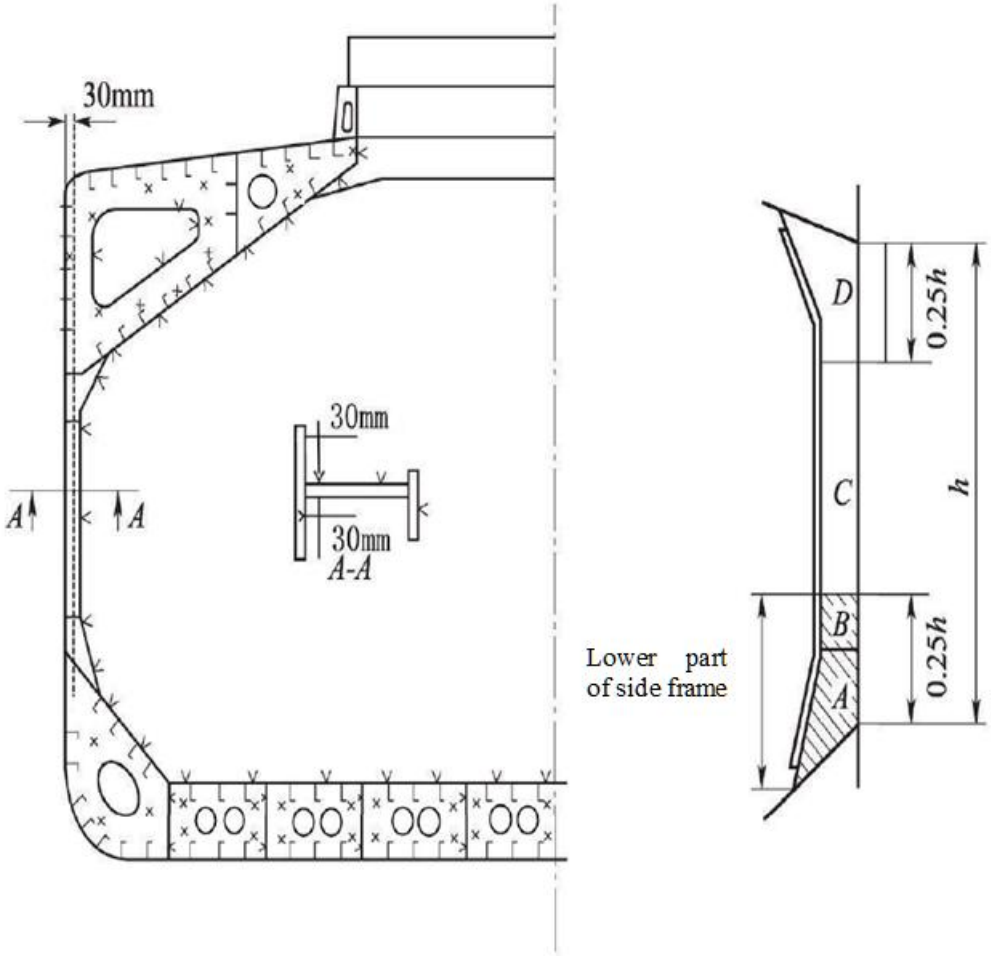


Notes:

1. Three sections at $L/4$, $L/2$, $3L/4$ of hatch cover length, including:
   - one measurement of each hatch cover plate and skirt plate;
   - measurements of adjacent beams and stiffeners;
   - one measurement of coaming plates and coaming flange, each side.

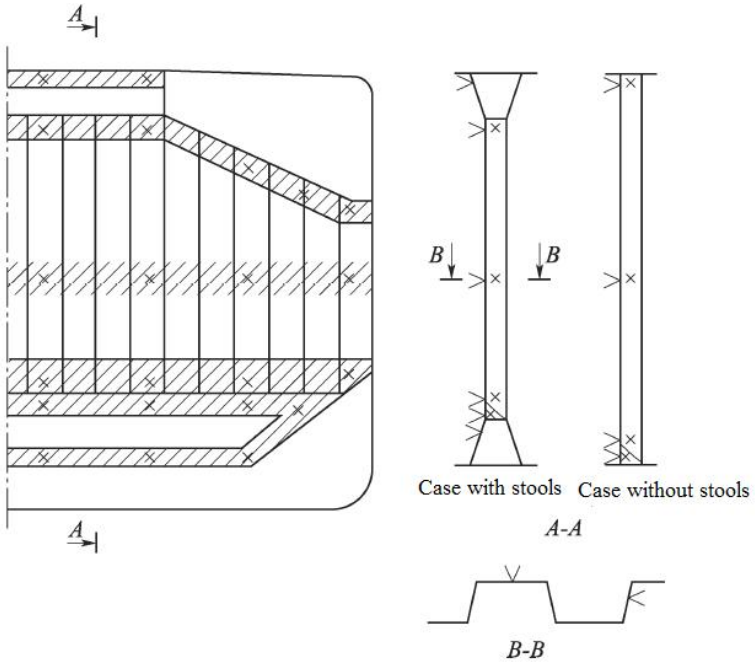
2. Measurements of both ends of hatch cover skirt plate, coaming plate and coaming flange.
3. One measurement (two points for web plate and one point for face plate) of one out of three hatch coaming brackets and bars, on both sides and both ends.

Figure 5.1.9.3(3)b Locations of Measurements on Hatch Covers and Coamings



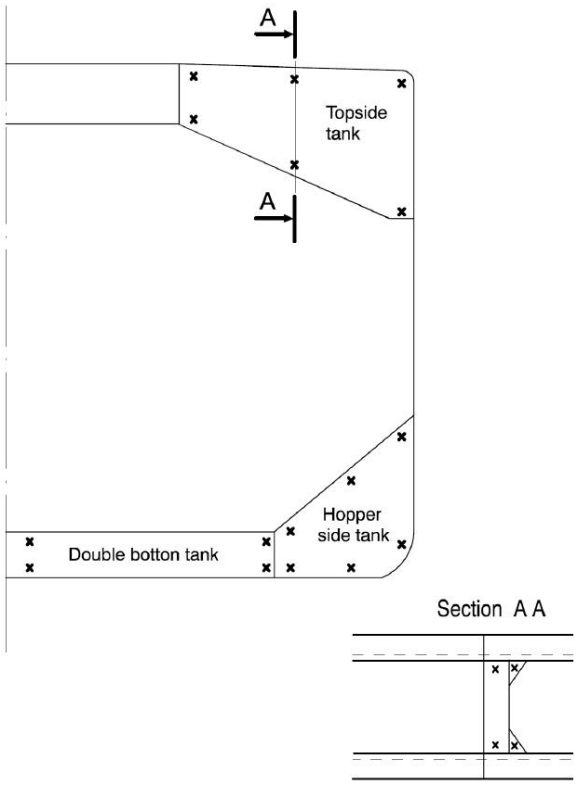
Note: The gauging pattern for web plating is to be a three point pattern for zones A, C and D, and a two point pattern for zone B (see Figure). The gauging report is to reflect the average reading. The average reading is to be compared with the allowable thickness. If the web plating has general corrosion, then this pattern is to be expanded to a five-point pattern.

Figure 5.1.9.3(3)c Locations of Measurements on Structural Members in Cargo Holds and Ballast Tanks of Single Side Skin Bulk Carriers



Note: Measurements to be taken in each shaded area as per views A - A and B - B.

Figure 5.1.9.3(3)d Locations of Measurements on Cargo Hold Transverse Bulkheads (additional measurements to internal structure of upper and lower stools to be added, e. g. two points in the upper and two points in the lower stools to be indicated in section A - A)



Note: Measurements to be taken in each vertical section as per view A - A.

Figure 5.1.9.3(3)e
Locations of Measurements on Transverse Bulkheads of Topside, Hopper and Double Bottom Tanks (two additional measurements to internal structure of double bottom tank to be added at midspan)

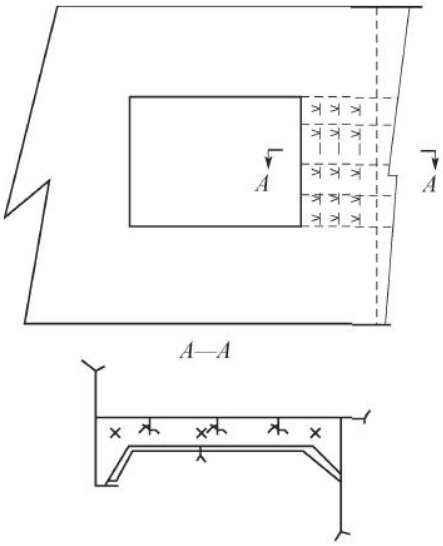
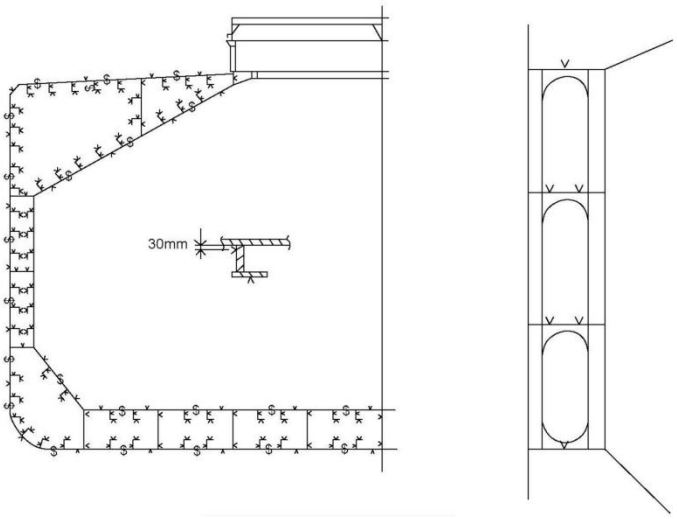


Figure 5.1.9.3(3)f Locations of Measurements on Underdeck Structure

Interpretations of Rule Requirements for the Locations and Number of Points to Be Measured for CSR Bulk Carriers (Double Skin) **Table 5.1.9.3(3)b**

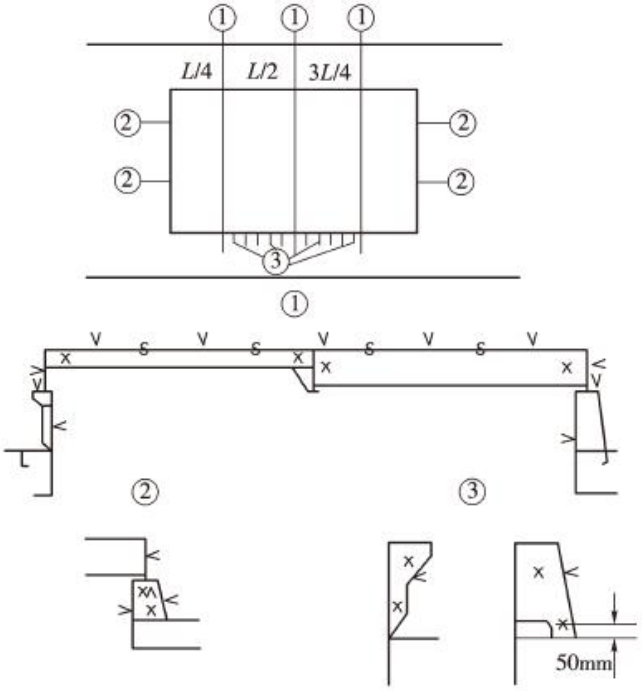
Item	Interpretation	Figure reference
Selected plates on deck, tank top, bottom, double bottom and wind-and-water area	"Selected" means at least a single point on one out of three plates, to be chosen on representative areas of average corrosion	
All deck, tank top and bottom plates and wind-and-water strakes	At least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion	
Transverse section	A transverse section includes all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom, hopper sides, inner sides and top wing inner sides	Figure 5.1.9.3(3)g
All cargo hold hatch covers and coamings	Including plates and stiffeners	Locations of points are given in Figure 5.1.9.3(3)h
Transverse section of deck plating outside line of cargo hatch openings	Two single points on each deck plate (to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion) between the ship sides and hatch coamings in the transverse section concerned	
All deck plating and underdeck structure inside line of hatch openings between cargo hold hatches	"All deck plating" means at least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion. "Under deck structure": at each short longitudinal girder: three points for web plating (fwd/middle/aft), single point for face plate, one point for web plating and one point for face plating of transverse beam in way. At each end of transverse beams, one point for web plating and one point for face plating	Extent of areas is shown in Sheet 13 of paragraph 13.4B, Appendix 13 of this Chapter; Locations of points are given in Figure 5.1.9.3(3)l
Transverse frames in double skin tank		Figure 5.1.9.3(3)g
Transverse bulkheads in cargo holds	Including bulkhead plating, stiffeners and girders, and including internal structure of upper and lower stools, where fitted. Two selected bulkheads: one is to be the bulkhead between the two foremost cargo holds and the second may be chosen in other positions	Areas of measurements are shown in Sheet 13 of paragraph 13.4B, Appendix 13 of this Chapter; Locations of points are given in Figure 5.1.9.3(3)j
One transverse bulkhead in each cargo hold	This means that the close-up survey and related thickness measurements are to be performed on one side of the bulkhead; the side is to be chosen based on the outcome of the overall survey of both sides. In the event of doubt, the Surveyor may also require (possibly partial) close-up survey on the other side	Areas of measurements are shown in Sheet 13 of paragraph 13.4B, Appendix 13 of this Chapter; Locations of points are given in Figure 5.1.9.3(3)j
Transverse bulkheads in one topside, hopper and double bottom ballast tank	Including bulkhead and stiffening systems. The ballast tank is to be chosen based on the history of ballasting among those prone to have the most severe conditions	Locations of points are given in Figure 5.1.9.3(3)k
Transverse webs in ballast tanks	Including web plating, face plates, stiffeners and associated plating and longitudinals. One of the representative tanks of each type (i.e. topside or hopper or side tank) is to be chosen in the forward part	Areas of measurements are shown in Sheet 13 of paragraph 13.4B, Appendix 13 of this Chapter; Locations of points are given in Figure 5.1.9.3(3)i



Double skin bulk carrier

Note: Measurements are to be taken on both port and starboard sides of the selected transverse section.

Figure 5.1.9.3(3)g Transverse Section of a Double Skin Bulk Carrier



Notes:

1. Three sections at $L/4$, $L/2$, $3L/4$ of hatch cover length, including:
   - one measurement of each hatch cover plate and skirt plate;
   - measurements of adjacent beams and stiffeners;
   - one measurement of coaming plates and coaming flange, each side.
2. Measurements of both ends of hatch cover skirt plate, coaming plate and coaming flange.
3. One measurement (two points for web plate and one point for face plate) of one out of three hatch coaming brackets and bars, on both sides and both ends.

Figure 5.1.9.3(3)h Locations of Measurements on Hatch Covers and Coamings

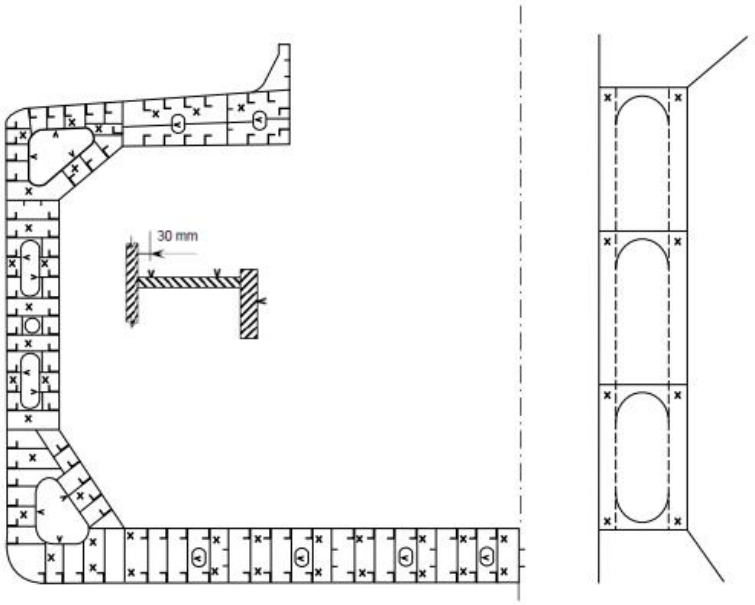
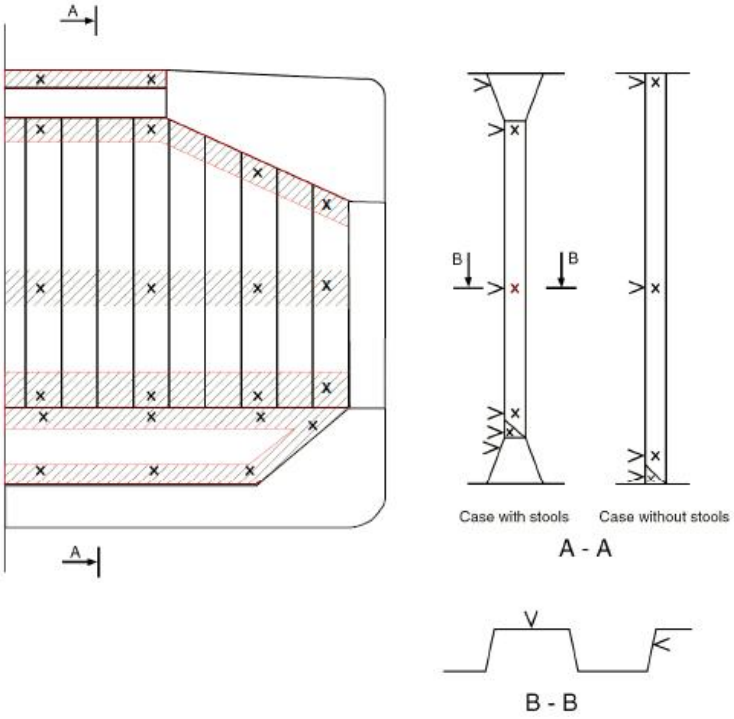
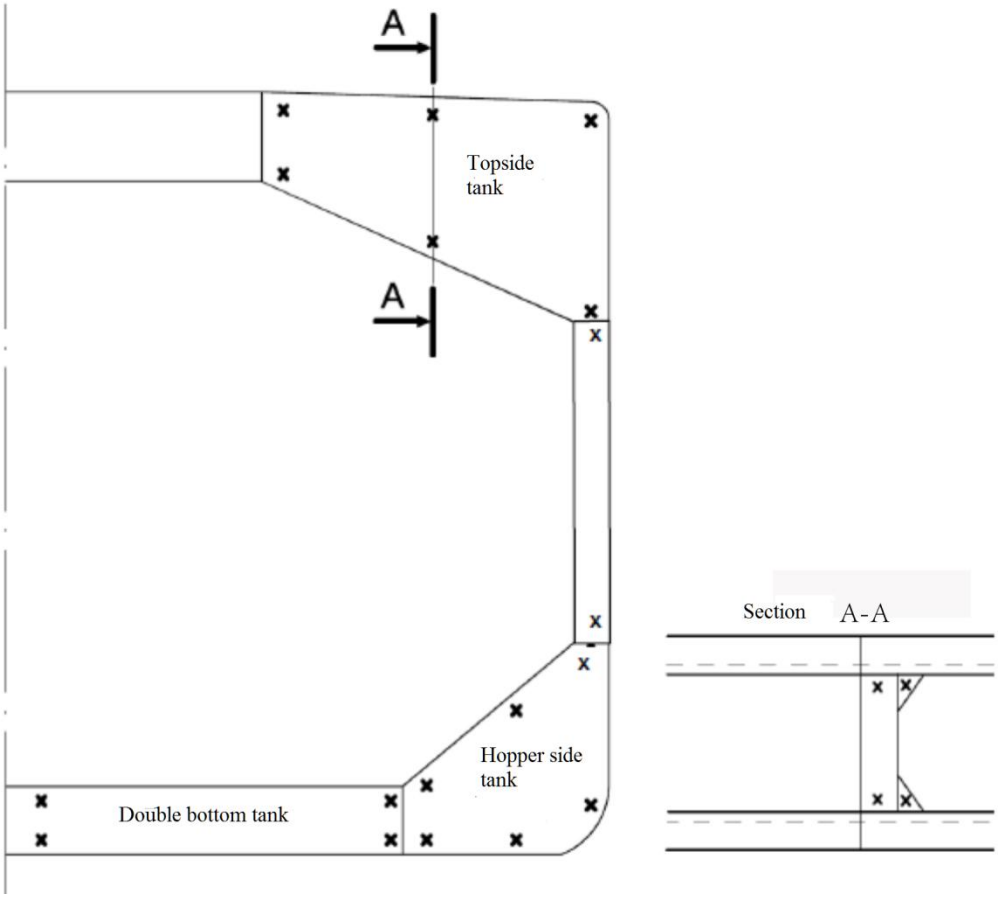


Figure 5.1.9.3(3)i
Locations of Measurements on Structural Members in Ballast Tanks of Double Skin Bulk Carriers (Topside or Hopper or Side Tank)



Note: Measurements to be taken in each shaded area as per views A - A and B - B.

Figure 5.1.9.3(3)j
Locations of Measurements on Cargo Hold Transverse Bulkheads (additional measurements to internal structure of upper and lower stools to be added, e.g. two points in the upper and two points in the lower stools to be indicated in section A - A)



Note: Measurements to be taken in each vertical section as per view A - A.

Figure 5.1.9.3(3)k

Locations of Measurements on Transverse Bulkheads of Topside, Hopper and Double Bottom Tanks (two additional measurements to internal structure of double bottom tank to be added at midspan)

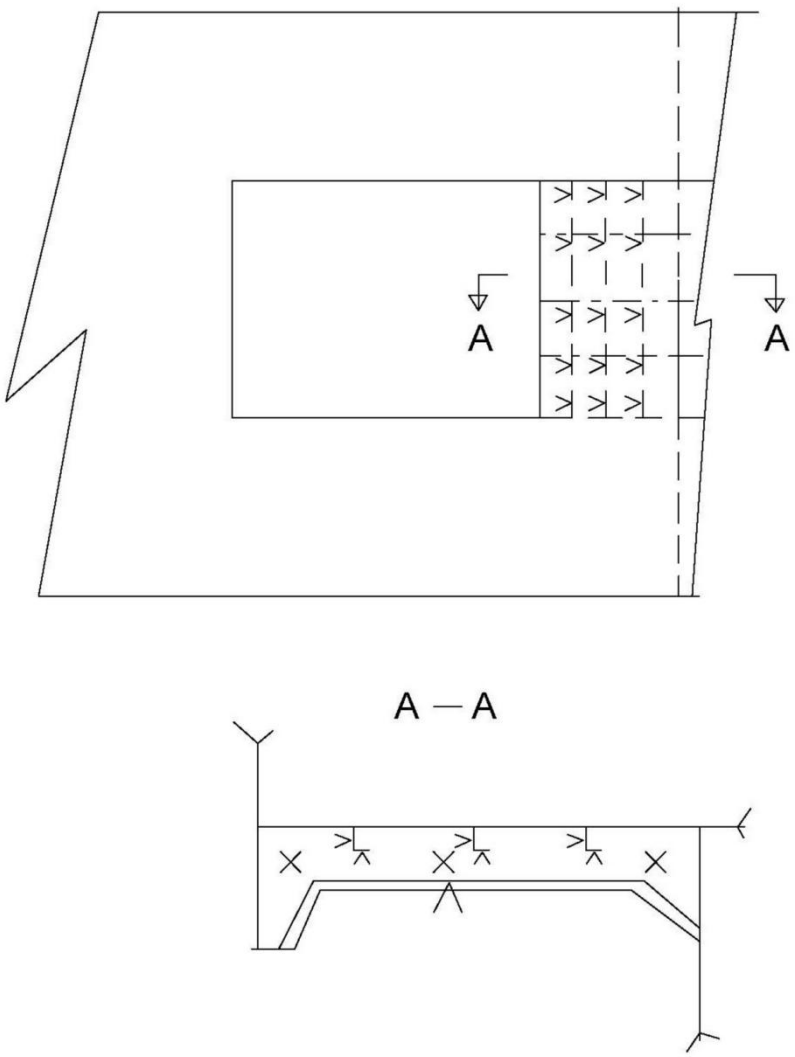


Figure 5.1.9.3(3)l Locations of Measurements on Underdeck Structure

Interpretations of Rule Requirements for the Locations and Number of Points to Be Measured for CSR Oil Tankers **Table 5.1.9.3(3)c**

Item	Interpretation	Figure reference
Selected plates	"Selected" means at least a single point on one out of three plates, to be chosen on representative areas of average corrosion	
Deck, bottom plates and wind-and-water strakes	At least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion	
Transverse section	Measurements to be taken on all longitudinal members such as plating, longitudinals and girders at the deck, side, bottom, longitudinal bulkheads, inner bottom and hopper. One point to be taken oneach plate. Both web and flange to be measured on longitudinals, if applicable. For tankers older than 10 years of age: within 0.1*D* (where *D* is the moulded depth) of the deck and bottom at each transverse section to be measured, every longitudinal and girder is to be measured on the web and face plate, and every plate is to be measured at one point between longitudinals	Figure 5.1.9.3(3)m
Transverse rings① in cargo and ballast tanks	At least two points on each plate in a staggered pattern and two points on the corresponding flange where applicable. Minimum 4 points on the first plate below deck. Additional points in way of curved parts. At least one point on each of two stiffeners between stringers/ longitudinal	Figure 5.1.9.3(3)n
Transverse bulkheads in cargo tanks	At least two points on each plate. Minimum 4 points on the first plate below main deck. At least one point on every third stiffener to be taken between each stringer. At least two points on each plate of stringers and girders, and two points on the corresponding flange. Additional points in way of curved part. Two points of each diaphragm plate of stools if fitted	Figure 5.1.9.3(3)o
Transverse bulkheads in ballast tanks	At least 4 points on plates between stringers/longitudinal girders, or per plate if stringers/girders not fitted. At least two points on each plate of stringers and girders, and two points on the corresponding flange. Additional points in way of curved part. At least one point on two stiffeners between each stringer/longitudinal girder	Figure 5.1.9.3(3)p
Adjacent structural members	On adjacent structural members one point per plate and one point on every third stiffener/longitudinal	

① Transverse rings means all transverse material appearing in a cross-section of the ship's hull, in way of a double bottom floor, vertical web and deck transverse.

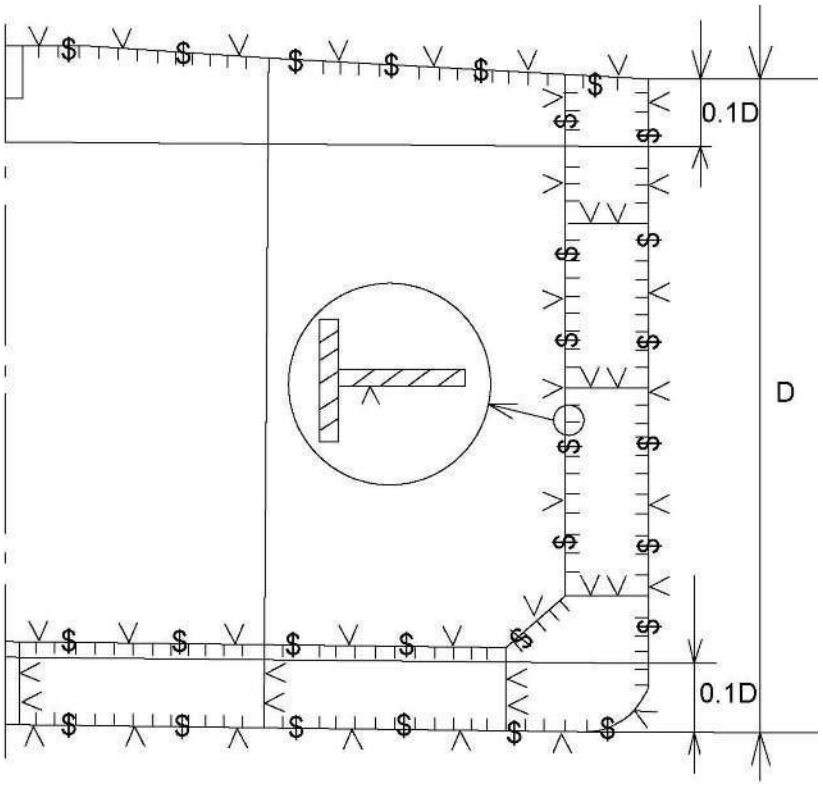


Figure 5.1.9.3(3)m Transverse Section

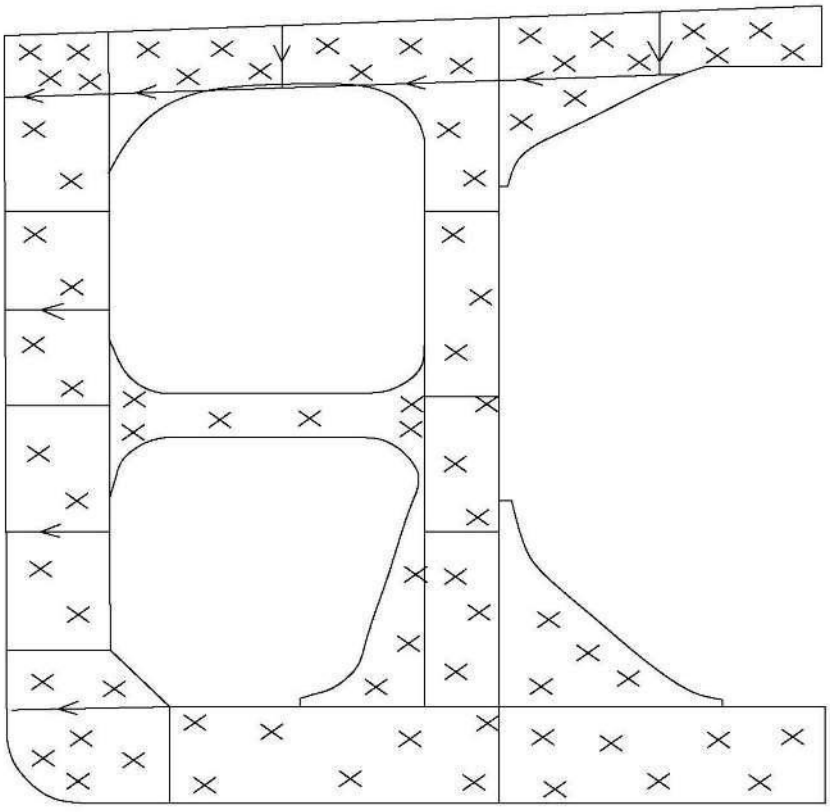


Figure 5.1.9.3(3)n Transverse Rings in Cargo and Ballast Tanks

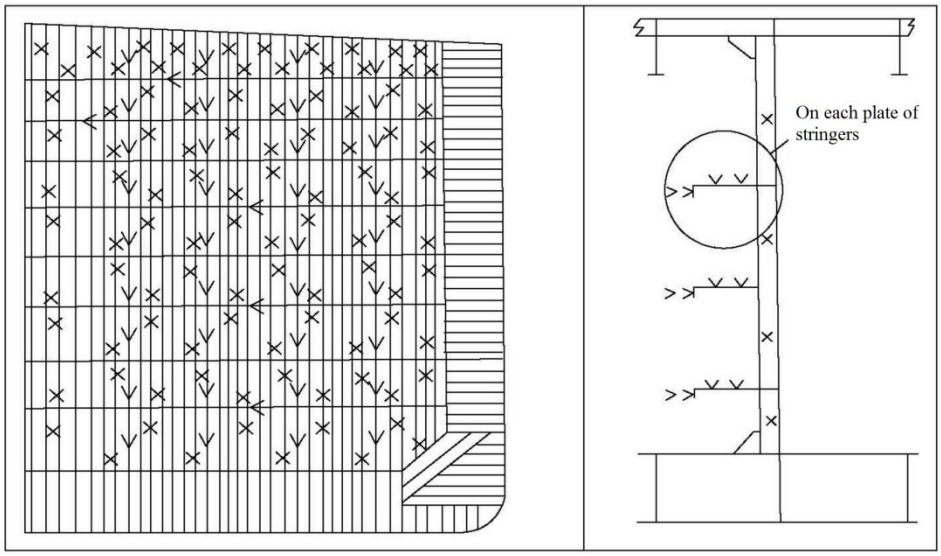


Figure 5.1.9.3(3)o Transverse Bulkheads in Cargo Tanks

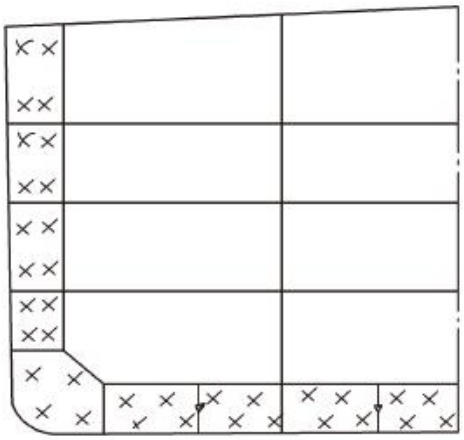


Figure 5.1.9.3(3)p Transverse Bulkheads in Ballast Tanks

5.1.9.4 Reporting

(1) A thickness measurement report is to be prepared. The report is to give the location of measurements, the thickness measured as well as corresponding original thickness. Furthermore, the report is to give the date when the measurements were carried out, type of measurement equipment, names of personnel and their qualifications and has to be signed by the operator. The thickness measurement report is to follow the principles as specified in the Recommended Procedures for Thickness Measurements contained in Appendix 10 of this Chapter.

(2) The Surveyor is to review the final thickness measurement report and countersign the cover page.

5.1.9.5 Monitoring of the thickness measurement process onboard

(1) The Surveyor is to decide final extent and location of thickness measurements after completion of overall survey of representative spaces onboard.

(2) In case the owner prefers to commence the thickness measurements prior to the overall survey, then the Surveyor is to require that the planned extent and locations of thickness measurements are subject to confirmation during the overall survey. If necessary, the Surveyor may require additional thickness measurements to be taken.

(3) The Surveyor is to direct the gauging operation by selecting locations such that readings taken represent, on average, the condition of the structure for that area.

(4) Thickness measurements taken mainly to evaluate the extent of corrosion, which may affect the hull girder strength, are to be carried out in a systematic manner such that all longitudinal structural members are gauged, as required.

(5) Where thickness measurements indicate substantial corrosion or wastage in excess of allowable diminution, the Surveyor is to direct locations for additional thickness measurements in order to delineate areas of substantial corrosion and to identify structural members for repairs/renewals.

5.1.9.6 Review and verification

(1) Upon completion of the thickness measurements, the Surveyor is to confirm that no further gaugings are needed, or if necessary, specify additional gaugings.

(2) Where any reduction is allowed to the extent of thickness measurements after special considerations by the Surveyor, these special considerations are to be reported, where appropriate.

(3) In case thickness measurements are partly carried out, the extent of remaining thickness measurements is to be reported for the use of the next Surveyor.

5.1.10 Repairs

5.1.10.1 Any damage in association with wastage over the allowable limits (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the ship's structural, watertight or weathertight integrity, is to be promptly and thoroughly repaired (see 5.1.5.1(8)).

(1) Areas to be considered for all ships include:

① side shell frames, their end attachments and adjacent shell plating;

② deck structure and deck plating;

③ bottom structure and bottom plating;

④ watertight or oiltight bulkheads;

⑤ hatch covers and coamings;

⑥ items in 5.4.2.2(2)⑥.

(2) Consideration is to be given to adding the following areas for bulk carriers including double side skin bulk carriers:

① side structure and side plating;

② inner bottom structure and inner bottom plating;

③ inner side structure and inner side plating;

④ annual survey items in 5.7.2.3(7) of Section 7 of this Chapter.

(3) Consideration is to be given to adding the following areas for oil tankers including double hull oil tankers:

① side structure and side plating;

② hatch covers or hatch coamings, where fitted (combination carriers).

(4) If it is difficult to complete the above repairs in the port where the above defects are found and with the consent of CCS, consideration may be given to allow the ship to proceed directly to a port with adequate repair facilities for completing the repairs. This may require discharging the cargo and/or temporary repairs for the intended voyage.

(5) Where the damage found on structure mentioned in paragraph 5.1.10.1(1) is isolated and of a localised nature which does not affect the ship's structural integrity, consideration may be given by the Surveyor to allow an appropriate temporary repair to restore watertight or weathertight integrity and impose a condition of class as required, with a specific time limit.

5.1.10.2 When a survey results in the identification of substantial corrosion or structural defects, either of which, in the opinion of the Surveyor, will impair the ship's fitness for continued service, remedial measures are to be implemented before the ship continues in service.

5.1.10.3 Where repairs to hull, machinery or equipment, which affect or may affect classification, are to be carried out by a riding crew during a voyage, they are to be planned in advance. A complete repair procedure including the extent of proposed repair and the need for Surveyor's attendance during the voyage is to be submitted to and agreed by CCS reasonably in advance. Failure to notify CCS, in advance of the repairs, may result in suspension of the ship's class. For surveys of voyage repairs, refer to Appendix 7 of this Chapter.

5.1.10.4 The ship's repairs are to be in compliance with Appendix 2 to Chapter 4 of this PART − Shipbuilding and Repair Quality Standard or the recognized standards acceptable to CCS.

5.1.11 Thickness measurements and close-up surveys

5.1.11.1 In any type of survey, i.e. special, intermediate, annual or other surveys having the scope of the foregoing ones, thickness measurements of structures in areas where close-up surveys are required, are to be carried out simultaneously with close-up surveys.

5.1.11.2 Consideration may be given by the attending Surveyor to allow use of Remote Inspection Techniques (RIT) as an alternative to close-up survey. Surveys conducted using a RIT are to be completed to the satisfaction of the attending Surveyor. When RIT is used for a close-up survey, temporary means of access for the corresponding thickness measurements as specified in this Chapter is to be provided unless such RIT is also able to carry out the required thickness measurements.

5.1.11.3 For structure built with a material other than steel, alternative thickness measurement requirements may be developed and applied as deemed necessary by CCS.

5.1.12 ESP Survey

5.1.12.1 On ships of 20,000 tonnes DWT and above, subject to ESP, starting with special survey No.3 at special and intermediate hull classification surveys, surveys of hull structures and piping systems in way of cargo holds / cargo tanks, cofferdams, cargo pump rooms, pipe tunnels, void spaces and the selected fuel oil tanks of bulk carriers within the cargo length area and all ballast tanks are to be performed by at least two qualified exclusive Surveyors at the same time.

5.1.12.2 On bulk carriers of single side skin construction and 100,000 DWT and above, the intermediate hull classification survey between 10 and 15 years of age, surveys of hull structures and piping systems in way of cargo holds, cofferdams, pipe tunnels, void spaces and the selected fuel oil tanks within the cargo length area and all ballast tanks are to be performed by at least two qualified exclusive Surveyors at the same time.

5.1.12.3 Where compatible with relevant laws and regulations, on dual class ships, the requirement for two Surveyors in 5.1.12.1 and/or 5.1.12.2 may be fulfilled by having one Surveyor attend from CCS and the Society related to the dual class.

5.1.13 Owner's hull inspection and maintenance schemes

5.1.13.1 CCS encourages owners to implement hull inspection and maintenance schemes as a means for maintaining compliance with classification and statutory requirements between surveys. However, these schemes are not to be accepted as an alternative to, or a substitute for, the performance of required classification and/or statutory surveys of the hull by CCS Surveyors. Where the hull inspection and maintenance scheme complies with relevant requirements of CCS Guidelines for Hull Inspection and Maintenance Scheme, class notation HIMS may be assigned.

5.1.14 Attendance for survey of ships detained by port States

5.1.14.1 The owner or the master is to notify CCS on all occasions when a ship is being detained by a port State authority, or the flag Administration has found deficiencies which affect the ship's classification or statutory certificates issued by CCS, prior to the ship's departure in order that CCS Surveyor may attend and carry out a survey for the purpose of assessing and insuring the correction, if necessary, of the reported deficiencies or other matters which affect or may affect classification or the validity of statutory certificates issued by CCS. If the Surveyor is not able to attend for any reason, CCS will notify the owner to arrange for attendance in the next port of call.

5.1.14.2 Should an owner not notify CCS of a detention, then CCS reserves the right to suspend or cancel classification of the ship or invalidate the related statutory certificate(s).

5.1.15 Attendance at port State request

5.1.15.1 In cooperation with the port State, CCS Surveyor will attend on board a classed ship when so requested by the Port State, and upon concurrence by the ship's master, will carry out a survey in order to facilitate the rectification of reported deficiencies or other discrepancies that affect or may affect classification.

5.1.15.2 CCS Surveyor will also provide inspectors of the port State with background information (e.g. conditions of class, due dates of surveys, and expiry dates of certificates), if requested.

5.1.16 Ships' safety management system

5.1.16.1 If during any survey, the attending CCS Surveyor finds evidence that the ship's safety management system is not in operation or functioning as required by the ISM Code, this will be communicated to the relevant flag Administration or the organization which issued the Safety Management Certificate on behalf of the flag Administration for their consideration and action.

5.1.17 Acceptance criteria

(1) General

① For CSR ships, the acceptance criteria are in accordance with Common Structural Rules[①] and as specified in (2) to (4) below.

② For non-CSR ships, the acceptance criteria are in accordance with the relevant requirements of Appendix 1 of this Chapter depending on ship's age and structural elements concerned, e.g. where applicable, 2.4 for corrugated transverse watertight bulkheads, 2.7 for the corrugated transverse watertight bulkheads between cargo holds Nos.1 and 2, 2.5 for all cargo hatch covers and hatch forward and side coamings on exposed decks in position 1, as defined in ILLC and 2.8 for side shell frames.

(2) Acceptance criteria for pitting corrosion of CSR ships

① Side structures of bulk carriers

If pitting intensity in an area where coating is required, according to Common Structural Rules[②] is higher than 15% (see Figure 5.1.5.1(20)), thickness measurements are to be performed to check the extent of pitting corrosion. The 15% is based on pitting or grooving on only one side of a plate.

In cases where pitting is exceeding 15%, as defined above, an area of 300 mm or more, at the most pitted part of the plate, is to be cleaned to bare metal and the thickness is to be measured in way of the five deepest pits within the cleaned area. The least thickness measured in way of any of these pits is to be taken as the thickness to be recorded.

The minimum remaining thickness in pits, grooves or other local areas is to be greater than:

(a) 75% of the as-built thickness, in the frame and end brackets webs and flanges;

(b) 70% of the as-built thickness, in the side shell, hopper tank and topside tank plating attached to the each side frame, over a width up to 30 mm from each side of it,

without being greater than t_{ren}.

② Other structures

For plates with pitting intensity less than 20% (see Figure 5.1.5.1(20)), the measured thickness t_m of any individual measurement is to meet the lesser of the following criteria:

$$t_m \geq 0.7\ (t_{as-built} - t_{vol\ add})\ \text{mm}$$

$$t_m \geq t_{ren} - 1\ \ \text{mm}$$

where:

$t_{as\text{-}built}$ As-built thickness of the member, in mm;

$t_{vol\ add}$ Voluntary thickness addition; thickness, in mm, voluntarily added as the Owner's extra margin for corrosion wastage in addition to t_C;

t_{ren} Renewal thickness; minimum allowable thickness, in mm, below which renewal of structural members is to be carried out. For oil tankers, t_{ren} is renewal criteria for general

---

① Section 12 "Ship in Operation Renewal Criteria", PART NINE and Chapter 13 "Ships in Operation, Renewal Criteria", PART TEN of the Rules (2012 version) and its 2013 and 2014 amendments or Chapter 13, PART 9-1 of the Rules (2015 version) and its subsequent versions (including amendments).

② Section 5, Chapter 3 of PART TEN of the Rules (2012 version) and its 2013 and 2014 amendments or Section 4, Chapter 3, PART 9-1 of the Rules (2015 version) and its subsequent versions (including amendments).

corrosion as defined in Common Structural Rules[①];

t_C Total corrosion addition, in mm, defined in Common Structural Rules[②];

t_m Measured thickness, in mm, on one item, i.e. average thickness on one item using the various measurements taken on this same item during periodical ship's in service surveys.

The average thickness across any cross section in the plating is not to be less than the renewal criteria for general corrosion given in Common Structural Rules[③].

(3) Acceptance criteria for edge corrosion of CSR ships

① Provided that the overall corroded height of the edge corrosion of the flange, or web in the case of flat bar stiffeners, is less than 25%, see Figure 5.1.5.1(21), of the stiffener flange breadth or web height, as applicable, the measured thickness, t_m, is to meet the lesser of the following criteria:

$$t_m \geq 0.7\ (t_{as-built} - t_{vol\ add})\ \text{mm}$$

$$t_m \geq t_{ren} - 1\ \text{mm}$$

② The average measured thickness across the breadth or height of the stiffener is not to be less than that defined in Common Structural Rules[④].

③ Plate edges at openings for manholes, lightening holes etc. may be below the minimum thickness given in Common Structural Rules[①] provided that:

(a) the maximum extent of the reduced plate thickness, below the minimum given in Common Structural Rules[①], from the opening edge is not more than 20% of the smallest dimension of the opening and does not exceed 100 mm;

(b) rough or uneven edges may be cropped-back provided that the maximum dimension of the opening is not increased by more than 10% and the remaining thickness of the new edge is not less than t_{ren} – 1 mm.

(4) Acceptance criteria for grooving corrosion of CSR ships

① Where the groove breadth is a maximum of 15% of the web height, but not more than 30 mm, see Figure 5.1.5.1(22), the measured thickness, t_m, in the grooved area is to meet the lesser of the following criteria:

$$t_m \geq 0.75\ (t_{as-built} - t_{vol\ add})\ \text{mm}$$

$$t_m \geq t_{ren} - 0.5\ \text{mm}$$

but is not to be less than

$$t_m = 6\ \text{mm}$$

② Structural members with areas of grooving greater than those in ①above are to be assessed based on the criteria for general corrosion as defined in Common Structural Rules[①] using the average measured thickness across the plating/stiffener.

5.1.18 Remote Inspection Techniques (RIT)[⑤]

5.1.18.1 The RIT is to provide the information normally obtained from a close-up survey. RIT surveys are to be carried out in accordance with the requirements given here-in and the requirements of IACS Recommendation 42 'Guidelines for Use of Remote Inspection Techniques for surveys'. These considerations are to be included in the proposals for use of a RIT which are to be submitted in advance of the survey so that satisfactory arrangements can be agreed with CCS.

5.1.18.2 The equipment and procedure for observing and reporting the survey using a RIT are to be discussed and agreed with the parties involved prior to the RIT survey, and suitable time is to be allowed to set-up, calibrate and test all equipment beforehand.

5.1.18.3 When using a RIT as an alternative to close-up survey, if not carried out by CCS itself, it is to be conducted by a firm approved as a service supplier according to Appendix 8 of this Chapter and is to be witnessed by an attending surveyor of CCS.

5.1.18.4 The structure to be examined using a RIT is to be sufficiently clean to permit meaningful

---

① 1.4.2.1, Section 12, PART NINE of the Rules (2012 version) and its 2013 and 2014 amendments or 2.1.1, Section 2, Chapter 13, PART 9-1 of the Rules (2015 version) and its subsequent versions (including amendments).

② Section 3, Chapter 3, PART TEN of the Rules (2012 version) and its 2013 and 2014 amendments or Section 3, Chapter 3, PART 9-1 of the Rules (2015 version) and its subsequent versions (including amendments).

③ 1.4.2.1, Section 12, PART NINE or Chapter 13, PART TEN of the Rules (2012 version) and its 2013 and 2014 amendments or Chapter 13, PART 9-1 of the Rules (2015 version) and its subsequent versions (including amendments).

④ 1.4.2, Section 12, PART NINE or Chapter 13, PART TEN of the Rules (2012 version) and its 2013 and 2014 amendments or Chapter 13, PART 9-1 of the Rules (2015 version) and its subsequent versions (including amendments).

⑤ Remote Inspection Techniques (RIT) is applicable to survey of ships specified in Sections 4, 5, 8 and 16 of this Chapter.

examination. Visibility is to be sufficient to allow for a meaningful examination. CCS is to be satisfied with the methods of orientation on the structure.

5.1.18.5 The Surveyor is to be satisfied with the method of data presentation including pictorial representation, and a good two-way communication between the Surveyor and RIT operator is to be provided.

5.1.18.6 If the RIT reveals damage or deterioration that requires attention, the Surveyor may require traditional survey to be undertaken without the use of a RIT.

5.1.19 Remote survey

5.1.19.1 Remote survey carried out on or after 1 January 2023 is to comply with the requirements of Appendix 24 of this Chapter. For CCS specific requirements about remote survey, refer to CCS Guidelines for Remote Survey of Ships..

Section 2 TYPES AND PERIODS OF SURVEYS

5.2.1 Annual surveys

5.2.1.1 Annual surveys are to be carried out on all ships within 3 months before or after each anniversary date from the date of the initial classification survey or of the completion of the last special survey. The surveys are to be carried out in accordance with the relevant requirements of Sections 4 to 10 of this Chapter.

5.2.2 Intermediate surveys

5.2.2.1 Intermediate surveys are to be carried out on all ships either at or between the 2nd and 3rd annual survey. Those items which are additional to the requirements of the annual surveys may be surveyed either at or between the 2nd and 3rd annual survey. The surveys are to be carried out in accordance with the relevant requirements of Sections 4 to 10 of this Chapter.

5.2.2.2 Concurrent crediting to both intermediate survey and special survey for surveys and thickness measurements of spaces are not acceptable.

5.2.3 Periodical surveys of the outside of the ship's bottom and related items

5.2.3.1 Examinations of the outside of the ship's bottom and related items of ships may be carried out with the ship in dry dock or on a slipway, or while the ship is afloat. The examinations in dry dock or on a slipway are considered as docking surveys and the examinations with the ship afloat as in-water surveys.

5.2.3.2 The owner is to notify CCS whenever the outside of the ship's bottom and related items can be examined in dry dock or on a slipway.

5.2.3.3 There is to be a minimum of two examinations of the outside of the ship's bottom and related items during each five-year special survey period. One such examination is to be carried out in conjunction with the special survey. In all cases the interval between any two such examinations is not to exceed 36 months. An extension of examination of the ship's bottom of 3 months beyond the due date may be granted in exceptional circumstances①. The surveys are to be carried out in accordance with relevant requirements in Section 11 of this Chapter.

5.2.3.4 Examinations of the outside of the ship's bottom and related items of ships are normally to be carried out with the ship in dry dock. However, consideration may be given to alternate examination while the ship is afloat as an in-water survey, subject to the provisions of Section 11 of this Chapter. Ships of less than 15 years of age may be permitted to carry out two consecutive in-water surveys, provided that relevant requirements of Appendix 21 of this Chapter are complied with. Special consideration is to be given to ships of 15 years or over before being permitted to have such examinations. For ESP ships of 15 years of age or over, such examinations are to be carried out with the ship in dry dock.

5.2.3.5 The interval between examinations of the outside of the ship's bottom and related items for ships operating in fresh water and for certain harbour or non-self-propelled craft may be greater than that given in 5.2.3.3.

5.2.3.6 Compliance with the requirements of the Rules for periodical surveys of the outside of the ship's bottom and related items does not absolve the owner from compliance with the requirements of SOLAS, as amended, especially when shorter intervals between examinations of the ship's bottom for certain types of ships are required.

---

① As defined in 2.1.3.1(28) of Chapter 2 of this PART.

5.2.3.7 For oil tankers, combination carriers, bulk carriers, chemical tankers, double hull oil tankers, double skin bulk carriers, general dry cargo ships and liquefied gas carriers, reference is also be made to the relevant requirements of Sections 5, 6, 7, 8 and 16 of this Chapter.
5.2.3.8 For passenger ships engaged on international voyages, the outside of the bottom of the ship is to be inspected once a year, for passenger ships engaged on non-international voyages, the outside of the bottom of the ship is to be inspected once every two years, and at least twice in dry-dock during each five-year special survey period. In-water surveys may be carried out in lieu of the others when the ship is afloat. The minimum number of inspections in dry-dock of the outside of the bottom of a passenger ship (which is not a ro-ro passenger ship) of 15 years of age or less during each five-year special survey period may be reduced from two to one if relevant technical requirements are met①. In such cases, the interval between consecutive inspections in dry-dock is not to exceed 60 months, unless otherwise specified by the flag Administration.

5.2.4 Special surveys
5.2.4.1 Hull and machinery (including electrical installations) are in general to be subject to special surveys at 5 years intervals to renew the classification certificate. The first special survey is to be completed within 5 years from the date of the initial classification survey and thereafter 5 years from the credited date of the previous special survey. For ships to which the classification certificate is issued for less than 5 years, the period of the special survey may be shortened.
5.2.4.2 The special survey may be commenced at the annual survey prior to its expiry date and be progressed during the succeeding year with a view to completion by its expiry date. When the special survey is commenced before the annual survey prior to its expiry date, the entire survey is to be completed within 15 months from the date of commencement of the special survey if such work is to be credited to the special survey.
5.2.4.3 Where the owner is not able to arrange the special survey by its expiry date in exceptional circumstances and upon the owner's request, CCS may grant an extension in accordance with 2.9.2.1(4)③a and/or b , provided that a written application is received before the expiry date.
5.2.4.4 For surveys completed more than 3 months before the expiry date of the special survey, the date of next special survey for class is to start from the survey completion date. For surveys completed within 3 months before the expiry date of the special survey, the date of next special survey for class is to start from the expiry date of the special survey. For surveys completed after the expiry date of the special survey, the date of next special survey for class is also to start from the expiry date of the special survey. In cases where the vessel has been laid up or has been out of service for a considerable period because of a major repair or modification and the owner elects to only carry out the overdue surveys, the next period of class will start from the expiry date of the special survey. If the owner elects to carry out the next due special survey, the period of class will start from the survey completion date.
5.2.4.5 Concurrent crediting to both intermediate survey and special survey for surveys and thickness measurements of spaces are not acceptable.
5.2.4.6 The special surveys are to be carried out in accordance with the relevant requirements of Sections 4 to 10 of this Chapter.

5.2.5 Screwshaft and tubeshaft surveys
5.2.5.1 The screwshaft and tubeshaft surveys to be carried out and the interval between the surveys are to be in accordance with the requirements of Section 12 of this Chapter.

5.2.6 Boiler surveys
5.2.6.1 The boiler surveys to be carried out and the interval between the surveys are to be in accordance with the requirements of Section 13 of this Chapter.

5.2.7 Continuous surveys
5.2.7.1 Continuous survey system for hull
(1) Continuous system for hull survey is an alternative survey system for special survey and is applicable to ships other than general dry cargo ships, oil tankers, bulk carriers, combination carriers and chemical tankers.
(2) The complete survey of the hull to meet the requirements of the hull special survey, can be carried out on the continuous survey system basis, when, at the request of the owner it has been agreed by CCS②.

---

① Refer to MSC.1/Circ.1348.
② Ships on the continuous survey system are not exempt from other periodical surveys.

(3) When such a system is adopted, all the requirements of the particular hull special survey must be completed at the end of the five-year class period.
(4) During each survey cycle, all items are to be surveyed (and tested, where required) in regular rotation, as far as practicable, with uniform annual share within the five-year class period.
(5) The owner is entitled to fix the sequence in which the individual items of the hull are intended to be surveyed. However, the sequence in each survey cycle is to be linked with that of the previous one in such a way that the interval between consecutive (in two cycles) examinations of each item will not exceed five years. The survey in dry dock may be held at any time within the five-year class period, provided all the requirements of Section 11 of this Chapter are also complied with. For ships more than 10 years of age, the ballast tanks are to be internally examined twice in each five-year class period, i.e. once within the scope of the intermediate survey and once within the scope of the continuous system for the hull special survey.
(6) The Surveyor may extend the inspection, at his discretion, to other items if the inspections carried out revealed any defect.
(7) The agreement for surveys to be carried out on a continuous survey system basis may be withdrawn at the discretion of CCS.
5.2.7.2 Continuous survey system for machinery
(1) At the request of the owner and with the consent of CCS, all examination and test items of the special survey of the machinery (including electrical installations), other than those specified in 5.9.4.3(1) and (2) of this Chapter, may be carried out on the continuous survey basis.
(2) When the continuous survey is carried out, the various items for special survey of the machinery (including electrical installations), other than those specified in 5.9.4.3(1) and (2) of this Chapter, are to be examined in rotation, evenly distributed within the cycle of the special survey (5 years).
(3) The longest interval between consecutive examinations of each item is not to exceed 5 years. All items to be inspected are to be submitted to the Surveyors for examination after opening and cleaning, as in the special survey. Control, alarm and safety systems are in general to be checked only by operation test or simulation test.
(4) At the request of the owner, the chief engineer of the ship may examine the items authorized by CCS. On completion of the examination, the chief engineer is to make an entry in the continuous survey report about the items examined by him, and a survey report is to be submitted for confirmation at the time of the next survey.
(5) CCS at its discretion, or the owner in view of the implementation of the continuous survey system, may terminate this system at any time and apply special survey.

5.2.8 Survey of planned maintenance scheme (PMS) for machinery

5.2.8.1 For machinery and installations which are subject to planned maintenance and with the consent of CCS, the survey of planned maintenance scheme (for details, see Appendix 16 of this Chapter) may be introduced to replace the continuous survey, provided that:
(1) a maintenance plan for all machineries, installations and equipment on board the ship is approved by CCS;
(2) crew members implementing the plan are to follow the approved maintenance plan, carry out planned maintenance and make relevant records;
(3) the records for implementing planned maintenance are examined once every year to confirm that the plan is well implemented.
5.2.8.2 When it is found upon examination of the records that the planned maintenance is not able to fully meet the requirements of surveys after construction, such scheme implemented will be canceled. Special survey or continuous survey will then be carried out.

5.2.9 Lay-up surveys

5.2.9.1 General requirements
(1) The owner is to inform CCS of any ship laid up with CCS class in writing.
(2) For maintaining the class of laid-up ships:
① initial lay-up survey is to be requested at the beginning of the lay-up period;
② annual lay-up condition survey is to be carried out during the lay-up period;
③ reactivation survey is to be requested at the termination of the lay-up period.
(3) Where a maintenance scheme agreed by CCS is available for a ship being laid up for a period beyond due date of the special classification survey, all surveys after construction which fall due during lay-up will then be held in abeyance until it is reactivated, subject to satisfactory completion of the annual lay-up condition survey stated in (2)② above.

(4) At the request of the owner, part or all of surveys after construction may be carried out for a laid-up ship, with particular attention being given to the scope and date of the surveys. Such surveys may be taken into account for determining the scope of a reactivation survey and/or determining the due date of next survey of the same type after construction.

5.2.9.2 Initial lay-up surveys

(1) The purpose of the survey at the beginning of the lay-up period is to confirm compliance of safety condition, maintenance measures, location and mooring arrangement of the ship with the lay-up maintenance scheme agreed by CCS. The scope and requirements of the survey may be in accordance with the relevant requirements of CCS Guidelines on Lay-up of Ships.

(2) Upon satisfactory completion of the initial lay-up survey, the lay-up report is to be issued and the classification certificate endorsed to the effect that the ship is laid up.

5.2.9.3 Annual lay-up condition surveys

(1) An annual lay-up survey is to be carried out, in lieu of the normal annual survey during the lay-up period, to determine whether the ship remains in compliance with the lay-up maintenance scheme. The scope of the survey is to include checking whether the lay-up arrangement has been changed, and whether the ship maintenance and testing have been carried out in accordance with the maintenance requirements and recorded in the lay-up log.

(2) Ships manned during lay-up are to comply with the requirements regarding fire safety. The requirements may be limited to engine room areas and any high fire risk area, if such ships are laid up in ballast condition and that cargo areas are clean and gas free.

(3) Upon satisfactory completion of the survey, the classification certificate is to be endorsed.

5.2.9.4 Reactivation surveys

(1) The owner is to inform CCS of termination of the lay-up period and apply for the following surveys prior to reactivation of the ship:

① an occasional survey, the scope of which depends on the duration of the lay-up period and the surveys carried out during the lay-up period;

② all other surveys after construction that are being held in abeyance according to 5.2.9.1(3), taking into account the requirements of 5.2.9.1(4).

(2) Where the date of reactivation is beyond the original due date of the special survey which is held in abeyance according to 5.2.9.1(3), and where surveys have been carried out according to 5.2.9.1(4), a complete special survey is to be carried out prior to the reactivation. Those items which have been surveyed in compliance with the special classification survey requirements within 15 months preceding the reactivation may be credited.

(3) Scope of reactivation surveys: The scope and requirements of the survey are to be in accordance with the relevant requirements of CCS Guidelines on Lay-up of Ships.

(4) Upon completion of the survey, the classification certificate is to be re-issued.

5.2.10 Initial classification surveys

5.2.10.1 An initial classification survey of a ship requesting to be classed with CCS is the examination of compliance of its documentation and of the design, configuration, technical condition and management of its structure and equipment with CCS rules and regulations for classification and other technical requirements recognized by it, prior to assigning CCS class and classification certificates to it for the first time.

5.2.10.2 The initial classification surveys of the existing ships and the ships constructed not under the supervision of CCS are to be carried out in accordance with the relevant requirements of Section 14 of this Chapter.

5.2.10.3 The initial classification surveys of newbuildings are to be carried out in accordance with the requirements of Chapter 4 of this PART for surveys during construction.

5.2.11 Occasional surveys

5.2.11.1 An occasional survey is any survey which is not a periodical survey. The survey may be defined as an occasional survey of hull, machinery, boilers, electrical installations, automatic and remote control systems, etc., depending on the part of the ship concerned.

5.2.11.2 An occasional survey is to be requested by the owner or his agent in any of the following cases:

(1) change of the ship' name, port of registry, flag and the owner or operator;

(2) damage which affects the class of the ship or its equipment;

(3) port State control inspection;

(4) any repair or alteration or conversion which affects class;

(5) postponement of surveys or recommendations.

5.2.11.3 An occasional survey may be general or partial as appropriate, and is to ensure that repairs and any renewal have been effectively carried out and that the ship and its equipment remain fit for the intended service.

Section 3 RETROSPECTIVE REQUIREMENTS FOR EXISTING SHIPS

5.3.1 General requirements

5.3.1.1 This Section contains class-related retrospective requirements of SOLAS Convention and/or IACS URs for the existing self-propelled ships engaged on international voyages.

5.3.2 Construction – structure, subdivision and stability, machinery and electrical installations

5.3.2.1 Safe access to tanker bows

(1) Application:

① every tanker constructed on or after 1 July 1998;

② for tankers constructed before 1 July 1998, such means of access are to be provided at the first scheduled dry-docking after 1 July 1998, but not later than 1 July 2001.

(2) Technical requirements: see Section 12, Chapter 1 of PART TWO of the Rules.

5.3.2.2 Emergency towing arrangements on tankers

(1) Application:

① every tanker of not less than 20,000 tonnes deadweight constructed on or after 1 July 2002;

② for tankers of not less than 20,000 tonnes deadweight constructed before 1 July 2002, the design and construction of emergency towing arrangements are to be approved.

(2) Technical requirements: see Section 5, Chapter 3 of PART TWO of the Rules.

5.3.2.3 Stability of ro-ro passenger ships in damaged condition

(1) Application:

① ro-ro passenger ships constructed on or after 1 January 2009 are to comply with Section 10, Chapter 1 of PART TWO of the Rules;

② ro-ro passenger ships constructed on or after 1 July 1997 and before 1 January 2009 are to comply with the November 1995 amendments, which were adopted by resolution 1 of the Conference of Contracting Governments to SOLAS, 1974 and amendments adopted by resolution MSC.47(66);

③ ro-ro passenger ships constructed before 1 July 1997 are to comply with the Rules not later than the date of the first periodical survey after the date of compliance prescribed in Table 5.3.2.3(1), according to the value of A/A_{max}.

Table 5.3.2.3(1)

Value of A/A_{max}	Compliance not later than
Less than 85%	1 October 1998
85% or more but less than 90%	1 October 2000
90% or more but less than 95%	1 October 2002
95% or more but less than 97.5%	1 October 2004
97.5% or more	1 October 2005

5.3.2.4 Special requirements for ro-ro passenger ships certified to carry 400 persons or more

(1) Application: Notwithstanding the requirements of 5.3.2.3:

① ro-ro passenger ships constructed on or after 1 January 2009 are to comply with Section 10, Chapter 1 of PART TWO of the Rules;

② ro-ro passenger ships certified to carry 400 persons or more constructed on or after 1 July 1997 and before 1 January 2009 are to comply with the November 1995 amendments, which were adopted by resolution 1 of the Conference of Contracting Governments to SOLAS, 1974 and amendments adopted by resolution MSC.47(66);

③ ro-ro passenger ships certified to carry 400 persons or more constructed before 1 July 1997 are to comply with the requirements of ② of this paragraph not later than the date of the first periodical survey after the date of compliance prescribed in Tables 5.3.2.4(1)① and 5.3.2.4(1)② or age of the ship[①] equal to or greater than 20 years, whichever is the latest.

Table 5.3.2.4(1)①

① The age of the ship means the time counted from the date on which the keel was laid or the date on which it was at a similar stage of construction or from the date on which the ship was converted to a ro-ro passenger ship.

Value of A/A_{max}	Compliance not later than
Less than 85%	1 October 1998
85% or more but less than 90%	1 October 2000
90% or more but less than 95%	1 October 2002
95% or more but less than 97.5%	1 October 2004
97.5% or more	1 October 2010

Table 5.3.2.4(1)②

Number of persons permitted to be carried	Compliance not later than
1,500 or more	1 October 2002
1,000 or more but less than 1,500	1 October 2006
600 or more but less than 1,000	1 October 2008
400 or more but less than 600	1 October 2010

5.3.2.5 Openings in watertight bulkheads in passenger ships
(1) Application: Ships constructed on or after 1 February 1992.
(2) Technical requirements: see Section 12, Chapter 1 of PART TWO of the Rules.
5.3.2.6 Construction and initial tests of watertight decks, trunks, etc., in ro-ro passenger ships
(1) Ro-ro passenger ships constructed before 1 July 1997 are to comply with the requirements of the Rules not later than the date of the first periodical survey after 1 July 1997.
(2) Technical requirements: see Section 12, Chapter 1 of PART TWO of the Rules.
5.3.2.7 Watertight integrity of the ro-ro deck (bulkhead deck) and below the ro-ro deck
(1) Application:
① ro-ro passenger ships constructed on or after 1 July 1997;
② ro-ro passenger ships constructed before 1 July 1997 are to comply with the requirements of the Rules not later than the date of the first periodical survey after 1 July 1997.
(2) Technical requirements: see Section 12, Chapter 1 of PART TWO of the Rules.
5.3.2.8 Integrity of the hull and superstructure, damage prevention and control
(1) Application: All ro-ro passenger ships constructed before 1 January 2009 are to comply with regulation 23-2 of the November 1995 amendments, which were adopted by resolution 1 of the Conference of Contracting Governments to SOLAS, 1974, but ro-ro passenger ships constructed before 1 July 1997 are to comply with paragraph 2 of regulation 23-2 of the above-mentioned amendments not later than the date of the first periodical survey after 1 July 1997.
5.3.2.9 Supplementary emergency lighting for ro-ro passenger ships
(1) Application: All ro-ro passenger ships, except that for ships constructed before 22 October 1989, this requirement is to apply not later than 22 October 1990.
(2) Technical requirements: see 2.2.2.3 of Chapter 2 of PART FOUR of the Rules.

5.3.3 Construction –Fire protection, fire detection and fire extinction

5.3.3.1 Protection of cargo pump-rooms in tankers
(1) Application: All tankers constructed before 1 July 2002 are to be fitted with the devices and a system for continuous monitoring of the concentration of hydrocarbon gases as required, at the first scheduled dry-docking after 1 July 2002, but not later than 1 July 2005.
(2) Technical requirements: see 1.1.1.1 of PART SIX of the Rules (SOLAS Reg. II-2/4.5.10.1.1 and 4.5.10.1.4).
5.3.3.2 Carriage of emergency escape breathing devices
(1) Application: All ships constructed before 1 July 2002 are to carry the required emergency escape breathing devices not later than the date of the first survey after 1 July 2002.
(2) Technical requirements: see 1.1.1.1 of PART SIX of the Rules (SOLAS Reg. II-2/13.3.4.2 to 13.3.4.5 and 13.4.3).
5.3.3.3 Part E, Operational requirements of SOLAS II-2
(1) Application: All ships constructed before 1 July 2002 are to comply with the relevant requirements not later than the date of the first survey after 1 July 2002.
(2) Technical requirements: see 1.1.1.1 of PART SIX of the Rules (relevant requirements of SOLAS II-2/Part E, excluding Reg. 16.3.2.2 and 16.3.2.3).
5.3.3.4 Fire-extinguishing systems using Halon 1211, 1301, and 2402 and perfluorocarbons
(1) Application: New installation of such systems is prohibited for all ships constructed before 1 July 2002.
(2) Technical requirements: see 1.1.1.1 of PART SIX of the Rules (SOLAS Reg. II-2/10.4.1.3).
5.3.3.5 Deep-fat cooking equipment
(1) Application: New installation of such equipment or replacement of the existing equipment with such

equipment for all ships constructed before 1 July 2002 is to comply with the relevant requirements.
(2) Technical requirements: see 1.1.1.1 of PART SIX of the Rules (SOLAS Reg. II-2/10.6.4).
5.3.3.6 Fixed water-based local application fire-extinguishing system
(1) Application: Passenger ships and ro-ro passenger ships of 2,000 gross tonnage and above constructed before 1 July 2002 are to be fitted with the required fixed water-based local application fire-extinguishing system not later than 1 October 2005.
(2) Technical requirements: see 1.1.1.1 of PART SIX of the Rules (SOLAS Reg. II-2/10.5.6).
5.3.3.7 Diesel engines: High-pressure fuel delivery lines protected with a jacketed piping system, surfaces with temperatures above 220℃ and isolation of fuel piping
(1) Application: All ships (ships to which the Rules apply, the same below) constructed on or after 1 February 1992 but before 1 July 1998 are to comply with the relevant requirements not later than 1 July 2003. However, an appropriate cover of the fuel injection pump serving more than one nozzles, in engines having a power output of 375 kW or below, may replace the required jacketed protection system.
(2) Technical requirements: see 1.1.1.1 of PART SIX of the Rules (SOLAS Reg. II-2/4.2.2.5.2, 4.2.2.5.3 and 4.2.2.6.1).
5.3.3.8 Secondary means for pressure/vacuum relief in cargo tanks
(1) Application: All tankers constructed before 1 July 1998 are to comply with the relevant requirements before the date of the first scheduled dry-docking after 1 July 1998, but not later than 1 July 2001.
(2) Technical requirements: see 1.1.1.1 of PART SIX of the Rules (SOLAS Reg. II-2/11.6.3.2 and 4.5.3.2.3).
5.3.3.9 Additional requirements for means of escape of ro-ro passenger ships
(1) Application: Ro-ro passenger ships constructed before 1 July 1997 are to comply with the relevant requirements at the date of the first periodical survey after 1 July 1997.
(2) Technical requirements: see 1.1.1.1 of PART SIX of the Rules (SOLAS Reg. II-2/13.7).
5.3.3.10 Inert gas systems
(1) Application: All tankers constructed before 1 September 1984:

① Tankers of 20,000 tonnes deadweight and upwards and carrying crude oil are to be fitted with a required inert gas system:
   a. for tankers of 70,000 tonnes deadweight and upwards, not later than 1 September 1984 or the date of delivery of the ship, whichever comes later;
   b. for tankers of less than 70,000 tonnes deadweight, not later than 1 May 1985 or the date of delivery of the ship, whichever comes later. However, tankers of less than 40,000 tonnes deadweight, which are not fitted with oil tank washing machines having an individual discharge capacity of more than 60 m^3/h, may not be fitted with the inert gas system.

② Tankers of 40,000 tonnes deadweight and upwards and carrying oils other than crude oil as well as tankers of 20,000 tonnes deadweight and upwards and carrying oils other than crude oil, both of which are fitted with oil tank washing machines having an individual discharge capacity of more than 60 m^3/h, are to be fitted with the required inert gas system:
   a. for tankers of 70,000 tonnes deadweight and upwards, not later than 1 September 1984 or the date of delivery of the ship, whichever comes later;
   b. for tankers of less than 70,000 tonnes deadweight, not later than 1 May 1985 or the date of delivery of the ship, whichever comes later.

(2) Technical requirements: see 1.1.1.2 of PART SIX of the Rules (Chapter 15 of the International Code for Fire Safety Systems (FSS Code)).

5.3.4 Additional safety measures for bulk carriers

5.3.4.1 Evaluation of scantlings of the transverse watertight corrugated bulkhead between cargo holds Nos.1 and 2, with cargo hold No.1 flooded, for existing bulk carriers
(1) These requirements apply to all bulk carriers of 150 m in length and above, in the foremost hold, intending to carry solid bulk cargoes having a density of 1.78 t/m^3 or above, with single deck, topside tanks and hopper tanks, fitted with vertically corrugated transverse watertight bulkheads between cargo holds Nos.1 and 2 where:

① the foremost hold is bounded by the side shell only for ships which were contracted for construction prior to 1 July 1998, and have not been constructed in compliance with IACS Unified Requirement S18; or

② the foremost hold is double side skin construction of less than 760 mm breadth measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999 and have not been constructed in compliance with IACS Unified

Requirement S18 (Rev.2, Sept. 2000).

(2) Technical requirements: see Appendix 17 of this Chapter.

5.3.4.2 Evaluation of Allowable Hold Loading of cargo hold No.1 with cargo hold No.1 flooded, for existing bulk carriers

(1) Application: All bulk carriers of 150 m in length and above, in the foremost hold, intending to carry solid bulk cargoes having a density of 1.78 t/m^3 or above, with single deck, topside tanks and hopper tanks, where:

① the foremost hold is bounded by the side shell only for ships which were contracted for construction prior to 1 July 1998, and have not been constructed in compliance with IACS Unified Requirement S20; or

② the foremost hold is double side skin construction of less than 760 mm breadth measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999 and have not been constructed in compliance with IACS Unified Requirement S20.

Early completion of a special survey coming due after 1 July 1998 to postpone compliance is not allowed.

(2) Technical requirements: see Appendix 18 of this Chapter.

5.3.4.3 Implementation of IACS Unified Requirements S19 and S22 for existing single side skin bulk carriers

(1) Application:

① The requirements for the corrugated bulkhead between cargo holds Nos.1 and 2 in 5.3.4.1 and the requirements for strengthening of double bottom structure of No.1 hold in 5.3.4.2 are to be applied in conjunction with the damage stability requirements set forth in this paragraph for withstanding flooding of the foremost cargo hold. The schedule for compliance is given in Table 5.3.4.3.

(2) Technical requirements: see Appendix 19 of this Chapter.

Table 5.3.4.3

No.	Age of ship	Schedule for compliance
1	20 years or more on 1 July 1998	Due date of the first intermediate survey, or due date of the first special survey to be held after 1 July 1998, whichever comes first
2	15 years or more but less than 20 years on 1 July 1998	Due date of the first special survey to be held after 1 July 1998, but not later than 1 July 2002
3	10 years or more but less than 15 years on 1 July 1998	Due date of the first intermediate survey or special survey to be held after the date on which the ship reaches 15 years of age but not later than the date on which the ship reaches 17 years of age
4	5 years or more but less than 10 years on 1 July 1998	Due date, after 1 July 2003, of the first intermediate or the first special survey after the date on which the ship reaches 10 years of age, whichever occurs first
5	Less than 5 years on 1 July 1998	The date on which the ship reaches 10 years of age

Notes: For the ships listed under No.4 of Table 5.3.4.3, attention is to be paid to the following:

① Where the due date of the intermediate or special survey is after 1 July 2003 (the due date of the intermediate survey means the third anniversary date of the annual survey) and the intermediate or special survey is completed before 1 July 2003, the evaluation required by 5.3.4.1, 5.3.4.2 and 5.3.4.3 is not allowed to be postponed, i.e. it is to be completed within 3 months after the due date of this intermediate survey or by the due date of the special survey.

② Where the due date of the intermediate survey is before 1 July 2003 and the intermediate survey is completed before 1 July 2003, this intermediate survey may be accepted, i.e. the evaluation required by 5.3.4.1, 5.3.4.2 and 5.3.4.3 may be performed at the first special survey after 1 July 2003.

5.3.4.4 Cargo hatch cover securing arrangements for bulk carriers

(1) Application: All bulk carriers which were not built in accordance with Section 11, Chapter 8 of PART TWO of the Rules.

(2) Schedule for compliance: The ships to which (1) applies are to comply with (3) in accordance with the following schedule:

① for ships which are 15 years of age or more on 1 January 2004 by the due date of the first intermediate or special survey after that date;

② for ships which are 10 years of age or more on 1 January 2004 by the due date of the first special survey after that date;

③ for ships which are less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.

Completion prior to 1 January 2004 of an intermediate or special survey with a due date after 1 January

2004 cannot be used to postpone compliance. However, completion prior to 1 January 2004 of an intermediate survey the window for which straddles 1 January 2004 can be accepted.
(3) Technical requirements: Hatch cover securing devices and stoppers for cargo hold hatchways No.1 and No.2 which are wholly or partially within 0.25 *L* of the fore perpendicular (except pontoon type hatch covers) are to comply with 8.11.5 of PART TWO of the Rules.

5.3.4.5 Renewal criteria for side shell frames and brackets in single side skin bulk carriers and single side skin OBO carriers

(1) Application:

① The requirements apply to the side shell frames and brackets of cargo holds bounded by the single side shell of bulk carriers which were not built in accordance with IACS UR S12[①] Rev. 1 or subsequent revisions.

② The requirements also apply to the side shell frames and brackets of cargo holds bounded by the single side shell of Oil/Bulk/Ore (OBO) carriers of single side skin construction.

(2) Schedule for compliance:

① Bulk carriers are to be assessed for compliance with the requirements and steel renewal, reinforcement or coating, where required, is to be carried out in accordance with the following schedule and at subsequent intermediate and special surveys:

a. for bulk carriers which are 15 years of age or more on 1 January 2004 by the due date of the first intermediate or special survey after that date;

b. for bulk carriers which are 10 years of age or more on 1 January 2004 by the due date of the first special survey after that date;

c. for bulk carriers which are less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.

Completion prior to 1 January 2004 of an intermediate or special survey with a due date after 1 January 2004 cannot be used to postpone compliance. However, completion prior to 1 January 2004 of an intermediate survey the window[②] for which straddles 1 January 2004 can be accepted.

② OBO carriers are to be assessed for compliance with the requirements and steel renewal, reinforcement or coating, where required, is to be carried out in accordance with the following schedule and at subsequent intermediate and special surveys:

a. for OBO carriers which are 15 years of age or more on 1 July 2005 by the due date of the first intermediate or special survey after that date;

b. for OBO carriers which are 10 years of age or more on 1 July 2005 by the due date of the first special survey after that date;

c. for OBO carriers which are less than 10 years of age on 1 July 2005 by the date on which the ship reaches 10 years of age.

Completion prior to 1 July 2005 of an intermediate or special survey with a due date after 1 July 2005 cannot be used to postpone compliance. However, completion prior to 1 July 2005 of an intermediate survey the window for which straddles 1 July 2005 can be accepted.

(3) The evaluation criteria are given in Appendix 20 of this Chapter.

5.3.4.6 Survey of the cargo hold structure of bulk carriers

Bulk carriers constructed before 1 July 1999, of 150 m in length and upwards of single side skin construction, of 10 years of age and over, are not to carry solid bulk cargoes having a density of 1.78 t/m^3 and above unless it has satisfactorily undergone either:
(1) a periodical survey in accordance with the enhanced programme of inspections required by SOLAS regulation XI-1/2; or
(2) a survey of all cargo holds to the same extent as required for periodical surveys in the enhanced survey programme of inspections required by regulation XI-1/2.

5.3.4.7 Requirements for the fitting of a forecastle

(1) Application: All bulk carriers (including ore carriers and combination carriers) which are contracted for construction on or after 1 January 2004, as defined in Appendix 2, Chapter 2 of this PART.
(2) Technical requirements: Section 13, Chapter 8 of PART TWO of the Rules is to be complied with.

5.3.4.8 Hold, ballast and dry space water level detectors

(1) Application: All bulk carriers of 500 gross tonnage and upwards and engaged on international voyages.
(2) Schedule for compliance:

① bulk carriers constructed on or after 1 July 2004 are to comply with the requirements of this

---

① IACS UR S12 - Side Structures in Single Side Skin Bulk Carriers.

② Windows means the time span allowed for completing a specific type of survey.

paragraph on the date of being commissioned;

② the water level alarm of bulk carriers constructed before 1 July 2004 is to comply with the requirements of this paragraph not later than the date of the annual, intermediate or special survey of the ship to be carried out after 1 July 2004, whichever comes first.

(3) Technical requirements: see Section 19, Chapter 2 of PART FOUR of the Rules.

5.3.4.9 Availability of pumping systems

(1) Application: Bulk carriers.

(2) Schedule for compliance: Bulk carriers constructed before 1 July 2004 are to comply with the requirements of this paragraph not later than the date of the first intermediate or special survey of the ship to be carried out after 1 July 2004, but in no case later than 1 July 2007.

(3) Technical requirements: see Section 12, Chapter 3 of PART THREE of the Rules.

5.3.4.10 Restriction on sailing with any cargo hold being empty

Bulk carriers of 150 m in length and upwards of single side skin construction, designed to carry cargoes having a density of 1.78 t/m^3 and above, where they comply neither with the requirement of SOLAS Reg. XII/5.1 for having sufficient strength to withstand flooding of any one cargo hold nor with resolution MSC.168(79) Standards and Criteria for Side Structures of Bulk Carriers of Single-Side Skin Construction, are not allowed to sail after the date of reaching 10 years of age if any cargo hold is loaded below 10% of the maximum permissible loading of that hold in the full load condition. For the purpose of this paragraph, the full load condition means that the ship is loaded to not less than 90% of its deadweight in relation to the freeboard assigned.

5.3.5 Strength and securing of small hatches on the exposed fore deck and air pipes, ventilator pipes and their closing devices thereover

5.3.5.1 Application

(1) General dry cargo ships (excluding container ships, vehicle carriers, ro-ro ships and woodchip carriers), ore carriers, combination carriers (e.g. oil/bulk/ore carriers, ore/oil carriers) and bulk carriers that are contracted for construction prior to 1 January 2004, of 100 m in length or more.

5.3.5.2 Schedule for compliance:

(1) The requirements of 5.3.5.3 are to be complied with in accordance with the following schedule:

① for ships which are 15 years of age or more on 1 January 2004 by the due date of the first intermediate or special survey after that date;

② for ships which are 10 years of age or more on 1 January 2004 by the due date of the first special survey after that date;

③ for ships which are less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.

Completion prior to 1 January 2004 of an intermediate or special survey with a due date after 1 January 2004 cannot be used to postpone compliance. However, completion prior to 1 January 2004 of an intermediate survey the window for which straddles 1 January 2004 can be accepted.

(2) Ships (on the exposed deck over the forward 0.25*L*, applicable to all ship types of sea-going service of 80 m in length or more, where the height of the exposed deck in way of the hatch is less than 0.1*L* or 22 m above the summer load waterline, whichever is the lesser) that are contracted for construction on or after 1 January 2004 are to comply by the time of delivery.

5.3.5.3 Technical requirements

(1) The strength and securing of the small hatches on the exposed deck giving access to spaces forward of the collision bulkhead (and to spaces which extend over this line aft-wards) is to comply with Section 7, Chapter 1 of PART TWO of the Rules.

(2) Air pipes, ventilator pipes and their closing devices in way of the locations referred to in (1) above are to comply with Section 7, Chapter 1 of PART TWO of the Rules.

5.3.6 Loading instruments

5.3.6.1 Loading instruments for strength calculation

(1) Application:

① Type I ships of 100 m or over in length, as defined in 2.2.8 of Section 2, Chapter 2 of PART TWO of the Rules.

② Bulk carriers (including ore carriers and combination carriers) of 150 m or over in length, as defined in 2.2.8 of Section 2, Chapter 2 of PART TWO of the Rules.

(2) Schedule for compliance:

① Bulk carriers (including ore carriers and combination carriers) of 150 m or over in length and

contracted for construction before 1 July 1998 are to be fitted with loading instruments not later than the date of delivery or 1 January 1999, whichever is later.

② Ships contracted for construction on or after 1 July 1998 are to be fitted with loading instruments before the date of delivery.

(3) Technical requirements: 2.2.8 of Section 2, Chapter 2 and Appendix 1, Chapter 2 of PART TWO of the Rules are to be complied with.

5.3.6.2 Loading instruments for providing intact stability information

(1) Application: All bulk carriers less than 150 m in length and constructed on or after 1 July 2006.

(2) Technical requirements: 1.9.1.3 of Section 9, Chapter 1 of PART TWO of the Rules is to be complied with.

5.3.6.3 Onboard computers for stability calculations

(1) Application: All ships contracted for construction on or after 1 July 2005 and fitted with computers for stability calculations.

(2) Technical requirements: 1.9.1.4 of Section 9, Chapter 1 of PART TWO of the Rules is to be complied with.

5.3.7 Requirements for the fitting of side shell doors, stern doors, bow doors and inner doors of ro-ro passenger ships

5.3.7.1 Side shell doors and stern doors

(1) Application: All existing ro-ro passenger ships with the date of building before 30 June 1996:

① The structural condition of side shell doors and stern doors, especially the primary structure, the securing and supporting arrangements and the hull structure alongside and above the doors, are to be specially examined and any defects rectified.

(2) The following measures are to be complied with by all existing ro-ro passenger ships with the date of building before 30 June 1996:

① The structural arrangement of securing devices and supporting devices of inwards opening doors in way of these securing devices and, where applicable, of the surrounding hull structure is to be reassessed in accordance with the applicable requirements of 9.5.5 of PART TWO of the Rules and modified accordingly.

② The securing and locking arrangements for side shell doors and stern doors which may lead to the flooding of a special category space or ro-ro space as defined in 9.5.1.6 of PART TWO of the Rules, are to comply with the following requirements:

a. separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned;

b. the indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light;

c. the indication panel on the navigation bridge is to be equipped with a mode selection function “harbour/sea voyage”, so arranged that audible alarm is given if the ship leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position;

d. a water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors.

③ Documented operating procedures for closing and securing side shell and stern doors are to be kept on board and posted at the appropriate places.

5.3.7.2 Bow doors and inner doors

(1) Application: All existing ro-ro passenger ships with the date of building before 30 June 1996. Technical requirements are as follows:

① The structural condition of bow doors and inner doors, especially the primary structure, the securing and supporting arrangements and the hull structure alongside and above the doors, are to be specially examined and any defects rectified.

②Tthe requirements of 9.4.8 of PART TWO of the Rules concerning operating procedures of the bow door and inner door are to be complied with.

(2) The following measures are to be complied with by all existing ro-ro passenger ships with the date of building before 30 June 1996:

① The location and arrangement of inner doors are to comply with 9.4.1.2(4) of PART TWO of the Rules.

② Ships with visor door are to comply with 9.4.6.2(7) of PART TWO of the Rules requiring redundant provision of securing devices preventing the upward opening of the bow door. In addition, where the visor door is not self-closing under external loads (i.e. the closing moment M_y calculated in accordance with 9.4.3.1(3) of PART TWO of the Rules is less than zero) then the opening moment M_o is not to be taken less than $-M_y$. If drainage arrangements in the space between the inner and bow doors are not fitted, the value of M_o is to be specially considered.
Where available space above the tank top does not enable the full application of 9.4.6.2(7) of PART TWO of the Rules, equivalent measures are to be taken to ensure that the door has positive means for being kept closed during seagoing operation.

③ Ships with visor door are to comply with 9.4.6.2(8) of PART TWO of the Rules requiring securing and supporting devices excluding hinges to be capable of bearing the vertical design force ($F_z - 10W$) without exceeding the permissible stresses given in 9.4.2.1 of PART TWO of the Rules.

④ For side-opening doors, the structural arrangements for supporting vertical loads, including securing devices, supporting devices and, where applicable, hull structure above the door, are to be re-assessed in accordance with the applicable requirements of 9.4.6 of PART TWO of the Rules and modified accordingly.

⑤ The securing and locking arrangements for bow doors and inner doors which may lead to the flooding of a special category space or ro-ro space as defined in the 9.4.1.3 of PART TWO of the Rules are to comply with the following requirements:

a. separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned;
b. the indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light;
c. the indication panel on the navigation bridge is to be equipped with a mode selection function "harbour/sea voyage", so arranged that audible alarm is given if the ship leaves harbour with bow doors or inner doors not closed or with any of the securing devices not in the correct position;
d. a water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors.

5.3.8 Watertightness of chain lockers

(1) Application: Ships of 24 m or over in length, the keels of which are laid or which are at a similar stage of construction on or after 1 July 2003.
(2) Technical requirements: 1.12.10.4 of Section 12, Chapter 1 of PART TWO of the Rules is to be complied with.

5.3.9 Ice class draught mark of ships intended for navigation in ice

5.3.9.1 Marking of warning triangle and ice class draught
(1) Application: Ships having class notations of Ice Class B1* to B3.
(2) Schedule for compliance:

① Ships constructed on or after 1 July 2007, of which the summer load line in fresh water is located at a higher level than the upper ice waterline (UIWL), are to comply with the requirements of this paragraph before the date of delivery.

② Ships constructed before 1 July 2007, of which the summer load line in fresh water is located below the upper ice waterline (UIWL), are to comply with the requirements of this paragraph not later than the first scheduled dry docking after 1 July 2007.

(3) Technical requirements: The ship's sides are to be provided with a warning triangle and with an ice class draught mark at the maximum permissible ice class draught amidships, in accordance with 4.2.1.4 to 4.2.1.8, Section 2, Chapter 4 of PART TWO of the Rules.
5.3.9.2 Documentation and certification requirements regarding ice class draught
(1) Application: Ships having class notations of Ice Class B1* to B3.
(2) Schedule for compliance: The requirements of this paragraph are to be complied with not later than 1 July 2007 or the date of subsequent renewal of the classification certificate.
(3) Technical requirements: 4.2.1 and 4.2.2 of Section 2, Chapter 4 of PART TWO of the Rules.

5.3.10 Requirements for electrical distribution system including harmonic filters

5.3.10.1 Application: for ships contracted for construction before 1 July 2017, the electrical distribution system of which includes harmonic filters. However, harmonic filters installed for single application frequency drives such as pump motors may be excluded from these requirements.

5.3.10.2 Schedule for compliance: for ships to which 5.3.10.1 applies, the due date of the first periodical survey on or after 1 July 2017.

5.3.10.3 Technical requirements: as a minimum, harmonic distortion levels of main busbar on board such existing ships are to be measured annually under seagoing conditions as close to the periodical machinery survey as possible so as to give a clear representation of the condition of the entire plant to the surveyor. Harmonic distortion readings are to be carried out when the greatest amount of distortion is indicated by the measuring equipment. An entry showing which equipment was running and/or filters in service is to be recorded in the log so this can be replicated for the next periodical survey. Harmonic distortion levels are also to be measured following any modification to the ship's electrical distribution system or associated consumers by suitably trained ship's personnel or from a qualified outside source. Records of all the above measurements are to be made available to the surveyor at each periodical survey.

Section 4 HULL AND EQUIPMENT SURVEYS

5.4.1 General requirements

5.4.1.1 Unless expressly provided otherwise, this Section applies to surveys of all ships. In addition, the hull structure, ballast tanks and piping of general dry cargo ships, oil tankers (including double hull oil tankers), bulk carriers (including double skin bulk carriers), chemical tankers and liquefied gas carriers are to meet the relevant requirements of Sections 5, 6, 7, 8 and 16 of this Chapter respectively. Chemical tankers and liquefied gas carriers are also to comply with the relevant requirements of CCS Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals and Rules for Construction and Equipment of Ships Carrying Liquefied Gases.

5.4.1.2 For additional requirements applicable to water level detectors fitted on single hold cargo ships, refer to the requirements of 5.5.2.6 and 5.5.4.8 of this Chapter.

5.4.1.3 Thickness measurements Acceptance Criteria

(1) The acceptance criteria for thickness measurements are according to relevant provisions of Appendix 1 of this Chapter depending on ship's age and structural elements concerned, e.g 2.4 for corrugated transverse bulkhead, 2.6 or 2.7 for all cargo hatch covers and coamings on exposed decks.

5.4.1.4 Special consideration may be given in application of relevant requirements of this Section to commercial ships owned or chartered by Governments, which are utilized in support of military operations or service.

5.4.2 Annual surveys

5.4.2.1 General requirements for all ships

(1) The annual survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull, hatch covers, hatch coamings, closing appliances, equipment and related piping are maintained in a satisfactory condition. The survey intervals are specified in Section 2 of this Chapter.

(2) During an annual survey, a general examination of weather decks, ship side plating above water line, hatch covers and watertight penetrations is to be carried out as far as practicable and their satisfactory condition confirmed.

(3) Annual surveys are to be carried out in conjunction with statutory annual surveys in so far as practicable.

5.4.2.2 Scope of the survey for all ships

(1) Hull

① examining, in general and as far as can be seen, the hull and its closing appliances;

② examining the anchoring (anchors, chain cables, windlass (including its foundation, prime mover and shafting), cable lifters, brakes, chain stoppers, etc. as far as practicable) and mooring equipment as far as can be seen. Confirming that the towing and mooring equipment is properly marked with any restriction associated with its safe operation for ships constructed after 1 January 2007;

③ examining the collision and the other watertight bulkheads and valves operable from above the bulkhead deck as far as can be seen;

④ examining and testing (locally and remotely) all the watertight doors in watertight bulkheads; examining the arrangements for closing openings in the shell plating below the freeboard deck;

⑤ examining each bilge pump and confirming that the bilge pumping system for each watertight compartment is satisfactory;
⑥ confirming that the drainage from enclosed cargo spaces situated on the freeboard deck is satisfactory; examining visually the drainage facilities for blockage or other damage and confirming the provision of means to prevent blockage of drainage arrangements, for closed vehicle and ro-ro spaces and special category spaces where fixed pressure water-spraying systems are used;
⑦ confirming, when appropriate and as far as is practicable when examining internal spaces on oil tankers and bulk carriers, that the means of access to cargo and other spaces remain in good condition;
⑧ examining the functionality of bilge well high water level alarms in all cargo holds and cargo conveyor tunnels;
⑨ inspecting water level detectors and their audible and visual alarms in holds, ballast tanks and dry spaces of bulk carriers;
⑩ checking the arrangements for availability of draining and pumping systems forward of the collision bulkhead of bulk carriers;
⑪ examining the cargo hold water level detector and its audible and visual alarms of single skin single-hold cargo ships;
⑫ confirming that no new installation of materials containing asbestos is on board since last survey.

(2) Load lines ― general requirements
① checking, in general, that the strength of the hull remains in compliance with rules;
② checking of the positions of the deck line and load line which, if necessary, are to be re-marked and re-painted;
③ checking that no alterations have been made to the hull or superstructures that would affect the calculations determining the position of the load lines;
④ examining the superstructure end bulkheads and the openings with their closing appliances therein;
⑤ examining the means of securing the weathertightness of cargo hatchways, other hatchways and other openings on the freeboard and superstructure decks;
⑥ examining the ventilators and air pipes, including their coamings and closing appliances, and in particular, examining the weld connection between air pipes and deck plating as well as external examination of all air pipe heads installed on the exposed decks;
⑦ examining the watertight integrity of the closures to any openings in the ship's side below the freeboard deck;
⑧ examining the scuppers, inlets and discharges;
⑨ examining the side scuttles and deadlights;
⑩ examining the bulwarks including the provision of freeing ports, special attention being given to any freeing ports fitted with shutters;
⑪ examining the guardrails, gangways, walkways and other means provided for the protection of the crew and for gaining access to and from crew's quarters and working spaces;
⑫ examining, when applicable, the means provided to minimize water ingress through the spurling pipes and chain lockers;
⑬ examining, when applicable, the garbage chutes;
⑭ special requirements for ships permitted to sail with type purling pipes and chain lockers;
⑮ checking, when applicable, the fittings and appliances for timber deck cargoes;
⑯ examining portholes, bow doors, stern doors and other similar openings and their closing appliances.

(3) Load lines ― protection of cargo hatches
① checking that no unapproved changes have been made to the hatch covers, hatch coamings and their securing and sealing devices since the last survey;
② exposed hatch covers are to be examined to confirm the structural integrity and capability of maintaining weathertightness. Where extensive areas of wastage and/or substantial corrosion of steel hatch covers are found, thickness measurements are to be carried out to confirm the extent of wastage or corrosion, and renewals or repairs made when wastage exceeds allowable margins;
③ where mechanically operated steel covers are fitted, checking the satisfactory condition of:
   a. hatch covers including plating;
   b. hatch coamings including stiffeners;
   c. tightness devices of longitudinal, transverse and intermediate cross junctions (gaskets, gasket

lips, compression bars, drainage channels);
d. clamping devices, retaining bars, cleating;
e. chain or rope pulleys;
f. guides;
g. guide rails and track wheels;
h. stoppers, etc.;
i. wires, chains, gypsies and tensioning devices;
j. hydraulic system essential to closing and securing;
k. safety locks and retaining devices;
l. random checking of stowage and securing of hatch covers in open condition;
m. random checking of proper fit, locking and efficiency of sealing of hatch covers in closed condition;
n. random checking of operational testing of hydraulic and power components, wires, chains, and link drives;

④ where portable covers, wooden or steel pontoons are fitted, checking the satisfactory condition of:
a. wooden covers and portable beams, carriers or sockets for the portable beams, and their securing devices;
b. steel pontoons;
c. tarpaulins;
d. hatch coamings including stiffeners;
e. cleats, battens and wedges;
f. hatch securing bars and their securing devices;
g. loading pads/bars and the side plate edge
h. guide plates and chocks;
i. compression bars, drainage channels and drain pipes (if any).

(4) Stability information and loading manual
① checking the approved stability information, loading manual, damage control plan and damage control manual (if applicable);
② the loading instrument, which is a supplement to the stability information, is to be confirmed in working order by use of the approved check conditions. The user's instruction manual for the loading instrument is to be confirmed on board (if applicable).

(5) Structural fire protection
① confirming that fire control plans are posted and kept as required;
② confirming that no significant changes have been made to the arrangement of structural fire protection;
③ checking integrity and efficiency of all manual and automatic fire doors, if fitted;
④ confirming that the means for escape from the accommodations, machinery spaces and other spaces are satisfactory.

(6) Fire-fighting equipment
① examining the fire pumps, fire mains, hydrants, hoses and nozzles and the international shore connection and checking that each fire pump, including the emergency fire pump, can by operated separately so that two jets of water are produced simultaneously from different hydrants at any part of the ship whilst the required pressure is maintained in the fire main;
② for ships designed to carry containers on or above the weather deck, as applicable, examining the water mist lance, and as appropriate, the mobile water monitors and all necessary hoses, fittings and required fixing hardware;
③ checking the provision and randomly examining the condition of the portable and non-portable fire extinguishers;
④ confirming that the firefighters' outfits including its self-contained compressed air breathing apparatus and emergency escape breathing devices (EEBDs) are complete and in good condition, that the cylinders, including the spare cylinders, of any required self-contained breathing apparatus are suitably charged, and that on board means of recharging breathing apparatus cylinders used during drills or a suitable number of spare cylinders to replace those used are provided, and provision of two-way portable radiotelephone apparatus of an explosion-proof type or intrinsically safe;
⑤ checking the operational readiness and maintenance of fire-fighting systems;
⑥ examining the fixed fire-fighting system for the machinery, cargo, vehicle, special category and ro-ro spaces, as appropriate, and confirming that its means of operation are clearly marked;

⑦ examining the fire extinguishing and special arrangements in the machinery spaces and confirming, as far as practicable and as appropriate, the operation of the remote means of control provided for the opening and closing of the skylights, the release of smoke, the closure of ventilation openings of the space enclosing the funnel, the closure of power-operated and other doors, the stopping of ventilation and boiler space forced and induced draft fans and the stopping of oil fuel and other pumps that discharge flammable liquids;

⑧ checking that fixed carbon dioxide fire-extinguishing systems for the protection of machinery spaces and cargo pump-rooms, where applicable, are provided with two separate controls, one for opening of the gas piping and one for discharging the gas from the storage container, each of them located in a release box clearly identified for the particular space; checking also that the release devices of carbon dioxide fire-extinguishing systems are operated in the required order, i.e. the gas piping is opened before the gas is discharged from the storage container;

⑨ examining, as far as possible, and testing, as feasible, any fire detection and alarm system an sample extraction smoke detection system;

⑩ checking the provision of a fire-extinguishing system for spaces containing paint and/or flammable liquids and deep-fat cooking equipment in accommodation and service spaces;

⑪ examining the helicopter facilities;

⑫ examining the arrangements for oil fuel, lubricating oil and other flammable oils and testing the remote closing of valves for oil fuel, lubricating oil and other flammable oils and the operation of the remote means of closing the valves on the tanks that contain oil fuel, lubricating oil and other flammable oils; examination of flame screens on vents to all bunker tanks;

⑬ examining and testing of the general emergency alarm system;

⑭ examining the fire protection arrangements in cargo, vehicle and ro-ro spaces, including the fire safety arrangements for vehicle carriers carrying motor vehicles with compressed hydrogen or natural gas in their tanks for their own propulsion as cargo, as applicable, and confirming, as far as practicable and as appropriate, the operation of the means for closing the various openings;

⑮ examining and testing the portable gas detectors suitable for the detection of the gas fuel, for vehicle carriers carrying motor vehicles with compressed hydrogen or natural gas in their tanks for their own propulsion as cargo;

⑯ examining, where applicable, the alternative design and arrangements for fire safety and arrangements, in accordance with the test, inspection and maintenance requirements, if any, specified in the approved documentation;

⑰ examining, where appropriate, the special arrangements for carrying dangerous goods, including checking of the electrical equipment and wiring, the ventilation, the provision of protective clothing and portable appliances, and the testing of water supply, bilge pumping and any water spray system.

(7) Suspect areas[①]

① overall examination of suspect areas of the hull, including overall and close-up survey of those suspect areas identified at previous surveys;

② thickness measurements of areas of substantial corrosion identified at previous surveys;

③ where extensive areas of wastage are found or when considered necessary by the Surveyor, thickness measurements are to be carried out and renewals or repairs made when wastage exceeds allowable margins. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increased to determine areas of substantial corrosion. Table 5.4.4.2(17)② may be used as guidance for these additional thickness measurements. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

(8) Salt water ballast spaces and/or combined cargo/salt water ballast spaces

Examination of ballast tanks when required as a consequence of the results of the special survey and intermediate survey is to be carried out. Where extensive areas of wastage are found or when considered necessary by the Surveyor, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increased to determine areas of substantial corrosion. Table 5.4.4.2(17)② may be used as guidance for these additional measurements. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

---

① These requirements are not applicable to cargo tanks of oil tankers (including double hull oil tankers) and chemical tankers surveyed in accordance with Sections 6 and 8 of this Chapter.

(9) Steering gear

① If applicable, main and auxiliary steering gear, including their associated equipment and control systems, are to be examined and tested and if appropriate, relevant entries in the logbook are to be verified.

(10) Watertight Cable Transits

① The Register is to be reviewed to confirm it is being maintained and as far as practicable the transits are to be examined to confirm their satisfactory condition.

② Where there are records entered since the last annual survey of any disruption to the cable transits or installation of new cable transits, the satisfactory condition of those transits is to be confirmed by review of records and, if deemed necessary, by examination. The results are to be recorded in the Register against the specific cable transit.

③ It is to be confirmed that cable transits have been installed, and where disrupted have been reinstated, in accordance with the manufacturer's requirements and in accordance with the requirements of Type Approval.

④ It is to be confirmed where specified, appropriate specialized tools have been used.

5.4.2.3 For the requirements for additional surveys of ro-ro ships, see Section 17 of this Chapter.

5.4.2.4 Passenger ships (including ro-ro passenger ships)

(1) In addition to the survey items in 5.4.2.2, for passenger ships (including ro-ro passenger ships), the following items are to be carried out:

① all shell plating below bulkhead deck;

② all gangways, cargo ports, inboard openings of ash shoots and rubbish shoots as well as their closing devices below bulkhead deck;

③ side scuttles including watertight steel covers and closing devices below bulkhead deck;

④ all openings including doors and similar openings and their closing devices in watertight bulkheads below bulkhead deck.

5.4.2.5 Non-self-propelled ships

(1) This paragraph applies to surveys of non-self-propelled ships, but not to surveys of floating docks, oil hulks, offshore installations, special equipment and machinery.

(2) Barges

① In addition to the survey items in 5.4.2.2, for barges engaged in transportation of dry bulk cargo over 15 years, the condition of the following structures of hull is to be examined:

a. hold, with special attention given to tank top;

b. structures below main deck;

c. side plating, frames and associated structures.

② The attending Surveyor may require thickness measurements if he deems it necessary, and means are then to be provided for access into not readily accessible areas.

(3) Other non-self-propelled ships

① Survey items in 5.4.2.2, as appropriate.

5.4.2.6 Dredgers

(1) In addition to the survey items in 5.4.2.2, the following additional items are to be carried out for dredgers (if applicable):

① The deck and relevant structural members in the following regions

a. in way of the main gantry and the bucket ladder gantry;

b. in way of cutter ladders and of supporting of the gantry;

c. in way of supporting of the spud;

d. in way of the gantry supporting the suction pipe;

e. in way of the winch seating;

f. in way of the grab machinery;

g. in way of other working regions of machinery;

h. in way of towing bollards;

i. structural members of hopper;

j. opening and closing devices of doors;

k. strake in way of areas where the drag head may run against bilge and side shell of trailing suction dredger.

② Dredging pump room

a. bottom framing of dredging pump room and surrounding structures;

b. watertight trunk;

c. dredging pump seating and surrounding structures.

③ Slots.

④ Rubbing bands.

⑤ Deck hinges.

⑥ Connection of hydraulic gearing.

⑦ Hydraulic gearing and connected pipes.

5.4.2.7 Containerships

(1) In addition to the survey items in 5.4.2.2, the following additional items are to be carried out for containerships (if applicable):

① Documentation

a. cargo securing manual;

b. any renewed securing devices (excluding cell guides) provided with product certificate or certification as required by the Rules and Research Institute.

② Cell guide system

a. guide, cell guide;

b. intersection between cell guide and cross ties;

c. demountable frames;

d. other equivalent restraint arrangements.

③ Fixed securing device

a. corner post;

b. lashing bridge;

c. lashing point.

④ Portable securing device.

(2) For ships assigned class notation of Open-Top Container Ship, the pipelines and nozzles of water spray systems are to be tested with compressed air for unimpeded passage, and pipelines and operating valves externally examined and an appropriate nozzle of the water spray system is to be selected for effectiveness test.

5.4.2.8 Timber carriers

(1) In addition to the survey items in 5.4.2.2, the following additional items are to be carried out for timber carriers (if applicable):

① cargo securing manual;

② arrangements for carrying timbers on the deck;

③ securing devices;

④ safe access.

5.4.2.9 Tugs

(1) In addition to the survey items in 5.4.2.2, the following additional items are to be carried out for tugs (if applicable):

① operations manual;

② towing hook;

③ release mechanism;

④ towing engine;

⑤ supporting structures.

⑥ towing winch emergency release system.

(2) Survey of towing winch emergency release systems, including:

① Operation of the towing winch emergency release system is to be confirmed with the reference to the documented instructions for surveys provided by the manufacturer. Operation of the winch emergency release system under no load condition is to be verified. Where practical, activation of the emergency release system may be confirmed by observation of the winch brake.

② The function of the alarms associated with the emergency release system is to be verified, as far as practicable and reasonable.

③ The condition of the emergency release system is to be visually examined to confirm it remains in satisfactory condition.

④ The means of emergency release of the towline in the event of a blackout is to be examined, and where additional sources of energy are arranged for this purpose, the sources of energy are to be visually inspected and operationally tested.

⑤ It is to be verified that the performance capabilities and operating instructions of the emergency

release system are documented and made available on board the ship on which the winch has been installed.

5.4.2.10 Offshore supply ships

(1) In addition to the survey items in 5.4.2.2, the following additional items are to be carried out for offshore supply ships (if applicable):

① operations manual;

② cargo securing manual;

③ cargo containment arrangement.

5.4.3 Intermediate surveys

5.4.3.1 General requirements

(1) The relevant requirements for interval of intermediate surveys are given in Section 2 of this Chapter.

(2) Intermediate surveys are to be carried out in conjunction with statutory intermediate surveys or docking surveys in so far as practicable. A survey planning meeting is to be held prior to the commencement of the survey.

(3) In addition to cover the applicable items specified in 5.4.2.2 of this Section, intermediate surveys are to include the items specified in 5.4.3.2 and such items are to be found satisfactory.

5.4.3.2 Survey items for all ships

(1) Fire-fighting equipment

① Check of quantity and efficiency of medium of fixed fire-extinguishing arrangements, examination and testing of fire-extinguishing system.

(2) Windlass

① Partial test of slipping and hauling anchors by windlass.

(3) Ballast tanks:

① Ships between 5 and 10 years of age:

A general, internal examination of representative ballast tanks is to be carried out. Where a full hard protective coating in POOR condition or any other defect is found, where soft or semi-hard coating has been applied, or where there is no full hard protective coating, the examination is to be extended to other ballast tanks of the same type.

② Ships over 10 years of age:

A general, internal examination of all ballast tanks is to be carried out.

③ If such examinations as stated in ① and ② above reveal no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains effective.

④ For ballast tanks, excluding double bottom tanks, where a full hard protective coating is found in POOR condition and it is not renewed, where soft or semi-hard coating has been applied, or where there is no full hard protective coating, the tanks in question are to be internally examined at annual intervals.

⑤ When such conditions as stated in ④ above are found in double bottom ballast tanks, the spaces in question may be internally examined at annual intervals.

(4) Cargo spaces

① For ships over 10 years of age, other than ships engaged in the carriage of dry cargoes only and oil tankers (including double hull oil tankers), chemical tankers and liquefied gas carriers complying with relevant provisions of Sections 6, 8 and 16 of this Chapter respectively, an internal examination of selected cargo holds is to be carried out.

② For ships over 15 years of age and engaged in the carriage of dry cargoes only, other than general dry cargo ships and bulk carriers (including double skin bulk carriers) which are subject to the relevant requirements of Sections 5 and 7 of this Chapter respectively, an internal examination of selected cargo spaces is to be carried out.

(5) Thickness measurements

Where extensive areas of wastage are found, thickness measurements are to be required and renewals made when wastage exceeds allowable margins.

5.4.4 Special surveys

5.4.4.1 General requirements

(1) The relevant requirements for interval of special surveys are given in Section 2 of this Chapter.

(2) Special surveys are to be carried out in conjunction with statutory renewal surveys in so far as practicable. A survey planning meeting is to be held prior to the commencement of the survey.

(3) In addition to the applicable items specified in 5.4.2.2 of this Section, special surveys are to include examination, tests and checks of the items listed in 5.4.4.2 to ensure that the hull, equipment and related piping (as required by 5.4.4.2(19)) are in satisfactory condition and that the ship is fit for the intended purpose for the next five (5) year class period, subject to proper maintenance and operation and the periodical surveys being carried out at the due dates. The examinations of the hull are to be supplemented by testing and thickness measurements as required in 5.4.4.2(5) and 5.4.4.2(17)①, ③, to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.
(4) Examination of underwater parts specified in Section 11 of this Chapter. However, surveys of the outside of the ship's bottom and related items completed within 15 months before the due date of the special survey may be accepted as a survey carried out at the same time with the special survey.

5.4.4.2 Survey items for all ships

(1) Hull and spaces in superstructures are to be examined.
(2) All spaces including holds and their 'tween decks where fitted; double bottom, deep, ballast, peak and cargo tanks; pump rooms, pipe tunnels, duct keels, machinery spaces, dry spaces, cofferdams and voids are to be internally examined including the plating and framing, bilges and drain wells, sounding, venting, pumping and drainage arrangements. Internal examination of tanks is to be carried out in accordance with Table 5.4.4.2(2). At special survey No.3 and subsequent special surveys, structural downflooding ducts and structural ventilation ducts are to be internally examined.

Internal Examination of Tanks **Table 5.4.4.2(2)**

Tank	Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
Salt water and/or cargo/salt water in turn	All	All	All	All
Fuel oil bunker tanks - Engine room - Cargo length area - If no tanks in cargo length area, additional fuel tank(s) outside of engine room (if fitted)	— — —	— One One	One Two One	One Half, minimum two Two
Lube oil	—	—	—	One
Fresh water	—	One	All	All
Fore and aft peaks (all uses)	All	All	All	All

Notes:
(1) Special attention is to be paid to the striking plate below the sounding pipe and the plating adjacent to the mouth piece when examining.
(2) These requirements apply to tanks of integral (structural) type.
(3) If a selection of tanks is accepted to be examined, then different tanks are to be examined at each special survey, on a rotational basis.
(4) At special survey No.3 and subsequent surveys, one deep tank for fuel oil in the cargo length area is to be included, if fitted.

(3) Where provided, the condition of corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom tanks, where a full hard protective coating is found in POOR condition and it is not renewed, where soft coating or semi-hard has been applied, or where a full hard protective coating was not applied from time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the surveyor.
(4) When such breakdown of full hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a full hard protective coating was not applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.
(5) Boundaries of double-bottom, deep, ballast, peak, and other tanks, including holds adapted for the carriage of salt water ballast, are to be tested with a head of liquid to the top of air pipes or to near the top of hatches for ballast/cargo holds. Boundaries of fuel oil, lube oil and fresh water tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions.
Tank testing of fuel oil, lube oil and fresh water tanks may be specially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results. The Surveyor may

extend the testing as deemed necessary.
(6) Hydraulic test for some tanks, when found difficult, may be substituted by airtightness test. Where hydraulic test is difficult to be carried out on the shipway or within the dock, it may be carried out while the ship is afloat. Appropriate means of examination before launching such as leakage test are to be carried out for parts that cannot be examined after launching and underwater parts of the hull, or examine tank internal bottom while the ship is afloat.
(7) Where repairs are effected to the shell plating or bulkheads, any tanks in way are to be tested on completion of these repairs.
(8) All decks and superstructures are to be examined.
(9) In cases where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is inspected, tested by beating and chipping, and found sound and adhering satisfactorily to the steel.
(10) Wood sheathing or other coverings on steel deck are to be examined. If it is found that such wood sheathing has worn by 15 mm or more, or that other coverings are broken, they are to be renewed and the condition of the plating under such wood sheathing or other deck coverings is to be examined.
(11) The hatch covers and coamings are to be surveyed as follows:

① a thorough inspection of the items listed in 5.4.2.2(3), including close-up survey of hatch cover plating and hatch coaming plating, is to be carried out. Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey is to be done of accessible parts of hatch covers structures;

② checking of the satisfactory operation of all mechanically operated hatch covers is to be made, including:

a. stowage and securing in open condition;
b. proper fit and efficiency of sealing in closed conditions;
c. operational testing of hydraulic and power components, wires, chains and link drives;

③ checking the effectiveness of sealing arrangements of all hatch covers by hose testing or equivalent is to be carried out.

(12) The masts and standing rigging (if fitted) are to be examined.
(13) The anchors and chain cables[①] are to be ranged, examined, and the required complement and condition verified. At special survey No.2 and subsequent special surveys, chain cables are to be gauged. If any length of chain cables is found to be reduced in mean diameter[②] at its most worn part by 12% or more from its nominal diameter as required in the Rules, it is to be renewed. The chain locker, holdfasts, hawse pipes, chain stoppers and windlass are to be examined and pumping arrangements of the chain locker tested.
(14) The anchors of positional mooring equipment are to be cleaned and examined. Wire rope anchor cables are to be examined. If cables are found to contain broken, badly corroded or birdcaging wires they are to be renewed. If any length of chain cables is found to be worn more than as specified under (13) above, it is to be renewed. The windlass(es) or winches are to be examined.
(15) Verifying that repairs made by crew and voyage repairs are in compliance with the Rules, and satisfactory in respect to workmanship, etc. and for the intended purpose of the ship.
(16) Engine room structure is to be examined. Particular attention is to be given to tank tops, shell plating in way of tank tops, brackets connecting side shell frames and tank tops, and engine room bulkheads in way of tank top and bilge wells. Particular attention is to be given to the sea suctions, seawater cooling pipes and overboard discharge valves[③] and their connections to the shell plating. Where wastage is evident or suspect, thickness measurements are to be carried out, and renewals or repairs made when wastage exceeds allowable limits.
(17) Thickness measurement

① The minimum requirements to thickness measurement are given in Table 5.4.4.2(17)①.

② Thickness measurements may be carried out at the commencement of the special survey, or the thickness measurement report prepared within 15 months before the due date of the special survey may be taken as the thickness measurement report of the special survey.

③ The Surveyor may extend the thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of thickness measurements is to be

---

① For examination of anchors and chain cables, refer to IACS Rec.No.79 “Guidance for Anchoring Equipment in Service”.
② The mean diameter is half the value of the sum of the minimum diameter found in one cross section of the link and of the diameter measured in a perpendicular direction in the same cross section.
③ Refer to IACS Rec.144 “Inspection of ship's side valves”.

increased to determine areas of substantial corrosion. Table 5.4.4.2(17)② may be used as guidance for the additional thickness measurements. These extended thickness measurements are to be carried out before the survey is credited as completed.

④ Thickness measurements are normally to be carried out by a company, certified by CCS according to the Procedures for Certification of Firms Engaged in Thickness Measurement of Hull Structures (Appendix 10 of this Chapter), by means of ultrasonic test equipment The accuracy of the equipment is to be proven to the Surveyor as required. The test personnel are to hold a qualification certificate acceptable to CCS.

⑤ The assessment of thickness measurement results may be based on longitudinal and local strength, or the evaluation of structural safety may be carried out in accordance with CCS rules. For generally allowable corrosion, refer to the provisions in Appendix 1 to this Chapter. Plates and structural members are to be renewed when corrosion exceeds allowable limits.

(18) Automatic air pipe heads are to be completely examined (both externally and internally) as indicated in Table 5.4.4.2(18). For designs where the inner parts cannot be properly inspected from outside, this is to include removal of the head from the air pipe. Particular attention is to be paid to the condition of the zinc coating in heads constructed from galvanised steel.

(19) All bilge and ballast piping systems are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.

(20) Inspection of Watertight Cable Transits

① The requirements for Special Survey may be undertaken by the attending Surveyor or by a firm approved as a service supplier according to Appendix 8 of this chapter.

② All transits are to be examined to confirm their satisfactory condition and the Register is to be reviewed to confirm it is being maintained. The Special Survey is to be recorded in the Register, in which a single record entry will be sufficient to record the survey of all transits.

③ From review of the Register, where there are records entered since the last special survey of any disruption to the cable transits or installation of new cable transits (except which are reviewed and examined at previous annual surveys), the satisfactory condition of those transits is to be confirmed by the attending Surveyor by review of records and examination of the transits; the results are to be recorded in the Register against each of those cable transits.

④ In case the cable transits have been examined by an approved service supplier, the attending surveyor is to review the Register in order to ascertain that it has been properly maintained by the owner and correctly endorsed by the service supplier.

Minimum Requirements for Thickness Measurements at Special Surveys Table 5.4.4.2(17)①

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
(1) Suspect areas throughout the ship	(1) Suspect areas throughout the ship	(1) Suspect areas throughout the ship	(1) Suspect areas throughout the ship
	(2) One transverse section of deck plating within the amidships 0.5*L* (in way of a cargo space, if applicable)	(2) Two transverse sections within the amidships 0.5*L* (in way of two cargo spaces, if applicable)	(2) A minimum of three transverse sections within the amidships 0.5*L* (in way of a cargo space, if applicable)
		(3) All cargo hold hatch covers and coamings (plating and stiffeners)	(3) All cargo hold hatch covers and coamings (plating and stiffeners)
		(4) Internals in forepeak and afterpeak ballast tanks	(4) Internals in forepeak and afterpeak ballast tanks
			(5) All exposed main deck plating full length
			(6) Representative exposed superstructure deck plating (poop, bridge, and forecastle deck)
			(7) Lowest strake and strakes in way of 'tween decks of all transverse bulkheads in cargo spaces together with internals in way
			(8) All wind- and water strakes, port and starboard, full length
			(9) All keel plates full length. Also,

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
			additional bottom plates in way of cofferdams, machinery space, and aft end of tanks
			(10) Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor

Notes: For thickness measurements reporting, the forms included in Appendix 13.1A of this Chapter may be used, as appropriate. The annexed forms are a recommendation and are not a mandatory requirement.

1. Thickness measurement locations are to be selected to provide the best representative sampling of areas likely to be most exposed to corrosion, considering cargo and ballast history and arrangement and condition of protective coatings.
2. Thickness measurements of internals may be specially considered by the Surveyor if the hard protective coating is in GOOD condition.
3. For ships less than 100 m in length, the number of transverse sections required at special survey No.3 may be reduced to one (1), and the number of transverse sections required at subsequent special surveys may be reduced to two (2).
4. For ships more than 100 m in length, at special survey No.3, thickness measurements of exposed deck plating within amidships 0.5*L* may be required.
5. Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, thickness measurement is to be done of accessible parts of hatch covers structures.

Guidance for Additional Thickness Measurements in Way of Substantial Corrosion

Table 5.4.4.2(17)②

Structural member	Extent of measurement	Pattern of measurement
Plating	Suspect area and adjacent plates	5-point pattern over 1 square meter
Stiffeners	Suspect area	3 measurements each in line across web and flange

Survey Requirements for Automatic Air Pipe Heads at Special Surveys

Table 5.4.4.2(18)

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Surveys No.3 and Subsequent Age > 10
(1) Two air pipe heads, one port and one starboard, located on the exposed decks in the forward 0.25*L*, preferably air pipes serving ballast tanks. (2) Two air pipe heads, one port and one starboard, on the exposed decks, serving spaces aft of 0.25*L*, preferably air pipes serving ballast tanks. (3) The selection of air pipe heads to be examined is left to the attending Surveyor. (4) According to the results of this examination, the Surveyor may require the examination of other heads located on the exposed decks	(1) All air pipe heads located on the exposed decks in the forward 0.25*L*. (2) At least 20% of air pipe heads on the exposed decks serving spaces aft of 0.25*L*, preferably air pipes serving ballast tanks. (3) The selection of air pipe heads to be examined is left to the attending Surveyor. (4) According to the results of this examination, the Surveyor may require the examination of other heads located on the exposed decks	All air pipe heads located on the exposed decks. Exemption may be considered for air pipe heads where there is substantiated evidence of replacement within the previous five years

5.4.4.3 Non-self-propelled ships

(1) In addition to the survey items in 5.4.4.2, the following items are to be examined and tested:

① waterhead test of tanks may be substituted with airtightness test;

② all pumps and pipes are to be generally examined and tested under working conditions;

③ all sea chests are to be opened up and examination;

④ for tankers carrying cargoes having a flashpoint not exceeding 60℃and having electrical installations in dangerous zones, the electrical installations are to be examined and tested in accordance with the provisions for self-propelled tankers;

⑤ pumps or prime movers on board are in general not required to be opened up for examination, unless deemed necessary as a consequence of the results of the examination or test.

5.4.4.4 Tugs

(1) In addition to the applicable survey items in 5.4.4.2, the additional survey of towing winch emergency release systems is to be carried out for tugs, including:

① The Annual Survey requirements in item 5.4.2.9(2) are to be carried out, with the additional instructions for special survey provided by the manufacturer, as appropriate, being followed.

② The full functionality of the emergency release system is to be tested to the satisfaction of the surveyor. Testing may be conducted either during a bollard pull test or by applying the load against a strong point on the deck of the tug or the shore that is certified to the appropriate load.

③ The emergency release system is to be tested at a towline load that is equal to the lesser of 30% of the maximum design load or 80% of vessel bollard pull in both a normal power condition and power blackout condition to the satisfaction of the surveyor.

Section 5 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF GENERAL DRY CARGO SHIPS①

5.5.1 General requirements

5.5.1.1 Application

(1) Unless provided otherwise, the requirements of this Section apply to all self-propelled general dry cargo ships of 500 gt and above carrying solid cargoes other than②:

① bulk carriers (including double skin bulk carriers);

② dedicated container carriers;

③ ro-ro cargo ships;

④ refrigerated cargo ships;

⑤ dedicated woodchip carriers;

⑥ dedicated cement carriers;

⑦ livestock carriers;

⑧ deck cargo ships③;

⑨ general dry cargo ships of double side-skin construction, with double side-skin extending for the length of the cargo area, and for the height of the cargo hold to the upper deck④.

(2) For General Dry Cargo Ships with hybrid cargo hold arrangements, e.g. with some cargo holds of single-side skin and others of double-side skin, the requirements of this Section are to be applied only to structure in way of the single-side skin cargo hold region.

(3) The requirements of this Section apply to surveys of hull structure and piping systems in way of cargo holds, cofferdams, pipe tunnels, void spaces and fuel oil tanks within the cargo area and all ballast tanks. The requirements are additional to the classification requirements applicable to the remainder of the ship. Refer to Section 4 of this Chapter.

(4) The requirements of this Section contain the minimum extent of examination, thickness measurements and tank testing. The survey is to be extended when substantial corrosion and/or structural defects are found and include additional close-up survey when necessary.

5.5.1.2 Thickness measurements Acceptance Criteria

(1) The acceptance criteria for thickness measurements are according to the relevant requirements of Appendix 1 of this Chapter depending on ship's age and structural elements concerned, e.g. 2.4⑤ for corrugated transverse bulkhead, 2.6⑥ or 2.7 for all cargo hatch covers and coamings on exposed decks.

5.5.2 Annual surveys

---

① For surveys, assessment and repair of hull structure, refer to IACS Rec.55 "General Dry Cargo Ships - Guidelines for Surveys, Assessment and Repair of Hull Structure".

② The requirements of paragraphs 5.5.2.6 and 5.5.4.8 also apply to those cargo ships, which, although belonging to the ship types that are excluded from the application of this Section, are fitted with a single cargo hold.

③ A ship that is designed to carry cargo exclusively above deck has no any access for cargo below deck.

④ Special consideration may also be given to ships that are of double side-skin construction but with single skin in way of several frame spaces e.g. in way of a cargo hold entrance or in way of forebody hull form at the forward end of the foremost cargo hold.

⑤ 2006 edition of the Rules or subsequent revisions or corrigenda as applicable.

⑥ For ships contracted for construction on or after 1 July 2012, see 2.20.2.10, Section 20, Chapter 2, PART TWO of 2012 edition of the Rules. For ships contracted for construction on or after 1 July 2016, see 2.20.2.10, Section 20, Chapter 2, PART TWO of 2016 Amendments of the Rules.

5.5.2.1 General requirements

(1) The annual survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition.

(2) The annual survey is to include the items specified in 5.5.2.2 through 5.5.2.6 and in addition, the applicable items specified in 5.4.2 of this Chapter.

5.5.2.2 Hull

(1) Examination of the hull plating and its closing appliances as far as can be seen;

(2) Examination of watertight penetrations as far as practicable.

5.5.2.3 Weather decks, hatch covers and coamings

(1) Confirmation is to be obtained that no unapproved changes have been made to the hatch covers, hatch coamings and their securing and sealing devices since the last survey.

(2) Where mechanically operated steel covers are fitted, checking the satisfactory condition of:

① hatch covers, including close-up survey of hatch cover plating;

② drainage channels, drain pipes and non-return devices on top of hatch coamings;

③ tightness devices of longitudinal, transverse and intermediate cross junctions (gaskets, gasket lips, compression bars, drainage channels);

④ clamping devices, retaining bars, cleating;

⑤ chain or rope pulleys;

⑥ guides;

⑦ guide rails and track wheels;

⑧ stoppers, etc.;

⑨ wires, chains, gypsies, tensioning devices;

⑩ hydraulic system essential to closing and securing;

⑪ safety locks and retaining devices.

(3) Where portable covers, wooden or steel pontoons are fitted, checking the satisfactory condition where applicable of:

① wooden covers and portable beams, carriers or sockets for the portable beam, and their securing devices;

② steel pontoons; including close-up survey of hatch cover plating;

③ tarpaulins;

④ cleats, battens and wedges;

⑤ hatch securing bars and their securing devices;

⑥ loading pads/bars and the side plate edge;

⑦ guide plates and chocks;

⑧ compression bars, drainage channels and drain pipes (if any).

(4) Checking the satisfactory condition of hatch coaming plating and their stiffeners including close-up survey.

(5) Random checking of the satisfactory operation of mechanically operated hatch covers is to be made including:

① stowage and securing in open condition;

② proper fit and efficiency of sealing in closed condition;

③ operational testing of hydraulic and power components, wires, chains, and link drives.

5.5.2.4 Suspect Areas

Suspect areas identified at previous surveys are to be examined. Thickness measurements are to be taken of the areas of substantial corrosion and the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. Table 5.4.4.2(17)② may be used as guidance for the additional thickness measurements. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

5.5.2.5 Examination of cargo holds

(1) Ships 10 to 15 years of age

① Overall survey of one forward and one after cargo hold and their associated 'tween-deck spaces.

② When considered necessary by the surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. Table 5.4.4.2(17)② may be used as guidance for these additional measurements. These extended thickness measurements are to be carried out

before the annual survey is credited as completed.

(2) Ships over 15 years of age

① Overall survey of all cargo holds and 'tween-deck spaces.

② Close-up examination of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approx. lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating in a forward lower cargo hold and one other selected lower cargo hold. Where this level of survey reveals the need for remedial measures, the survey is to be extended to include a close-up survey of all of the shell frames and adjacent shell plating of those cargo holds and associated 'tween-deck spaces (as applicable) as well as a close-up survey of sufficient extent of all remaining cargo holds and 'tween-deck spaces (as applicable).

③ When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. Table 5.4.4.2(17)② may be used as guidance for these additional measurements. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

④ Where the protective coating in cargo holds, as applicable, is found to be in GOOD condition, the extent of close-up surveys may be specially considered.

⑤ All piping and penetrations in cargo holds, including overboard piping, are to be examined.

5.5.2.6 For single hold cargo ships complying with the requirements of SOLAS Reg. II-I/25 for hold water level detectors, the annual survey is to include an examination and a test, at random, of the water ingress detection system and of their alarms.

5.5.3 Intermediate surveys

5.5.3.1 General requirements

(1) The intermediate survey extent is dependent on the age of the ship as specified in 5.5.3.2 to 5.5.3.4 of this Section.

(2) The intermediate survey is also to include the applicable items specified in 5.4.3 of this Chapter and 5.5.2 of this Section.

5.5.3.2 Ships 5 to 10 years of age

(1) Ballast tanks

① For ballast tanks, an overall survey of representative tanks selected by the Surveyor is to be carried out. If such overall survey reveals no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains efficient.

② Where POOR coating condition, soft or semi-hard coating, corrosion or other defects are found in ballast tanks or where a full hard protective coating was not applied from the time of construction, the examination is to be extended to other ballast tanks of the same type.

③ In ballast tanks other than double bottom tanks, where a full hard protective coating is found in POOR condition and it is not renewed, where soft or semi-hard coating has been applied, or where a full hard protective coating was not applied from time of construction, the tanks in question are to be examined and thickness measurements carried out as considered necessary at annual intervals. When such breakdown of full hard protective coating is found in double bottom ballast tanks, where a soft or semi-hard coating has been applied, or where a full hard protective coating has not been applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

④ In addition to the requirements above, areas found suspect at previous surveys are to be surveyed in accordance with the provisions indicated in 5.5.2.4 of this Chapter.

(2) Cargo holds

① An overall survey of one forward and one after cargo hold and their associated 'tween-deck spaces.

② Areas found suspect at previous surveys are to be surveyed in accordance with the provisions indicated in 5.5.2.4.

5.5.3.3 Ships 10 to 15 years of age

(1) Ballast tanks

① For ballast tanks, an overall survey of all tanks is to be carried out. If such overall survey reveals no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains efficient.

② The requirements of 5.5.3.2(1)③ and ④ also apply.

(2) Cargo holds

① An overall survey of all cargo holds and 'tween-deck spaces.

② Areas found suspect at previous surveys are to be surveyed in accordance with the provisions indicated in 5.5.2.4 of this Chapter.

③ When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. Table 5.4.4.2(17)② may be used as guidance for these additional measurements. These extended thickness measurements are to be carried out before the survey is credited as completed.

5.5.3.4 Ships over 15 years of age:

(1) The requirements of the intermediate survey are to be to the same extent as the previous special survey as required in 5.5.4, except for item 2c in column 4 of Table 5.5.4.5(1). However, tank testing specified in 5.5.4.6, survey of automatic air pipe heads (see 5.4.4.2(18)) and internal examination of fuel oil, lube oil and fresh water tanks (see 5.5.4.4(1)) are not required unless deemed necessary by the attending Surveyor.

(2) In application of (1), the intermediate survey may be commenced at the second annual survey and be progressed during the succeeding year with a view to completion at the third annual survey in lieu of the application of 5.2.4.2 of this Chapter.

(3) In lieu of the requirements of 5.5.4.1(5), an in-water survey, according to the provisions of 5.2.3.4 of this Chapter, may be considered as equivalent.

5.5.4 Special surveys

5.5.4.1 General requirements

(1) The special survey is to include, in addition to the requirements of 5.4.4 of this Chapter and 5.5.2 of this Section, examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in 5.5.4.1(3), are in a satisfactory condition and fit for the intended purpose for the new period of class of 5 years to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

(2) All cargo holds, ballast tanks, including double bottom tanks, pipe tunnels, cofferdams and void spaces bounding cargo holds, decks and outer hull are to be examined, and if necessary, this examination is to be supplemented by thickness measurement and testing as required in 5.5.4.5 and 5.5.4.6, to ensure that the structural integrity remains effective.

The internal examination of other tanks is to be in accordance with 5.4.4.2(2) of this Chapter. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.

(3) All piping systems within the above spaces are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.

(4) The survey extent of ballast tanks converted to void spaces is to be specially considered in relation to the requirements for ballast tanks.

(5) A survey in dry dock is to be a part of the special survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions[①] of the cargo holds and ballast tanks are to be carried out in accordance with the applicable requirements for special surveys, if not already performed.

5.5.4.2 Tank protection

(1) Where provided, the condition of corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom tanks, where a full hard protective coating is found in POOR condition and it is not renewed, where soft or semi-hard coating has been applied, or where a full hard protective coating was not applied from the time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the Surveyor.

(2) When such breakdown of full hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a full hard protective coating was not applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

(3) Where the hard protective coating in tanks is found to be in a GOOD condition, the extent of close-up surveys and thickness measurements may be specially considered.

---

① Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line.

5.5.4.3 Hatch covers and coamings

(1) A thorough inspection of the items listed in 5.5.2.3 of this Section is to be carried out.

(2) Checking of the satisfactory operation of all mechanically operated hatch covers is to be made, including:

① stowage and securing in open condition;

② proper fit and efficiency of sealing in closed conditions;

③ operational testing of hydraulic and power components, wires, chains and link drives.

(3) Checking the effectiveness of sealing arrangements of all hatch covers by hose testing or equivalent is to be carried out.

(4) Close-up survey and thickness measurement① of the hatch cover and coaming plating and stiffeners is to be carried out as given in Table 5.5.4.4(2) and Table 5.5.4.5(1).

5.5.4.4 Extent of overall and close-up survey

(1) An overall survey of all tanks and spaces, excluding fuel oil, lube oil and fresh water tanks, is to be carried out at each special survey. (Note: For fuel oil, lube oil and fresh water tanks, reference is to be made to Table 5.4.4.2(2).)

(2) The minimum requirements for close-up surveys at special survey are given in Table 5.5.4.4(2).

(3) The Surveyor may extend the close-up survey as deemed necessary taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.

(4) For areas in spaces where hard protective coatings are found to be in a GOOD condition, the extent of close-up surveys according to Table 5.5.4.4(2) may be specially considered.

---

① Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/thickness measurement shall be done of accessible parts of hatch covers structures.

Minimum Requirements for Close-up Surveys at Hull Special Surveys of General Dry Cargo Ships

Table 5.5.4.4(2)

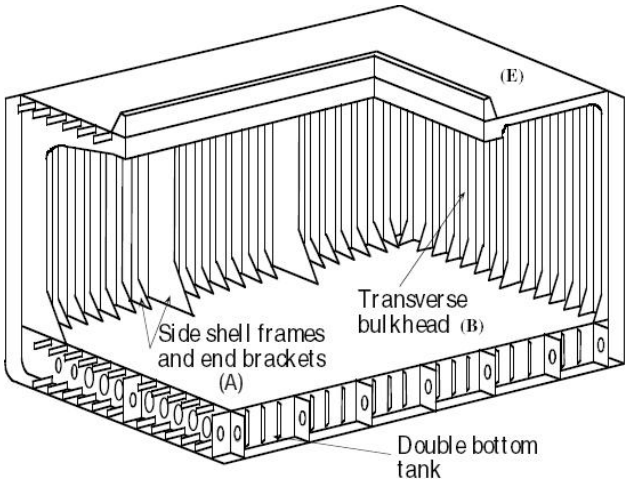
Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
(A) Selected shell frames in one forward and one aft cargo hold and associated 'tween-deck spaces. (B) One selected cargo hold transverse bulkhead. (D) All cargo hold hatch covers and coamings (plating and stiffeners)	(A) Selected shell frames in all cargo holds and 'tween-deck spaces. (B) One transverse bulkhead in each cargo hold. (B) Forward and aft transverse bulkhead in one side ballast tank, including stiffening system. (C) One transverse web with associated plating and framing in two representative water ballast tanks of each type (i.e. topside, hopper side, side tank or double bottom tank) (D) All cargo hold hatch covers and coamings (plating and stiffeners). (E) Selected areas of all deck plating and underdeck structure inside line of hatch openings between cargo hold hatches. (F) Selected areas of inner bottom plating	(A) All shell frames in the forward lower cargo hold and 25% frames in each of the remaining cargo holds and 'tween-deck spaces including upper and lower end attachments and adjacent shell plating. (B) All cargo hold transverse bulkheads. (B) All transverse bulkheads in ballast tanks, including stiffening system. (C) All transverse webs with associated plating and framing in each ballast tank. (D) All cargo hold hatch covers and coamings (plating and stiffeners). (E) All deck plating and underdeck structure inside line of hatch openings between cargo hold hatches. (F) All areas of inner bottom plating	(A) All shell frames in all cargo holds and 'tween-deck spaces including upper and lower end attachments and adjacent shell plating. Areas (B) – (F) as for Special Survey No.3

Notes: (A) Cargo hold transverse frames.
(B) Cargo hold transverse bulkhead plating, stiffeners and girders.
(C) Transverse web frame or watertight transverse bulkhead in water ballast tanks.
(D) Cargo hold hatch covers and coamings. Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/thickness measurement is to be done of accessible parts of hatch covers structures.
(E) Deck plating and underdeck structure inside line of hatch openings between cargo hold hatches.
(F) Inner bottom plating.

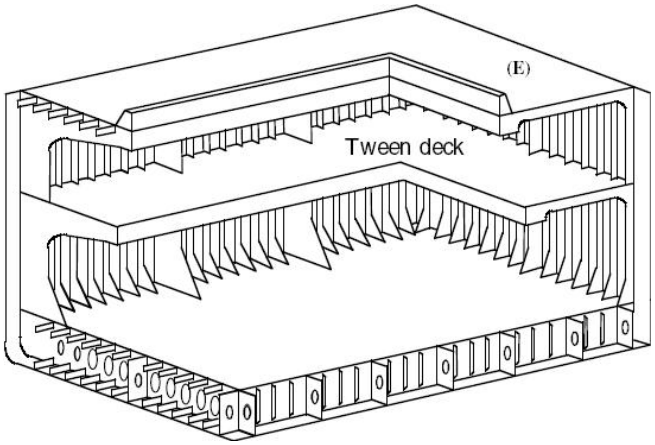
See Figures 5.5.4.4(2)a and 5.5.4.4(2)b for the areas corresponding to (A), (B), (C), (D), (E) and (F).

Close-up survey of cargo hold transverse bulkheads to be carried out at the following levels:

a. Immediately above the inner bottom and immediately above the 'tween decks, as applicable.
b. Mid-height of the bulkheads for holds without 'tween decks.
c. Immediately below the main deck plating and 'tween deck plating.

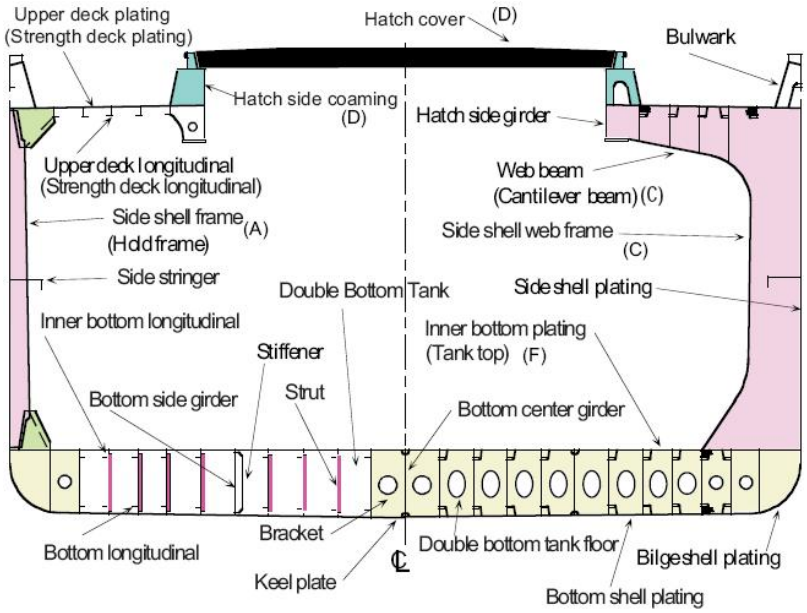


(a) Single deck ship



(b) Tween deck ship

Figure 5.5.4.4(2)a Areas for Close-Up Survey of General Dry Cargo Ships



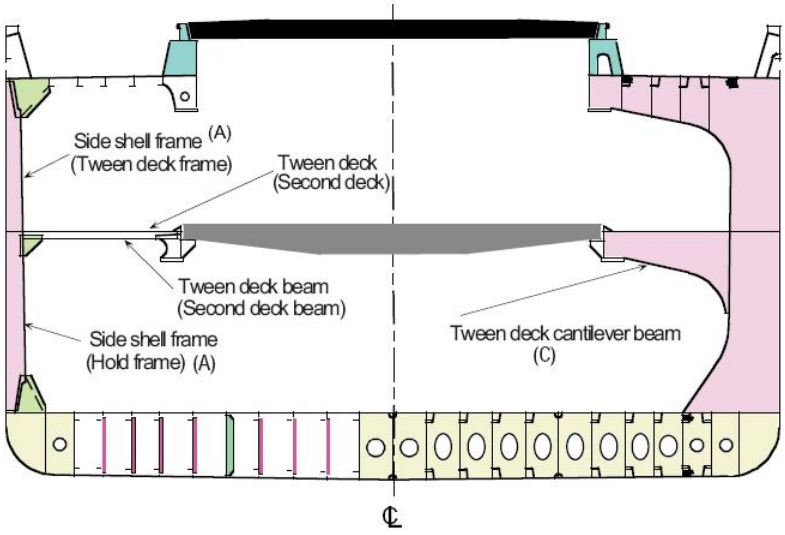


Figure 5.5.4.4(2)b Areas for Close-Up Survey of General Dry Cargo Ships

5.5.4.5 Extent of thickness measurement

(1) The minimum requirements for thickness measurements at special survey are given in Table 5.5.4.5(1).

Minimum Requirements for Thickness Measurements at Hull Special Surveys of General Dry Cargo Ships **Table 5.5.4.5(1)**

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
1. Suspect areas	1. Suspect areas. 2. One transverse section of deck plating in way of a cargo space within the amidships 0.5*L*. 3. Measurement for general assessment and recording of corrosion pattern of those structural members subject to close-up survey according to Table 5.5.4.4(2) of this Section	1. Suspect areas. 2. Two transverse sections within the amidships 0.5*L* in way of two different cargo spaces. 3. Measurement for general assessment and recording of corrosion pattern of those structural members subject to close-up survey according to Table 5.5.4.4(2) of this Section. 4. Within the cargo length, each deck plate outside line of cargo hatch openings. 5. All wind and water strakes within the cargo length area. 6. Selected wind and water strakes outside the cargo length area	1. Suspect areas. 2. Within the cargo length: a) A minimum of three transverse sections within the amidships 0.5*L*. b) Each deck plate outside line of cargo hatch openings. c) Each bottom plate, including lower turn of bilge. d) Duct keel or pipe tunnel plating and internals. 3. Measurement for general assessment and recording of corrosion pattern of those structural members subject to close-up survey according to Table 5.5.4.4(2) of this Section 4. All wind and water strakes full length

Notes: 1. Thickness measurement locations should be selected to provide the best representative sampling of areas likely to be most exposed to corrosion, considering cargo and ballast history and arrangement and condition of protective coatings.

2. For ships less than 100 m in length, the number of transverse sections required at special survey No.3 may be reduced to one and the number of transverse sections at special survey No.4 and subsequent surveys may be reduced to two.

(2) The Surveyor may extend the thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. Table 5.4.4.2(17)② may be used as guidance for these additional thickness measurements.

(3) For areas in spaces where hard protective coatings are found to be in a GOOD condition, the extent of thickness measurement according to Table 5.5.4.5(1) may be specially considered.

(4) Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

(5) For the assessment of thickness measurement results, see 5.4.4.2(17)⑤ of this Chapter.

5.5.4.6 Extent of tank testing
(1) All boundaries of ballast tanks and deep tanks used for water ballast within the cargo length area are to be pressure tested. For fuel oil tanks, the representative tanks are to be pressure tested.
(2) The Surveyor may extend the tank testing as deemed necessary.
(3) Tank testing of fuel oil tanks is to be carried out with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil tanks may be specially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.
5.5.4.7 Automatic air pipe heads
(1) For examination of automatic air pipe heads installed on the exposed decks, reference is to be made to 5.4.4.2(18) of this Chapter.
5.5.4.8 For single hold cargo ships complying with the requirements of SOLAS Reg. II-I/25 for hold water level detectors, the special survey is to include an examination and a test of the water ingress detection system and their alarms.

Section 6 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF OIL TANKERS

5.6.1 General requirements

5.6.1.1 Application
(1) This Section applies to surveys of hull and equipment for all single or double hull oil tankers, including oil/ore carriers and oil/bulk/ore carriers.
(2) This Section applies to surveys of hull structure and piping systems in way of cargo tanks, pump rooms, cofferdams, pipe tunnels, void spaces within the cargo area and all ballast tanks. The requirements of this Section are additional to the classification requirements applicable to the remainder of the ship.
(3) This Section contains the minimum extent of examination, thickness measurements and tank testing. The survey is to be extended when substantial corrosion and/or structural defects are found and include additional close-up survey when necessary.
(4) Except as stated otherwise, this Section applies to single or double hull oil tankers (including those oil tankers of which the distance between inner hull and outer hull is not in compliance with Regulation 13F of Annex I to MARPOL) having one of the following type notations:
- Oil Tanker;
- Oil Tanker, Double Hull (double hull oil tankers complying with Chapter 5, PART TWO of the Rules).

5.6.1.2 Special tankers
(1) For certain special tankers, CCS may accept the provisions of special guidelines for survey.
5.6.1.3 Evaluation of longitudinal strength
(1) In case of oil tankers of 130 m in length and upwards (as defined in the International Convention on Load Lines in force), the ship's longitudinal strength is to be evaluated by using the thickness of structural members measured (see 5.6.4.4(6)), renewed or reinforced, as appropriate, during the special survey after the ship reaches 10 years of age in accordance with Appendix 2 of this Chapter, Criteria for Longitudinal Strength of Hull Girder for Oil Tankers.
(2) The final result of evaluation of the ship's longitudinal strength required in (1) above, after renewal or reinforcement work of structural members, if carried out as a result of initial evaluation, is to be reported as a part of the Executive Hull Summary.

5.6.2 Annual surveys

5.6.2.1 General requirements
(1) The annual survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition and should take into account the service history, condition and extent of the corrosion prevention system of ballast tanks and areas identified in the survey report file.
(2) The annual survey is to include the items specified in 5.6.2.2 through 5.6.2.6 and in addition, the applicable items specified in 5.4.2 of this Chapter.
5.6.2.2 Hull
(1) Examination of the hull plating and its closing appliances as far as can be seen.
(2) Examination of watertight penetrations as far as practicable.

5.6.2.3 Weather decks
(1) Examination of cargo tank openings including gaskets, covers, coamings and flame screens.
(2) Examination of cargo tank pressure/vacuum valves and flame screens.
(3) Examination of flame screens on vents to all bunker, oily ballast, oily slop tanks and void spaces.
(4) Examination of cargo, crude oil washing, ballast and stripping systems both on deck and in cargo pump rooms, and bunker and vent piping systems on deck including vent masts and headers.
(5) Examination of cargo tank venting, purging, gas-freeing and other ventilation systems.
5.6.2.4 Cargo pump rooms and pipe tunnels if fitted
(1) Confirming that potential sources of ignition such as loose gear, combustible materials, etc., in or near the cargo pump room are eliminated, that there are no signs of undue leakage and that access ladders are in good condition.
(2) Examination of all pump room bulkheads for signs of leakage or fractures, and in particular, the sealing arrangements of all penetrations in these bulkheads.
(3) Examination of the condition of all piping systems in the cargo pump room so far as practicable.
(4) Confirming that installed pressure gauges on cargo discharge lines and level indicator systems are operational.
(5) Examination, so far as practicable, of cargo, bilge, ballast and stripping pumps in the cargo pump room for excessive gland seal leakage, verification of proper operation of electrical and mechanical remote operating and shutdown devices and operation of pump room bilge system, and checking that pump foundations are intact.
(6) Confirming that the pump room ventilation system is operational, ducting intact, dampers operational and screens are clean.
(7) Confirming that temperature sensing devices for bulkhead glands and audible and visible alarms in pump rooms are in good condition, if applicable.
(8) Confirming that bilge level monitoring devices and alarms in pump rooms are in good condition (if applicable).
(9) Examination of the fixed fire-fighting system for cargo pump rooms, and confirming, as far as practicable and when appropriate, the operation of the remote means for closing the various openings.
(10) Checking interlock between lighting and ventilation.
(11) Checking gas detection system.
5.6.2.5 Other equipment
(1) Checking the deck foam system, including the supplies of foam concentrate and testing that the minimum number of jets of water at the required pressure in the fire main is obtained, when the system is in operation.
(2) Examination of emergency towing arrangements at both ends of tankers of not less than 20,000 tonnes deadweight and verification that they are in good working condition, in so far as practicable.
(3) Examination of safe access to bow.
(4) Examination of instrumentation for continuously monitoring concentration of hydrocarbon gas, if applicable.
(5) Confirming, when appropriate, that the main steering gear comprises the necessary two or more identical power units and the requisite arrangements to regain steering capability in the event of a single failure.
(6) Examination of level indicator systems, all electrical equipment in dangerous zones, piping and stopping valves of cargo tanks.
(7) Confirming that a corrosion prevention system is fitted in dedicated ballast water tanks of oil tankers; Confirming that the coating system in cargo oil tanks of crude oil tankers, when appropriate, is maintained and that in-service maintenance and repair activities are recorded in the coating technical file.
(8) Examining the emergency lighting in all cargo pump rooms of oil tankers constructed after 1 July 2002.
(9) checking, for all tankers, the provision of at least two portable instruments for measuring oxygen and two for measuring flammable vapour concentrations, and suitable means for the calibration of these instruments.
(10) examining the arrangements for gas measurement in double-hull spaces and double bottom spaces, including the fitting of permanent gas sampling lines, where appropriate.
(11) examining, as far as possible, and testing the fixed hydrocarbon gas detection system.
(12) testing any fire detection and alarm system and any sample extraction smoke detection system.
5.6.2.6 Ballast tanks
(1) Examination of ballast tanks where required as a consequence of the results of the special survey (see 5.6.4) and intermediate survey (see 5.6.3.2(1) and (2)) is to be carried out. When considered necessary by the Surveyor, or when extensive corrosion exists, thickness measurements are to be carried out and if the

results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tables 5.6.4.4(2)①a to d and 5.6.4.4(2)②a to e respectively for oil tankers and double hull oil tankers. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken. For CSR ships, the identified substantial corrosion areas are required to be examined and additional thickness measurements are to be carried out.

5.6.2.7 Examining, for oil tankers of 150 m in length and above, where appropriate, the ship's structure in accordance with the Ship Construction File, taking into account identified areas that need special attention, and verifying that the Ship Construction File is updated, where applicable[①].

5.6.3 Intermediate surveys

5.6.3.1 General requirements

(1) The intermediate survey extent is dependent on the age of the ship as specified in 5.6.3.2 to 5.6.3.4 and Table 5.6.3 of this Section.

Minimum Requirements for Overall and Close-Up Survey and Thickness Measurements at Intermediate Survey of Double Hull Oil Tankers **Table 5.6.3**

Age of ship at time of intermediate survey due date		
5 < age ≤ 10	10 < age ≤ 15	age > 15
Overall survey of Representative ballast tanks selected by the attending surveyor (see 5.6.3.2)	The requirements of the previous Special Survey (see 5.6.3.3)	The requirements of the previous Special Survey (see 5.6.3.4)
Suspect areas identified at previous surveys are to be examined (see 5.6.3.2)		

(2) The intermediate survey is also to include the applicable items specified in 5.4.3 of this Chapter and 5.6.2 of this Section.

(3) For weather decks, an examination as far as applicable of cargo, crude oil washing, bunker, ballast, steam and vent piping systems as well as vent masts and headers is to be carried out. If upon examination there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, thickness measured or both; particular attention is to be paid to repairs such as welded doublers.

(4) For CSR ships, the identified substantial corrosion areas are required to be examined and additional thickness measurements are to be carried out.

5.6.3.2 Oil Tankers 5 to 10 years of age

(1) All ballast tanks are to be examined. When considered necessary by the Surveyor, thickness measurement and testing are to be carried out to ensure that the structural integrity remains effective. In the case of double hull oil tankers, for tanks used for salt water ballast, an overall survey of representative tanks selected by the Surveyor is to be carried out. If such inspections reveal no visible structural defects, the examination may be limited to a verification that the hard protective coating remains in GOOD condition.

(2) A ballast tank is to be examined at subsequent annual intervals where:

① a hard protective coating has not been applied from the time of construction, or

② a soft or semi-hard coating has been applied, or

③ substantial corrosion is found within the tank, or

④ the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

(3) In addition to the above, suspect areas identified at previous surveys are to be examined.

5.6.3.3 Oil Tankers 10 to 15 years of age

(1) The requirements of the intermediate survey are to be to the same extent as the previous special survey as required in 5.6.4 and 5.1.6.5. However, pressure testing of cargo and ballast tanks and the requirements for longitudinal strength evaluation of hull girders as required in 5.6.1.3 are not required unless deemed necessary by the attending Surveyor.

(2) In application of (1) above, the intermediate survey may be commenced at the second annual survey and be progressed during the succeeding year with a view to completion at the third annual survey.

(3) In application of (1) above, an underwater survey may be considered in lieu of the requirements of 5.6.4.1(4).

---

① Refer to Annex B to the International Code on the Enhanced Programme of Inspections during Surveys of Bulk Carriers and Oil Tankers, 2011(Resolution A.1049(27)),as amended.

5.6.3.4 Oil tankers over 15 years of age

(1) The requirements of the intermediate survey are to be to the same extent as the previous special survey as required in 5.6.4 and 5.1.6.5. However, pressure testing of cargo and ballast tanks and the requirements for longitudinal strength evaluation of hull girders as required in 5.6.1.3 are not required unless deemed necessary by the attending Surveyor.

(2) In application of (1) above, the intermediate survey may be commenced at the second annual survey and be progressed during the succeeding year with a view to completion at the third annual survey.

(3) In application of (1) above, a survey in dry dock is to be part of the intermediate survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions[①] of the cargo tanks and ballast tanks are to be carried out in accordance with the applicable requirements for intermediate surveys, if not already performed.

5.6.4 Special surveys

5.6.4.1 General requirements

(1) The special survey is to include, in addition to the applicable requirements of 5.4.4 of this Chapter and 5.6.2 of this Section, examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in 5.6.4.1(3), is in a satisfactory condition and is fit for its intended purpose for the new period of class of 5 years to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

(2) All cargo tanks, ballast tanks, including double bottom tanks, pump rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing required in 5.6.4.4 and 5.6.4.5, to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.

(3) Cargo piping on deck, including crude oil washing (COW) piping, cargo and ballast piping within the above tanks and spaces are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces, and Surveyors are to be advised on all occasions when this piping, including valves and fittings are open during repair periods and can be examined internally.

(4) A survey in dry dock is to be a part of the special survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions[①] of the cargo tanks and ballast tanks are to be carried out in accordance with the applicable requirements for special surveys, if not already performed.

5.6.4.2 Tank protection

(1) Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined.

(2) A ballast tank is to be examined at subsequent annual intervals where:

① a hard protective coating has not been applied from the time of construction, or

② a soft or semi-hard coating has been applied, or

③ substantial corrosion is found within the tank, or

④ the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurements are to be carried out as deemed necessary by the Surveyor.

5.6.4.3 Extent of overall and close-up surveys

(1) An overall survey of all tanks and spaces is to be carried out at each special survey.

(2) The minimum requirements for close-up surveys at special survey are given as follows, for ships not having the notation ESP, the Surveyor may carry out the close-up survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system.

① The minimum requirements for close-up surveys of oil tankers are given in Table 5.6.4.3(2)①.

② The minimum requirements for close-up surveys of double hull oil tankers are given in Table 5.6.4.3(2)②.

(3) The Surveyor may extend the close-up survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:

① in particular, tanks having structural arrangements or details which have suffered defects in similar tanks or on similar ships according to available information;

② in tanks which have structures approved with reduced scantlings due to an approved corrosion control system.

---

① Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

(4) For areas in tanks where hard protective coatings are found to be in a GOOD condition as defined in 5.1.5.1(15), the extent of close-up surveys according to Table 5.6.4.3(2)① or ② may be specially considered.

Minimum Requirements for Close-up Surveys at Special Surveys of Oil Tankers, Ore/Oil Ships, etc.

Table 5.6.4.3(2)①

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age >15
(A) One web frame ring (in a ballast wing tank, if any, or a cargo wing tank used primarily for water ballast). (B) One deck transverse (in a cargo oil tank). (D) One transverse bulkhead (in a ballast tank). (D) One transverse bulkhead (in a cargo oil tank). (D) One transverse bulkhead (in a cargo oil centre tank)	(A) All web frame rings (in a ballast wing tank, if any, or a in cargo wing tank, used primarily for water ballast). (B) One deck transverse (in each of the remaining ballast tanks, if any). (B) One deck transverse (in a cargo wing tank). (B) One deck transverse (in two cargo centre tanks). (C) Both transverse bulkheads (in a wing ballast tank, if any, or a cargo wing tank used primarily for water ballast. (D) One transverse bulkhead (in each remaining ballast tank). (D) One transverse bulkhead (in a cargo oil wing tank). (D) One transverse bulkhead (in two cargo centre tanks)	(A) All web frame rings (in all ballast tanks). (A) All web frame rings (in a cargo wing tank). (A) A minimum of 30%① of all complete transverse web frame rings in each remaining cargo wing tank. (C) All transverse bulkheads (in all cargo and ballast tanks. (E) A minimum of 30%① of deck and bottom transverses including adjacent structural members in each cargo centre tank. (F) As considered necessary by the Surveyor	As special survey No.3; additional transverses included as deemed necessary by CCS

Notes: (A) Complete transverse web frame ring including adjacent structural members.
(B) Deck transverse including adjacent deck structural members.
(C) Transverse bulkhead complete—including girder system and adjacent structural members.
(D) Transverse bulkhead lower part—including girder system and adjacent structural members.
(E) Deck and bottom transverse—including adjacent structural members.
(F) Additional complete transverse web frame ring.

Minimum Requirements for Close-up Surveys at Special Surveys of Double Hull Oil Tankers

Table 5.6.4.3(2)②

<table>
<tr><th>Special Survey No.1
Age ≤ 5</th><th>Special Survey No.2
5 < Age ≤ 10</th><th>Special Survey No.3
10 < Age ≤ 15</th><th>Special Survey No.4 and Subsequent
Age > 15</th></tr>
<tr><td>One web frame (1), in a ballast tank (see Note 1)</td><td>All web frames (1), in a ballast tank (see Note 1).
The knuckle area and the upper part (5 m approximately) of one web frame in each remaining ballast tank (6)</td><td>All web frames (1), in all ballast tanks</td><td rowspan="5">As special survey for age from 10 to 15 years.

Additional transverse areas as deemed necessary by CCS</td></tr>
<tr><td>One deck transverse (2), in a cargo oil tank</td><td>One deck transverse (2), in two cargo oil tanks</td><td>All web frames (7), including deck transverse and cross ties, if fitted, in a cargo oil tank.

One web frame (7), including deck transverse and cross ties, if fitted, in each remaining cargo oil tank</td></tr>
<tr><td>One transverse bulkhead (4), in a complete ballast tank (see Note 1)</td><td>One transverse bulkhead (4), in each ballast tank (see Note 1)</td><td rowspan="2">All transverse bulkheads, in all cargo oil (3) and ballast (4) tanks</td></tr>
<tr><td>One transverse bulkhead (5) in a cargo oil centre tank

One transverse bulkhead (5), in a cargo oil wing tank (see Note 2)</td><td>One transverse bulkhead (5), in two cargo oil centre tanks

One transverse bulkhead (5), in a cargo oil wing tank (see Note 2)</td></tr>
</table>

① The 30% is to be rounded up to the next whole integer.

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
(1), (2), (3), (4), (5), (6) and (7) are areas to be subjected to close-up surveys and thickness measurements (see Figure 5.6.4.3(2)②): (1) Web frame in a ballast tank means vertical web in side tank, hopper web in hopper tank, floor in double bottom tank and deck transverse in double deck tank (where fitted), including adjacent structural members. In fore and aft peak ballast tanks, web frame means a complete transverse web frame ring including adjacent structural members. (2) Deck transverse, including adjacent deck structural members (or external structure on deck in way of the tank, where applicable). (3) Transverse bulkhead complete in cargo tanks, including girder system, adjacent structural members (such as longitudinal bulkheads) and internal structure of lower and upper stools, where fitted. (4) Transverse bulkhead complete in ballast tanks, including girder system and adjacent structural members, such as longitudinal bulkheads, girders in double bottom tanks, inner bottom plating, hopper side, connecting brackets. (5) Transverse bulkhead lower part in cargo tanks, including girder system, adjacent structural members (such as longitudinal bulkheads) and internal structure of lower stool, where fitted. (6) The knuckle area and the upper part (5 m approximately), including adjacent structural members. Knuckle area is the area of the web frame around the connections of the slope hopper plating to the inner hull bulkhead and the inner bottom plating, up to 2 m from the corners both on the bulkhead and the double bottom. (7) Web frame in a cargo oil tank means deck transverse, longitudinal bulkhead structural elements and cross ties, where fitted, including adjacent structural members.			

Notes: 1 Ballast tank: Apart from the fore and aft peak tanks, the term "ballast tank" has the following meaning:

① all ballast compartments (hopper tank, side tank and double-deck tank, if separate from double-bottom tank) located on one side, i.e. portside or starboard side, and additionally double-bottom tank on portside plus starboard side, when the longitudinal central girder is not watertight and, therefore, the doublebottom tank is a unique compartment from portside to starboard side; or

② all ballast compartments (double-bottom tank, hopper tank, side tank and double-deck tank) located on one side, i.e. portside or starboard side, when the longitudinal central girder is watertight and, therefore, the portside double-bottom tank separate from the starboard-side double-bottom tank..

2 Where no centre cargo tanks are fitted (as in the case of center longitudinal bulkhead), transverse bulkheads in wing tanks are to be surveyed.

5.6.4.4 Extent of thickness measurement

(1) The minimum requirements for thickness measurements at special surveys are given in Table 5.6.4.4(1)① For ships not having the notation ESP, the minimum requirements for thickness measurements are given in Table 5.6.4.4(1)②.

(2) Provisions for extended measurements for areas with substantial corrosion are given as follows, and as may be additionally specified in the survey programme as required by 5.1.6.5. For ships not having the notation ESP, provisions for extended measurements for areas with substantial corrosion are given in Table 5.4.4.2(17)②.

① For oil tankers, the provisions for extended measurements of areas with substantial corrosion are given in Table 5.6.4.4(2)①a to d.

② For double hull oil tankers, the provisions for extended measurements of areas with substantial corrosion are given in Table 5.6.4.4(2)②a to e. For CSR ships, the identified substantial corrosion areas are required to be examined and additional thickness measurements are to be carried out at annual and intermediate surveys.

These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

(3) The Surveyor may further extend the thickness measurements as deemed necessary.

(4) For areas in tanks where hard protective coating is found to be in a GOOD condition as defined in 5.1.5.1(15), the extent of thickness measurements according to Table 5.6.4.4(1) may be specially considered.

(5) Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

(6) In cases where two or three sections are to be measured, at least one is to include a ballast tank within 0.5*L* amidships.

In case of oil tankers of 130 m in length and upwards (as defined in the International Convention on Load Lines in force) and more than 10 years of age, for the evaluation of the ship's longitudinal strength as required in 5.6.1.3, the sampling method of thickness measurements is given in Annex 3 to Appendix 2 of

this Chapter.
(7) For the assessment of thickness measurement results, see 5.4.4.2(17)⑤ of this Chapter.

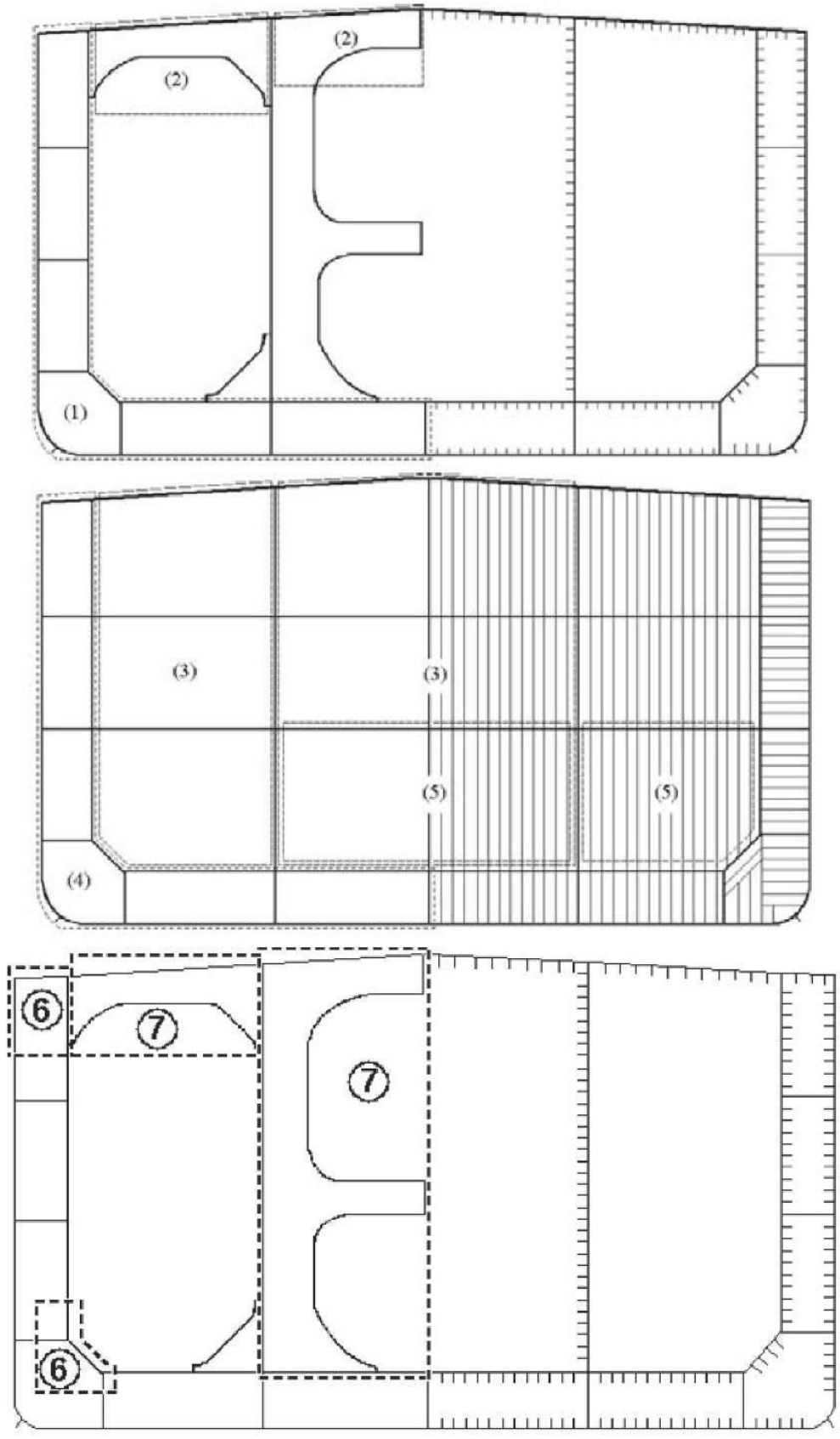


Figure 5.6.4.3(2)②　Close-up Survey Requirements for Double Hull Oil Tankers Areas (1) to (7)

Minimum Requirements for Thickness Measurements at Special Surveys of Oil Tankers, Ore/Oil Ships, etc. **Table 5.6.4.4(1)①a**

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
1. One section of deck plating for the full beam of the ship within the cargo area (in way of a ballast tank, if any, or a cargo tank used primarily for water ballast). 2. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tables 5.6.4.3(2)① of this Section. 3. Suspect areas	1. Within the cargo area: a) Each deck plate. b) One transverse section. 2. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tables 5.6.4.3(2)① of this Section. 3. Suspect areas. 4. Selected wind and water strakes outside the cargo area	1. Within the cargo area: a) Each deck plate. b) Two transverse sections(1). c) All wind and water strakes. 2. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tables 5.6.4.3(2)① of this Section. 3. Suspect areas. 4. Selected wind and water strakes outside the cargo area	1. Within the cargo area: a) Each deck plate. b) Three transverse sections(1). c) Each bottom plate. 2. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tables 5.6.4.3(2)① of this Section. 3. Suspect areas. 4. All wind and water strakes, full length

Note: (1) At least one section is to include a ballast tank within 0.5*L* amidships.

Minimum Requirements for Thickness Measurements at Special Surveys of Double Hull Oil Tankers **Table 5.6.4.4(1)①b**

Special Survey No.1 Age ≤ 5	**Special Survey No.2 5 < Age ≤ 10**	**Special Survey No.3 10 < Age ≤ 15**	**Special Survey No.4 and Subsequent Age > 15**
1. Suspect areas	1. Suspect areas 2. Within the cargo area: a) Each deck plate b).2 One transverse section 3. Selected wind and water strakes outside the cargo area 4. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.6.4.3(2)②	1. Suspect areas 2. Within the cargo area: a) Each deck plate b) Two transverse section(1) c) All wind and water strakes 3. Selected wind and water strakes outside the cargo area 4. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.6.4.3(2)②	1. Suspect areas 2. Within the cargo area: a) Each deck plate b) Three transverse section(1) c) Each bottom plate 3. All wind and water strakes, full length. 4. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.6.4.3(2)②

Note: (1) At least one section is to include a ballast tank within 0.5*L* amidships.

Minimum Requirements for Thickness Measurements at Special Surveys of Oil Tankers (Including Double Hull Oil Tankers), Ore/Oil Ships, etc., not having the notation ESP **Table 5.6.4.4(1)②**

Age ≤ 10	10 < age ≤ 15	Age > 15
1. Suspect areas throughout the ship	1. Suspect areas throughout the ship	1. Suspect areas throughout the ship
	2. Within the cargo area: a) Each deck plate. b) Two transverse sections. c) All wind and water strakes	2. Within the cargo area: a) Each deck plate. b) Three transverse sections. c) Each bottom plate
	3. Selected wind and water strakes outside the cargo area	3. For combined carrier, all cargo hold hatch covers and coamings (plating and stiffeners)
		4. Internals in forepeak and afterpeak ballast tanks
		5. All exposed main deck plating full length
		6. Representative exposed superstructure deck plating (poop, bridge, and forecastle deck)

Age ≤ 10	10 < age ≤ 15	Age > 15
		7. Lowest strake and centre strake in way of all transverse bulkheads in cargo spaces together with internals in way
		8. All wind and water strakes, port and starboard, full length
		9. All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks
		10. Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion
(Special Survey of Oil Tankers, Ore/Oil Ships, etc., within the Cargo Tank Length)
Bottom Structure **Table 5.6.4.4(2)①a**

Structural Member	Extent of Measurement	Pattern of Measurement
1. Bottom plating	Minimum of 3 bays across tank including aft bay. Measurements around and under all bell mouths	5-point pattern for each panel between longitudinals and webs
2. Bottom longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across flange and 3 measurements on vertical web
3. Bottom girders and brackets	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of three measurements. Two measurements across face flat. 5-point pattern on girder/bulkhead brackets
4. Bottom transverse webs	3 webs in bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over about 2 m^2 area. Single measurement on face flat
5. Panel stiffening	Where applicable	Single measurements

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion
(Special Survey of Oil Tankers, Ore/Oil Ships, etc., within the Cargo Tank Length)
Deck Structure **Table 5.6.4.4(2)①b**

Structural Member	Extent of Measurement	Pattern of Measurement
1. Deck plating	Two bands across tank	Minimum of three measurements per plate per band
2. Deck longitudinals	Minimum of 3 longitudinals in each of two bays	3 measurements in line vertically on webs, and 2 measurements on flange (if fitted)
3. Deck girders and brackets	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurement on web plating with one measurement between each panel stiffener, or a minimum of three measurements. Two measurements across face flat. 5-point pattern on girder/bulkhead brackets
4. Deck transverse webs	Minimum of two webs with measurements at middle and both ends of span	5-point pattern over about 2 m^2 area. Single measurements on face flat
5. Panel stiffening	Where applicable	Single measurements

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion
Special Survey of Oil Tankers, Ore/Oil Ships, etc., within the Cargo Tank Length
(Side Shell and Longitudinal Bulkheads) **Table 5.6.4.4(2)①c**

Structural Member	Extent of Measurement	Pattern of Measurement
1. Deckhead and bottom strakes, and strakes in way of stringer platforms	Plating between each pair of longitudinals in a minimum of 3 bays	Single measurement
2. All other strakes	Plating between every third pair of longitudinals in same 3 bays	Single measurement
3. Longitudinals－deckhead and bottom strakes	Each longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
4. Longitudinals－all others	Every third longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
5. Longitudinals－brackets	Minimum of three at top, middle and bottom of tank in same 3 bays	5-point pattern over area of bracket
6. Web frames and cross ties	3 webs with minimum of three locations on each web, including in way of cross tie connections	5-point pattern over about 2 m^2 area, plus single measurements on web frame and cross tie face flat

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion
(Special Survey of Oil Tankers, Ore/Oil Ships, etc., within the Cargo Tank Length)
Transverse Bulkheads and Swash Bulkheads Table 5.6.4.4(2)①d

Structural Member	Extent of Measurement	Pattern of Measurement
1. Deckhead and bottom strakes, and strakes in way of stringer platforms	Plating between pair of stiffeners at three locations－approx. 1/4, 1/2 and 3/4 width of tank	5-point pattern between stiffeners over 1 m length
2. All other strakes	Plating between pair of stiffeners at middle location	Single measurement
3. Strakes in corrugated bulkheads	Plating for each change of scantling at center of panel and at flange or fabricated connection	5-point pattern over about 1 m^2 of plating
4. Stiffeners	Minimum of three typical stiffeners	For web, 5-point pattern over span between bracket connections (2 measurements across web at each bracket connection, and one at center of span). For flange, single measurements at each bracket toe and at center of span
5. Brackets	Minimum of three at top, middle and bottom of tank	5-point pattern over areas of bracket
6. Deep webs and girders	Measurements at toe of bracket and at center of span	For web, 5-point pattern over about 1 m^2. 3 measurements across face flat
7. Stringer platforms	All stringers with measurements at both ends and middle	5-point pattern over 1 m^2 area plus single measurements near bracket toes and on face flats

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion
(Special Survey of Double Hull Oil Tankers within the Cargo Area Length)
Bottom, Inner bottom and Hopper Structure Table 5.6.4.4(2)②a

Structural Member	Extent of Measurement	Pattern of Measurement
1. Bottom, inner bottom and hopper structure plating	Minimum of three bays across double bottom tank, including aft bay. Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and floors
2. Bottom, inner bottom and hopper structure longitudinals	Minimum of three longitudinals in each bay where bottom plating measured	Three measurements in line across flange and three measurements on vertical web
3. Bottom girders, including the watertight ones	At fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with one measurement between each panel stiffener, or a minimum of three measurements
4. Bottom floors, including the watertight ones	Three floors in bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over two square metre area
5. Hopper structure web frame ring	Three floors in bays where bottom plating measured	5-point pattern over one square metre of plating. Single measurements on flange
6. Hopper structure transverse watertight bulkhead or swash bulkhead	·lower 1/3 of bulkhead	5-point pattern over one square metre of plating
	·upper 2/3 of bulkhead	5-point pattern over two square metre of plating
	·stiffeners (minimum of three)	For web, 5-point pattern over span (two measurements across web at each end and one at center of span). For flange, single measurements at each end and center of span
7. Panel stiffening	Where applicable	Single measurements

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion (Special Survey of Double Hull Oil Tankers within the Cargo Area Length)

Deck Structure **Table 5.6.4.4(2)②b**

Structural Member	Extent of Measurement	Pattern of Measurement
1. Deck plating	Two transverse bands across tank	Minimum of three measurements per plate per band
2. Deck longitudinals	Every third longitudinal in each of two bands with a minimum of one longitudinal	three measurements in line vertically on webs and two measurements on flange (if fitted)
3. Deck girders and brackets (usually in cargo tanks only)	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of three measurements. Two measurements across flange. 5-point pattern on girder/bulkhead brackets
4. Deck transverse webs	Minimum of two webs, with measurements at both ends and middle of span	5-point pattern over one square metre area. Single measurements on flange
5. Vertical web and transverse bulkhead in wing ballast tank (two metres from deck)	Minimum of two webs, and both transverse bulkheads	5-point pattern over one square metre area
6. Panel stiffening	Where applicable	Single measurements

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion (Special Survey of Double Hull Oil Tankers within the Cargo Area Length)

Structure in Wing Ballast Tanks **Table 5.6.4.4(2)②c**

Structural Member	Extent of Measurement	Pattern of Measurement
1. Side shell and longitudinal bulkhead plating:		
Upper strake and strakes in way of horizontal girders.	Plating between each pair of longitudinals in a minimum of three bays (along the tank).	Single measurement.
All other strakes	Plating between every third pair of longitudinals in same three bays	Single measurement
2. Side shell and longitudinal bulkhead longitudinals on:		
Upper strake.	Each longitudinal in same three bays.	3 measurements across web and 1 measurement on flange.
All other strakes	Every third longitudinal in same three bays	3 measurements across web and 1 measurement on flange
3. Longitudinals−brackets	Minimum of three at top, middle and bottom of tank in same three bays	5-point pattern over area of bracket
4. Vertical web and transverse bulkheads (excluding deckhead area):		
Strakes in way of horizontal girders.	Minimum of two webs and both transverse bulkheads.	5-point pattern over approx. two square metre area.
Other strakes	Minimum of two webs and both transverse bulkheads	Two measurements between each pair of vertical stiffeners
5. Horizontal girders	Plating on each girder in a minimum of three bays	Two measurements between each pair of longitudinal girder stiffeners
6. Panel stiffening	Where applicable	Single measurements

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion (Special Survey of Double Hull Oil Tankers within the Cargo Area Length)
Longitudinal Bulkheads in Cargo Tanks Table 5.6.4.4(2)②d

Structural Member	Extent of Measurement	Pattern of Measurement
1. Deckhead and bottom strakes, and strakes in way of the horizontal stringers of transverse bulkheads	Plating between each pair of longitudinals in a minimum of three bays	Single measurement
2. All other strakes	Plating between every third pair of longitudinals in same three bays	Single measurement
3. Longitudinals on deckhead and bottom strakes	Each longitudinal in same three bays	Three measurements across web and one measurement on flange
4. All other longitudinals	Each third longitudinal in same three bays	Three measurements across web and one measurement on flange
5. Longitudinals - brackets	Minimum of three at top, middle and bottom of tank in same three bays	5-point pattern over area of bracket
6. Web frames and cross ties	Three webs with minimum of three locations on each web, including in way of cross tie connections	5-point pattern over approximately two square metre area of webs, plus single measurements on flanges of web frame and cross ties
7. Lower end brackets (opposite side of web frame)	Minimum of three brackets	5-point pattern over approximately two square metre area of brackets, plus single measurements on bracket flanges

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion (Special Survey of Double Hull Oil Tankers within the Cargo Area Length)
Transverse Watertight and Swash Bulkheads in Cargo Tanks Table 5.6.4.4(2)②e

Structural Member	Extent of Measurement	Pattern of Measurement
1. Upper and lower stool, where fitted	Transverse band within 25 mm of welded connection to inner bottom/deck plating Transverse band within 25 mm of welded connection to shelf plate	5-point pattern between stiffeners over one metre length
2. Deckhead and bottom strakes, and strakes in way of horizontal stringers	Plating between pair of stiffeners at three locations: approximately 1/4, 1/2 and 3/4 width of tank	5-point pattern between stiffeners over one metre length
3. All other strakes	Plating between pair of stiffeners at middle location	Single measurement
4. Strakes in corrugated bulkheads	Plating for each change of scantling at center of panel and at flange of fabricated connection	5-point pattern over about one square metre of plating
5. Stiffeners	Minimum of three typical stiffeners	For web, 5-point pattern over span between bracket connections (two measurements across web at each bracket connection and one at center of span). For flange, single measurements at each bracket toe and at center of span
6. Brackets	Minimum of three at top, middle and bottom of tank	5-point pattern over area of bracket
7. Horizontal stringers	All stringers with measurements at both ends and middle	5-point pattern over one square metre area, plus single measurements near bracket toes and on flanges

5.6.4.5 Extent of tank testing

(1) The minimum requirements for ballast tank testing are given in (3) of this paragraph and Table 5.6.4.5(1); the minimum requirements for cargo tank testing are given in (4) of this paragraph and Table 5.6.4.5(1). Cargo tank testing carried out by the ship's crew under the direction of the Master may be accepted by the Surveyor provided the following conditions are complied with:

① a tank testing procedure, specifying fill heights, tanks being filled and bulkheads being tested, has been submitted by the Owner and reviewed by CCS prior to the testing being carried out;

② the tank testing is carried out prior to overall survey or close-up survey;

③ the tank testing is carried out within the special survey window and not more than 3 months prior to

the date on which the overall or close-up survey is completed;

④ the tank testing has been satisfactorily carried out and there is no record of leakage, distortion or substantial corrosion that would affect the structural integrity of the tank;

⑤ the satisfactory results of the testing is recorded in the ship's logbook; and

⑥ the internal and external condition of the tanks and associated structure are found satisfactory by the Surveyor at the time of the overall and close-up survey.

(2) The Surveyor may extend the tank testing as deemed necessary.

(3) Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

(4) Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions.

(5) For double hull oil tankers, the testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

Minimum Requirements to Tank Testing at Special Surveys of Oil Tankers (Including Double Hull Oil Tankers), Ore/Oil Ships, etc. **Table 5.6.4.5(1)**

Special Survey No.1 Age ≤ 5	Special Survey No.2 and Subsequent Age > 5
1. All ballast tank boundaries 2. Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump rooms or cofferdams	1. All ballast tank boundaries 2. All cargo tank bulkheads

5.6.4.6 Examination of emergency towing arrangements (if fitted)

(1) Confirming that strong points, towing pennants, towing connection, pick-up gear, chafing gear and mark buoys are in good and efficient condition.

(2) Verifying that wear of towing pennant, pick-up gear and chafing gear is under permissible limits.

(3) Verifying that fairleads are maintained in a normal condition as required.

5.6.4.7 The availability and normal maintenance of bow and stern loading/unloading arrangements (if fitted) are to be verified.

5.6.4.8 Automatic air pipe heads

(1) For examination of automatic air pipe heads installed on the exposed decks, reference is to be made to 5.4.4.2(18) of this Chapter.

Section 7 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF BULK CARRIERS

5.7.1 General requirements

5.7.1.1 Application

(1) This Section applies to surveys of hull, equipment and piping systems for all bulk carriers or the double skin bulk carriers as defined in 5.1.5.3(2) of this Chapter.

(2) This Section applies to surveys of hull structure and piping systems in way of the cargo holds, cofferdams, pipe tunnels, void spaces, fuel oil tanks within the cargo length area and all ballast tanks. The requirements of this Section are additional to the classification requirements applicable to the remainder of the ship.

(3) This Section contains the minimum extent of examination, thickness measurement and tank testing. The survey is to be extended when substantial corrosion and/or structural defects are found and include additional close-up survey when necessary.

(4) Ships which are required to comply with Appendix 17 of this Chapter are subject to the additional thickness measurement guidance contained in Appendix 3 of this Chapter for the purpose of determining compliance with Appendix 17 of this Chapter prior to the relevant compliance deadline stipulated in Appendix 19 of this Chapter and at subsequent intermediate surveys (for ships over 10 years of age) and special surveys for the purpose of verifying continuing compliance with Appendix 17 of this Chapter.

(5) Ships which are required to comply with Appendix 20 of this Chapter are subject to the additional thickness measurement guidance contained in Appendix 6 of this Chapter for the purpose of determining compliance with Appendix 20 of this Chapter prior to the relevant compliance deadline stipulated in Appendix 20 of this Chapter and at subsequent intermediate and special surveys for the purpose of verifying continuing compliance with Appendix 20 of this Chapter.

(6) For bulk carriers with hybrid cargo hold arrangements, e.g. with some cargo holds of single side skin and others of double side skin, the requirements of this Section for single side skin bulk carriers are to apply to cargo holds of single side skin and the requirements of this Section for double side skin bulk carriers are to apply to cargo holds of double side skin and associated wing spaces.
(7) For existing bulk carriers, where owners may select to coat or recoat cargo holds as required by 1.6.1.3 of Chapter 1, PART TWO of the Rules, consideration may be given to the extent of the close-up and thickness measurement surveys. Prior to the coating of cargo holds of such ships, scantlings are to be ascertained in the presence of a Surveyor.
5.7.1.2 Except as stated otherwise, the requirements regarding double skin bulk carriers in this Section apply to double side skin bulk carriers and bulk carriers of which the distance between inner hull and outer hull is less than 1,000 mm, as required by Chapter 8 of PART TWO of the Rules.

5.7.2 Annual surveys
5.7.2.1 General requirements
(1) The annual survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull, weather deck hatch covers, coamings and piping are maintained in a satisfactory condition and should take into account the service history, condition and extent of the corrosion prevention system of ballast tanks and areas identified in the survey report file.
(2) The annual survey is to include the items specified in 5.7.2.2 through 5.7.2.6 and in addition, the applicable items specified in 5.4.2 of this Chapter.
5.7.2.2 Hull
(1) Examination of the hull plating and its closing appliances as far as can be seen.
(2) Examination of watertight penetrations as far as practicable.
5.7.2.3 Weather decks, hatch covers and coamings
(1) Confirmation is to be obtained that no unapproved changes have been made to the hatch covers, hatch coamings and their securing and sealing devices since the last survey.
(2) A thorough survey of cargo hatch covers and coamings is only possible by examination in the open as well as closed positions and is to include verification of proper opening and closing operation. As a result, the hatch cover sets within the forward 25% of the ship's length and at least one additional set, such that all sets on the ship are assessed at least once in every 5-year period, are to be surveyed open, closed and in operation to the full extent in each direction at each annual survey, including:
① stowage and securing in open condition;
② proper fit and efficiency of sealing in closed condition; and
③ operational testing of hydraulic and power components, wires, chains and link drives.
The closing of the covers is to include the fastening of all peripheral, and cross joint cleats or other securing devices. Particular attention is to be paid to the condition of hatch covers in the forward 25% of the ship's length, where sea loads are normally greatest.
(3) If there are indications of difficulty in operating and securing hatch covers, additional sets above those required by (2), at the discretion of the Surveyor, are to be tested in operation.
(4) Where the cargo hatch securing system does not function properly, repairs are to be carried out under the supervision of CCS. Where hatch covers or coamings undergo substantial repairs, the strength of securing devices should be upgraded to comply with the requirements of 8.11.5, Section 11, Chapter 8, PART TWO of the Rules.
(5) For each cargo hatch cover set, at each annual survey, the following items are to be surveyed:
① cover panels, including side plates, and stiffener attachments that may be accessible in the open position by close-up survey (for corrosion, cracks, deformation);
② sealing arrangements of perimeter and cross joints (gaskets for condition and permanent deformation, flexible seals on combination carriers, gasket lips, compression bars, drainage channels and non-return valves);
③ clamping devices, retaining bars, cleating (for wastage, adjustment, and condition of rubber components);
④ closed cover locating devices (for distortion and attachment);
⑤ chain or rope pulleys;
⑥ guides;
⑦ guide rails and track wheels;
⑧ stoppers;
⑨ wires, chains, tensioners and gypsies;

⑩ hydraulic system, electrical safety devices and interlocks; and

⑪ end and interpanel hinges, pins and stools, where fitted.

(6) At each hatchway, at each annual survey, the coamings, with plating, stiffeners and brackets are to be checked for corrosion, cracks and deformation, especially of the coaming tops, including close-up survey.

(7) Where considered necessary by the Surveyor, the effectiveness of sealing arrangements may be proved by hose or chalk testing supplemented by dimensional measurements of seal compressing components.

(8) Where portable covers, wooden or steel pontoons are fitted, checking the satisfactory condition, where applicable, of:

① wooden covers and portable beams, carriers or sockets for the portable beam, and their securing devices;

② steel pontoons, including close-up survey of hatch cover plating;

③ tarpaulins;

④ cleats, battens and wedges;

⑤ hatch securing bars and their securing devices;

⑥ loading pads/bars and the side plate edge;

⑦ guide plates and chocks;

⑧ compression bars, drainage channels and drain pipes (if any).

(9) Examination of flame screens on vents to all bunker tanks.

(10) Examination of bunker and vent piping systems, including ventilators.

5.7.2.4 Examination of cargo holds

(1) Bulk carriers 10 to 15 years of age

① Bulk carriers:

a. Overall survey of all cargo holds.

b. Close-up examination of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approx. lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating in the forward cargo hold. Where this level of survey reveals the need for remedial measures, the survey is to be extended to include a close-up survey of all of the shell frames and adjacent shell plating of that cargo hold as well as a close-up survey of sufficient extent of all remaining cargo holds.

c. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tables 5.7.4.5(2)①a to e. These thickness measurements are to be carried out before the annual survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken. For CSR ships, the annual thickness gauging may be omitted where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in "GOOD" condition.

d. Where the protective coating (as required by 1.6.1.3 of Chapter 1, PART TWO of the Rules) in cargo holds is found to be in GOOD condition, the extent of close-up surveys and thickness measurements may be specially considered.

e. All piping and penetrations in cargo holds, including overboard piping, are to be examined.

② Double side skin bulk carriers:

a. Overall survey of two selected cargo holds.

b. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tables 5.7.4.5(2)②a to d. These extended thickness measurements are to be carried out before the annual survey is credited as complete. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken. For CSR ships, the annual thickness gauging may be omitted where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in "GOOD" condition.

c. All piping and penetrations in cargo holds, including overboard piping, are to be examined.

(2) Bulk carriers over 15 years of age

① Bulk carriers:

a. Overall survey of all cargo holds.

b. Close-up examination of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approx. lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating in the forward cargo hold and one other selected cargo hold. Where this level of survey reveals the need for remedial measures, the survey is to be extended to include a close-up survey of all of the shell frames and adjacent shell plating of that cargo hold as well as a close-up survey of sufficient extent of all remaining cargo holds.

c. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tables 5.7.4.5(2)①a to e. These extended thickness measurements are to be carried out before the annual survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken. For CSR ships, the annual thickness gauging may be omitted where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in "GOOD" condition.

d. Where a hard protective coating as required by 1.6.1.3 of Chapter 1, PART TWO of the Rules is fitted in cargo holds and is found in GOOD condition, the extent of close-up surveys and thickness measurements may be specially considered.

e. All piping and penetrations in cargo holds, including overboard piping, are to be examined.

② Double side skin bulk carriers:

a. Overall survey of all cargo holds.

b. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tables 5.7.4.5(2)②a to d. These extended thickness measurements are to be carried out before the annual survey is credited as complete. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken. For CSR ships, the annual thickness gauging may be omitted where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in "GOOD" condition.

c. All piping and penetrations in cargo holds, including overboard piping, are to be examined.

5.7.2.5 Examination of ballast tanks

(1) Examination of ballast tanks when required as a consequence of the results of the special survey and intermediate survey is to be carried out. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tables 5.7.4.5(2)①a to e for bulk carriers or in accordance with Tables 5.7.4.5(2)②a to d for double skin bulk carriers. These extended thickness measurements are to be carried out before the survey is credited as completed.

Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken. For CSR ships, the annual thickness gauging may be omitted where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in "GOOD" condition.

(2) Confirming that the corrosion prevention system fitted to dedicated ballast tanks of bulk carriers when appropriate is maintained.

5.7.2.6 Additional annual survey requirements after determining compliance with SOLAS XII/12 and XII/13:

(1) For ships complying with the requirements of SOLAS XII/12 for hold, ballast and dry space water level detectors, the annual survey is to include an examination and a test, at random, of the water ingress detection systems and of their alarms.

(2) For ships complying with the requirements of SOLAS XII/13 for the availability of pumping systems, the annual survey is to include an examination and a test, of the means for draining and pumping ballast tanks forward of the collision bulkhead and bilges of dry spaces any part of which extends forward of the foremost cargo hold, and of their controls.

5.7.2.7 In the case of bulk carriers of 150 m in length and upwards of single side skin construction, carrying solid bulk cargoes having a density of 1,780 kg/m^3 and above, contracted for construction before 1 July 1999 and constructed with an insufficient number of transverse watertight bulkheads to enable them to

withstand flooding of the foremost cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium as specified in SOLAS XII/4.3, the following additional survey requirements for the foremost cargo hold of such ships are to apply:

(1) Bulk carriers over 5 and up to 15 years of age

① An overall survey of No.1 cargo hold, including a close-up survey of sufficient extent, minimum 25% of frames, is to be carried out to establish the technical condition of shell frames including their upper and lower end attachments, adjacent shell plating, transverse bulkheads and areas found suspect at the previous surveys.

② Where considered necessary by the Surveyor as a result of the overall and close-up surveys as described in ① above, the survey is to be extended to include a close-up survey of all of the shell frames, their end attachments and adjacent shell plating of that cargo hold.

(2) Bulk carriers over 15 years of age

① An overall survey of No.1 cargo hold, including a close-up survey, is to be carried out to establish the technical condition of all shell frames including their end attachments, adjacent shell plating, transverse bulkheads and areas found suspect at previous surveys.

(3) Extent of thickness measurements

① Thickness measurements are to be carried out to an extent sufficient to determine both general and local corrosion levels at areas subject to close-up surveys as described in (1)① and ② above. As a minimum, thickness measurements are to be carried out at areas found suspect at previous surveys. Where substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tables 5.7.4.5(2)①a to e of this Section.

② The thickness measurements may be dispensed with provided the Surveyor is satisfied by the close-up survey, that there is no structural diminution and the protective coating, where applied, remains effective.

(4) Where the protective coating in No.1 cargo hold is found to be in GOOD condition (in compliance with 1.6.1.3 of Chapter 1, PART TWO of the Rules), the extent of close-up survey and thickness measurements may be specially considered.

5.7.2.8 Examining, for bulk carriers of 150 m and above, where appropriate, the ship's structure in accordance with the Ship Construction File, taking into account identified areas that need special attention.

5.7.2.9 Examination of double-side skin void spaces for bulk carriers exceeding 20 years of age and of 150 m in length and upwards

(1) Examination of double-side skin void spaces, for bulk carriers exceeding 20 years of age and of 150 m in length and upwards, are to be carried out as required by 5.7.4.2(4) and 5.7.3.4(1) of this Section. When considered necessary by the Administration, or when extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Table 5.7.4.5(2)②a～d of this Section. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

(2) For CSR ships, the annual thickness gauging may be omitted where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in good condition.

5.7.3 Intermediate surveys

5.7.3.1 General requirements

(1) The intermediate survey extent is dependent on the age of the ship as specified in 5.7.3.2 to 5.7.3.4 of this Section.

(2) The intermediate survey is also to include the applicable items specified in 5.4.3 of this Chapter and 5.7.2 of this Section.

(3) The survey requirements for double skin bulk carriers are also to be in compliance with Table 5.7.3.1(3).

Minimum Requirements of Overall and Close-Up Survey and Thickness Measurements at Intermediate Survey of Double Skin Bulk Carriers **Table 5.7.3.1(3)**

5 < Age ≤ 10	10 < Age ≤ 15	Age > 15
Overall survey of representative ballast tanks selected by the attending Surveyor (the selection is to include fore and aft peak tanks and a number of other tanks, taking into account the total number and type of ballast tanks)	The requirements of the previous special survey (See 5.7.3.3)	The requirements of the previous special survey (See 5.7.3.4)

Overall and close-up survey of suspect areas identified as previous (intermediate or special) surveys		
Overall survey of all cargo holds		
Thickness measurements to an extent sufficient to determine both general and local corrosion levels at areas subject to close-up survey at suspect areas identified at previous surveys		

5.7.3.2 Bulk carriers 5 to 10 years of age

① Ballast tanks

a. For tanks used for water ballast, an overall survey of representative spaces selected by the Surveyor is to be carried out. The selection is to include fore and aft peak tanks and a number of other tanks, taking into account the total number and type of ballast tanks. If such overall survey reveals no visible structural defects, the examination may be limited to verification that the corrosion prevention system remains efficient.

b. Where a hard coating is found to be in less than GOOD condition, corrosion or other structural defects are found in water ballast tanks or where a hard protective coating was not applied from the time of construction, the examination is to be extended to other ballast tanks of the same type.

c. In ballast tanks other than double bottom tanks, where a hard protective coating is found to be in less than GOOD condition and it is not renewed, or where a soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question are to be examined and thickness measurements carried out as considered necessary at annual intervals. When such breakdown of hard protective coating is found in ballast double bottom tanks, or where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

d. In addition to the requirements above, suspect areas identified at previous surveys are to be subjected to overall and close-up surveys.

② Cargo holds

a. Bulk carriers

(a) An overall survey of all cargo holds, including close-up survey of sufficient extent, minimum 25 % of frames, is to be carried out to establish the condition of:

a) shell frames including their upper and lower end attachments, adjacent shell plating, and transverse bulkheads in the forward cargo hold and one other selected cargo hold;

b) areas found suspect at previous surveys.

(b) Where considered necessary by the Surveyor as a result of the overall and close-up survey as described in (a) above, the survey is to be extended to include a close-up survey of all of the shell frames and adjacent shell plating of that cargo hold as well as a close-up survey of sufficient extent of all remaining cargo holds.

b. Double skin bulk carriers

(a) An overall survey of all cargo holds is to be carried out.

(b) Where considered necessary by the Surveyor as a result of the overall survey as described in (a) above, the survey is to be extended to include a close-up survey of those areas of structure in the cargo holds selected by the Surveyor.

③ Extent of thickness measurements

a. Bulk carriers

(a) Thickness measurements are to be carried out to an extent sufficient to determine both general and local corrosion levels at areas subject to close-up survey as described in 5.7.3.2②a(a). The minimum requirement for thickness measurements at the intermediate survey are areas found to be suspect areas at previous surveys.

(b) The extent of thickness measurement may be specially considered provided the Surveyor is satisfied by the close-up survey, that there is no structural diminution and the hard protective coatings are found to be in a GOOD condition.

(c) Where substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with the requirements of Tables 5.7.4.5(2)①a to e. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

For CSR ships, the identified substantial corrosion areas may be:

a) protected by coating applied in accordance with the coating manufacturer's requirements and examined at annual intervals to confirm the coating in way is still in "GOOD" condition, or alternatively

b) required to be measured at annual intervals.

(d) Where the hard protective coating (as required by 1.6.1.4 of Chapter 1, PART TWO of the Rules) in cargo holds is found to be in GOOD condition, the extent of close-up surveys and thickness measurements may be specially considered. For existing bulk carriers, where owners may select to coat or recoat cargo holds as noted above, special consideration may be given to the extent of close-up surveys and thickness measurements. Prior to the coating of cargo holds of existing ships, scantlings are to be ascertained by the Surveyor.

b. Double skin bulk carriers

(a) Thickness measurements are to be carried out to an extent sufficient to determine both general and local corrosion levels at areas subject to close-up survey, where required as per 5.7.3.2②b(b), and as provided in 5.7.3.2.①c.

(b) The extent of thickness measurement may be specially considered provided the Surveyor is satisfied by the close-up survey that there is no structural diminution and the hard protective coatings are found to be in a GOOD condition.

(c) Where substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with the requirements of Tables 5.7.4.5(2)②a to d. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

For CSR ships, the identified substantial corrosion areas may be:

a) protected by coating applied in accordance with the coating manufacturer's requirements and examined at annual intervals to confirm the coating in way is still in "GOOD" condition, or alternatively

b) required to be measured at annual intervals.

(d) Where the protective coating in cargo holds (as required by 1.6.1.3 of Chapter 1, PART TWO of the Rules) is found to be in GOOD condition, the extent of close-up surveys and thickness measurements may be specially considered. Prior to the coating of cargo holds, scantlings should be ascertained in the presence of the Surveyor. For existing bulk carriers, where owners may select to coat or recoat cargo holds as noted above, special consideration may be given to the extent of close-up surveys and thickness measurements. Prior to the coating of cargo holds of existing ships, scantlings are to be ascertained by the Surveyor.

5.7.3.3 Bulk carriers 10 to 15 years of age

(1) The requirements of the intermediate survey are to be to the same extent to the previous special survey as required in 5.7.4 of this Section and 5.1.6.5. However, internal examination of fuel tanks and pressure testing of all tanks are not required unless deemed necessary by the attending Surveyor.

(2) In application of (1), the intermediate survey may be commenced at the second annual survey and be progressed during the succeeding year with a view to completion at the third annual survey in lieu of the application of 5.2.4.2.

(3) In application of (1), an underwater survey may be considered in lieu of the requirements of 5.7.4.1(5).

5.7.3.4 Bulk carriers over 15 years of age

(1) The requirements of the intermediate survey are to be to the same extent to the previous special survey as required in 5.7.4 of this Section and 5.1.6.5. However, internal examination of fuel tanks and pressure testing of all tanks are not required unless deemed necessary by the attending Surveyor.

(2) In application of (1), the intermediate survey may be commenced at the second annual survey and be progressed during the succeeding year with a view to completion at the third annual survey in lieu of the application of 5.2.4.2.

(3) A survey in dry dock is to be part of the intermediate survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and ballast tanks① are to be carried out in accordance with the applicable requirements for intermediate surveys, if not already performed.

5.7.4 Special surveys

5.7.4.1 General requirements

---

① Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line.

(1) The special survey is to include, in addition to the applicable requirements of 5.4.4 of this Chapter and 5.7.2 of this Section, examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in 5.7.4.1(3), is in a satisfactory condition and is fit for its intended purpose for the new period of class of 5 years to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.
(2) All cargo holds, ballast tanks, including double bottom tanks, pipe tunnels, cofferdams, double side tanks (if fitted) and void spaces bounding cargo holds, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in 5.7.4.5 and 5.7.4.6, to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.
(3) All piping systems (or ballast piping systems in the case of double skin bulk carriers) within the above spaces are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.
(4) The survey extent of ballast tanks converted to void spaces is to be specially considered in relation to the requirements for ballast tanks.
(5) A survey in dry dock is to be a part of the special survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and ballast tanks (Note: Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line) are to be carried out in accordance with the applicable requirements for special surveys, if not already performed.

5.7.4.2 Space protection

(1) Where provided, the condition of the corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom tanks, where a hard protective coating is found to be in less than GOOD condition and it is not renewed, or where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the Surveyor.
(2) When such breakdown of hard protective coating is found in water ballast double bottom tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.
(3) Where a hard protective coating is provided in cargo holds and is found in GOOD condition, the extent of close-up surveys and thickness measurements may be specially considered.
(4) For double-side skin void spaces bounding cargo holds for bulk carriers exceeding 20 years of age and of 150 m in length and upwards, where provided, the condition of the corrosion prevention system of void spaces is to be examined. Where a hard protective coating is found to be in POOR condition, and it is not renewed, or where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the void spaces in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the surveyor.

5.7.4.3 Hatch covers and coamings

(1) A thorough inspection of the items listed in 5.7.2.3 is to be carried out, in addition to all hatch covers and coamings.
(2) Checking of the satisfactory operation of all mechanically operated hatch covers is to be made, including:
① stowage and securing in open condition;
② proper fit and efficiency of sealing in closed condition;
③ operational testing of hydraulic and power components, wires, chains, and link drives.
(3) Checking the effectiveness of sealing arrangements of all hatch covers by hose testing or equivalent.
(4) Close-up survey and thickness measurement① of the hatch cover and coaming plating and stiffeners is to be carried out for bulk carriers and double skin bulk carriers as given in Table 5.7.4.4(1)②, 5.7.4.4(2)② and Tables 5.7.4.5(1)① and ②.

5.7.4.4 Extent of overall and close-up surveys

(1) Bulk carriers

---

① Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/thickness measurement shall be done of accessible parts of hatch covers structures.

① An overall survey of all tanks and spaces is to be carried out at each special survey. Fuel oil tanks in the cargo length area are to be surveyed in accordance with Table 5.4.4.2(2) of this Chapter.
② The minimum requirements for close-up surveys at special survey are given in Table 5.7.4.4(1)② of this Section. For ships not having the notation ESP, the Surveyor may carry out the close-up survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system.
③ The Surveyor may extend the close-up survey as deemed necessary taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.
④ For areas in spaces where hard protective coatings are found to be in a GOOD condition, the extent of close-up surveys according to Table 5.7.4.4(1)② may be specially considered.

Minimum Requirements for Close-up Survey at Special Hull Survey of Bulk Carriers

Table 5.7.4.4(1)②

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
(A) 25% of shell frames in the forward cargo hold at representative positions. (A) Selected frames in remaining cargo holds. (B) One transverse web with associated plating and longitudinals in two representative water ballast tanks of each type (i.e. topside, hopper side tank). (C) Two selected cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted. (D) All cargo hold hatch covers and coamings (plating and stiffeners)	(A) All shell frames in the forward cargo hold and 25% of shell frames in each of the remaining cargo holds, including upper and lower end attachments and adjacent shell plating. For bulk carriers of 100,000 DWT and above, all shell frames in the forward cargo hold and 50% of shell frames in each of the remaining cargo holds, including upper and lower end attachments and adjacent shell plating①. (B) One transverse web with associated plating and longitudinals in each water ballast tank. (B) Forward and aft transverse bulkhead in one ballast tank, including stiffening system. (C) All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted. (D) All cargo hold hatch covers and coamings (plating and stiffeners). (E) All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches	(A) All shell frames in the forward and one other selected cargo hold and 50% of frames in each of the remaining cargo holds, including upper and lower end attachments and adjacent shell plating. (B) All transverse webs with associated plating and longitudinals in each water ballast tank. (B) All transverse bulkheads in ballast tanks, including stiffening system. Areas (C), (D) and (E) as for Special Survey No.2	(A) All shell frames in all cargo holds including upper and lower end attachments and adjacent shell plating. Areas (B) to (E) as for special survey No.3

① This requirement applies to surveys of bulk carriers of 100,000 DWT and above on and after 1 July 2007.

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
Notes: (A), (B), (C), (D) and (E) are areas to be subjected to close-up surveys and thickness measurements (See Figure 5.7.4.4(2)): (A) Cargo hold transverse frames. (B) Transverse web frame or watertight transverse bulkhead in water ballast tanks. (C) Cargo hold transverse bulkhead plating, stiffeners and girders. (D) Cargo hold hatch covers and coamings. Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/thickness measurement is to be done of accessible parts of hatch covers structures. (E) Deck plating and under deck structure inside line of hatch openings between cargo hold hatches. Close-up survey of transverse bulkheads are to be carried out at the following levels: a. Immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for ships without lower stool. b. Immediately above and below the lower stool shelf plate (for those ships fitted with lower stools), and immediately above the line of the shedder plates. c. About mid-height of the bulkhead. d. Immediately below the upper deck plating and immediately adjacent to the upper wing tank, and immediately below the upper stool shelf plate for those ships fitted with upper stools, or immediately below the topside tanks.			

(2) Double skin bulk carriers

① An overall survey of all tanks and spaces is to be carried out at each special survey. Fuel oil tanks in the cargo length area are to be surveyed in accordance with Table 5.4.4.2(2) of this Chapter.

② The minimum requirements for close-up surveys at special survey of double skin bulk carriers are given in Table 5.7.4.4(2)②. The minimum requirements for close-up surveys at special survey of ore carriers are given in Table 5.7.4.4(2)③.

③For ships not having the notation ESP, the Surveyor may carry out the close-up survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system.

④ The Surveyor may extend the close-up survey as deemed necessary taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.

⑤ For areas in spaces where hard protective coatings are found to be in a GOOD condition, the extent of close-up surveys according to Table 5.7.4.4(2)② or Table 5.7.4.4(2) ③ may be specially considered.

Minimum Requirements for Close-Up Survey at Special Hull Survey of Double Skin Bulk Carriers, Excluding Ore Carriers **Table 5.7.4.4(2)②**

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
One transverse web with associated plating and longitudinals in two representative ballast tanks of each type (This is to include the foremost topside and double side ballast tanks on either side) (A)	One transverse web with associated plating and longitudinals as applicable in each ballast tank (A). Forward and aft transverse bulkheads including stiffening system in a transverse section including topside, hopper side and double side ballast tanks on one side of the ship (i.e. port or starboard) (A)	All transverse webs with associated plating and longitudinals as applicable in each water ballast tank (A). All transverse bulkheads including stiffening system in each water ballast tank (A)	All transverse webs with associated plating and longitudinals as applicable in each water ballast tank (A). All transverse bulkheads including stiffening system in each water ballast tank. (A)
	25% of ordinary transverse frames for transverse framing system or 25% of longitudinals for longitudinal framing system on side shell and inner side plating at forward, middle and aft parts, in the foremost double side tanks (B)	25% of ordinary transverse frames for transverse framing system or 25% of longitudinals for longitudinal framing system on side shell and inner side plating at forward, middle and aft parts, in all double side tanks (B)	All ordinary transverse frames for transverse framing system or all of longitudinals for longitudinal framing system on side shell and inner side plating at forward, middle and aft parts, in all double side tanks (B)
Two selected cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (C)	One transverse bulkhead in each cargo hold, including internal structure of upper and lower stools, where fitted (C)	All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (C)	Areas (C) to (E) as for age interval 10 to 15 years
All cargo hold hatch covers and coamings (platings and stiffeners) (D)	All cargo hold hatch covers and coamings (platings and stiffeners) (D)	All cargo hold hatch covers and coamings (platings and stiffeners) (D)	
	All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches (E)	All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches (E)	

Note: (A), (B), (C), (D) and (E) are areas to be subjected to close-up surveys and thickness measurements (see Figure 5.7.4.4(2)).

(A) Transverse web frame or watertight transverse bulkhead in topside, hopper side and double side ballast tanks. In fore and aft peak tanks transverse web frame means a complete transverse web frame ring including adjacent structural members.

(B) Ordinary transverse frame in double side tanks.

(C) Cargo hold transverse bulkhead plating, stiffeners and girders.

(D) Cargo hold hatch covers and coamings. Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/thickness measurement is to be done of accessible parts of hatch covers structures.

(E) Deck plating and under deck structure inside line of hatch openings between cargo hold hatches.

Close-up survey of transverse bulkheads are to be carried out at four levels:

Level (a): Immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for ships without lower stool.

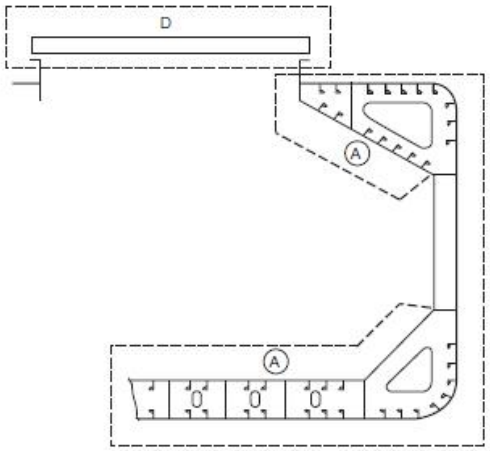
Level (b): Immediately above and below the lower stool shelf plate (for those ships fitted with lower stools), and immediately above the line of the shedder plates.

Level (c): About mid-height of the bulkhead.

Level (d): Immediately below the upper deck plating and immediately adjacent to the upper wing tank, and immediately below the upper stool shelf plate for those ships fitted with upper stools, or immediately below the topside tanks.

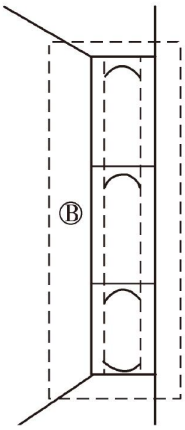
Typical transverse section

Areas (A) and (D)



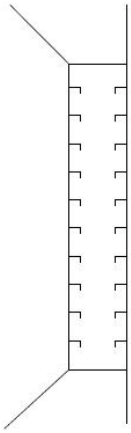
Thickness to be reported on TM3-BC, TM4-BC, TM6-BC and TM7-BC in Appendix 13.2A of this Chapter, as appropriate

Ordinary transverse frame in double skin tank
Area B

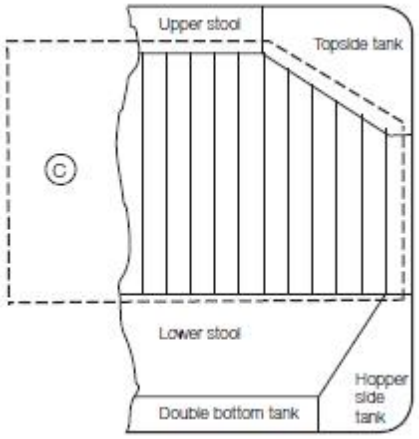


Thickness to be reported on TM4-BC in Appendix 13.2A of this Chapter

Ordinary longitudinal structure in double skin tank

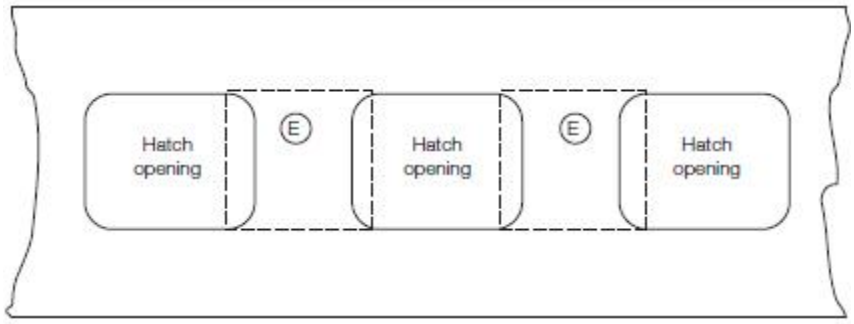


A cargo hold, transverse bulkhead
Area C



Thickness to be reported on TM5-BC in Appendix 13.2A of this Chapter

Typical areas of deck plating and underdeck structure inside line of hatch openings between cargo hold hatches
Area E



Thickness to be reported on TM6-BC in Appendix 13.2A of this Chapter

Figure 5.7.4.4(2) Close-up Survey and Thickness Measurement Areas

Minimum Requirements for Close-Up Survey at Special Hull Survey of Ore Carriers

Table 5.7.4.4(2)③

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
One web frame ring complete including adjacent structural members in a ballast wing tank (A) One transverse bulkhead lower part – including girder system and adjacent structural members - in a ballast tank (A)	All web frame rings complete including adjacent structural members in a ballast wing tank (A) One deck transverse including adjacent deck structural members in each remaining ballast tank (A) Forward and aft transverse bulkheads complete – including girder system and adjacent structural members - in a ballast wing tank (A) One transverse bulkhead lower part - including girder system and adjacent structural members - in each remaining ballast tank (A)	All web frame rings complete including adjacent structural members in each ballast tank (A) All transverse bulkheads complete – including girder system and adjacent structural members - in each ballast tank (A) One web frame ring complete including adjacent structural members in each wing void space (A) Additional web frame rings in void spaces as deemed necessary by CCS (A)	As for Special Survey for age from 10 to 15 years
Two selected cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (C)	One transverse bulkhead in each cargo hold, including internal structure of upper and lower stools, where fitted (C)	All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (C)	Areas (C) to (E) as for age interval 10 to 15 years
All cargo hold hatch covers and coamings (plating and stiffeners) (D)	All cargo hold hatch covers and coamings (plating and stiffeners) (D)	All cargo hold hatch covers and coamings (plating and stiffeners) (D)	
	All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches (E)	All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches (E)	

Note: (A), (C), (D) and (E) are areas to be subjected to close-up surveys and thickness measurements (see Figure 5.7.4.4(2)).

(A): Transverse web frame or watertight transverse bulkhead in ballast wing tanks and void spaces. In fore and aft peak tanks transverse web frame means a complete transverse web frame ring including adjacent structural members.

(C): Cargo hold transverse bulkheads plating, stiffeners and girders.

(D): Cargo hold hatch covers and coamings. Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/thickness measurement is to be done of accessible parts of hatch covers structures.

(E): Deck plating and under deck structure inside line of hatch openings between cargo hold hatches.

Close-up survey of transverse bulkheads to be carried out at four levels:

Level (a): Immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for ships without lower stool.

Level (b): Immediately above and below the lower stool shelf plate (for those ships fitted with lower stools), and immediately above the line of the shedder plates.

Level (c): About mid-height of the bulkhead.

Level (d): Immediately below the upper deck plating and immediately adjacent to the upper wing tank, and immediately below the upper stool shelf plate for those ships fitted with upper stools, or immediately below the topside tanks.

5.7.4.5 Extent of thickness measurement

(1) The minimum requirements for thickness measurement at special survey are given in Tables 5.7.4.5(1)① and 5.7.4.5(1)② respectively for bulk carriers and double skin bulk carriers. For ships not having the notation ESP, the minimum requirements for thickness measurements are given in Table 5.7.4.5(1)③.

(2) Provisions for extended measurements for areas with substantial corrosion are given in Tables 5.7.4.5(2)①a to e and 5.7.4.5(2)②a to d respectively for bulk carriers and double skin bulk carriers and as may be additionally specified in the survey programme as required by 5.1.6.5. For ships not having the notation ESP, provisions for extended measurements for areas with substantial corrosion are given in Table 5.4.4.2(17)②. These extended thickness measurements are to be carried out before the survey is credited as

completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.
For CSR ships, the identified substantial corrosion areas may be:

a) protected by coating applied in accordance with the coating manufacturer's requirements and examined at annual intervals to confirm the coating in way is still in "GOOD" condition, or alternatively
b) required to be measured at annual intervals.

(3)The Surveyor may further extend the thickness measurements as deemed necessary.
(4) For areas in tanks where hard protective coatings are found to be in a GOOD condition, the extent of thickness measurement according to Tables 5.7.4.5(1)① and 5.7.4.5(1)② may be specially considered.
(5) Transverse sections are to be chosen where largest reductions are suspected to occur or are revealed from deck plating measurements, one of which is to be in the amidships area.
(6) Representative thickness measurement to determine both general and local levels of corrosion in the shell frames and their end attachments in all cargo holds and water ballast tanks (for double skin bulk carriers, in the transverse web frames in all water ballast tanks) is to be carried out. Thickness measurement is also to be carried out to determine the corrosion levels on the transverse bulkhead plating. The extent of thickness measurements may be specially considered provided the Surveyor is satisfied by the close-up survey, that there is no structural diminution, and the hard protective coating where applied remains efficient.
(7) Thickness measurements may be carried out at the commencement of the special survey, or the thickness measurement report prepared within 15 months before the due date of the special survey may be taken as the thickness measurement report of the special survey.
(8) For the assessment of thickness measurement results, see 5.4.4.2(17)⑤ of this Chapter.

Minimum Requirements for Thickness Measurements at Special Hull Survey of Bulk Carriers

Table 5.7.4.5(1)①

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
1. Suspect areas	1. Suspect areas. 2. Within the cargo length: Two transverse section of deck plating outside line of cargo openings. 3. Wind and water strakes in way of the two transverse sections considered above and Selected wind and water strakes outside the cargo length area. 4. Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.7.4.4(1)②. 5. Side shell frames and brackets[2] complying with 5.7.1.1(5) of this Section	1. Suspect areas. 2. Within the cargo length: a) Each deck plate outside line of cargo hatch openings. b) Two transverse sections, one in the amidship area, outside line of cargo hatch opening. c) All wind and water strakes. 3. Selected wind and water strakes outside the cargo length area. 4. Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.7.4.4(1)②. 5. The vertically corrugated transverse watertight bulkhead[1] between cargo holds Nos.1 and 2, if applicable. 6. Item 5 as for special survey No.2	1. Suspect areas. 2. Within the cargo length: a) Each deck plate outside line of cargo hatch openings. b) Three transverse sections, one in the amidship area, outside line of cargo hatch opening. c) Each bottom plate. 3. All wind and water strakes, full length. Points 4, 5 and 6 as for special survey No.3

Notes: 1 The specific requirements for the vertically corrugated transverse watertight bulkhead between cargo hold Nos.1 and 2 are given in Appendix 3 of this Chapter.
2 The requirements for thickness measurements of side shell frames and brackets complying with 5.7.1.1(5) of this Section are given in Appendix 6 of this Chapter.

Minimum Requirements for Thickness Measurements at Special Hull Survey of Double Skin Bulk Carriers **Table 5.7.4.5(1)②**

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
Suspect areas	Suspect areas	Suspect areas	Suspect areas
	Within the cargo length: ▪ Two transverse sections of deck plating outside line of cargo hatch openings	Within the cargo length: ▪ Each deck plate outside line of cargo hatch openings. ▪ Two transverse sections, one in the amidship area, outside line of cargo hatch openings. ▪ All wind and water strakes	Within the cargo length: ▪ Each deck plate outside line of cargo hatch openings. ▪ Three transverse sections, one in the amidship area, outside line of cargo hatch openings. ▪ Each bottom plate
	Wind and water strakes in way of the two transverse sections considered above. Selected wind and water strakes outside the cargo length area	Selected wind and water strakes outside the cargo length area	All wind and water strakes, full length
	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.7.4.4(2) ② or Table 5.7.4.4(2)③, as appropriate	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.7.4.4(2) ② or Table 5.7.4.4(2)③, as appropriate	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.7.4.4(2) ② or Table 5.7.4.4(2)③, as appropriate

Minimum Requirements for Thickness Measurements at Special Hull Survey of Bulk Carriers not Having the Notation ESP (Including Double Skin Bulk Carriers)

Table 5.7.4.5(1)③

Age ≤ 10	10 < age ≤ 15	Age > 15
1. Suspect areas throughout the ship	1. Suspect areas throughout the ship	1. Suspect areas throughout the ship
	2. Within the cargo length: a. Each deck plate outside line of cargo hatch openings. b. Two transverse sections, one in the 0.5*L* amidship area, outside line of cargo hatch openings. c. All wind and water strakes	2. Within the cargo length: a. Each deck plate outside line of cargo hatch openings. b. Three transverse sections, one in the 0.5*L* amidship area, outside line of cargo hatch openings. c. Each bottom plate
	3. Selected wind and water strakes outside the cargo area	3. All cargo hold hatch covers and coamings (plating and stiffeners)
		4. Internals in forepeak and afterpeak ballast tanks
		5. All exposed main deck plating full length
		6. Representative exposed superstructure deck plating (poop, bridge, and forecastle deck)
		7. Lowest strake and centre strake in way of all transverse bulkheads in cargo spaces together with internals in way
		8. All wind- and water strakes, port and starboard, full length
		9. All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks
		10. Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion
(Special Survey of Bulk Carriers within the Cargo Area)
Bottom and Shell Structures **Table 5.7.4.5(2)①a**

Structural member	Extent of measurement	Pattern of measurement
1. Bottom and side shell plating	a) Suspect plate, plus four adjacent plates. b) See other tables for particulars on gauging in way of tanks and cargo holds	a) 5-point pattern for each panel between longitudinals
2. Bottoms/side shell longitudinals	Minimum of three longitudinals in way of suspect areas	3 measurements in line across web, 3 measurements on flange

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion
(Special Survey of Bulk Carriers within the Cargo Area)
Transverse Bulkheads in Cargo Holds **Table 5.7.4.5(2)①b**

Structural member	Extent of measurement	Pattern of measurement
1. Lower stool	a) Transverse band within 25 mm of welded connection to inner bottom. b) Transverse band within 25 mm of welded connection to shelf plate	a) 5-point between stiffeners over 1 m length. b) 5-point between stiffeners over 1 m length
2. Transverse bulkhead	a) Transverse band at approximately mid height. b) Transverse band at part of bulkhead adjacent to upper deck or below upper stool shelf plate (for those ships fitted with upper stools)	a) 5-point pattern over 1 m^2 of plating. b) 5-point pattern over 1 m^2 of plating

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion
(Special Survey of Bulk Carriers within the Cargo Area)
Deck Structure
(Including Cross Strips, Main Cargo Hatchways, Hatch Covers, Coamings and Topside Tanks)
Table 5.7.4.5(2)①c

Structural member	Extent of measurement	Pattern of measurement
1. Cross deck strip plating	Suspect cross deck strip plating	5-point pattern between underdeck stiffeners over 1 m length
2. Underdeck stiffeners	a) Transverse members; b) Longitudinal member	a) 5-point pattern at each end and mid span; b) 5-point pattern on both web and flange
3. Hatch covers	a) Side and end skirts, each 3 locations; b) 3 longitudinal bands, outboard strakes (2) and centerline strake (1)	a) 5-point pattern at each location; b) 5-point measurement each band
4. Hatch coamings	Each side and end of coaming, one band lower 1/3, one band upper 2/3 of coaming	5-point measurement each band, i.e. end or side coaming
5. Topside water ballast tanks	a) Watertight transverse bulkheads: a. Lower 1/3 of bulkhead; b. Upper 2/3 of bulkhead; c. Stiffeners	a. 5-point pattern over 1 m^2 of plating; b. 5-point pattern over 1 m^2 of plating; c. 5-point pattern over 1 m length
	b) 2 representative swash transverse bulkheads: a. Lower 1/3 of bulkhead; b. Upper 2/3 of bulkhead; c. Stiffeners	a. 5-point pattern over 1 m^2 of plating; b. 5-point pattern over 1 m^2 of plating; c. 5-point pattern over 1 m length
	c) 3 representative bays of slope plating: a. Lower of 1/3 tank; b. Lower of 2/3 tank	a. 5-point pattern over 1 m^2 of plating; b. 5-point pattern over 1 m^2 of plating
	d) Longitudinals, suspect and adjacent	d) 5-point pattern on both web and flange over 1 m length
6. Main deck plating	Suspect plates and adjacent (4)	5-point pattern over 1 m^2 of plating
7. Main deck longitudinals	Minimum of 3 longitudinals where plating measured	5-point pattern on both web and flange over 1 m length
8. Web frames/transverses	Suspect plates	5-point pattern over 1 m^2

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion (Special Survey of Bulk Carriers within the Cargo Area)

Double Bottom and Hopper Structure **Table 5.7.4.5(2)①d**

Structural member	Extent of measurement	Pattern of measurement
1. Inner/double bottom plating	Suspect plate plus all adjacent plates	5-point pattern for each panel between longitudinals over 1 m length
2. Inner/double bottom longitudinals	Three longitudinals where plates measured	3 measurements in line across web and 3 measurements on flange
3. Longitudinal girders or transverse floors	Suspect plates	5-point pattern over about 1 m^2
4. Watertight bulkheads (WT floors)	a) Lower 1/3 of tank; b) Upper 2/3 of tank	a) 5-point pattern over 1 m^2 of plating; b) 5-point pattern alternate plates over 1 m^2 of plating
5. Web frames	Suspect plate	5-point pattern over 1 m^2 of plating
6. Bottoms/side shell longitudinals	Minimum of three longitudinals in way of suspect areas	3 measurements in line across web and 3 measurements on flange

Requirements for Extent of Thickness Measurement at Those Areas of Substantial Corrosion (Special Survey of Bulk Carriers within the Cargo Area)

Cargo Holds **Table 5.7.4.5(2)①e**

Structural member	Extent of measurement	Pattern of measurement
Side shell frames	Suspect frame and each adjacent	a) At each end and mid span: 5-point pattern of both web and flange; b) 5-point pattern within 25 mm of welded attachment to both shell and lower slope plate

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion of Double Skin Bulk Carriers within the Cargo Length Area

Bottom, Inner Bottom and Hopper Structure **Table 5.7.4.5(2)②a**

Structural member	Extent of measurement	Pattern of measurement
Bottom, inner bottom and hopper structure plating	Minimum of three bays across double bottom tank, including aft bay. Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and floors
Bottom, inner bottom and hopper structure longitudinals	Minimum of three longitudinals in each bay where bottom plating measured	Three measurements in line across flange and three measurements on the vertical web
Bottom girders, including the watertight ones	At fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with one measurement between each panel stiffener, or a minimum of three measurements
Bottom floors, including the watertight ones	Three floors in the bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over two square metre area
Hopper structure web frame ring	Three floors in bays where bottom plating measured	5-point pattern over one square metre of plating; Single measurements on flange
Hopper structure transverse watertight bulkhead or swash bulkhead	Lower 1/3 of bulkhead	5-point pattern over one square metre of plating
	Upper 2/3 of bulkhead	5-point pattern over two square metre of plating
	Stiffeners (minimum of three)	For web, 5-point pattern over span (two measurements across web at each end and one at centre of span). For flange, single measurements at each end and centre of span
Panel stiffening	Where applicable	Single measurements

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion of Double Skin Bulk Carriers within the Cargo Length Area
Deck Structure
(Including Cross Strips, Main Cargo Hatchways, Hatch Covers, Coamings and Topside Tanks)

Table 5.7.4.5(2)②b

Structural member	Extent of measurement	Pattern of measurement
Cross deck strip plating	Suspect cross deck strip plating	5-point pattern between underdeck stiffeners over 1 metre length
Underdeck stiffeners	Transverse members	5-point pattern at each end and mid span
	Longitudinal members	5-point pattern on both web and flange
Hatch covers	Side and end skirts, each three locations. Three longitudinal bands, outboard strakes (2) and centerline strake (1)	5-point pattern at each location. 5-point measurement each band
Hatch coamings	Each side and end of coaming, one band lower 1/3, one band upper 2/3 of coaming	5-point measurement each band, (i.e. end or side coaming
Topside ballast tanks	a) Watertight transverse bulkheads: − Lower 1/3 of bulkhead − Upper 2/3 of bulkhead − Stiffeners	 5-point pattern over 1 m^2 of plating. 5-point pattern over 1 m^2 of plating. 5-point pattern over 1 metre length
Topside ballast tanks	b) Two representative swash transverse bulkheads: − Lower 1/3 of bulkhead − Upper 2/3 of bulkhead − Stiffeners	 5-point pattern over 1 m^2 of plating. 5-point pattern over 1 m^2 of plating. 5-point pattern over 1 metre length
Topside ballast tanks	c) Three representative bays of slope plating: − Lower 1/3 of tank − Upper 2/3 of tank	 5-point pattern over 1 m^2 of plating. 5-point pattern over 1 m^2 of plating
Topside ballast tanks	d) Longitudinals, suspect and adjacent	5-point pattern on both web and flange over 1 metre length
Main deck plating	Suspect plates and adjacent (4)	5-point pattern over 1 m^2 of plating
Main deck longitudinals	Suspect plates	5-point pattern on both web and flange over 1 metre length
Web frames/transverses	Suspect plates	5-point pattern over 1 m^2

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion of Double Skin Bulk Carriers within the Cargo Length Area
Double Side Structure (Including Wing Void Spaces of Ore Carriers)

Table 5.7.4.5(2)②c

Structural member	Extent of measurement	Pattern of measurement
Side shell and inner plating: • Upper strake and strakes in way of horizontal girders. • All other strakes	• Plating between each pair of transverse frames/longitudinals in a minimum of three bays (along the tank). • Plating between every third pair of longitudinals in same three bays	• Single measurement • Single measurement
Side shell and inner side transverse frames/longitudinals on: • Upper strake. • All other strakes	• Each transverse frame/longitudinal in same three bays. • Every third transverse frame/longitudinal in same three bays	• Three measurements across web and 1 measurement on flange. • Three measurements across web and 1 measurement on flange
Transverse frames/longitudinals - brackets	Minimum of three at top, middle and bottom of tank in same three bays	5-point pattern over area of bracket
Vertical web and transverse bulkheads: • Strakes in a way of horizontal girders. • Other strakes	• Minimum of two webs and both transverse bulkheads. • Minimum of two webs and both transverse bulkheads	• 5-point pattern over approx. two square metre area. • Two measurements between each pair of vertical stiffeners
Horizontal girders	Plating on each girder in a minimum of three bays	Two measurements between each pair of longitudinal girder stiffeners
Panel stiffening	Where applicable	Single measurements

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion of Double Skin Bulk Carriers within the Cargo Length Area

Transverse Bulkheads in Cargo Holds **Table 5.7.4.5(2)②d**

Structural member	Extent of measurement	Pattern of measurement
Lower stool, where fitted	• Transverse band within 25 mm of welded connection to inner bottom. • Transverse band within 25 mm of welded connection to shelf plate	• 5-point pattern between stiffeners over one metre length. • 5-point pattern between stiffeners over one metre length
Transverse bulkheads	• Transverse band at approximately mid height. • Transverse band at part of bulkhead adjacent to upper deck or below upper stool shelf plate (for those ships fitted with upper stools)	• 5-point pattern over one square metre of plating. • 5-point pattern over one square metre of plating

5.7.4.6 Extent of tank testing

(1) All boundaries of water ballast tanks, deep tanks and cargo holds used for water ballast within the cargo length area are to be pressure tested. For fuel oil tanks, only representative tanks are to be pressure tested.

(2) The Surveyor may extend the tank testing as deemed necessary.

(3) Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

(4) Boundaries of ballast holds are to be tested with a head of liquid to near to the top of hatches.

(5) Boundaries of fuel oil tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil tanks may be specially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.

(6) The testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

5.7.4.7 Automatic air pipe heads

(1) For examination of automatic air pipe heads installed on the exposed decks, reference is to be made to 5.4.4.2(18) of this Chapter.

5.7.4.8 Additional surveys are to be carried out for ships after determining compliance with SOLAS XII/12 and XII/13 as follows:

(1) For ships complying with the requirements of SOLAS XII/12 for hold, ballast and dry space water level detectors, the special survey is to include an examination and a test of the water ingress detection systems and of their alarms.

(2) For ships complying with the requirements of SOLAS XII/13 for the availability of pumping systems, the special survey is to include an examination and a test of the means for draining and pumping ballast tanks forward of the collision bulkhead and bilges of dry spaces any part of which extends forward of the foremost cargo hold, and of their controls.

Section 8 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF CHEMICAL TANKERS

5.8.1 General requirements

5.8.1.1 This Section applies to all self-propelled chemical tankers fitted with integral tanks, i.e. ships with IMO certificate of fitness for the carriage of dangerous chemicals in bulk. If a chemical tanker is constructed with both integral and independent tanks, this Section is applicable only to that portion of the cargo length containing integral tanks. Combined gas carriers/chemical tankers with independent tanks within the hull, are to be surveyed as gas carriers.

5.8.1.2 This Section applies to surveys of hull structure and piping systems in way of cargo tanks, pump rooms, cofferdams, pipe tunnels, void spaces within the cargo area and all ballast tanks. The requirements are additional to the classification requirements applicable to the remainder of the ship. The requirements are not applicable for independent tanks on deck.

5.8.1.3 This Section contains the minimum extent of examination, thickness measurements and tank testing. The survey is to be extended when substantial corrosion and/or structural defects are found and include additional close-up survey when necessary.

5.8.2 Annual surveys

5.8.2.1 General requirements
(1) The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition and should take into account the service history, condition and extent of the corrosion prevention system of ballast tanks and areas identified in the survey report file.
(2) The annual survey is to include the items specified in 5.8.2.2 through 5.8.2.5 of this Section and in addition, the applicable items specified in 5.4.2 of this Chapter.
5.8.2.2 Hull
(1) Examination of the hull plating and its closing appliances as far as can be seen.
(2) Examination of watertight penetrations as far as practicable.
5.8.2.3 Examination of weather decks
(1) Examination of cargo tank openings including gaskets, covers, coamings and flame screens.
(2) Examination of cargo tank pressure/vacuum valves and flame screens.
(3) Examination of flame screens on vents to all bunker tanks.
(4) Examination of cargo, bunker and vent piping systems, including vent masts and headers.
5.8.2.4 Examination of cargo pump rooms and pipe tunnels if fitted
(1) Examination of all pump room bulkheads for signs of chemical leakage or fractures and, in particular, the sealing arrangements of all penetrations of pump room bulkheads.
(2) Examination of the condition of all piping systems.
5.8.2.5 Examination of ballast tanks
(1) Examination of ballast tanks where required as a consequence of the results of the special survey (see 5.8.4) and intermediate survey (see 5.8.3.2) is to be carried out. When considered necessary by the Surveyor, or when extensive corrosion exists, thickness measurements are to be carried out and if the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Table 5.8.4.4(2). These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

5.8.3 Intermediate surveys
5.8.3.1 General requirements
(1) The intermediate survey extent is dependent on the age of the ship as specified in 5.8.3.2 to 5.8.3.4 of this Section.
(2) The intermediate survey is also to include the applicable items specified in 5.4.3 of this Chapter and 5.8.2 of this Section.
(3) For weather decks, an examination as far as applicable of cargo, bunker, ballast, steam and vent piping systems as well as vent masts and headers is to be carried out. If upon examination there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, thickness measured or both.
5.8.3.2 Chemical tankers 5 to 10 years of age
(1) For ballast tanks, an overall survey of representative tanks selected by the Surveyor is to be carried out. If such inspections reveal no visible structural defects, the examination may be limited to a verification that the hard protective coating remains in GOOD condition.
(2) A ballast tank is to be examined at subsequent annual intervals where:
① a hard protective coating has not been applied from the time of construction, or
② a soft or semi-hard coating has been applied, or
③ substantial corrosion is found within the tank, or
④ the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.
(3) In addition to the requirements above, suspect areas identified at previous surveys are to be examined.
5.8.3.3 Chemical tankers 10 to 15 years of age
(1) The requirements of the intermediate survey are to be to the same extent as the previous special survey as required in 5.8.4 of this Section and 5.1.6.5. However, pressure testing of cargo and ballast tanks is not required unless deemed necessary by the attending Surveyor.
(2) In application of (1), the intermediate survey may be commenced at the second annual survey and be progressed during the succeeding year with a view to completion at the third annual survey in lieu of the application of 5.2.4.2.
(3) In application of (1), an underwater survey may be considered in lieu of the requirements of 5.8.4.1(4).
5.8.3.4 Chemical tankers over 15 years of age

(1) The requirements of the intermediate survey are to be to the same extent as the previous special survey as required in 5.8.4 of this Section and 5.1.6.5. However, pressure testing of cargo and ballast tanks is not required unless deemed necessary by the attending Surveyor.
(2) In application of (1), the intermediate survey may be commenced at the second annual survey and be progressed during the succeeding year with a view to completion at the third annual survey in lieu of the application of 5.2.4.2.
(3) In application of (1), a survey in dry dock is to be part of the intermediate survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks① are to be carried out in accordance with the applicable requirements for intermediate surveys, if not already performed.

5.8.4 Special surveys

5.8.4.1 General requirements

(1) The special survey is to include, in addition to the applicable requirements of 5.4.4 of this Chapter and 5.8.2 of this Section, examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in 5.8.4.1(3), is in a satisfactory condition and is fit for its intended purpose for the new period of class of 5 years to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.
(2) All cargo tanks, ballast tanks including double bottom tanks, pump rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in 5.8.4.5 and 5.8.4.6, to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.
(3) Cargo piping on deck and cargo and ballast piping within the above tanks and spaces are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces, and Surveyors are to be advised on all occasions when this piping, including valves and fittings are open during repair periods and can be examined internally.
(4) A survey in dry dock is to be a part of the special survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks① are to be carried out in accordance with the applicable requirements for special surveys, if not already performed.

5.8.4.2 Tank protection

(1) Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined. A ballast tank is to be examined at subsequent annual intervals where:

① a hard protective coating has not been applied from the time of construction, or
② a soft or semi-hard coating has been applied, or
③ substantial corrosion is found within the tank, or
④ the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurements are to be carried out as deemed necessary by the Surveyor.

5.8.4.3 Extent of overall and close-up surveys

(1) An overall survey of all tanks and spaces is to be carried out at each special survey. The survey of stainless steel tanks may be carried out as an overall survey supplemented by close-up survey as deemed necessary by the surveyor.
(2) The minimum requirements for close-up surveys at special survey of chemical tankers are given in Table 5.8.4.3(2)① and those of double skin chemical tankers in Table 5.8.4.3(2)②. For ships not having the notation ESP, the Surveyor may carry out the close-up survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system.

Minimum Requirements for Close-Up Surveys at Special Survey of Chemical Tankers

Table 5.8.4.3(2)①

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
A) One web frame ring (in a ballast wing tank)	A) All web frame rings (in a ballast wing tank or	A) All web frame rings (in all ballast tanks)	As special survey No.3

① Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

B) One deck transverse (in a cargo tank or on deck) D) One transverse bulkhead (lower part in a ballast tank) D) One transverse bulkhead (lower part in a cargo wing tank) D) One transverse bulkhead (lower part in a cargo centre tank) (see Note II)	double bottom ballast tank) (see Note I) B) One deck transverse (in each remaining ballast tank or on deck) B) One deck transverse (in a cargo wing tank or on deck) B) One deck transverse (in two cargo centre tanks or on deck) C) Both transverse bulkheads (in a ballast wing tank) D) One transverse bulkhead (lower part in each remaining ballast tank) D) One transverse bulkhead (lower part in two cargo centre tanks) (see Note II) D) One transverse bulkhead (lower part in a cargo wing tank)	A) All web frame rings (in a cargo wing tank) A) One web frame ring (in each remaining cargo tank) C) All transverse bulkheads (in all cargo tanks) C) All transverse bulkheads (in all ballast tanks)	Additional transverse areas as deemed necessary by CCS

Notes:

I: Ballast double hull tank means double bottom tank plus double side tank plus double deck tank, as applicable, even if these tanks are separate.

II: Where no centre cargo tanks are fitted (as in the case of centre longitudinal bulkhead), transverse bulkheads in wing tanks are to be surveyed.

A to D are areas to be subjected to close-up surveys and thickness measurements (see Figures 5.8.4.3(2)a and 5.8.4.3(2)b).

A): Complete transverse web frame ring, including adjacent structural members.

B): Deck transverse, including adjacent deck structural members.

C): Transverse bulkhead complete, including girder system and adjacent structural members.

D): Transverse bulkhead lower part, including girder system and adjacent structural members.

Minimum Requirements for Close-Up Surveys at Special Survey of Double Skin Chemical Tankers

Table 5.8.4.3(2)②

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent: Age > 15
(1) One web frame ring (in a ballast double hull tank) (see Note I) (2) One deck transverse (in a cargo tank or on deck) (4) One transverse bulkhead (in a ballast tank) (see Note I) (5) One transverse bulkhead (in a cargo wing tank) (5) One transverse bulkhead (in a cargo centre tank) (see Note II)	(1) All web frame rings (in a ballast wing tank or ballast double hull tank) (see Note I) (6) The knuckle area and the upper part (3 metres approx) of one web frame in each remaining ballast tank (2) One deck transverse (in two cargo tanks) (4) One transverse bulkhead (in each ballast tank) (see Note I) (5) One transverse bulkhead (in two cargo centre tanks) (see Note II) (5) One transverse bulkhead (in a cargo wing tank)	(1) All web frame rings (in all ballast tanks) (7) All web frame rings (in a cargo wing tank) (7) One web frame ring (in each remaining cargo tank) (3) All transverse bulkheads (in all cargo tanks) (4) All transverse bulkheads (in all ballast tanks)	As special survey No.3 Additional transverse areas as deemed necessary by CCS

(1), (2), (3), (4), (5), (6) and (7) are areas to be subjected to close-up surveys and thickness measurements (see Figures 5.8.4.3(2)②a to c).

(1): Web frame in a ballast tank means vertical web in side tank, hopper web in hopper tank, floor in double bottom tank and deck transverse in double deck tank (where fitted), including adjacent structural members. In fore and aft peak ballast tanks web frame means a complete transverse web frame ring including adjacent structural members.

(2): Deck transverse, including adjacent deck structural members (or external structure on deck in way of the tank, where

applicable).

(3): Transverse bulkhead complete in cargo tanks, including girder system, adjacent structural members (such as longitudinal bulkheads) and internal structure of lower and upper stools, where fitted.

(4): Transverse bulkhead complete in ballast tanks, including girder system and adjacent structural members, such as longitudinal bulkheads, girders in double bottom tanks, inner bottom plating, hopper side, connecting brackets.

(5): Transverse bulkhead lower part in cargo tank, including girder system, adjacent structural members (such as longitudinal bulkheads) and internal structure of lower stool, where fitted.

(6): The knuckle area and the upper part (3 metres approximately), including adjacent structural members. Knuckle area is the area of the web frame around the connections of the slope hopper plating to the inner hull bulkhead and the inner bottom plating, up to 2 metres from the corners both on the bulkhead and the double bottom.

(7): Web frame in a cargo tank means deck transverse, longitudinal bulkhead structural elements and cross ties, where fitted, including adjacent structural members.

Note I: Ballast double hull tank means double bottom tank plus double side tank plus double deck tank, as applicable, even if these tanks are separate.

Note II: Where no centre cargo tanks are fitted (as in the case of centre longitudinal bulkhead), transverse bulkheads in wing tanks are to be surveyed.

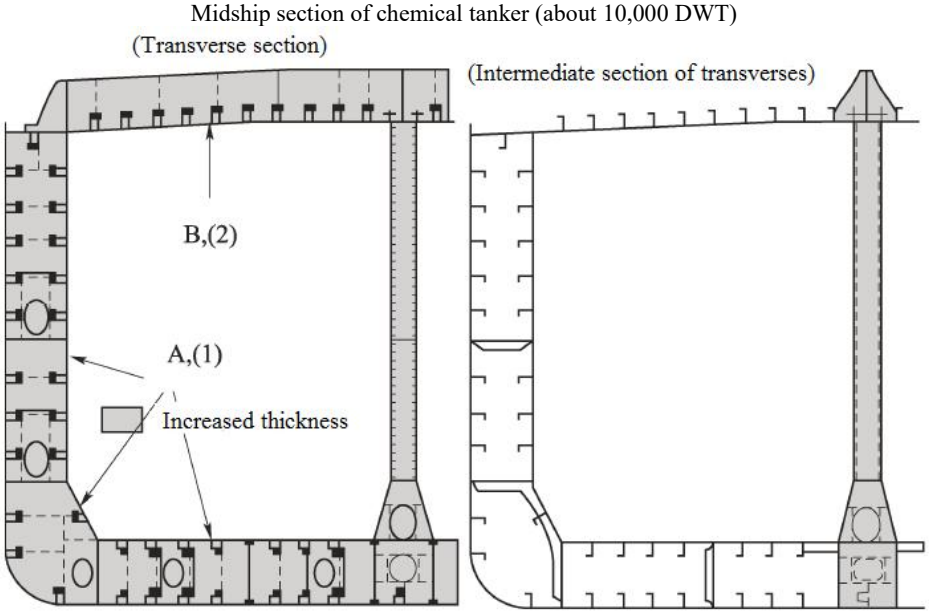


Figure 5.8.4.3(2)a
Representative Transverse Section of Chemical Tanker. Areas A & B and 1 & 2

Transverse BHD of chemical tanker (about 10,000 DWT)

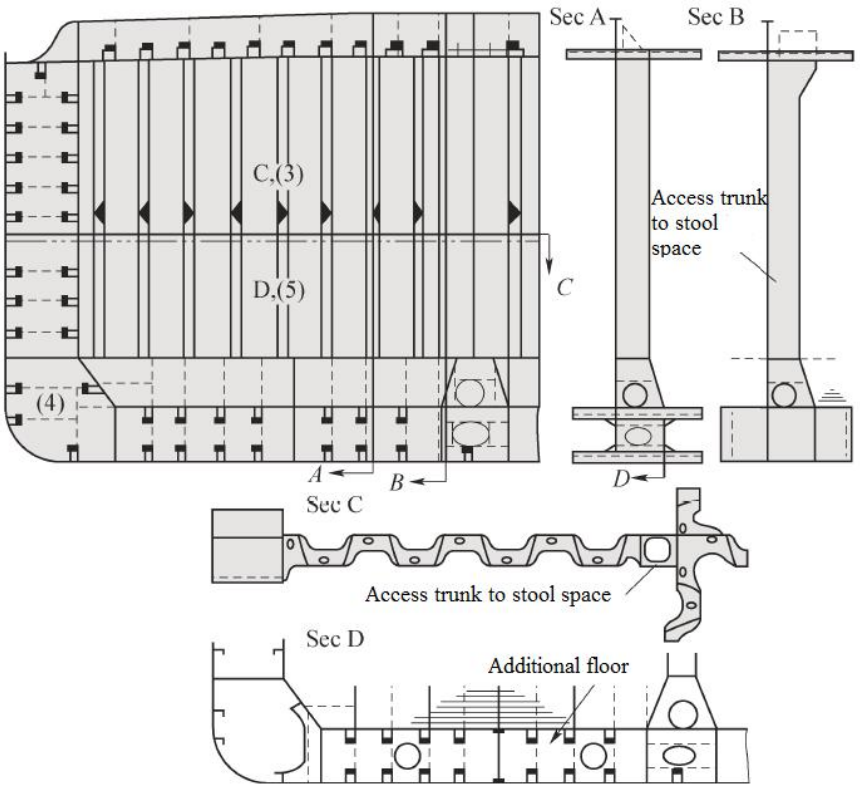


Figure 5.8.4.3(2)b
Representative Transverse Section of Chemical Tanker. Areas C & D and 3, 4 & 5

Midship section of chemical tanker (about 10,000 DWT)

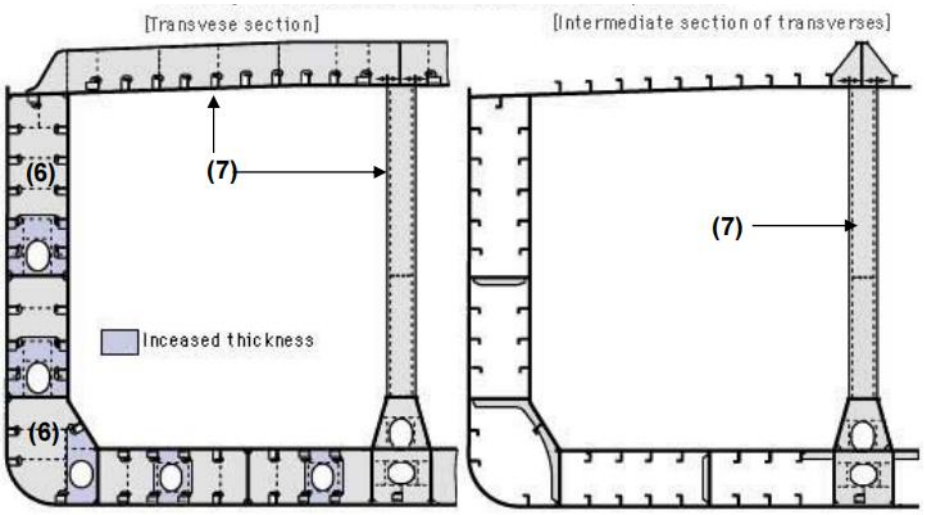


Figure 5.8.4.3(2)c
Representative Transverse Section of Chemical Tanker. Areas 6 & 7

(3) The Surveyor may extend the close-up survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:

① in particular, tanks having structural arrangements or details which have suffered defects in similar tanks or on similar ships according to available information;

② in tanks which have structures approved with reduced scantlings due to an approved corrosion control system.

(4) For areas in tanks where hard protective coatings are found to be in a GOOD condition**,** the extent of

close-up surveys according to Table 5.8.4.3(2) may be specially considered.

5.8.4.4 Extent of thickness measurement

(1) The minimum requirements for thickness measurements at special survey are given in Table 5.8.4.4(1)a. Thickness measurement of stainless steel hull structure and piping may be waived, except for clad steel plating. For ships not having the notation ESP, the minimum requirements for thickness measurements are given in Table 5.8.4.4(1)b.

(2) Provisions for extended measurements for areas with substantial corrosion are given in Table 5.8.4.4(2)a to d, and as may be additionally specified in the survey programme as required by 5.1.6.5. For ships not having the notation ESP, provisions for extended measurements for areas with substantial corrosion are given in Table 5.4.4.2(17)②. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous special surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

Minimum Requirements for Thickness Measurements at Special Survey of Chemical Tankers

Table 5.8.4.4(1)a

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent: Age > 15
1. Suspect areas	1. Suspect areas	1. Suspect areas	1. Suspect areas
	2. Within the cargo area: a) Each deck plate b) One transverse section	2. Within the cargo area: a) Each deck plate b) Two transverse sections(1) c) All wind and water strakes	2. Within the cargo area: a) Each deck plate b) Three transverse sections(1) c) Each bottom plate
	3. Selected wind and water strakes outside the cargo area	3. Selected wind and water strakes outside the cargo area	3. All wind and water strakes, full length
	4. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.8.4.3(2)① or ② of this Section, as appropriate	4. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.8.4.3(2)① or ② of this Section, as appropriate	4. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.8.4.3(2)① or ② of this Section, as appropriate

Note: (1) At least one section is to include a ballast tank within 0.5*L* amidships.

Minimum Requirements for Thickness Measurements at Special Survey of Chemical Tankers not Having the Notation ESP

Table 5.8.4.4(1)b

Age ≤ 10	10 < age ≤ 15	Age > 15
1. Suspect areas throughout the ship	1. Suspect areas throughout the ship	1. Suspect areas throughout the ship
	2. Within the cargo area: a) Each deck plate b) Two transverse sections c) All wind and water strakes	2. Within the cargo area: a) Each deck plate b) Three transverse sections c) Each bottom plate
	3. Selected wind and water strakes outside the cargo area	3. Internals in forepeak and afterpeak ballast tanks
		4. All exposed main deck plating full length
		5. Representative exposed superstructure deck plating (poop, bridge, and forecastle deck)
		6. Lowest strake and centre strake in way of all transverse bulkheads in cargo spaces together with internals in way
		7. All wind- and water strakes, port and starboard, full length
		8. All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks
		9. Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by

Age ≤ 10	10 < age ≤ 15	Age > 15
		the attending Surveyor

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion
(Special Survey of Chemical Tankers within the Cargo Area Length)
Bottom, Inner Bottom and Hopper Structure Table 5.8.4.4(2)a

Structural member	Extent of measurement	Pattern of measurement
1. Bottom, inner bottom and hopper structure plating	Minimum of three bays across tank, including aft bay Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and floors
2. Bottom, inner bottom and hopper structure longitudinals	Minimum of three longitudinals in each bay where bottom plating measured	Three measurements in line across the flange and three measurements on vertical web
3. Bottom girders, including the watertight ones	At fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with one measurement between each panel stiffener, or a minimum of three measurements. Two measurements across face flat where fitted
4. Bottom floors, including the watertight ones	Three floors in bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over two square metre area
5. Hopper structure web frame ring	Three floors in bays where bottom plating measured	5-point pattern over one square metre of plating. Single measurements on flange
6. Hopper structure transverse watertight bulkhead or swash bulkhead	– lower 1/3 of bulkhead	– 5-point pattern over one square metre of plating
	– upper 2/3 of bulkhead	– 5-point pattern over two square metre of plating
	– stiffeners (minimum of three)	– For web, 5-point pattern over span (two measurements across web at each end and one at centre of span). For flange, single measurements at each end and centre of span
7. Panel stiffening	Where applicable	Single measurements

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion
(Special Survey of Chemical Tankers within the Cargo Area Length)
Deck Structure Table 5.8.4.4(2)b

Structural member	Extent of measurement	Pattern of measurement
1. Deck plating	Two transverse bands across tank	Minimum of three measurements per plate per band
2. Deck longitudinals	Every third longitudinal in each of two bands with a minimum of one longitudinal	Three measurements in line vertically on webs and two measurements on flange (if fitted)
3. Deck girders and brackets	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of three measurements. Two measurements across flange. 5-point pattern on girder/bulkhead brackets
4. Deck transverse webs	Minimum of two webs, with measurements at both ends and middle of span	5-point pattern over one square metre area. Single measurements on flange
5. Vertical web and transverse bulkhead in wing ballast tank for double hull design (two metres from deck)	Minimum of two webs, and both transverse bulkheads	5-point pattern over one square metre area
6. Panel stiffening	Where applicable	Single measurements

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion
(Special Survey of Chemical Tankers within the Cargo Area Length)
Side Shell and Longitudinal Bulkheads Table 5.8.4.4(2)c

Structural member	Extent of measurement	Pattern of measurement
1. Side shell and longitudinal bulkhead plating: – Deckhead and bottom strakes, and strakes in way of horizontal girders – All other strakes	– Plating between each pair of longitudinals in a minimum of three bays (along the tank) – Plating between every third pair of longitudinals in same three bays	Single measurement
2. Side shell and longitudinal bulkhead longitudinals on: – Deckhead and bottom strakes – All other strakes	– Each longitudinal in same three bays – Every third longitudinal in same three bays	3 measurements across web and 1 measurement on flange
3. Longitudinals - brackets	Minimum of three at top, middle and bottom of tank in same three bays	5-point pattern over area of bracket
4. Vertical web and transverse bulkheads of double side tanks (excluding deck area): – Strakes in way of horizontal girders – Other strakes	– Minimum of two webs and both transverse bulkheads – Minimum of two webs and both transverse bulkheads	– 5-point pattern over approx. two square metre area – Two measurements between each pair of vertical stiffeners
5. Web frames and cross ties for other tanks than double side tanks	Three webs with minimum of three locations on each web, including in way of cross tie connections and lower end bracket	5-point pattern over approximately two square metre area of webs, plus single measurements on flanges of web frame and cross ties
6. Horizontal girders	Plating on each girder in a minimum of three bays	Two measurements between each pair of longitudinal girder stiffeners
7. Panel stiffening	Where applicable	Single measurements

Requirements for Extent of Thickness Measurements at Those Areas of Substantial Corrosion

(Special Survey of Chemical Tankers within the Cargo Area Length)

Transverse Watertight and Swash Bulkheads Table 5.8.4.4(2)d

Structural member	Extent of measurement	Pattern of measurement
1. Upper and lower stool, where fitted	– Transverse band within 25 mm of welded connection to inner bottom/deck plating – Transverse band within 25 mm of welded connection to shelf plate	5-point pattern between stiffeners over one metre length
2. Deckhead and bottom strakes, and strakes in way of horizontal stringers	Plating between pair of stiffeners at three locations: approximately 1/4, 1/2 and 3/4 width of tank	5-point pattern between stiffeners over one metre length
3. All other strakes	Plating between pair of stiffeners at middle location	Single measurement
4. Strakes in corrugated bulkheads	Plating for each change of scantling at centre of panel and at flange of fabricated connection	5-point pattern over about one square metre of plating
5. Stiffeners	Minimum of three typical stiffeners	For web, 5-point pattern over span between bracket connections (two measurements across web at each bracket connection and one at centre of span). For flange, single measurements at each bracket toe and at centre of span
6. Brackets	Minimum of three at top, middle and bottom of tank	5-point pattern over area of bracket
7. Horizontal stringers	All stringers with measurements at both ends and middle	5-point pattern over one square metre area, plus single measurements near bracket toes and on flanges
8. Deep webs and girders	Measurements at toe of bracket and at centre of span	For web, 5 point pattern over about 1 square metre. 3 measurements across face flat

(3) The Surveyor may further extend the thickness measurements as deemed necessary.

(4) For areas in tanks where hard protective coatings are found to be in a GOOD condition, the extent of thickness measurements according to Table 5.8.4.4(1) may be specially considered.

(5) Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

(6) In cases where two or three sections are to be measured, at least one is to include a ballast tank within

0.5*L* amidships.
(7) Thickness measurements may be carried out at the commencement of the special survey, or the thickness measurement report prepared within 15 months before the due date of the special survey may be taken as the thickness measurement report of the special survey.
(8) For the assessment of thickness measurement results, see 5.4.4.2(17)⑤ of this Chapter.

5.8.4.5 Extent of tank testing

(1) The minimum requirements for ballast tank testing are given in (3) of this paragraph and Table 5.8.4.5(1); the minimum requirements for cargo tank testing are given in (4) of this paragraph and Table 5.8.4.5(1). Cargo tank testing carried out by the ship's crew under the direction of the Master may be accepted by the Surveyor provided the following conditions are complied with:

① a tank testing procedure, specifying fill heights, tanks being filled and bulkheads being tested, has been submitted by the Owner and reviewed by CCS prior to the testing being carried out;

② there is no record of leakage, distortion or substantial corrosion that would affect the structural integrity of the tank;

③ the tank testing has been satisfactorily carried out within a special survey window not more than 3 months prior to the date of the survey on which the overall or close-up survey is completed;

④ the satisfactory results of the testing is recorded in the ship's logbook;

⑤ the internal and external condition of the tanks and associated structure are found satisfactory by the Surveyor at the time of the overall and close-up survey.

(2) The Surveyor may extend the tank testing as deemed necessary.
(3) Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.
(4) Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions.
(5) The testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

Minimum Requirements to Tank Testing at Special Survey of Chemical Tankers

Table 5.8.4.5(1)

Special Survey No.1 Age ≤ 5	Special Survey No.2 and Subsequent Age > 5
1. All ballast tank boundaries. 2. Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump rooms or cofferdams	1. All ballast tank boundaries. 2. All cargo tank bulkheads

5.8.4.6 Chemical tankers over 10 years of age

(1) Selected steel cargo pipes outside cargo tanks and ballast pipes passing through cargo tanks are to be:

① thickness measured at random or selected pipe lengths to be opened for internal inspection;

② pressure tested to the maximum working pressure.

Special attention is to be given to cargo/slop discharge piping through ballast tanks and void spaces.

Section 9 SURVEYS OF MACHINERY

5.9.1 General requirements

5.9.1.1 This Section applies to surveys of machinery installations for all self-propelled ships. However, boilers and thermal oil heaters, screwshaft and tubeshaft as well as the machineries covered by Section 11 of this Chapter and PART FIVE of the Rules are excluded.

5.9.1.2 The purpose of surveys for machinery is to confirm that machinery installations are properly maintained, in good and effective condition and fit for their intended purposes. Surveys for machinery are normally to be carried out in conjunction with corresponding hull surveys.

5.9.1.3 The owner and manager of the ship are to make appropriate preparations for different types of surveys in advance, including cleaning and illumination of spaces, providing safe access to survey items, safety facilities, and sufficient information, instructions, diagrams and lists as necessary.

5.9.1.4 Special consideration may be given in application of relevant requirements of this Section to commercial ships owned or chartered by Governments, which are utilized in support of military operations or service.

5.9.1.5 Surveys of machinery may be carried out on a PMS basis (Reference to Appendix 16 of this

Chapter).
5.9.1.6 Surveys of machinery may be carried out on a CM / CBM basis (Reference to Appendix 22 of this Chapter).

5.9.2 Annual surveys

5.9.2.1 The relevant requirements for interval of annual surveys are given in Section 2 of this Chapter.
5.9.2.2 The purpose of annual surveys is to confirm that the general condition of machinery installations in question is properly maintained since last survey and is fit for their intended purposes.
5.9.2.3 Survey items for all ships
(1) Confirming that the machinery, boilers and other pressure vessels, associated piping systems and fittings are installed and protected so as to reduce to a minimum any danger to persons on board, due regard being given to moving parts, hot surfaces and other hazards.
(2) Confirming that the normal operation of the propulsion machinery can be sustained or restored even though one of the essential auxiliaries becomes inoperative.
(3) Confirming that means are provided so that the machinery can be brought into operation from the dead ship condition without external aid.
(4) Carrying out a general examination of the machinery, the boilers, all steam, hydraulic, pneumatic and other systems and their associated fittings to see whether they are being properly maintained and with particular attention to the fire and explosion hazards.
(5) Examining and testing the operation of main and auxiliary steering arrangements, including their associated equipment and control systems.
(6) Confirming that the various alarms required for hydraulic power-operated, electric and electro-hydraulic steering gears are operating satisfactorily and that the re-charging arrangements for hydraulic power-operated steering gears are being maintained.
(7) Examining the means for the operation of the main and auxiliary machinery essential for the propulsion and the safety of the ship, including, when applicable, the means of remotely controlling the propulsion machinery from the navigating bridge (including the control, monitoring, reporting, alert and safety actions) and the arrangements to operate the main and other machinery from a machinery control room.
(8) Confirming the operation of the ventilation for the machinery spaces.
(9) Examining the arrangements for periodically unattended machinery spaces and, in particular, the random testing of alarm, automatic and shutdown functions.
(10) Confirming, as far as practicable, that no changes have been made in the structural fire protection, examining any manual and automatic fire doors and proving their operation, testing the fire dampers of ventilation ducts and the means of closing the main inlets and outlets of all ventilation systems and testing the means of stopping power ventilation systems from outside the space served.
(11) Confirming that the means of escape from accommodation, machinery and other spaces are satisfactory.
(12) Examining visually the condition of any expansion joints in seawater systems.
(13) Confirming that no unapproved changes have been made to the structures of machinery spaces and boiler spaces.
(14) Confirming that doors in machinery spaces and boiler spaces are in a good working condition, and escape routes are free from obstruction.
(15) Confirming that maintenance of main propulsion plant including main propulsion machinery, gear units and shafting systems is in accordance with the Rules and that they are in a good working condition.
(16) Confirming that pump and piping systems associated with the main propulsion system are maintained in a good working condition.
(17) Confirming that generator prime mover and other auxiliary machinery and associated pump and piping systems are in a good working condition.
(18) Confirming that essential safety and protective devices including safety valves of boilers, exhaust boilers, economizers, steam heated steam generators, boilers used not for propulsion services having a working pressure exceeding 0.35 MPa and a heating surface exceeding 4.5 m^2, thermal oil and hot water units, relief valves of pressure vessels having a working pressure exceeding 0.7 MPa, safety devices and emergency cut-off devices for oil supply and burning units, etc. are in a good working condition, and that safety means for all moving parts and hot surfaces are in a good working condition and effective.
(19) Examining the bilge pumping systems and bilge wells, including operation of pumps, extended spindles and level alarms, in machinery spaces and boiler spaces as far as practicable; operational testing of emergency bilge pumping systems in machinery spaces of passenger ships for confirming their good working condition.
(20) Confirming that initial starter is effective.

(21) Confirming that the means of communication between the navigation bridge and machinery spaces, steering gear compartment and where fitted, emergency steering positions are operating satisfactorily.
(22) Confirming that voyage repairs made by crew are satisfactory.
(23) Confirming that recommendations and remaining items from previous surveys have been dealt with in accordance with related requirements.

5.9.2.4 Additional items for oil tankers

(1) In addition to 5.9.2.3, the following items are also to be examined:

① confirming that no potential sources of ignition such as loose gear, excessive products in the bilges, excessive vapours, combustible materials, etc., are present in the cargo pump room and that access ladders are in good condition;
② confirming that cargo pump rooms and all pump room bulkheads have no signs of leakage and, in particular, paying attention to the sealing arrangements of all penetrations in these bulkheads;
③ confirming that ventilation system of cargo pump rooms and pump rooms including ducting, dampers and flame screens and their control devices outside cargo pump rooms and pump rooms are in good condition;
④ examination of all piping systems in cargo pump rooms and pump rooms, in so far as practicable and confirming that they are in good condition;
⑤ confirming in so far as practicable, that shaft glands of cargo, bilge, ballast and stripping pumps, and remote operating and shutoff devices of cargo pump room bilge system are in good condition, and checking that the pump foundations are intact;
⑥ confirming that the fixed fire-fighting system for the cargo pump room is in good condition and that all openings are capable of being closed quickly from outside;
⑦ confirming that fixed deck foam system is in good condition.

5.9.2.5 Additional survey requirements for ships having inert gas system notation (IGS)

(1) For ships having an inert gas system (IGS), an examination and/or test of the following items is to be carried out to confirm that the system is in a good working condition:

① visual examination of all piping and venting pipes on decks and discharges in the shell plating in cargo areas to confirm that there is no any sign of gas or effluent leakage;
② confirming the proper operation of both inert gas blowers;
③ confirming the proper operation of the scrubber-room ventilation system;
④ checking the deck water seal for automatic filling and draining, and the arrangements for protecting the system against freezing;
⑤ where a double block and bleed valve is installed, checking the automatic operations of the block and the bleed valves upon loss of power;
⑥ where two shut-off valves in series with a venting valve in between are used as non-return devices, checking the automatic operation of the venting valve, and the alarm for faulty operation of the valves;
⑦ examining the operation of all remotely operated or automatically controlled valves and, in particular, the flue gas isolating valves;
⑧ observing a test of the interlocking feature of soot blowers;
⑨ observing that the gas pressure regulating valve automatically closes when the inert gas blowers are secured;
⑩ checking the means for separating the cargo tank not being inerted from the inert gas main;
⑪ checking the alarms of the two oxygen sensors positioned in the space or spaces containing the inert gas system;
⑫ checking/testing, as far as practicable, the following alarms and safety devices of the inert gas system using simulated conditions where necessary:
   a. high oxygen content of gas in the inert gas main;
   b. low gas pressure in the inert gas main;
   c. low pressure in the supply to the deck water seal;
   d. high temperature of gas in the inert gas main;
   e. low water pressure or low water-flow rate;
   f. accuracy of portable and fixed oxygen-measuring equipment by means of calibration gas;
   g. high water level in the scrubber;
   h. failure of the inert gas blowers;
   i. failure of the power supply to the automatic control system for the gas regulating valve and to the

instrumentation of continuous indication and permanent recording of pressure and oxygen content in the inert gas main;

j. high pressure of gas in the inert gas main;

⑬ checking the proper operation of the inert gas system.

5.9.2.6 Additional survey requirements for ships having class notations of machinery control and automation

(1) For ships having class notations of machinery control and automation, a general examination or performance test of the following items is to be carried out, in so far as practicable, to confirm that they are in a good working condition:

① function test of alarm indicators;

② checking functions of control systems of main and auxiliary engines:

a. automatic control of main engines;

b. automatic control of main and auxiliary boilers;

c. automatic start and control of emergency generators;

d. automatic start or change-over of standby pumps for essential pumps serving main engines;

e. performance test of engine room bilge level detection and alarm system and of start of pumps;

③ communication and extended alarm between the navigating bridge and engineers' accommodation;

④ checking functions of fixed fire detection and fire alarm systems;

⑤ performance test of repaired items of automatic and remote control systems of other essential machineries;

⑥ examining the machinery records to check the performance of the control system throughout the period since the last survey and to establish if there has been any abnormal functioning or failures and what corrective measures had been taken to preclude their recurrence.

5.9.2.7 For ships having class notations for other machinery installations, e.g. SCM, ECM, a general survey is to be carried out in accordance with respective requirements in the Rules to confirm that such installations are in good working condition and effective.

5.9.2.8 Examining, where applicable, the alternative design and arrangements for machinery or electrical installations, low-flashpoint fuel storage and distribution systems, or fire safety, in accordance with the test, inspection and maintenance requirements, if any, specified in the approved documentation.

5.9.3 Intermediate surveys

5.9.3.1 The relevant requirements for interval of intermediate surveys are given in Section 2 of this Chapter.

5.9.3.2 Survey items for all ships

(1) In addition to the applicable requirements for annual surveys, the following items are to be added:

① prime movers of driving generators are to be operationally tested under working conditions to verify that they are in a good working condition;

② sea chests and overboard discharge valves in machinery and boiler spaces are to be inspected;

③ a general examination of windlass and a partial load test by slipping and hauling anchors are to be carried out.

5.9.4 Special surveys

5.9.4.1 The relevant requirements for interval of special surveys are given in Section 2 of this Chapter.

5.9.4.2 Conditions for survey

(1) The owner is to provide the necessary conditions and safety facilities for the survey, e.g. disassembling or opening and cleaning, safe access to and illumination for survey items.

(2) Special surveys are to include examinations, tests, and checks of sufficient extent to ensure that the machinery installations are properly maintained and are fit for the intended purpose for the new period of class of 5 years.

5.9.4.3 Survey and test items for all ships

(1) The items in 5.9.3.2 of this Chapter applicable to the ship.

(2) The items in 5.11.2.1 of this Chapter applicable to the ship. However, a docking survey is considered to coincide with the special survey when carried out within 15 months prior to the due date of the special survey.

(3) All shafts (excluding screwshaft, tubeshaft, directional propeller and water jet propulsion arrangements) and bearings of the main propulsion system are to be examined. The lower half of the bearings need not be exposed if alignment and wear are found in order.

(4) All gear units are to be opened up and their pinions and wheels, shafts, bearings, thrust bearings and

lubricating system examined. Conventional gear units 1,120 kW and below and all epicyclic gear units need not be opened up provided that satisfactory operating records are provided by the owner.
(5) Auxiliary engines including air compressors, filters, oily water separator, intercoolers and safety devices are to be examined.
(6) All pumps and associated parts serving the propulsion machinery are to be opened up and examined.
(7) Steering arrangements together with the main and auxiliary steering gears are to be examined, and a hydrostatic check of the steering system to the relief valve setting is to be conducted.
(8) Examination of anchor windlass, including operational check, check of the brake and foundation, and testing of safety devices.
(9) Foundation bolts and gaskets of main and auxiliary engines, gearboxes as well as thruster and intermediate shaft pedestals are to be examined.
(10) All heat exchangers (including intercoolers) and pressure vessels with working pressures of 0.7 MPa and over together with associated attachments and valves are to be opened up and examined and where corrosion or damage is found, pressure tested to determine the working pressure. Their relief valves are to be checked in service conditions. Where it is difficult to open up certain small heat exchangers or pressure vessels with working pressures of 0.7 MPa and over, an alternative hydraulic test to 1.25 times the working pressure may be accepted.
(11) Valves, cocks and strainers of bilge system together with pipelines are to be tested in service conditions.
(12) Connection and blanking arrangements of fuel oil, lubricating oil, cooling water, feed water and ballast systems are to be examined or tested and if necessary opened up for examination.
(13) Fuel oil tanks constructed not forming part of hull structure are to be examined and if deemed necessary by the Surveyor, to be pressure tested. If fuel oil tanks are found satisfactory during the external examination, the internal examination of such tanks may be exempted for ships less than 10 years of age.

5.9.4.4 Additional survey requirements for ships having class notations of machinery control and automation

(1) In addition to 5.9.2.7, a general examination of the following items is to be carried out to confirm that they are in a good working condition.

① Simulated performance test of automated system of main propulsion machinery:
   a. main control system (including automatic control of start, operation, stopping and reversing of main propulsion machinery, remote control of engine room centralized control room and navigating bridge);
   b. control system changeover and communication;
   c. safety system;
   d. alarm system;
   e. overriding control system;
   f. automatic start of standby machinery;
   g. confirming changeover to manual control in case of failure of remote control system;
   h. function test of control, safety and alarm systems when power (electrical, hydraulic or pneumatic) is restored after a power failure.

② Simulated performance test of automated system of boilers:
   a. safety system for burning (including automatically stopping fuel supply pump, automatically starting and stopping feed pump, scavenging, automatically controlling temperature);
   b. monitoring and alarm systems;
   c. manual control.

③ Automatic controls and alarms of generating system and power plant (including automatic start, switch-in, parallel operation, load distribution and shutoff of standby generating sets) are to be examined.

④ Simulated performance test of other essential machinery:
   a. performance test of control, safety and alarm systems (including alarm indicators, displays) are to be carried out so far as is practicable;
   b. components (elements, valves, actuators, instruments) of automatic and remote control systems are to be visually examined and if necessary, opened up for examination and test.

⑤ Remote operation test of suction valves and discharge valves below waterline.

⑥ Checking records of fault recorder and reviewing log book entries regarding automatic and remote control equipment to confirm operational reliability of all systems.

5.9.4.5 Additional survey requirements for ships having the class notation of inert gas system (IGS)

(1) For ships having the class notation of inert gas system (IGS), the following items are to be examined

and/or tested to confirm that they are in a good working condition:

① inert gas generator and scrubber are to be opened up if there is any sign of gas or effluent leakage;

② inert gas piping and stop valve together with interlocking feature of soot blowers are to be disassembled and examined if there is any abnormality;

③ deck water seal and non-return valve are to be opened up;

④ water cooling system including discharge pipe and scrubber overboard discharge pipe are to be examined, and valves are to be disassembled and examined;

⑤ function test of all automatic closing appliances and alarm systems;

⑥ examining the integrity of the system under working condition;

⑦ at the request of the owner and upon approval by CCS, a system of continuous surveys may be undertaken whereby the special survey requirements are carried out in regular rotation, i.e. every mechanical item of the inert gas system is to be opened up and examined, so far as practicable, at the specified interval (normally five (5) years). The interval between consecutive examinations of each item is not to exceed five (5) years. Surveys are to be arranged annually for about a fifth of all items. If any defect is found during the survey, related components and parts are to be opened up and examined. Such defects are to be dealt with to the satisfaction of the Surveyor;

⑧ examining the whole system under working condition.

5.9.4.6 Diesel engines

(1) For diesel engines, the following parts (if fitted) are to be disassembled/opened up for examination.

① Cylinder liners, cylinder covers, valves and their transmitting gear, pistons, piston rods, crossheads, guides, connecting rods, crankshaft and all bearings, crankcases, bedplates, frames and entablatures, crankcase door fastenings and explosion relief devices, scavenger relief devices, scavenging pump or blowers, superchargers and their associated coolers, fuel pumps and fittings, camshafts and their transmitting gear together with balance weights, torsional vibration dampers or detuners, flexible couplings, clutches, reverse gears, attached pumps and cooling arrangements.

② Selected portion of pipes in the starting air system is to be removed for internal examination and acoustic test. If lube oil accumulation is found, in addition to steam blowing, the portions of pipes adjacent to main starting valve and air discharge from compressor are to be removed for examination.

③ Test of engine operation and test of initial starting arrangement.

④ The survey of diesel engines with bores 300 mm or below may be carried out according to the manufacturer’s scheduled maintenance program, provided the engines are maintained under the program. The records of the program, including lubrication servicing, are to be made available to the Surveyor. Periodical overhauls, required by the manufacturer’s scheduled maintenance program, are to be witnessed by the Surveyor.

5.9.4.7 Gas turbines

(1) For gas turbines, the following parts are to be opened out for examination.

① Impellers or blading, rotors and casings of the air compressors, combustion chambers, intercoolers, gas and air piping, starting and reversing arrangements.

② Gas turbines may be opened and maintained in accordance with the manufacturer’s recommendations. The owner is to submit for approval maintenance schedules for each type of gas turbine in service, specifying proposed intervals for combustion checks, hot-gas-path examinations and other items.

③ For units in continuous service, at least one hot-gas-path examination is to be scheduled each survey period (normally five (5) years) and is to include an examination of turbine rotors, fixed blading (nozzle ring), combustors, inlet casings, exhaust casing, air control valves and protective apparatus. Other parts and associated equipment, if any obvious change has been made to them as shown in comparison with previous records available, are to be opened up for examination.

④ Opening of compressor sections is to be scheduled in conjunction with other items, provided that examination of the blades visible from the inlet plenum during the hot-gas-path examination reveals no evidence of defects.

⑤ The required examinations of auxiliary gas turbine units, at least once each period (normally five years), are to be based on manufacturer's recommendations, as appropriate for the actual operating hours and conditions, together with an operation test including protective apparatus.

⑥ Where units are arranged such that the unit is removed from the ship and dismantled at another facility, the internal examination may be carried out at the facility. The reinstallation is to be carried out to the satisfaction of the Surveyor.

⑦ Upon reassembly/reinstallation, all fuel lines, lube oil piping, the unit itself and exhaust system are to be checked under full speed operational conditions for leakage. All shielding and fuel oil double wall piping is to be examined.

⑧ Cylinders, pistons, end covers, valves and valve gear, pumps and fittings, synchronizing and control gear, cooling system, explosion relief devices including bypass arrangements of free piston gas generators are to be opened out and examined.

⑨ Air compressors including rotors and casings, combustion chambers, burners, intercoolers, heat exchangers, gas and air piping of gas turbines are to be opened out and examined.

5.9.4.8 Steam turbines

(1) For main and auxiliary steam turbines, the following parts are to be opened out for examination.

① Rotor with blading and shrouding and bearings.

② Nozzles, stationary blading, interstage packing and gland seals with oil barriers.

③ Bleed controls and foundation expansion arrangements.

④ Throttle valves are to be operationally tested and opened as deemed necessary.

⑤ In general, lifting of the main propulsion turbine casing may be waived for new-installed ones within the 5-years period of the special survey No.1, provided the turbines are of a well known type and fitted with rotor position indicators and vibration indicators of an approved type, as well as steam pressure measuring equipment at appropriate locations in the steam flow path. Rotor bearings, thrust bearings and the flexible coupling are to be opened and examined. The low pressure turbine exhaust trunk is to be opened for examination of the last row of low pressure and astern wheels. Turbine operating records are to be reviewed. The arrangements for changeover in case of emergency operation of the plant are to be readily available. The turbines are to be operationally tested.

⑥ Turbine casings are to be lifted for confirming the effectiveness of the maintenance arrangement at special survey No.2 and subsequent special surveys. However, the lifting of main propulsion turbine casings may be waived at special survey No.3 and subsequent special surveys, provided that:

a. an approved preventative maintenance arrangement has been established, including vibration monitoring, lubricating oil analysis and rotor position checks;
b. the rotor journal bearings, thrust bearings and flexible couplings are opened up for examination, the low-pressure turbine exhaust trunk is opened for examination of the last row of low pressure and astern wheels;
c. the turbine operating records are reviewed and all considered satisfactory by the Surveyor, at least in compliance with the manufacturer's recommendations;
d. the turbines are to be operationally tested.

5.9.4.9 As part of the Special Survey of Machinery, a dock trial is to be carried out to attending Surveyors' satisfaction to confirm satisfactory operation of main and auxiliary machinery. If significant repairs are carried out to main or auxiliary machinery or steering gear, consideration should be given to a sea trial to attending Surveyors' satisfaction.

5.9.4.10 If the significant repairs as stated in 5.9.4.9, is considered by CCS to have any impact on response characteristics of the propulsion systems, then the scope of sea trial is also to include a test plan for astern response characteristics based on those required for such an equipment or systems when fitted to the new ship. Refer to 1.2.4, Chapter 1, PART THREE of the Rules for astern testing requirements.

The tests are to demonstrate the satisfactory operation of the equipment or system under realistic service conditions at least over the manoeuvring range of the propulsion plant, for both ahead and astern directions. Depending on the actual extent of the repair, CCS may accept a reduction of the test plan.

Section 10 SURVEYS OF ELECTRICAL INSTALLATIONS

5.10.1 General requirements

5.10.1.1 This Section applies to surveys of electrical installations for all ships.

5.10.2 Annual surveys

5.10.2.1 The relevant requirements for interval of annual surveys are given in Section 2 of this Chapter.

5.10.2.2 Survey items

(1) Confirming that means of communication between the navigation bridge and steering gear compartment and the means of indicating the angular position of the rudder are operating satisfactorily.

(2) Confirming that with ships having emergency steering position there are means of relaying heading information and, when appropriate, supplying visual compass readings to the emergency steering position;
(3) Confirming that the engine room telegraph, the second means of communication between the navigation bridge and the machinery spaces and the means of communication with any other positions from which the engines are controlled are operating satisfactorily.
(4) Confirming that the engineer's alarm is clearly audible in the engineer's accommodation.
(5) Examining, as far as practicable, visually and in operation, the electrical installations, including the main source of power, main and emergency lighting systems and cables.
(6) Satisfactory operation of main power source, emergency power source including its starting device and emergency power supply of the equipment essential to ship safety is to be tested. Where these power sources are provided with automatic power supply, the test is to be carried out in automatic mode.
(7) Examining, in general, that the precautions provided against shock, fire and other hazards of electrical origin are being maintained, e.g. bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.
(8) Electric propulsion plant, position-keeping mooring and auxiliary propulsion plant as well as controls are to be tested.
(9) Confirming that generators, motors driving essential machineries together with controls are in normal working condition.
(10) Failure indicators and alarms associated with electrical equipment essential to safety of ship are to be examined and tested.
(11) Confirming voyage repairs made by crew.
(12) Confirming that no potential sources of fire exist in dangerous spaces, and that all electrical equipment in dangerous zones is suitable for such locations, is in good condition and is being properly maintained.
(13) For oil tankers, electrical installations, cables, controls, explosion-proof equipment and appliances in cargo oil pump rooms and spaces above and adjacent to cargo area are to be examined to verify that there are no improperly installed or unapproved equipment and dead end wiring, etc.
(14) Where the electrical distribution system on board a ship includes harmonic filters, the total harmonic distortion (THD) recorded onboard the ship is to be checked.
(15) Checking the schedule of batteries used for essential and emergency services, confirming that relevant records have been updated after replacement of batteries.

5.10.3 Intermediate surveys

5.10.3.1 The relevant requirements for interval of intermediate surveys are given in Section 2 of this Chapter.

5.10.3.2 Survey items

(1) The items in 5.10.2.2 of this Section applicable to the ship.
(2) Generators are to be operationally tested under working conditions to verify that they are in a good working condition.
(3) Electrical equipment in dangerous zones or circuits passing through dangerous zones are to be examined to verify that there are no dangers, defects, improperly installed or unapproved equipment and dead end wiring, etc.
(4) Insulation resistance of electrical circuits in dangerous zones (such as cargo pump rooms and spaces adjacent to cargo tanks) is to be tested, but in cases where a proper record of testing is maintained, consideration should be given to accepting recent readings.

5.10.4 Special surveys

5.10.4.1 The relevant requirements for interval of special surveys are given in Section 2 of this Chapter.

5.10.4.2 Conditions for survey: The owner is to provide the necessary conditions and safety facilities for the survey, e.g. disassembling or opening and cleaning, safe access to and illumination for survey items.

5.10.4.3 Survey and test items

(1) The items in 5.10.3.2 of this Section applicable to the ship.
(2) The items in 5.11.2.1 of this Chapter applicable to the ship. However, a docking survey is considered to coincide with the special survey when carried out within 15 months prior to the due date of the special survey.
(3) Insulation resistance of electrical equipment and circuits are to be tested.
(4) The fittings on the main and emergency switchboard, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.
(5) Air circuit breakers of generators are to be tested to verify satisfactory operation and delay of protective

devices.
(6) All cables are to be examined to verify that there are no loosening clamps and casings.
(7) Motors and their auxiliary control and operating mechanisms for essential services are to be examined and if considered necessary, to be operated under working conditions. All generators and steering motors are to be examined and tested under working conditions and if considered necessary, a full-load test may be carried out simultaneously.
(8) Where transformers of essential power supply are of wet type, the owner is to submit the liquid sample to an authoritative institution for testing its breakdown voltage, acidity and moisture. The report of test results is to be submitted to the Surveyor.
(9) Navigation lights are to be tested under working condition to verify correct indication and alarm on failure of power supply or of the lights.
(10) Emergency power source together with its automatic device and auxiliary power source are to be tested.
(11) Emergency lighting, temporary emergency lighting, supplementary emergency lighting, general alarm and public address system are to be tested in so far as practicable.
(12) For electrically propelled ships, the propulsion motors, generators, cables and all ancillary equipment and controls are to be examined and insulation resistance measured.

Section 11 SURVEYS OF THE OUTSIDE OF THE SHIP'S BOTTOM AND RELATED ITEMS

5.11.1 General requirements

5.11.1.1 Examinations of the outside of the ship's bottom and related items can be carried out with the ship in dry dock or on a slipway. Alternate examination may be carried out while the ship is afloat as an in-water survey, subject to provisions of 5.2.3 in Section 2 of this Chapter.
5.11.1.2 The interval between examinations of the outside of the ship's bottom and related items is to be in compliance with the provisions given in Section 2 of this Chapter.
5.11.1.3 Special consideration may be given in application of relevant requirements of this Section to commercial ships owned or chartered by Governments, which are utilized in support of military operations or service.

5.11.2 Scope of survey of the outside of the ship's bottom

5.11.2.1 General requirements
(1) When a ship is in dry dock or on a slipway, it is to be placed on blocks of sufficient height and with the necessary staging to permit the examination of elements such as shell plating including bottom and bow plating, stern frame and rudder, sea chests and valves, propeller, etc.
(2) The shell plating is to be examined for excessive corrosion, or deterioration due to chafing or contact with the ground and for any undue unfairness or buckling. Special attention is to be paid to the connection between the bilge strakes and the bilge keels. Important plate unfairness or other deterioration which do not necessitate immediate repairs is to be recorded.
(3) Sea chests and their gratings, sea connections and overboard discharge valves and cocks and their fastenings to the hull or sea chests are to be examined. Valves and cocks need not be opened up more than once in a special survey period unless considered necessary by the Surveyor.
(4) Visible parts of rudder, rudder pintles, rudder shafts and couplings and stern frame are to be examined. If considered necessary by the Surveyor, the rudder is to be lifted or the inspection plates removed for the examination of pintles. The clearance in the rudder bearings is to be ascertained and recorded. Limiting values for rudder bearing wear clearance are given in Appendix 4 of this Chapter. Where practicable, pressure test of the rudder may be required as deemed necessary by the Surveyor.
(5) Visible parts of propeller and stern bush are to be examined. The clearance in the stern bush and the efficiency of the shaft seals, if fitted, are to be ascertained and recorded. For controllable pitch propellers, the Surveyor is to be satisfied with the fastenings and tightness of hub and blade sealing. Dismantling need not to be carried out unless considered necessary by the Surveyor.
(6) Visible parts of side thrusters are to be examined. Other propulsion systems which also have manoeuvring characteristics (such as directional propellers, vertical axis propellers, water jet units) are to be examined externally with focus on the condition of gear housing, propeller blades, bolt locking and other fastening arrangements. Sealing arrangement of propeller blades, propeller shaft and steering column is to be verified.

5.11.3 In-water surveys

5.11.3.1 General requirements

(1) For the ships with In-Water Survey class notation, the in-water survey may be carried out to examine the underwater portions of the hull and machinery in addition to the provisions of 5.2.3. Specific requirements for in-water surveys are given in Chapter 12 of PART EIGHT of the Rules.

(2) At the request of the owner and under particular ambient conditions, CCS may agree to carry out the in-water survey to the ships without In-Water Survey class notation to replace the docking survey as described in 5.11.2 of this Section.

5.11.3.2 Conditions for in-water surveys

(1) In principle, there are to be no overdue repair items for the underwater portions of shell plating, rudder, propeller and propeller shaft, unless considered by CCS that such repairs are practicable when the ship is afloat.

(2) The in-water survey is to be carried out with the ship in sheltered water and preferably with weak tidal streams and currents. The in-water visibility and the cleanliness of the hull below the waterline is to be clear enough to permit a meaningful examination which allows the surveyor and the in-water survey firm to determine the condition of the plating, appendages and the welding. CCS is to be satisfied with the methods of orientation of the divers or Remotely Operated Vehicle (ROV) on the plating, which should make use where necessary of permanent markings on the plating at selected points.

(3) The equipment and procedure for observing and reporting the survey are to be discussed with the parties involved prior to the in-water survey, and suitable time is to be allowed to permit the in-water survey firm to test all equipment beforehand.

(4) The in-water survey is to be carried out under the surveillance of a CCS surveyor by an in-water survey firm approved as a service supplier by CCS according to Appendix 8 of this Chapter. A good two-way communication between the Surveyor and divers is to be provided.

5.11.3.3 Scope of the survey and survey report

(1) The in-water survey is to provide the information normally obtained from a docking survey. The scope of in-water survey is to be the same as the survey items listed in 5.11.2.1, so far as practicable. Special consideration may be given to ascertaining rudder bearing clearances and stern bush clearances of oil stern bearings based on a review of the operating history, on board testing and stern oil sample reports. These considerations are to be included in the proposals for in-water survey which are to be submitted by the owner or ship management company in advance of the survey so that satisfactory arrangements can be agreed with CCS.

(2) Upon completion of an in-water survey, a detailed report together with a video tape and photos showing main parts under survey are to be submitted by the in-water survey firm to the Surveyor.

(3) If the in-water survey reveals any damage or deterioration that requires early attention, the Surveyor is to require that the ship be dry-docked in order that a detailed survey can be undertaken and the necessary repairs carried out.

Section 12 SURVEYS OF PROPELLER SHAFTS AND TUBE SHAFTS

5.12.1 General requirements

5.12.1.1 Application

(1) Unless alternative means are provided to assure the condition of the propeller shaft assembly, these requirements apply to all vessels with conventional shafting fitted with a propeller as follows:

① from 1 January 2016 for ships delivered on or after 1 January 2016;

② after the first shaft survey scheduled on or after 1 January 2016, for ships delivered before 1 January 2016[①].

5.12.1.2 Definitions (see Figure 5.12.1.2)

(1) Shaft: For the purpose of this Section, shaft is a general definition, including:

① propeller shaft;

② tube shaft.

The definition does not include the intermediate shaft(s) which is(are) considered part of the propulsion shafting inside the vessel.

---

① Upon the completion of the first shaft survey scheduled on or after 1 January 2016, the designation of dates for the next shaft survey is to be made based upon the requirements of this Section.

(2) Propeller shaft: Propeller shaft is the part of the propulsion shaft to which the propeller is fitted. It may also be called screwshaft or tailshaft.
(3) Tube shaft: Tube shaft is a shaft placed between the intermediate shaft and propeller shaft, normally arranged within a stern tube or running in open water. It may also be called stern tube shaft.

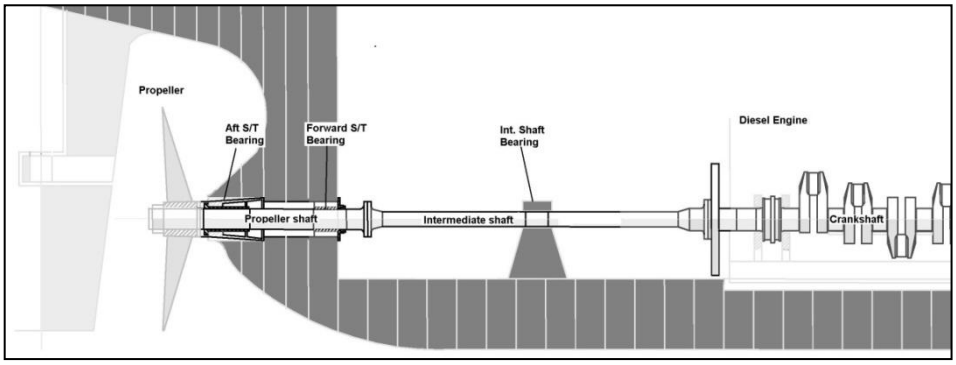


Figure 5.12.1.2 Typical Shafting Arrangement

(4) Sterntube: Tube or pipe fitted in the shell of a ship at the stern (or rear part of the ship), below the water-line, through which passes the tube shaft or aftermost section of the propeller-shaft. Sterntube is the housing of the shaft bearings, generally two (one aft and one fore), that sustain the shaft and allows its rotation with less frictional resistance. The stern tube also accommodates the shaft sealing arrangement.
(5) Closed loop (system) oil lubricated bearing: Closed loop oil lubricating systems use oil to lubricate the bearings and are sealed against the environment (seawater) by adequate sealing / gland devices.
(6) Water lubricated bearing: Water lubricated bearings are bearings cooled / lubricated by water (fresh or salt).
(7) Closed loop system fresh water lubricated bearing: Closed loop water lubricating systems use fresh water to lubricate the bearings and are sealed against the environment (such as seawater) by adequate sealing / gland devices.
(8) Open systems (water): Open water lubricating systems use water to lubricate the bearings and are exposed to the environment.
(9) Adequate means for protection against corrosion: An adequate means for protection against corrosion is an approved means for full protection of the core shaft against sea water intrusion and subsequent corrosion attack. Such means are used for the protection of common steel material against corrosion particularly in combination with water lubricated bearings. Typical means are for example:

① continuous metallic, corrosion resistant liners;
② continuous cladding;
③ multiple layer synthetic coating;
④ multiple layer of fiberglass;
⑤ combinations of above mentioned;
⑥ rubber / elastomer covering coating.

The means for protection against corrosion are installed / applied according to CCS approved procedures.
(10) Corrosion resistant shaft: Corrosion resistant shaft is made in approved corrosion resistant steel as core material for the shaft.
(11) Sterntube sealing system: Sterntube sealing system is the equipment installed on the inboard extremity and, for closed systems, at outboard extremity of the sterntube. Inboard seal is the device fitted on the fore part of the sterntube that achieve the sealing against the possible leakage of the lubricant media in to the ship internal. Outboard seal is the device fitted on the aft part of the sterntube that achieve the sealing against the possible sea water ingress and the leakage of the lubricant media.
(12) Service records: Service records are regularly recorded data showing in-service conditions of the shaft(s) and may include, as applicable: lubricating oil temperature, bearing temperature and oil consumption records (for oil lubricated bearings) or water flow, water temperature, salinity, pH, make-up water and water pressure (for closed loop fresh water lubricated bearings depending on design).
(13) Oil sample examination: An oil sample examination is a visual examination of the stern tube lubricating oil taken in presence of the surveyor with a focus on water contamination.
(14) Lubricating oil analysis: Lubricating oil analysis is to be carried out at regular intervals not exceeding six (6) months taking into account IACS Rec. 36. The documentation on lubricating oil analysis is to be available on board. Oil samples, to be submitted for the analysis, are to be taken under service conditions.

(15) Fresh water sample test[①]: Fresh water sample test is to be carried out at regular intervals not exceeding six (6) months. Samples are to be taken under service conditions and are to be representative of the water circulating within the sterntube. Analysis results are to be retained on board and made available to the surveyor. At time of survey the sample for the test has to be taken at the presence of the surveyor. Fresh water sample test is to include the following parameters:

① chlorides content;

② pH value;

③ presence of bearing particles or other particles (only for laboratory analysis, not required for tests carried out in presence of the surveyor).

(16) Keyless connection: Keyless connection is the forced coupling Methodology between the shaft and the propeller without a key achieved through interference fit of the propeller boss on the shaft tapered end.

(17) Keyed connection: Keyed connection is the forced coupling Methodology between the shaft and the propeller with a key and keyway achieved through the interference fit of the propeller boss on the shaft tapered end.

(18) Flanged connection: Flanged connection is the coupling Methodology, between the shaft and the propeller, achieved by a flange, built in at the shaft aft end, bolted to propeller boss.

(19) Alternative means: Shafting arrangements such as, but not limited to, an approved Condition Monitoring Scheme and / or other reliable approved means for assessing and monitoring the condition of the tail shaft, bearings, sealing devices and the stern tube lubricant system capable to assure the condition of the propeller shaft assembly with an equivalent level of safety as obtained by survey methods as applicable in this section.

5.12.2 Oil lubricated shafts or closed loop system fresh water lubricated shafts (closed system)

5.12.2.1 Shaft survey methods

(1) Method 1

The survey is to consist of:

① Drawing the shaft and examining the entire shaft, seals system and bearings.

② For keyed and keyless connections:

a. removing the propeller to expose the forward end of the taper;

b. performing a non-destructive examination (NDE) by an approved surface crack-detection method all around the shaft in way of the forward portion of the taper section, including the keyway (if fitted). For shaft provided with liners the NDE is to be extended to the after edge of the liner.

③ For flanged connection:

a. whenever the coupling bolts of any type of flange-connected shaft are removed or the flange radius is made accessible in connection with overhaul, repairs or when deemed necessary by the Surveyor, the coupling bolts and flange radius are to be examined by means of an approved surface crack-detection method.

④ Checking and recording the bearing clearances.

⑤ Verification that the propeller is free of damages which may cause the propeller to be out of balance.

⑥ Verification of the satisfactory conditions of inboard and outboard seals during the re-installation of the shaft and propeller.

⑦ Recording the bearing weardown measurements (after re-installation).

(2) Method 2

The survey is to consist of:

① For keyed and keyless connections:

a. removing the propeller to expose the forward end of the taper;

b. performing a non-destructive examination (NDE) by an approved surface crack-detection method all around the shaft in way of the forward portion of the taper section, including the keyway (if fitted).

② For flanged connection:

a. whenever the coupling bolts of any type of flange-connected shaft are removed or the flange radius is made accessible in connection with overhaul, repairs or when deemed necessary by the surveyor, the coupling bolts and flange radius are to be examined by means of a an approved surface crack-detection method.

③ Checking and recording the bearing weardown measurements.

---

① Fresh water sample procedure, refer to IACS REC143, Recommended procedure for the determination of contents of metals and other contaminants in a closed fresh water system lubricated stern tube.

④ Visual Inspection of all accessible parts of the shafting system.
⑤ Verification that the propeller is free of damages which may cause the propeller to be out of balance.
⑥ Seal liner found to be or placed in a satisfactory condition.
⑦ Verification of the satisfactory re-installation of the propeller including verification of satisfactory conditions of inboard and outboard seals.

Pre-requisites to satisfactorily verify in order to apply Method 2:
① Review of service records.
② Review of test records of:
a. lubricating oil analysis (for oil lubricated shafts), or
b. fresh water sample test (for closed system fresh water lubricated shafts).
③ Oil sample Examination (for oil lubricated shafts), or Fresh Water Sample test (for closed system fresh water lubricated).
④ Verification of no reported repairs by grinding or welding of shaft and/or propeller.

(3) Method 3

The survey is to consist of:
① Checking and recording the bearing weardown measurements.
② Visual Inspection of all accessible parts of the shafting system.
③ Verification that the propeller is free of damages which may cause the propeller to be out of balance.
④ Seal liner found to be or placed in a satisfactory condition.
⑤ Verification of the satisfactory conditions of inboard and outboard seals.

Pre-requisites to satisfactorily verify in order to apply Method 3:
① Review of service records.
② Review of test records of:
a. lubricating oil analysis (for oil lubricated shafts), or
b. fresh water sample test (for closed system fresh water lubricated shafts).
③ Oil sample examination (for oil lubricated shafts), or fresh water sample test (for closed system fresh water lubricated).
④ Verification of no reported repairs by grinding or welding of shaft and/or propeller.

5.12.2.2 Shaft extension surveys - Extension types

(1) Extension up to 2.5 years

The survey is to consist of:
① Checking and recording the bearing weardown measurements, as far as practicable.
② Visual Inspection of all accessible parts of the shafting system.
③ Verification that the propeller is free of damages which may cause the propeller to be out of balance.
④ Verification of the effectiveness of inboard and outboard seals.

Pre-requisites to satisfactorily verify in order to apply extension up to 2.5 years:
① Review of service records.
② Review of test records of:
a. lubricating oil analysis (for oil lubricated shafts), or
b. fresh water sample test (for closed system fresh water lubricated shafts).
③ Oil sample Examination (for oil lubricated shafts), or fresh water sample test (for closed system fresh water lubricated).
④ Verification of no reported repairs by grinding or welding of shaft and/or propeller.
⑤ Confirmation from the Chief Engineer that the shafting arrangement is in good working condition.

(2) Extension up to 1 year

The survey is to consist of:
① Visual Inspection of all accessible parts of the shafting system.
② Verification that the propeller is free of damages which may cause the propeller to be out of balance.
③ Verification of the effectiveness of inboard and outboard seals.

Pre-requisites to satisfactorily verify in order to apply extension up to 1 year:
① Review of the previous weardown and/or clearance recordings.
② Review of service records.
③ Review of test records of:
a. lubricating oil analysis (for oil lubricated shafts), or
b. fresh water sample test (for closed system fresh water lubricated shafts).

④ Oil sample examination (for oil lubricated shafts), or fresh water sample test (for closed system fresh water lubricated).
⑤ Verification of no reported repairs by grinding or welding of shaft and/or propeller.
⑥ Confirmation from the Chief Engineer that the shafting arrangement is in good working condition.

(3) Extension up to 3 months

The survey is to consist of:

① Visual Inspection of all accessible parts of the shafting system.
② Verification of the effectiveness of the inboard seal.

Pre-requisites to satisfactorily verify in order to apply extension up to 3 months:

① Review of the previous weardown and/or clearance recordings.
② Review of service records.
③ Review of test records of:
a. lubricating oil analysis (for oil lubricated shafts), or
b. fresh water sample test (for closed system fresh water lubricated shafts).
④ Oil sample examination (for oil lubricated shafts), or fresh water sample test (for closed system fresh water lubricated).
⑤ Verification of no reported repairs by grinding or welding of shaft and/or propeller.
⑥ Confirmation from the Chief Engineer that the shafting arrangement is in good working condition.

5.12.2.3 Oil lubricated shafts

(1) Survey intervals

For surveys completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

① Flanged propeller connection
The following methods are applicable:
a. Method 1 every 5 years, or
b. Method 2 every 5 years (pre-requisites have to be fulfilled), or
c. Method 3 every 5 years (pre-requisites have to be fulfilled).
② Keyless propeller connection
The following methods are applicable:
a. Method 1 every 5 years, or
b. Method 2 every 5 years (pre-requisites have to be fulfilled), or
c. Method 3 every 5 years (pre-requisites have to be fulfilled). The maximum interval between two surveys carried out according to Method 1 or Method 2 is not to exceed 15 years, except in the case when one extension for no more than three months is granted.
③ Keyed propeller connection
The following Methods are applicable:
a. Method 1 every 5 years, or
b. Method 2 every 5 years (pre-requisites have to be fulfilled).

(2) Survey extensions

For all types of propeller connections, the interval between two consecutive surveys may be extended after the execution of extension survey as follows:

① Extension up to a maximum of 2.5 years: no more than one extension can be granted. No further extension, of other type, can be granted.
② Extension up to a maximum of 1 year: no more than two consecutive “one year extension” can be granted. In the event an additional extension is requested the requirements of the “2.5 year extension” are to be carried out and the shaft survey due date, prior to the previous extension(s), is extended for a maximum of 2.5 years.
③ Extension up to a maximum of 3 months: no more than one “three months extension” can be granted. In the event an additional extension is requested the requirements of the “one year extension” or “2.5 years extension” are to be carried out and the shaft survey due date, prior to the previous extension, is extended for a maximum of one year or 2.5 years.

The extension survey is to normally be carried out within 1 month of the shaft survey due date and the extension counts from the shaft survey due date.

If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date of the extension survey was completed.

5.12.2.4 Closed loop system fresh water lubricated shafts

The maximum interval between two surveys carried out according to Method 1 is not to exceed 15 years.

An extension for no more than three months can be granted.

(1) Survey intervals

For surveys completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

① Flanged propeller connection

The following methods are applicable:

a. Method 1 every 5 years, or
b. Method 2 every 5 years (pre-requisites have to be fulfilled), or
c. Method 3 every 5 years (pre-requisites have to be fulfilled).

② Keyless propeller connection

The following methods are applicable:

a. Method 1 every 5 years, or
b. Method 2 every 5 years (pre-requisites have to be fulfilled), or
c. Method 3 every 5 years (pre-requisites have to be fulfilled).

③ Keyed propeller connection

The following methods are applicable:

a. Method 1 every 5 years, or
b. Method 2 every 5 years (pre-requisites have to be fulfilled).

(2) Survey extensions

For all types of propeller connections, the interval between two consecutive surveys may be extended after the execution of extension survey as follows:

① Extension up to a maximum of 2.5 years, no more than one extension can be granted. No further extension, of other type, can be granted.

② Extension up to a maximum of 1 year, no more than two consecutive extensions can be granted. In the event an additional extension is requested the requirements of the "2.5 year extension" are to be carried out and the shaft survey due date, prior to the previous extension(s), is extended for a maximum of 2.5 years.

③ Extension up to a maximum of 3 months, no more than one "three months extension" can be granted. In the event an additional extension is requested the requirements of the "one year extension" or "2.5 years extension" are to be carried out and the shaft survey due date prior to the previous extension is extended for a maximum of one year or 2.5 years.

The extension survey is to normally be carried out within 1 month of the shaft survey due date and the extension counts from the shaft survey due date.

If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date of the extension survey was completed.

The maximum interval between two surveys carried out according to Method 1 is not to exceed 15 years, except in the case when one extension for no more than three months is granted.

5.12.2.5 Table of survey intervals (closed systems)

Survey intervals (closed systems)			
Oil lubricated			
	Flanged propeller coupling	Keyless propeller coupling	Keyed propeller coupling[b]
Every five years[a]	Method1 or Method 2 or Method 3	Method1 or Method 2 or Method 3[c]	Method1 or Method 2
Extension 2,5 Y	Yes[d]	Yes[d]	Yes[d]
Extension 1 Y	Yes[e]	Yes[e]	Yes[e]
Extension 3 M	Yes[f]	Yes[f]	Yes[f]
Closed loop system fresh water lubricated			
	Flanged propeller coupling	Keyless propeller coupling	Keyed propeller coupling[b]
Every five years[a]	Method1[g] or Method 2 or Method 3	Method1[g] or Method 2 or Method 3	Method1[g] or Method 2
Extension 2,5 Y	Yes[d]	Yes[d]	Yes[d]
Extension 1 Y	Yes[e]	Yes[e]	Yes[e]
Extension 3 M	Yes[f]	Yes[f]	Yes[f]
General notes: For surveys (Method 1, or Method 2, or Method 3) completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date. The extension survey is to normally be carried out within 1 month of the shaft survey due date and the extension counts from the shaft survey due date. If the extension survey is carried out more than 1 month prior to the shaft survey due date,			

then the period of extension counts from the date of the extension survey was completed.

Notes:
a: Unless an extension type (Extension 2,5 Y, Extension 1 Y, Extension 3 M) is applied in between.
b: Method 3 not allowed.
c: The maximum interval between two surveys carried out according to Method 1 or Method 2 is not to exceed 15 years, except in the case when one extension for no more than three months is granted.
d: No more than one extension can be granted. No further extension of other type can be granted.
e: No more than two consecutive extensions can be granted. In the event an additional extension is requested the requirements of the "2.5 year extension" are to be carried out and the shaft survey due date, prior to the previous extension(s), is extended for a maximum of 2.5 years.
f: No more than one three months extension can be granted. In the event an additional extension is requested the requirements of the one year extension or "2.5 years extension" are to be carried out and the shaft survey due date prior to the previous extension is extended for a maximum of one year or 2.5 years.
g: The maximum interval between two surveys carried out according to Method 1 is not to be more than 15 years.

5.12.3 Water lubricated shafts (open systems)

5.12.3.1 Shaft Survey Methods

(1) Method 4

The survey is to consist of:

① Drawing the shaft and examining the entire shaft (including liners, corrosion protection system and stress reducing features, where provided), inboard seal system and bearings.

② For keyed and keyless connections:

a. removing the propeller to expose the forward end of the taper;

b. performing a non-destructive examination (NDE) by an approved surface crack-detection method all around the shaft in way of the forward portion of the taper section, including the keyway (if fitted). For shaft provided with liners the NDE is to be extended to the after edge of the liner.

③ For flanged connection:

a. whenever the coupling bolts of any type of flange-connected shaft are removed or the flange radius is made accessible in connection with overhaul, repairs or when deemed necessary by the surveyor, the coupling bolts and flange radius are to be examined by means of an approved surface crack-detection method.

④ Checking and recording the bearing clearances.

⑤ Verification that the propeller is free of damages which may cause the propeller to be out of balance.

⑥ Verification of the satisfactory conditions of inboard seal during re-installation of the shaft and propeller.

5.12.3.2 Shaft extension surveys - extension types

(1) Extension up to 1 year

The survey is to consist of:

① Visual Inspection of all accessible parts of the shafting system.

② Verification that the propeller is free of damages which may cause the propeller to be out of balance.

③ Checking and recording the clearances of bearing.

④ Verification of the effectiveness of the inboard seal.

Pre-requisites to satisfactorily verify in order to apply extension up to 1 year:

① Review of the previous clearance recordings.

② Service records.

③ Verification of no reported repairs by grinding or welding of shaft and/or propeller.

④ Confirmation from the Chief Engineer that the shafting arrangement is in good working condition.

(2) Extension up to 3 months

The survey is to consist of:

① Visual Inspection of all accessible parts of the shafting system.

② Verification that the propeller is free of damages which may cause the propeller to be out of balance.

③ Verification of the effectiveness of the inboard seal.

Pre-requisites to satisfactorily verify in order to apply extension up to 3 months:

① Review of the previous clearance recordings.

② Service records.

③ Verification of no reported repairs by grinding or welding of shaft and/or propeller.

④ Confirmation from the Chief Engineer that the shafting arrangement is in good working condition.

5.12.3.3 Shaft survey intervals

(1) Survey intervals

The following survey intervals between surveys according to Method 4 are applicable to all types of propeller connections. For keyless propeller connections the maximum interval between two consecutive dismantling and verifications of the shaft cone by means of non-destructive examination (NDE) is not to exceed 15 years. For surveys completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

① Configurations allowing 5 year intervals:

a. single shaft operating exclusively in fresh water;
b. single shaft provided with adequate means of corrosion protection, single corrosion resistant shaft;
c. all kinds of multiple shafts arrangements.

② Other systems.

Shaft not belonging in one of the configurations listed in 5.12.3.3(1)① has to be surveyed according to Method 4 every 3 years.

(2) Survey extensions

For all types of propeller connections, the interval between two consecutive surveys may be extended after the execution of extension survey as follows:

① Extension up to a maximum of 1 year: no more than one extension can be granted. No further extension, of other type, can be granted.

② Extension up to a maximum of 3 months: no more than one "three months extension" can be granted. In the event an additional extension is requested the requirements of the "one year extension" are to be carried out and the shaft survey due date prior to the previous extension is extended for a maximum of one year.

The extension survey is to normally be carried out within 1 month of the shaft survey due date and the extension counts from the shaft survey due date.

If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date of the extension survey was completed.

5.12.3.4 Table of survey intervals (open systems)

<table>
<tr><td colspan="4">Survey intervals (open systems)</td></tr>
<tr><td colspan="2">− Single shaft operating exclusively in fresh water
− Single shaft provided with adequate means of corrosion protection, single corrosion resistant shaft
− All kinds of multiple shafts arrangements</td><td colspan="2" rowspan="2">Other shaft configuration</td></tr>
<tr><td colspan="2">All kinds of propeller coupling[d]</td></tr>
<tr><td colspan="2">All kinds of propeller coupling[d]</td><td colspan="2">All kinds of propeller coupling[d]</td></tr>
<tr><td>Every five years[a]</td><td>Method 4</td><td>Every three years[a]</td><td>Method 4</td></tr>
<tr><td>Extension 1 Y</td><td>Yes[b]</td><td>Extension 1 Y</td><td>Yes[b]</td></tr>
<tr><td>Extension 3 M</td><td>Yes[c]</td><td>Extension 3 M</td><td>Yes[c]</td></tr>
<tr><td colspan="4">General notes:
For surveys (Method 4) completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.
The extension survey is to normally be carried out within 1 month of the shaft survey due date and the extension counts from the shaft survey due date. If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date of the extension survey was completed.

Notes:
a: Unless an extension type (Extension 1 Y, Extension 3 M) is applied in between.
b: No more than one extension can be granted. No further extension, of other type, can be granted.
c: No more than one extension can be granted. In the event an additional extension is requested the requirements of the one year extension are to be carried out and the shaft survey due date prior to the previous extension is extended for a maximum of one year.
d: For keyless propeller connections the maximum interval between two consecutive dismantling and verifications of the shaft cone by means of non-destructive examination (NDE) is not to exceed 15 years.</td></tr>
</table>

5.12.4 Survey related to notation SCM

5.12.4.1 For ships which are assigned the notation SCM in accordance with Appendix 14 "Guidelines for Screwshaft Condition Monitoring System" of this Chapter, if they are found satisfactory at a survey of the items specified in 5.12.4.3, 5.12.4.4 or 5.12.4.5, it may be not necessary to consider items related to the drawing of oil lubricated screwshaft for examination when the examination is carried out in accordance with 5.12.2.1(1) or 5.12.3.1(1), and the interval of drawing may be extended to a maximum period not exceeding 15 years for water lubricated screwshaft.

5.12.4.2 Notwithstanding the notation SCM, the survey is to comply with 5.12.2.1(1) or 5.12.3.1(1).
5.12.4.3 For oil-lubricated propeller shafts, the shaft condition monitoring (SCM) is to be verified during each annual survey of the ship, covering:
(1) onboard condition monitoring records, including lubricating oil consumption records, lubricating oil operating temperature records, propeller shaft condition records, etc.;
(2) confirmation that lubricating oil samples have been submitted to an approved analysis organization at least once every 6 months for analysis and test of water content, chloride content, content of bearing metal particles and oil aging (resistance to oxidation);
(3) verification that analysis and test records of the analysis organization together with a conclusion on the condition and suitability of the oil are kept on board;
(4) verification of an oil analysis report from the last 6 months.
5.12.4.4 For closed water-lubricated propeller shafts, the shaft condition monitoring (SCM) is to be verified during each annual survey of the ship, covering:
(1) propeller shaft condition records, including alarm records, examination and maintenance records, lubricating water sampling / testing records and closed cycle lubricating water consumption records;
(2) confirmation that lubricating water samples have been submitted to a laboratory analysis organization complying with international standards (e.g. ISO/IEC 17025) or accepted by CCS complying with equivalent standards at least once every 6 months for analysis and test of the samples; the water quality parameters include at least:
① chloride content;
② PH value;
③ content of bearing particles.
(3) verification that water quality analysis report issued by the analysis organization, together with a qualification certificate of the organization and a conclusion on the condition and suitability of the water, are kept on board; the Surveyor is to verify a water quality analysis report from the last 6 months;
(4) examination and confirmation that the lubricating water supply system (including pumping and water filters/separators), alarm system and shaft starting interlock are in normal condition.
5.12.4.5 For open water-lubricated propeller shafts, the SCM is to be verified during the annual survey, covering:
(1) propeller shaft condition records, including alarm records, examination and maintenance records, lubricating water sampling / testing records, etc.;
(2) confirmation that the ship has developed procedures for sampling and testing supply water and is provided with the testing kit. Lubricating water is sampled at least once every 6 months to test the size of particles in the supply water so as to confirm that the water complies with the design requirements of the manufacturer. The ship can also submit the water samples to a laboratory analysis organization complying with international standards (e.g. ISO/IEC 17025) or accepted by CCS complying with equivalent standards for analysis and test. In the absence of procedures for sampling and testing supply water or records for sampling and testing, there is to be other equivalent means to prove that the supply water system is in a satisfactory working condition, and specific equivalent means may be referred to 1.3.2.5, Appendix 14 Guidelines for Screwshaft Condition Monitoring System of this Chapter.
(3) Check the supply water treatment system (including pumping and filtration or separation units), alarm system and shaft starting interlock, and confirm that they are in normal condition.
5.12.4.6 For ships assigned with the SCM notation, when the survey may be carried out without drawing of the shaft, if the surveyor deems that the available information is not satisfactory or any doubt exists, the shaft is to be sufficiently drawn to permit an entire examination.

5.12.5 Surveys of other propulsion arrangements

5.12.5.1 An operational test is to be carried out to the controllable pitch propellers to detect leakage. The controllable pitch propellers are to be dismantled for examining the working parts and control gear when considered necessary.
5.12.5.2 Azimuth propulsion arrangements (Z propulsion arrangement, Duck propulsion arrangement, REX propulsion arrangement and steering oar arrangement) are to be dismantled for examining propeller, shafts, gearing and control gear.
5.12.5.3 Water jet propulsion arrangements are to be dismantled for examining impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlet channels, steering nozzles, reversion units and control gear.

Section 13 BOILER SURVEYS

5.13.1 General requirements

5.13.1.1 This Section applies to surveys of the ship's main boilers, auxiliary boilers for essential services, superheaters, steam heated steam generators, economizers, thermal oil and hot water units, boilers for non-essential services having working pressure exceeding 0.35 MPa and a heating surface exceeding 4.5 m^2 and steam pipes.

5.13.1.2 Special consideration may be given in application of relevant requirements of this Section to commercial ships owned or chartered by Governments, which are utilized in support of military operations or service.

5.13.1.3 Definitions

(1) Main boilers are boilers supplying steam for main propulsion engines.

(2) Auxiliary boilers for essential services (including exhaust boilers, economizers and steam heated steam generators) are boilers supplying steam for auxiliary machineries essential for the safety or the operation of the ship at sea, but not for main propulsion engines.

(3) Auxiliary boilers for nonessential services are boilers supplying steam not exclusively for the safety or the operation of the ship at sea.

(4) Exhaust gas heated economizers are forced-circulation exhaust gas heat exchangers not capable of directly supplying steam, and requiring fired boilers as steam storage for supplying steam.

(5) Exhaust gas boilers are exhaust gas heat exchangers capable of directly supplying steam or forced-circulation exhaust gas heat exchangers. The latter, which is not capable of directly supplying steam, supplies steam by means of its steam reservoir.

(6) Thermal oil units are heaters which heat organic liquid (thermal oil) by fuel oil, exhaust gas or electricity, and in which the temperature of the heated organic liquid is constantly kept below its boiling temperature at atmospheric pressure.

(7) Hot water units are heaters which heat water by fuel oil, exhaust gas or electricity, and in which the temperature of the heated water is constantly kept below its boiling temperature at atmospheric pressure.

5.13.2 Interval of surveys

5.13.2.1 Main boilers

(1) For all main boilers up to 10 years of age, a minimum of two internal inspections is to be carried out during each 5-year special periodical survey period. In all cases, the interval between any two such inspections is not to exceed 36 months.

(2) Water tube boilers over 10 years of age used for main propulsion:

① for ships fitted with 2 or more water tube boilers, a minimum of two internal inspections is to be carried out during each 5-year special periodical survey period. In all cases, the interval between any two such inspections is not to exceed 36 months;

② for ships fitted with one water tube boiler, an internal inspection is to be carried out annually.

(3) For water tube boilers over 10 years of age, an internal inspection is to be carried out annually.

5.13.2.2 For auxiliary boilers for essential services, superheaters, thermal oil heaters, boilers for non-essential services having working pressure exceeding 0.35 MPa and a heating surface exceeding 4.5 m^2, a minimum of two internal inspections is to be carried out during each 5-year special periodical survey period. In all cases, the interval between any two such inspections is not to exceed 36 months.

5.13.2.3 A general inspection of the outside of boilers is to be carried out annually in the course of the annual survey of a ship.

5.13.2.4 Periods of steam pipe surveys

(1) Steam pipes over 76 mm external diameter where working temperature is not over 450℃, and copper and copper alloy steam pipes over 76 mm external diameter are to be surveyed for the first time at the 10th year from the date of fabrication (or installation) and thereafter at five-yearly intervals.

(2) Steam pipes over 76 mm external diameter where working temperature is over 450℃ are to be surveyed for the first time at the 5th year from the date of fabrication (or installation) and thereafter at five-yearly intervals.

5.13.3 Scope of surveys

5.13.3.1 The internal examination of steam boilers is to cover the following:

(1) at each survey, the boilers, superheaters, economizers, and steam heated steam generators are to be examined internally on water-steam side and fire side, including drum, shell, tubes, stays and insulation;

(2) boiler mountings and safety valves are to be examined at each survey and opened out as considered necessary by CCS;

(3) when direct visual internal inspection is not feasible due to the limited size of the internal spaces, such

as for small boilers and/or narrow internal spaces, this may be replaced by a hydrostatic pressure test or by alternative verifications as determined by CCS;
(4) the adjustment of the safety valves is to be verified under steam during each boiler internal survey. Boiler safety valve and its relieving gear (emergency cut-off device) are to be examined and tested to verify satisfactory operation;
(5) for exhaust gas heated economizers and boilers, if steam cannot be raised at port, the safety valves may be set by the chief engineer at sea, and the results recorded in the logbook for review by CCS;
(6) instrumentation and automatic equipment, and the thermal oil burning equipment and systems with which they are associated, are to be examined and tested;
(7) pumps serving for forced-circulation boilers or economizers are to be opened out for examination;
(8) review of the following records since the last boiler survey is to be carried out as part of the survey:
① operation;
② maintenance;
③ repair history;
④ feedwater chemistry;
(9) when considered necessary by the Surveyor, any part may be tested by hydraulic pressure, measured for thickness and/or detected for cracks;
(10) where an internal examination of a boiler cannot be directly carried out due to its structure, an alternative hydraulic test with a pressure 1.25 times the working pressure may be accepted.
5.13.3.2 The external examination of boilers is to cover the following:
(1) external survey of boilers is to be carried out annually, within the window of the annual survey of a ship;
(2) external survey of boilers includes test of safety and protective devices, and test of safety valve using its relieving gear;
(3) foundations, insulation, fittings, collision chocks, rolling stays, piping, combustion system, safety and protective systems including relieving gear are to be examined for confirming that they are in a good working condition;
(4) for exhaust gas heated economizers and boilers, the safety valves are to be tested by the chief engineer at sea within the annual survey window. This test is to be recorded in the logbook for review by the attending Surveyor.
5.13.3.3 The examination of exhaust gas heated economizers is to cover the following:
(1) in addition to the requirements for internal examination of exhaust gas heated economizers of the shell type, all accessible welded joints are to be subjected to a visual examination for cracking;
(2) when necessary, nondestructive testing may be required for this purpose.
5.13.3.4 The survey of thermal oil units is to cover the following:
(1) a general examination of the main body and fittings of the units is to be carried out. The internal examination may be dispensed with if no any sign of oil-caused internal corrosion is found;
(2) the internal examination by means of lifting is to be carried out so far as practicable, including examination of pipes, pipe holders and hangers, to verify that no corrosion and friction-caused roughness exists. Where heaters and fittings can not be lifted for internal examination, they are to be operationally tested under working pressure to ensure their integrity;
(3) particular attention is to be paid to the integrity of burning system and safety device;
(4) foundations, insulation, fittings, collision chocks, rolling stays, piping, combustion system, safety and protective systems together with emergency cut-off devices for combustion are to be examined for confirming that they are in a good working condition;
(5) safety valves of pressure pumps are to be calibrated under working pressure.

5.13.4 Survey extensions

5.13.4.1 An extension of the internal examination of the boiler up to 3 months beyond the due date may be granted in exceptional circumstances[①], where the following examinations and/or review are satisfactorily carried out:
(1) external examination of the boiler;
(2) boiler safety valve relieving gear (easing gear) is to be examined and operationally tested;
(3) boiler protective devices operationally tested;
(4) review of the records of operation, maintenance, repair history and feedwater chemistry since the last boiler survey.

---

① As defined in ②, ③ and ④ in 2.1.3.1(28) of Chapter 2 of this PART.

5.13.5 Surveys of steam pipes

5.13.5.1 Scope of surveys

(1) A selected number of main steam pipes, also of auxiliary steam pipes, are to be removed for internal examination and are to be hydraulically tested to 1.5 times the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested.

(2) Copper and copper ally steam pipes are to be hydraulically tested to 2 times the working pressure.

5.13.5.2 Where it is inconvenient to fulfill the requirements of 5.13.5.1(1) and (2) and at the request of the owner, consideration may be given to postponement of the survey, either wholly or in part.

Section 14 INITIAL CLASSIFICATION SURVEYS OF SHIPS CONSTRUCTED NOT UNDER THE SUPERVISION OF CCS

5.14.1 General requirements

5.14.1.1 The initial classification surveys of ships constructed not under the supervision of CCS includes:

(1) initial classification surveys of ships which are under construction;

(2) initial classification surveys of ships after construction.

5.14.1.2 The initial classification surveys specified in this Section include surveys related to class notations.

5.14.1.3 Whenever CCS is requested by an owner to accept the transfer of class for a ship and the losing Society is the Society accepted by CCS, CCS is to immediately notify the owner in writing that:

(1) the relevant surveys specified in 5.14.3.1 are required to be satisfactorily completed for entry into class;

(2) for ships less than 15 years of age, a Certificate of Class can be issued only after CCS has completed:

① all overdue surveys; and

② all overdue recommendations/conditions of class previously issued against the ship as specified to the owner by the losing Society;

(3) for ships 15 years of age and over, a Certificate of Class can be issued only after confirmation by CCS that the losing Society has completed:

① all overdue surveys; and

② all overdue recommendations/conditions of class previously issued against the ship;

(4) any outstanding recommendations/conditions of class are to be dealt with by their due dates;

(5) the principles given in items (1), (2) and (3) above apply to any additional recommendations/conditions of class issued against the ship arising from surveys which were not included in the initial survey status provided by the losing Society because the surveys were carried out in close proximity to the request for transfer of class. Such additional recommendations/conditions of class if received after the issuance of the Interim Certificate of Class by CCS and which are overdue are to be dealt with at the first port of call by the relevant Society depending on the age of the ship;

(6) copies of the plans listed in this Section are to be provided to CCS as a prerequisite to confirming the final classification of ships.

5.14.1.4 If found satisfactory at the survey, load lines will be marked in accordance with Section 11, Chapter 1 of PART TWO of the Rules.

5.14.2 Initial classification surveys of ships under construction

5.14.2.1 Initial classification surveys of ships which have been surveyed by the Societies accepted by CCS

(1) All plans, calculations and other technical documents for construction (approved by the losing Society according to their rules) are to be submitted to CCS for check. The construction of these ships may, in general, continue in accordance with the approved plans.

(2) In addition to the normal items for newbuildings, the following items are to be checked (unless they have been checked and relevant records made by the losing Society):

① the shipyard is to submit records of the checked or confirmed items for review;

② the Surveyor is to carry out an overall survey of the compartments, spaces and installations which have been inspected and confirm that materials, scantlings, workmanship and arrangements are in compliance with the approved plans;

③ the information on the attended inspections and tests of compartments is to be accepted when such information is confirmed as authentic. When some of the compartments are to be tested again, e.g.

functional tests during sea trial and in particular the inspection and testing of cargo holds and ballast tanks, the new tests are to be attended;

④ the records of NDTs are to be checked and if necessary, sampled. Any NDT is to comply with the provisions of the Rules;

⑤ the materials (including forgings and castings) used for construction, and manufacturing and testing of anchors and anchor chains are to meet the requirements of the accepted standards;

⑥ main propulsion machinery and essential auxiliaries are to be manufactured, installed and tested in accordance with CCSs rules or the standards acceptable to CCS;

⑦ the anchors and anchor chains are to be inspected and certified in accordance with the CCS rules, if they have not been delivered to the shipyard;

⑧ all outstanding recommendations are to be completed.

5.14.2.2 Initial classification surveys of ships which have been surveyed by other Societies

(1) All plans, calculations and other technical documents for construction are to be submitted to CCS for examination and approval. Where any change is made in the originally approved plans as the result of the examination, the construction is to be changed in accordance with the re-approved plans.

(2) In principle, the surveys are to be carried out in accordance with the same requirements as specified in 5.14.2.1 of this Section and if necessary, the completed items may be sampled.

5.14.2.3 Requirements for double classed ships or dual class ships:

(1) for double classed ships, the scope of survey is to be in accordance with 5.14.2.1 or 5.14.2.2;

(2) for dual class ships:

① Plans submission and survey are to be in accordance with 4.6.2, Section 6, Chapter 4 of this PART;

② If the ship applies for the dual class before the date of launching, the plans submission and scope of survey are to be in accordance with 5.14.2.1 or 5.14.2.2.

5.14.3 Initial classification surveys of ships after construction

5.14.3.1 Initial classification surveys of ships which have been surveyed by the Societies accepted by CCS

(1) Initial classification surveys of ships which have been certified by the Societies accepted by CCS:

① When applying for an initial classification survey, as the prerequisite for issuance of a long-term classification certificate by CCS, the owner is to submit at least one copy each of the plans, calculations and other technical documents to CCS for check, including at least the following:

a. Main plans:
   (a) General arrangement;
   (b) Capacity plan;
   (c) Hydrostatic curves;
   (d) Loading manual (if required);
   (e) Damage Stability calculation, where required.

b. Plans of hull structure:
   (a) Transverse midship section;
   (b) Construction profile, including longitudinal section, decks, inner bottom structure, superstructure and deckhouse;
   (c) Transverse bulkhead;
   (d) Shell expansion;
   (e) Rudder and rudder stock;
   (f) Hatch covers;
   (g) For CSR ships, plans showing, for each structural element, both as-built and renewal thicknesses and any thickness for "voluntary addition";
   (h) Plan of stern frame (if required).

c. Plans of machinery:
   (a) Engine room arrangement;
   (b) Intermediate shaft, thrust shaft and propeller shaft;
   (c) Propeller;
   (d) Main engine, propulsion machinery and clutch systems (or manufacturer, model and specifications);
   (e) In addition, main boiler, superheater and economizer (or manufacturer, model and specifications) and steam piping for steam turbine ships;
   (f) Bilge and ballast piping diagram;

(g) Wiring Diagram;
(h) Steering gear piping system and arrangement, manufacturer and model.

d. Torsional vibration calculations for shafting to be submitted for ships less than 2 years of age.

e. Elastic coupling of propulsion shafting and/or shaft torque limiter (or manufacturer, model and specifications) additionally required for ships with ice class notation.

f. Additional plans required for oil tankers:
(a) Pumping arrangement at the forward and after ends and drainage of cofferdams and pump rooms.

g. Additional plans required for periodically unattended machinery spaces:
(a) Checklist of measuring instruments and alarms;
(b) Arrangement of fixed fire alarm system;
(c) List of automatic safety functions (e.g. slowdowns, shutdowns, etc.);
(d) Diagram of functional tests.

h. Any other information requested by the flag State Administration.

i. Document(s) of approval of alternative design and arrangements, if any.

② Where the plans and documents can not be submitted according to (1) above, it is recommended that the owner authorize the losing Society to transfer copies of such plans and documents as it may possess directly to CCS. CCS may accept other relevant technical information as equivalent.

③ Where the information on stability including intact, subdivision and damage stability and the loading manual have been approved by the flag State Administration or an organization authorized by it and compliance of the arrangement on board the ship with the approved information has been confirmed by CCS, CCS may accept the approved information as the basis for assigning class or issuing certificates.

④ In addition to the items corresponding to ship's age and losing class status, the extent of surveys is to include the following:

a. Hull:
(a) For ships of less than 5 years, an annual survey is to be carried out.
(b) For ships between 5 and 10 years of age the survey is to include an Annual Survey and inspection of a representative number of ballast spaces, such as fore peak, aft peak, topside tank, hopper tank, double bottom tank, etc.
(c) For ships of 10 years of age and above but less than 20 years of age, the survey is to include an Annual Survey and inspection of a representative number of ballast spaces and cargo spaces, except for:
For gas carriers, in lieu of internal inspection of cargo spaces, the following applies:
ⓐ Inspection of surrounding ballast tank(s) and void spaces, including external inspection of independent cargo tank(s) and associated supporting systems as far as possible;
ⓑ review of cargo log books and operational records to verify the correct functioning of the cargo containment system.
For oil tankers (including product carriers), and chemical tankers of 10 years of age and above but less than 15 years of age, in lieu of an internal inspection of cargo tanks without internal stiffening and framing, inspections of surrounding ballast tank(s) and void spaces and deck structure, are to be applied.
(d) For oil tankers (including double hull oil tankers), chemical tankers and bulk carriers (including double skin bulk carriers) of 15 years and over, the requirements for special or intermediate surveys (whichever is due) are to be complied with, i.e., if the ship is in the first year after completion of the special survey, the intermediate survey is to be completed at the time of transfer of class, and if the ship is in the third or fourth year after completion of the intermediate survey, the special survey is to be completed.
(e) For ships of 20 years and over, the requirements for special surveys are to be complied with, and this applies also to ships under continuous hull survey.
(f) If a dry-docking of the ship is not due at the time of transfer of class, and subject to consent of the Headquarters of CCS, an underwater examination may be taken in lieu of dry-docking required in (d) and (e).
(g) In the context of applying items a) to f) above, as applicable, the anchors and anchor chain cables ranging and gauging for vessels over 15 years of age is not required to be carried out as part of the class entry survey unless the class entry survey is being credited as a periodical survey for maintenance of class.
If the class entry survey is to be credited as a periodical survey for maintenance of class and

the anchors and anchor chain cables ranging and gauging of the losing society are to be carried out by CCS within the applicable survey window of the periodical survey in question, at the request of the owner and approved by CCS Headquarters, consideration may be given by CCS to the acceptance of measurement report by the losing Society.

(h) In the context of applying items (a) to (f) above, as applicable,
- if the class entry survey is to be credited as a periodical survey for maintenance of class, consideration may be given by CCS to the acceptance of thickness measurements taken by the losing Society, provided they were carried out within the applicable survey window of the periodical survey in question; or
- if the class entry survey is not to be credited as a periodical survey for maintenance of class, consideration may be given by CCS to the acceptance of thickness measurements taken by the losing Society, provided they were carried out within 15 months prior to completion of the class entry survey when it is in the scope of a special survey, within 18 months prior to completion of the class entry survey when it is in the scope of an intermediate survey,

in both cases, at the request of the owner and approved by CCS Headquarters, the thickness measurements are to be reviewed by CCS for compliance with the applicable survey requirements, and confirmatory gauging are to be taken to the satisfaction of CCS.

(i) In the context of applying (c) to (f) above, as applicable, tank testing for ships over 15 years of age is not required to be carried out as part of the class entry survey unless the class entry survey is being credited as a periodical survey for maintenance of class. If the class entry survey is to be credited as a periodical survey for maintenance of class, consideration may be given by CCS to the acceptance of the tank testing carried out by the losing society provided they were carried out within the applicable survey window of the periodical survey in question.

(j) In the context of applying (a) to (f) above, as applicable, compliance with rules (e.g. 5.3.5 of Section 3 of this Chapter) that require compliance at the forthcoming due periodical surveys are not required to be carried out/completed as part of the class entry survey unless the class entry survey is credited as a periodical survey for maintenance of class.

b. Machinery (including electrical installations):

(a) A general examination of all essential machinery is to be held and is generally to include[①]:
- ⓐ examination under working conditions of oil fuel burning equipment of boiler, economizers and steam/steam generators. The adjustment of safety valves of this equipment is to be verified by checking the records on the ship;
- ⓑ compliance of all pressure vessels with submitted drawings and certificates is to be verified, and all pressure vessels are to be examined in working conditions;
- ⓒ insulation resistance, generator circuit breakers, preference tripping relays and generator prime mover governors are to be tested and paralleling and load sharing to be proved;
- ⓓ in all cases, navigating lights and indicators are to be examined and their working and alternative sources of power verified;
- ⓔ bilge pumps, emergency fire pumps and remote controls for oil valves, oil fuel pumps, lubricating oil pumps and forced draught fans are to be examined under working conditions;
- ⓕ compliance of recirculating and ice-clearing arrangements with class notations is to be verified, if any;
- ⓖ the main and all auxiliary machinery necessary for operation of the ship at sea together with essential controls and steering gear are to be tested under working conditions. Alternative means of steering are to be tested. A short sea trial is to be held at the Surveyor's discretion if the ship has been laid up for a long period;
- ⓗ initial start arrangements are to be verified;
- ⓘ in the case of oil tankers, the cargo oil system and electrical installations in way of hazardous spaces are to be checked for compliance with rules. Where intrinsically safe equipment is installed, the Surveyors are to satisfy themselves that such equipment has been approved by the Society accepted by CCS or an organization authorized by it. The

① For the transfer of class to CCS or adding CCS class at a ship's delivery, items ⓒ and ⓘ may be verified by reviewing the ship's record.

safety devices, alarms and essential instruments of the inert gas system are to be verified and the plant generally examined to ensure that it does not constitute a hazard to the ship.

c. When repair and survey facilities are not available in the first port of initial classification survey (also referred to as "survey for transfer of class") required by 5.14.3.1(1), the survey may be carried out stepwise and CCS may allow the ship to undertake a direct voyage to a port where such facilities are available to complete all surveys required. Such surveys are to be carried out by CCS or the losing Society, to the maximum extent practicable at the first port of survey, but in no case less than the scope of annual hull survey and additional machinery surveys as required in 5.14.3.1(1)④b.

d. The surveys for transfer of class may be carried out in conjunction with required periodical surveys after construction. Where such surveys are not carried out in conjunction with periodical classification surveys related, the conditions of class which are not overdue and required to be completed in conjunction with periodical surveys need not be completed at surveys for transfer of class.

e. After the surveys stated in 5.14.3.1(1)① to ④ of this Section, the interval between surveys may be corresponding to that of the losing society.

f. Requirements for double classed ships or dual class ships:

(a) for double classed ships, the scope of survey is to be in accordance with 5.14.3.1(1)① and ④;

(b) for dual class ships, the scope of survey is to be at least in accordance with that of annual surveys. If the ship applies for the dual class after construction, the scope of survey is to be in accordance with 5.14.3.1(1)① and ④.

(2) Initial classification surveys of ships which have not been certified by the Societies accepted by CCS:

① submission of plans and documents for review and survey items are to be in accordance with 5.14.3.1(1) of this Section;

② the owner is to submit records and reports related to surveys, testing and measurement during construction as well as certificates, test information, etc. for main marine products;

③ the Surveyors are to examine main structural dimensions to confirm compliance with relevant provisions of the Rules;

④ if necessary, test and/or survey for confirmation is to be carried out.

5.14.3.2 Initial classification surveys of ships which have been surveyed by other Societies

(1) This paragraph applies to ships which are constructed not in accordance with CCS rules and were not classed with CCS or any classification society acceptable to CCS.

(2) In general, such ships are to comply with the present rules of CCS, at least with CCS rules applicable during construction of the ships.

(3) The plans of such ships are in general to be submitted as required for ships under construction in CCS rules. Where it is difficult to submit plans related to quality control during construction, methods are to be provided for assessment and verification of related structures or equipment. Where such methods are assessed by CCS as acceptable and verified during classification surveys, exemption from submission of related plans may be granted. In cases where the vessel has been previously classed by the Society, the submission of plans and the extent of plan appraisal may be specially considered subject to confirmation of no alteration/modification to the vessel. In any case, it is to be ensured that at least the plans, calculations and other technical documents listed in 5.14.3.1(1)① are submitted to CCS for approval.

(4) The surveys are to be based on the requirements for special surveys in CCS rules for ships of the same type and age and include dry-dock survey, and surveys of propeller shafts and tube shafts, boilers and as applicable, inert gas systems. In addition, the following items are to be included:

① hull thickness measurements according to the minimum requirements for thickness measurements at the 4th special survey;

② any further survey required by CCS according to inspection of the condition of the ship and review of its service and repair history, including non-destructive testing of important welds of hull structures to a certain proportion and increasing the extent of testing as appropriate;

③ examination of records of surveys, tests and measurements of the ship during construction, including materials used, means of construction and testing, standards and extent of non-destructive testing of hull welds, records of mooring test and sea trial, and certificates of marine products, together with necessary verification during survey;

④ verification of related structures or equipment using the methods accepted in (3) above.

⑤ Where the vessel has, during any portion of the five years prior to the request for classification being received, been previously classed by the Society or a Society subject to verification of compliance with QSCS and has not been subject to alteration or modification since class was withdrawn, the survey requirements may be specially considered but are not to be less than the following:

a. for vessels previously classed with the Society – all overdue surveys and overdue conditions of class, or

b. for vessels previously classed with a Society subject to verification of compliance with QSCS –surveys the same as those required by 5.14.3.1.(1)④.

Section 15 OTHER SURVEYS

5.15.1 Surveys of repairs, alterations and modifications of a major character①

5.15.1.1 General requirements

(1) This paragraph applies to surveys of repairs, alterations and modifications which substantially change one or more of the following characteristics of existing ships (hereinafter referred to as major conversions):

① main dimensions of a ship;

② ship type;

③ level of subdivision of a ship;

④ carrying capacity of a ship;

⑤ passenger accommodation spaces;

⑥ increasing a ship's service life;

⑦ other major conversions in the opinion of the Administration.

5.15.1.2 Surveys

(1) Plans and documents for ships to undergo a major conversion are to be submitted to CCS for approval. The converted part of the hull structure is to comply with the requirements of the present rules. The ship's structural strength after conversion is to be evaluated according to the present rules. Other altered items, e.g. machineries (including electrical installations), inert gas systems, automation systems and other equipment related to classification, are to be treated as those of newbuildings, i.e. the present rules of CCS are to be complied with.

(2) Grades of the materials used for the alteration are in general to be the same as or equivalent to those indicated in the approved plans.

(3) Welds are to be tested for tightness and where the tightness test is impracticable or will affect the performance of fittings and equipment, visual inspections or inspections by other equivalent means are to be carried out and in addition, certain essential welds are to be subject to non-destructive test in accordance with CCS rules.

(4) CCS will carry out overall or local surveys and tests of the altered ship as appropriate to ensure that the materials used and workmanship are satisfactory in all respects and that the ship is fit for the intended purpose, and if applicable, the load lines are to be marked in accordance with Section 11, Chapter 1 of PART TWO.

(5) New certificates will be issued for altered ships according to their new dimensions, types and intended purposes. The period of validity of new certificates is to be based on the survey status and is in general to be corresponding to that of the existing certificates.

(6) Where new characters of classification and ship type notation(s) are intended to be assigned to a converted ship, the initial classification survey required of the new ship type is to be carried out and appropriate survey documents are to be issued.

(7) Inclining tests are in general to be carried out for ships which have undergone a major conversion. The inclining test may be dispensed with upon approval by the flag State Administration.

(8) Sea trials are to be carried out for ships which have undergone a major conversion, except all of the following conditions are met:

① the main propulsion system is not altered;

② the steering system is not altered;

③ the main dimensions and moulded line of the ship are not altered;

④ the draft of the ship is not increased.

---

① See Guidelines for Implementation of Major Conversions of Ships, 2008.

5.15.2 Occasional surveys

5.15.2.1 General requirements

(1) For any occasional survey covered by 5.2.11 of this Chapter, the owner or operator of the ship is to make an application to CCS.

(2) If the owner or operator of the ship, in respect to any damage or repairs of the ship, directly applies for any related periodical survey specified in the Rules, a separate application for an occasional survey need not be made.

(3) When applying for an occasional survey, the relevant requirements of this paragraph and in addition, of Section 2 of this Chapter are to be complied with.

(4) Where any defect is found during the occasional survey, the Surveyor may extend the survey as deemed necessary.

5.15.2.2 Damage surveys

(1) In the event of any sea or machinery damage which affects or may affect the class of the ship, the owner is to apply to CCS for a survey promptly so as to enable the Surveyor to ascertain the extent of the damage and necessary repairs, if any.

(2) The damage survey is to be carried out so far as necessary for fully revealing the causes and extent of the damage, generally covering damaged items and/or damage locations as well as adjacent/associated compartments, machinery and equipment.

(3) Any damage which affects the class of the ship is to be repaired according to relevant rules and with respect to the scope and extent of the damage. The scope and plan of repairs are to be such as to ensure that the condition of the ship will be so recovered that its class may be reinstated or maintained. The damage survey covers in general any damaged item affecting the class.

(4) If any damaged item, which can not be repaired immediately and thoroughly, is considered to be not affecting safety of the ship upon assessment by CCS at the request of the owner, such item may not be subject to repair for a limited period of time or may be subject to a local or suitable temporary repair plan, provided that appropriate operational restrictions in writing are signed.

5.15.2.3 Repair surveys

(1) Any repair which affects the class of the ship is to be subject to supervision by the Surveyor to ensure that any defects will be removed, the original technical condition restored and no major change made to the structure and characteristics of the ship.

(2) For any repair which affects the class of the ship, the owner or operator of the ship is to apply to CCS for survey. During any periodical survey specified in the Rules, the Surveyor is to be informed of the repairs which affect the class of the ship, if any.

(3) The repair survey is to check the defect or damage, require repairs, confirm repair plan and carry out supervision of repairs① to ensure that the repairs will be completed in compliance with the rules.

(4) Compliance of temporary repair items with the requirements for safety, reliability and restricted service is to be ensured.

(5) After completion of the repair survey, a survey report stating the nature of repairs, confirming the technical condition and making other necessary suggestions, is to be signed.

5.15.2.4 Port State control inspections

(1) Where defects are found as a result of a port State control inspection, the owner is to promptly report this to CCS and apply for an occasional survey to confirm such defects.

(2) The defects, when related to the classification certificate or the statutory certificates issued by the Society as authorized, are to be rectified and/or the necessary repair work is to be carried out within the due time.

5.15.2.5 Surveys for change of ship's name, port of registry, owner② or operator and flag

(1) When the ship's name, port of registry, owner or operator and flag is to be changed, the owner is to inform CCS of the relevant information so far as practicable in advance and apply for an occasional survey.

(2) Survey requirements

① The survey for the change of a ship's name or port of registry is in general to check the ship's names or ports of registry in relevant documents and certificates and make appropriate changes and upon confirmation of such changes, modify the classification certificate or issue a new classification certificate with the changed name or port of registry of the ship and issue a survey report accordingly.

---

① Supervision of repairs may consist of review of repair procedures, inspections and tests.

② When the owner of the ship is changed, any information related to the class of the ship is not to be provided or confirmed to any third party, unless the requesting party formally signs a written document or is authorized by the present owner.

② When the owner of a ship is changed, the existing class of the ship may be maintained provided that the new owner makes an application to CCS and accepts CCS rules and conditions of class, if any.
③ The survey for the change of a ship's flag is to confirm the ship's certificate of nationality and check the ship and its relevant documents and certificates in respect to the flag State, etc. Such surveys are to be carried out in conjunction with statutory surveys.

Section 16 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF LIQUEFIED GAS CARRIERS

5.16.1 General requirements

5.16.1.1 The requirements of this Section apply to all self-propelled ships carrying liquefied gases in bulk.

5.16.1.2 The requirements of this Section apply to surveys of hull structures and piping systems, except cargo piping covered, in way of pump rooms, compressor rooms, cofferdams, pipe tunnels, void spaces and fuel oil tanks within the cargo area and all ballast tanks. The requirements are additional to the classification requirements applicable to the remainder of the ship, refer to Section 4 of this Chapter. The requirements for periodical surveys of cargo installations on ships carrying liquefied gases in bulk are given in Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

5.16.1.3 The requirements of this Section contain the minimum extent of examination, thickness measurements and tank testing. The survey is to be extended when substantial corrosion and/or structural defects are found and include additional close-up survey when necessary.

5.16.2 Annual surveys

5.16.2.1 General requirements

(1) The annual survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition.

(2) The annual survey is to include the items specified in 5.16.2.2 through 5.16.2.6 and in addition, the applicable items specified in 5.4.2 of this Chapter.

5.16.2.2 Examination of the hull is to include:

(1) examination of the hull plating and its closing appliances as far as can be seen;

(2) examination of watertight penetrations as far as practicable.

5.16.2.3 Examination of weather decks is to include:

(1) examination of flame screens on vents to all bunker tanks;

(2) examination of bunker and vent piping systems.

5.16.2.4 Examination of cargo pump rooms and compressor rooms and, as far as practicable, pipe tunnels if fitted, including:

(1) examination of all pump room and compressor room bulkheads for signs of leakage or fractures and, in particular, the sealing arrangements of all penetrations of pump room and compressor room bulkheads;

(2) examination of the condition of all piping systems, except cargo piping systems.

Note: For survey of air pipes, flame screens on vents and ventilators, refer to relevant requirements in Section 4 of this Chapter.

5.16.2.5 Suspect areas: Suspect areas identified at previous surveys are to be examined. Thickness measurements are to be taken of the areas of substantial corrosion and the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. Table 5.4.4.2(17)② may be used as guidance for these additional thickness measurements. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

5.16.2.6 Examination of ballast tanks: Examination of ballast tanks when required as a consequence of the results of the special survey and intermediate survey is to be carried out. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. Table 5.4.4.2(17)② may be used as guidance for these additional measurements. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

5.16.3 Intermediate surveys

5.16.3.1 General requirements

(1) The intermediate survey is to be held at or between either the 2nd or 3rd annual survey.

(2) A survey planning meeting is to be held prior to the commencement of the survey.

5.16.3.2 Ballast tanks

(1) For ships between 5 and 10 years of age, an overall survey of representative ballast tanks is to be carried out. If there is no hard protective coating, soft or semi-hard coating or POOR coating condition, the examination is to be extended to other ballast tanks of the same type.

(2) For ships over 10 years of age, an overall survey of all ballast tanks is to be carried out.

(3) If such examinations reveal no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains efficient.

(4) For ballast tanks, excluding double bottom tanks, if there is no hard protective coating, soft or semi-hard coating, or POOR coating condition and it is not renewed, the tanks in question are to be internally examined at annual intervals.

(5) When such conditions are found in double bottom ballast tanks, the tanks in question may be internally examined at annual intervals.

(6) The minimum requirements for close-up surveys at intermediate survey are given in Table 5.16.3.2(6).

Minimum Requirements for Close-Up Surveys at Hull Intermediate Surveys of Liquefied Gas Carriers **Table 5.16.3.2(6)**

10 < Age ≤ 15	Age > 15
All web frames and both transverse bulkheads in a representative ballast tank (1) and (2)	All web frames and both transverse bulkheads in two representative ballast tanks (1) and (2)
The upper part of one web frame in another representative ballast tank	
One transverse bulkhead in another representative ballast tank (2)	
(1) Complete transverse web frame including adjacent structural members. (2) Transverse bulkhead complete, including girder system and adjacent members, and adjacent longitudinal bulkhead structure. Note 1: Ballast tanks include topside, double hull side, double bottom, hopper side, or any combined arrangement of the aforementioned, and peak tanks where fitted. Note 2: For areas in tanks where protective coating is found to be in GOOD condition, the extent of close-up survey may be specially considered. Note 3: For ships having independent tanks of type C, with a midship section similar to that of a general cargo ship, the extent of close-up surveys may be specially considered.① Note 4: The extent of close-up surveys may be extended by the Surveyor as deemed necessary, taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases: ① in particular, in tanks having structural arrangements or details which have suffered defects in similar tanks, or on similar ships according to available information; ② in tanks having structures approved with reduced scantlings.	

5.16.4 Special surveys

5.16.4.1 General requirements

(1) A survey planning meeting is to be held prior to the commencement of the survey.

(2) The special survey is to include, in addition to the applicable requirements in 5.4.4 of this Chapter and 5.16.2 of this Section, examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in 5.16.4.1(4), are in a satisfactory condition and fit for the intended purpose for the new period of class of 5 years to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

(3) Ballast tanks, including double bottom tanks, pump rooms, compressor rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in 5.16.4.5 and 5.16.4.6, to ensure that the structural integrity remains effective. The examination is to be carried out to an extent sufficient to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.

(4) All piping systems within the above spaces, except cargo piping systems, are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.

(5) The survey extent of ballast tanks converted to void spaces is to be specially considered in relation to the requirements for ballast tanks.

---

① The extent of the close-up survey is to be in accordance with the requirements for close-up survey of general dry cargo ships and the close-up survey of the saddle and its adjacent compartments.

5.16.4.2 Dry dock survey: A survey in dry dock is to be a part of the special survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the ballast tanks are to be carried out in accordance with the applicable requirements for special surveys, if not already performed.

5.16.4.3 Tank protection

(1) Where applicable, the condition of corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom tanks, where one of the following conditions exists, the tanks in question are to be examined at annual intervals and thickness measurements are to be carried out as deemed necessary by the Surveyor:

① a hard protective coating is found in POOR condition and it is not renewed;

② soft or semi-hard coating has been applied; or

③ a hard protective coating was not applied from time of construction.

(2) When any of the conditions described in (1) above is found in double bottom ballast tanks, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

(3) Where the hard protective coating in ballast tanks is found to be in a GOOD condition, the extent of close-up surveys and thickness measurements may be specially considered.

5.16.4.4 Extent of overall and close-up survey

(1) An overall survey of all tanks and spaces, excluding fuel oil, lube oil and fresh water tanks[①], is to be carried out at each special survey.

(2) The minimum requirements for close-up surveys at special survey are given in Table 5.16.4.4(2).

(3) The Surveyor may extend the close-up survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and where:

① in particular, tanks have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information;

② tanks have structures approved with reduced scantlings due to an approved corrosion control system.

(4) For areas in tanks where hard protective coatings are found to be in a GOOD condition, the extent of close-up surveys according to Table 5.16.4.4(2) may be specially considered.

Minimum Requirements for Close-Up Surveys at Hull Special Surveys of Liquefied Gas Carriers

Table 5.16.4.4(2)

Special Survey No.1 (Age ≤ 5)	Special Survey No.2 (5 < Age ≤ 10)	Special Survey No.3 (Age > 10)
One web frame in a representative ballast tank of the topside, hopper side and double hull side type (1)	All web frames in a ballast tank, which is to be a double hull side tank or a topside tank. If such tanks are not fitted, another ballast tank is to be selected (1)	All web frames in all ballast tanks (1)
One transverse bulkhead in a ballast tank (3)	One web frame in each remaining ballast tank (1)	All transverse bulkheads in all ballast tanks (2)
	One transverse bulkhead in each ballast tank (2)	

(1) Complete transverse web frame including adjacent structural members.

(2) Transverse bulkhead complete, including girder system and adjacent members, and adjacent longitudinal bulkhead structure.

(3) Transverse bulkhead lower part including girder system and adjacent structural members.

Note 1: Ballast tanks include topside, double hull side, double bottom, hopper side, or any combined arrangement of the aforementioned, and peak tanks where fitted.

Note 2: For areas in tanks where coatings are found to be in GOOD condition, the extent of close-up surveys may be specially considered.

Note 3: For ships having independent tanks of type C, with a midship section similar to that of a general cargo ship, the extent of close-up surveys may be specially considered.

Note 4: The Surveyor may extend the close-up survey as deemed necessary, taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:

① in particular, in tanks having structural arrangements or details which have suffered defects in similar tanks, or on similar ships according to available information;

② in tanks having structures approved with reduced scantlings.

5.16.4.5 Extent of thickness measurement

(1) The minimum requirements for thickness measurements at special survey are given in Table 5.16.4.5(1).

(2) The Surveyor may extend the thickness measurements as deemed necessary. When thickness

① For fuel oil, lube oil and fresh water tanks, reference is to be made to Table 5.4.4.2(2), Section 4 of this Chapter.

measurements indicate substantial corrosion, the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. Table 5.4.4.2(17)② may be used as guidance for these additional thickness measurements.
(3) For areas in tanks where hard protective coatings are found to be in a GOOD condition, the extent of thickness measurement according to Table 5.16.4.5(1) may be specially considered.
(4) Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

Minimum Requirements for the Thickness Measurement at Hull Special Survey of Liquefied Gas Carriers **Table 5.16.4.5(1)**

<table>
<tr><td>Special Survey No.1
(Age ≤ 5)</td><td>Special Survey No.2
(5 < Age ≤ 10)</td><td>Special Survey No.3
(10 <Age ≤ 15)</td><td>Special Survey No.4 and subsequent
(Age > 15)</td></tr>
<tr><td rowspan="2">One section of deck plating for the full beam of the ship within 0.5 L amidships in way of a ballast tank, if any</td><td>Within the cargo area:
① each deck plate
② one transverse section within 0.5 L amidships in way of a ballast tank, if any</td><td>Within the cargo area:
① each deck plate
② two transverse sections (1)
③ all wind and water strakes</td><td>Within the cargo area:
① each deck plate
② three transverse sections (1)
③ each bottom plate
④ duct keel plating and internals</td></tr>
<tr><td colspan="2">Selected wind and water strakes outside the cargo area</td><td>All wind and water strakes, full length</td></tr>
<tr><td colspan="4">Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.16.4.4(2)</td></tr>
<tr><td colspan="4">Suspect areas</td></tr>
<tr><td colspan="4">(1) At least one section is to include a ballast tank within 0.5L amidships, if any.
Note 1: For ships having independent tanks of type C, with a midship section similar to that of a general cargo ship, the extent of thickness measurements may be increased to include the tank top plating at the discretion of the Surveyor.
Note 2: For areas in spaces where coatings are found to be in GOOD condition, the extent of thickness measurements may be specially considered.
Note 3: The Surveyor may extend the thickness measurements as deemed necessary. Where substantial corrosion is found, the extent of thickness measurements is to be increased to the satisfaction of the Surveyor.</td></tr>
</table>

5.16.4.6 Extent of tank testing
(1) All boundaries of ballast tanks and deep tanks used for water ballast within the cargo area are to be pressure tested. For fuel oil tanks, the representative tanks are to be pressure tested.
(2) The Surveyor may extend the tank testing as deemed necessary.
(3) Tank testing of fuel oil tanks is to be carried out with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil tanks may be specially considered by the Surveyor, based on the following:
① a satisfactory external examination of the tank boundaries; and
② a confirmation from the master stating that the pressure testing has been carried out according to the requirements with satisfactory results.
5.16.4.7 For examination of automatic air pipe heads, reference is to be made to Table 5.4.4.2(18), Section 4 of this Chapter.

Section 17 ADDITIONAL REQUIREMENTS FOR SURVEYS OF RO-RO SHIPS

5.17.1 General requirements

5.17.1.1 The requirements of this Section apply to the survey of inner and outer doors (including bow, side shell and stern doors) of ro-ro ships and other similar ships. The requirements of this Section are to be implemented for the first relevant survey commenced on or after 1 January 2012.
5.17.1.2 Special consideration may be given to the application of the relevant requirements of this Section to commercial ships owned or chartered by Governments, which are utilized in support of military operations or service.

5.17.2 Definitions

5.17.2.1 For the purpose of this Section, the relevant definitions applicable to ro-ro ships are as follows:
(1) **Ro-ro spaces**: spaces not normally sub-divided in any way and normally extending to either a

substantial length or the entire length of the ship, in which motor vehicles with fuel in their tanks for their own propulsion and / or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or, other receptacles) can be loaded and unloaded normally in a horizontal direction.
(2) **Special category spaces**: those enclosed vehicle spaces above or below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.
(3) **Securing device**: a device used to keep the door closed by preventing it from rotating about its hinges.
(4) **Supporting device**: a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure.
(5) **Locking device**: a device that locks a securing device in the closed position.

5.17.3 Annual survey

5.17.3.1 The annual survey is to consist of an examination to verify, as far as is practicable, that the bow, inner, side shell and stern doors are maintained in a satisfactory condition.
5.17.3.2 Confirmation is to be obtained that no unapproved changes have been made to the bow, inner, side shell and stern doors since the last survey.
5.17.3.3 Documents
(1) If an Operating and Maintenance Manual (OMM) is required, it is to be verified that an approved copy is on board and any possible modifications are included.
(2) It is to be verified that documented operating procedures for closing and securing doors are kept on board and posted at an appropriate place.
(3) The Surveyor is to examine the OMM with special attention to the register of inspections and its contents as a basis for the survey.
5.17.3.4 Structural examination
Bow, inner, side shell and stern doors are to be examined with particular attention paid to:
(1) structural arrangement of doors including plating, primary structure, secondary stiffeners, hinging arms and welding;
(2) shell structure surrounding the opening of the doors and the securing, supporting and locking devices including shell plating, secondary stiffeners, primary structure, and welding;
(3) hinges and bearings, thrust bearings;
(4) hull and door side supports for securing, supporting and locking devices;
(5) close-up survey of securing, supporting and locking devices including welding, refer to Table 5.17.3.4(5).
Whenever a crack is found, an examination with NDT is to be carried out in the surrounding area and for similar items as considered necessary by the Surveyor.

Minimum Requirements for Close-Up Surveys of Doors, Locking, Securing and Supporting Devices and Fittings **Table 5.17.3.4(5)**

The following is a list of the devices and fittings and associated welding to be subject to close-up survey by the attending Surveyor.
(1) Cylinder securing pins, supporting brackets, back-up brackets (where fitted) and their welded connections
(2) Hinge pins, supporting brackets, back-up brackets (where fitted) and their welded connections
(3) Locking hooks, securing pins, supporting brackets, back-up brackets (where fitted) and their welded connections
(4) Locking pins, supporting brackets, back-up brackets (where fitted) and their welded connections
(5) Locating and stopper devices and their welded connections

5.17.3.5 Measurement of clearances
(1) Clearances of hinges, bearings and thrust bearings are to be taken, where no dismantling is required. Where the function test is not satisfactory, dismantling may be required to measure the clearances. If dismantling is carried out, a visual examination of hinge pins and bearings together with NDT of the hinge pin is to be carried out. Clearances of securing, supporting and locking devices are to be measured, where indicated in the OMM.
5.17.3.6 Sealing arrangement
(1) An examination of packing material / rubber gaskets and retaining bars or channels, including welding is to be carried out.

5.17.3.7 Drainage arrangement
(1) An examination of drainage arrangement, including bilge wells and drain pipes is to be carried out, where fitted. A test of the bilge system between the inner and outer doors is to be carried out.
5.17.3.8 Function test of doors
Checking of the operation of the bow, inner, side shell and stern doors during a complete opening and closing operation is to be made, with the results to the satisfaction of the Surveyor, as applicable, including:
(1) proper working of the hinging arms and hinges;
(2) proper engagement of the thrust bearings;
(3) device for locking the door in the open position;
(4) securing, supporting and locking devices;
(5) proper sequence of the interlock system for the opening / closing system and the securing and locking devices;
(6) mechanical lock of the securing devices;
(7) proper locking of hydraulic securing devices in the event of a loss of the hydraulic fluid, according to the procedure provided by the OMM;
(8) correct indication of open / closed position of doors and securing / locking devices at navigation bridge and other control stations;
(9) isolation of the hydraulic securing / locking devices from other hydraulic systems;
(10) confirmation that the operating panels are inaccessible to unauthorized persons;
(11) verification that a notice plate giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour is placed at each operating panel and supplemented by warning indicator lights;
(12) examination of electrical equipment for opening, closing and securing the doors.
5.17.3.9 Function test of the indicator system
Checking of the satisfactory operation of the indicator system, where fitted, is to be carried out, as applicable, including:
(1) proper visible indication and audible alarm on the navigation bridge panel, according to the selected function "harbour / sea voyage" and on the operating panel;
(2) lamp test function on both panels;
(3) verification that it is not possible to turn off the indicator light on both panels;
(4) verification of fail-safe performance, according to the procedure provided by the OMM;
(5) confirmation that power supply for indicator system is supplied by the emergency source or other secure power supply (e.g. UPS) and independent of the power supply for operating the doors;
(6) proper condition of sensors and protection from water, ice formation and mechanical damage.
5.17.3.10 Test of water leakage detection system
(1) Where fitted, the water leakage detection system is to be tested including proper audible alarm on the navigation bridge panel and on the engine control room panel, according to the procedure provided by the OMM.
5.17.3.11 Test of television surveillance system
(1) Where fitted, the television surveillance system is to be tested including proper indication on the navigation bridge monitor and on the engine control room monitor.
5.17.3.12 Tightness test
(1) A hose test or equivalent is to be carried out. If the visual examination and function test have shown satisfactory results, the tightness test of shell doors on ro-ro cargo ships need not be carried out unless considered necessary by the attending Surveyor.
5.17.3.13 NDT and thickness measurements
(1) When considered necessary by the Surveyor, NDT and thickness measurements may be required after visual examination and function test.

5.17.4 Special survey
5.17.4.1 The special survey is to include, in addition to the requirements of the annual survey as required in 5.17.3, examination, tests and checks of sufficient extent to verify that the bow, inner, side shell and stern doors, are in satisfactory condition and considered able to remain in compliance with applicable requirements, subject to proper maintenance and operation in accordance with the Operation and Maintenance Manual (OMM) or the manufacturer's recommendations and the periodical surveys being carried out at the due dates for the five year period until the next special survey.
5.17.4.2 The examinations of the doors are to be supplemented by thickness measurements① and testing

① Corrosion criteria of doors are in accordance with corrosion criteria of adjacent structures.

to verify compliance with applicable requirements so that the structural and weathertight integrity remain effective. The aim of the examination is to identify corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.

5.17.4.3 The bow, inner, side shell and stern doors are to be surveyed as follows:

(1) A survey of the items listed in 5.17.3.4, including close-up survey of securing, supporting and locking devices, together with welding, is to be carried out, refer to Table 5.17.3.4(5).

(2) Non-destructive testing and thickness measurements are to be carried out on securing, supporting and locking devices, to the extent considered necessary by the Surveyor. Whenever a crack is found, an examination with NDT is to be carried out in the surrounding area and for similar items as considered necessary by the Surveyor.

(3) The maximum thickness diminution of hinging arms, securing, supporting and locking devices is to be treated according to the normal procedure for primary structures, but is not to be more than 15% of the as-built thickness. Certain designs may be subject to special consideration of CCS.

(4) Checking the effectiveness of sealing arrangements by hose testing or equivalent is to be carried out.

(5) Clearances of hinges, bearings and thrust bearings are to be taken. Unless otherwise specified in the OMM or by the manufacturer's recommendation, the measurement of clearances on ro-ro cargo ships may be limited to representative bearings where dismantling is needed in order to measure the clearances.

If dismantling is carried out, a visual examination of hinge pins and bearings together with NDT of the hinge pin is to be carried out.

(6) The non-return valves of the drainage system are to be dismantled and examined.

Section 18 ADDITIONAL REQUIREMENTS FOR SURVEYS OF LIVESTOCK CARRIERS

5.18.1 General requirements

5.18.1.1 In addition to applicable survey items in Section 4 of this Chapter, livestock carriers are to satisfy relevant provisions of this Section.

5.18.2 Annual survey

5.18.2.1 Confirmation is to be obtained that no unapproved changes have been made to hull structures of livestock carriers, livestock pens, passageways as well as the arrangement and protection of livestock since the last survey; confirming that passageways and exits of the escape route of pen area are unblocked; confirming that two means of egress in each livestock space are not separated by the pen or other obstructions.

5.18.2.2 Checking that special requirements for the stability of livestock carriers are included in the approved stability information.

5.18.2.3 Confirming that ventilation pipings of livestock space are intact and the operation of fans, including fan starters, failure indicators and alarms at different positions is normal. If only one fan is provided, confirmation is to be obtained that spare parts are adequate.

5.18.2.4 Confirming that fodder and drinking water supply, fresh water supply system, water washing system and sewage drainage and discharge system of livestock space are in good condition. The fodder tanks and the fresh water tanks of at least two livestock spaces are to be internally examined.

5.18.2.5 Confirming that all fire hydrants and fire hose connections arranged in the pen area have the same diameter.

5.18.2.6 Checking the instructions for the changeover between main and secondary sources of power and vice-versa and confirming the function of the changeover between main and secondary sources of power and vice-versa.

5.18.2.7 Visual examination of lamp casings on light fittings for the livestock space.

5.18.3 Special survey

5.18.3.1 The special survey is to include, in addition to the requirements of 5.18.2, examination, tests and checks of sufficient extent to ensure that the hull, equipment and related piping are in a satisfactory condition.

5.18.3.2 All fresh water pumps, sewage pumps and system components are to be opened up and examined.

5.18.3.3 Performance test of fodder system, fresh water supply system, water washing system and sewage drainage and discharge system.

5.18.3.4 The motor of fan in the livestock space together with its control and operational mechanism are to be inspected and if necessary, operationally tested in working condition.

5.18.3.5 Interlocking devices of fan starters in the livestock space are to be tested.

5.18.3.6 Means of access for livestock to and from the ship is to be load tested in accordance with the requirements of 2.2.4, Section 2, Chapter 2, PART EIGHT of the Rules.

Appendix 1 CRITERIA FOR RENEWAL OF HULL STRUCTURAL MEMBERS

This Appendix does not apply to the ships constructed in accordance with Common Structural Rules① and CCS Rules for Structures of Container Ships.

1 Criteria for longitudinal strength

1.1 For ships of 65 m and over in length, the hull girder section modulus at deck and bottom within 0.4 *L* amidships is not to be less than 0.9 times the hull girder section modulus required in the Rules.

1.2 The criteria for longitudinal strength for hull girders of oil tankers of 130 m in length and upwards are given in Appendix 2 of this Chapter.

2 Criteria for local strength

2.1 For a ship constructed in accordance with CCS rules and the keel of which was laid before 15 January 1983, the renewal thickness of hull plating and structural members is not to be less than the value obtained by multiplying their as-built thickness and the relevant percentage shown in Table 2.1 below:

Table 2.1

Structural member	Minimum renewal thickness		
	Unrestricted service	Service category 1	Service categories 2 and 3
Strength deck, side and bottom shell	75%	70%	65%
Continuous longitudinal strength members and web frames	75%	70%	65%
Foundations of main engines, cranes and windlasses	75%	75%	75%
Other structural members defined in the Rules	70%	60%	55%

2.2 For a ship constructed in accordance with CCS rules and the keel of which was laid on or after 15 January 1983, the renewal thickness of hull plating and structural members is not to be less than the value obtained by multiplying their as-built thickness and the relevant percentage shown in Table 2.2 below:

Table 2.2

Structural member	Minimum renewal thickness	
	$L \geq 90$ m	$L < 90$ m
① Strength deck plating, side shell, top strake, bilge strake, bottom shell, flat plate keel, inner bottom, continuous longitudinal bulkhead, hopper tank and topside tank plating. ② Main longitudinal continuous members, e.g. deck girders, hatch side girders, side girders, bottom girders, bulkhead girders, continuous hatch coamings. ③ Main transverse members, e.g. side frame webs, deck transverses, double plate floors, bulkhead webs, watertight and oiltight transverse bracket plates. ④ Transverse bulkhead plating in holds, upper and lower bulkhead stool sloping plating, watertight bulkhead plating in deep tanks	80%	75%
Other plating and members, e.g. deck within line of openings, deck longitudinals, side longitudinals, bottom longitudinals, inner bottom longitudinals, bulkhead longitudinals, face plates of side frames, brackets of structural members, hatch covers, non-continuous hatch coamings, sea chests	75%	70%
Note: For bulk carriers designed in accordance with the Rules and assigned the class notations of "Strengthened for Heavy Cargoes" and "Grab* (×)", the minimum renewal thickness of inner bottom may be taken as the value obtained by multiplying the as-built thickness and 75%		

2.3 For a ship constructed in accordance with the Rules and the scantlings of which as required by the Rules are indicated in their plans, or for a ship the scantlings of which are to be assessed in accordance with the Rules, the renewal thickness of hull plating and structural members is not to be less than the value obtained by multiplying the thickness specified in the Rules and the relevant percentage shown in Table 2.2 above.

2.4 For bulk carriers of 150 m in length and upwards, contracted for construction on or after 1 July 1998

① PART NINE or TEN of the Rules (2012 version) and its 2013 and 2014 amendments or PART NINE of the Rules (2015 version) and its subsequent versions (including amendments).

and carrying solid bulk cargoes having a density of 1.0 t/m^3 and above, steel renewal is required where the gauged thickness of watertight corrugated bulkheads is less than t_{net} + 0.5 mm and coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, with t_{net} being net thickness and obtained in accordance with Section 9, Chapter 8 of PART TWO of the Rules, except for:

(1) double skin bulk carriers the keels of which were laid or which were at a similar stage of construction before 1 July 1999;

(2) double skin bulk carriers the keels of which were laid or which were at a similar stage of construction before 1 January 2000, with distance between inner and outer skins being not less than 760 mm;

(3) double skin bulk carriers the keels of which were laid or which were at a similar stage of construction after 1 January 2000, with distance between inner and outer skins being not less than 1,000 mm.

2.5 For bulk carriers contracted for construction on or after 1 July 1998 and complying with Section 11, Chapter 8, PART TWO of the Rules, steel renewal is required where the gauged thickness of hatch covers is less than t_{net} + 0.5 mm. Where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. For internal members of double skin hatch covers, steel renewal is required where the gauged thickness is less than t_{net} or the Surveyor deems it necessary based on the corrosion or deformation. t_{net} is net thickness and to be obtained in accordance with Section 11, Chapter 8 of PART TWO of the Rules.

For bulk carriers, ore carriers and combination carriers① contracted for construction on or after 1 January 2004 and complying with Section 11, Chapter 8, PART TWO of the Rules, steel renewal is required where the gauged thickness is less than t_{net} + 0.5 mm for single skin hatch cover and double skin hatch cover platings, hatching coamings and coaming stays. Where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. For internal members of double skin hatch covers, thickness measurement is required when CCS Surveyor deems it necessary based on the corrosion or deformation. Where the gauged thickness is less than t_{net}, the internal structure is to be renewed.

2.6 For ships other than bulk carriers, ore carriers and combination carriers, contracted for construction on or after 1 July 2012 and complying with Section 20, Chapter 2, PART TWO of the Rules②, and for all weathertight steel cargo hatch covers on exposed decks, steel renewal is required where the gauged thickness of the plating of double skin hatch covers, single skin hatch covers, hatch coamings, coaming stays and stiffeners is less than t_{net} + 0.5 mm. Where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, coating③ or annual gauging may be adopted as an alternative to steel renewal. For the internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when deemed necessary, at the discretion of CCS Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than t_{net}. For corrosion addition t_S = 1.0 mm, the thickness for steel renewal is t_{net}, and when gauged thickness is between t_{net} and t_{net} + 0.5 mm, coating or annual gauging may be adopted as an alternative to steel renewal, where t_{net} being the net thickness, to be calculated in accordance with 2.20.2, Section 20, Chapter 2, PART TWO of the Rules.

2.7 For all weathertight steel cargo hatch covers on exposed decks of ships contracted for construction on or after 1 July 2024, steel renewal is required where the gauged thickness of the plating of double skin hatch covers, single skin hatch covers, hatch coamings, coaming stays and stiffeners is less than t_{net} + 0.5 mm. Where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, coating④ or annual gauging may be adopted as an alternative to steel renewal. For the internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when deemed necessary, at the discretion of CCS Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than t_{net}. For corrosion addition t_s = 1.0 mm, the thickness for steel renewal is t_{net}, and when gauged thickness is between t_{net} and t_{net} + 0.5 mm, coating or annual gauging may be adopted as an alternative to steel renewal, where t_{net} being the net thickness, to be calculated in accordance with 2.20.2, Section 20, Chapter 2, PART TWO of the Rules.

---

① Bulk carriers, ore carriers and combination carriers are defined in Appendix 2, Chapter 2 of this PART.

② For the definitions of bulk carriers, ore carriers and combination carriers, refer to Appendix 2, Chapter 2 of this PART.

③ Coating is to be maintained in GOOD condition, as defined in 5.1.5.1(15) of this Chapter.

④ Coating is to be maintained in GOOD condition, as defined in 5.1.5.1(15) of this Chapter.

2.8 For the following bulk carriers of 150 m in length and upwards and carrying solid bulk cargoes having a density of 1.78 t/m^3 and above, steel renewal is required where the gauged thickness of transverse watertight corrugated bulkheads between cargo holds Nos.1 and 2 is less than t_{net} + 0.5 mm and coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, with t_{net} being calculated in accordance with IACS UR S19:

(1) bulk carriers contracted for construction before 1 July 1998 and not complying with IACS UR S18;

(2) bulk carriers the keels of which were laid or which were at a similar stage of construction before 1 July 1999 and not complying with IACS UR S18.

2.9 For bulk carriers which were not built in accordance with Section 3, Chapter 8 of PART TWO of the Rules, steel renewal is required where the gauged thickness of side shell frames of cargo holds is less than t_{REN} mm. Where the gauged thickness is within the range t_{REN} mm and t_{COAT} mm, sand blasting, coating and reinforcements are to be done and the coating is to be maintained in "as-new" or an equivalent condition (i.e. without breakdown or rusting) at special and intermediate surveys. The t_{REN} and t_{COAT} above are to be calculated in accordance with IACS UR S31.

2.10 For Polar Class ships, steel renewal is required where the shell plating corrosion/abrasion additions within the ice-strengthened hull areas is greater than the value specified in Table 13.2.11.2, Chapter 13, PART EIGHT of the Rules minus 0.5 mm.

Appendix 2 CRITERIA FOR LONGITUDINAL STRENGTH OF HULL GIRDER FOR OIL TANKERS

1 General requirements

1.1 These criteria are to be used for the evaluation of longitudinal strength of the ship's hull girder as required by 5.6.1.3 of Section 6, Chapter 5 of this PART.

1.2 In order that ship's longitudinal strength to be evaluated can be recognized as valid, fillet welding between longitudinal internal members and hull envelopes are to be in sound condition so as to keep integrity of longitudinal internal members with hull envelopes.

2 Evaluation of longitudinal strength

On oil tankers of 130 m in length and upwards and of over 10 years of age, the longitudinal strength of the ship's hull girder is to be evaluated in compliance with the requirements of this Appendix on the basis of the thickness measured, renewed or reinforced, as appropriate, during the special survey.

The condition of the hull girder for longitudinal strength evaluation is to be determined in accordance with the methods specified in Annex 3 of this Appendix.

2.1 Calculation of transverse sectional areas of deck and bottom flanges of hull girder

2.1.1 The transverse sectional areas of deck flange (deck plating and deck longitudinals) and bottom flange (bottom shell plating and bottom longitudinals) of the ship's hull girder are to be calculated by using the thickness measured, renewed or reinforced, as appropriate, during the special survey.

2.1.2 If the diminution of sectional areas of either deck or bottom flange exceeds 10% of their respective as-built area (i.e. original sectional area when the ship was built), either one of the following measures is to be taken:

(1) to renew or reinforce the deck or bottom flanges so that the actual sectional area is not less than 90% of the as-built area; or

(2) to calculate the actual section moduli (Z_{act}) of transverse section of the ship's hull girder by applying the calculation method specified in Annex 1 of this Appendix, by using the thickness measured, renewed or reinforced, as appropriate, during the special survey.

2.2 Requirements for transverse section modulus of hull girder

2.2.1 The actual section moduli of transverse section of the ship's hull girder calculated in accordance with 2.1.2(2) above is to satisfy either of the following provisions, as applicable:

(1) for ships constructed on or after 1 July 2002, the actual section moduli (Z_{act}) of the transverse section of the ship's hull girder calculated in accordance with the requirements of 2.1.2(2) above is not to be less than the diminution limits determined by CCS①; or

(2) for ships constructed before 1 July 2002, the actual section moduli (Z_{act}) of the transverse section of the ship's hull girder calculated in accordance with the requirements of 2.1.2(2) above is to meet the criteria for minimum section modulus for ships in service required by CCS, provided that in no case Z_{act} is to be less than the diminution limit of the minimum section modulus (Z_{mc}) as specified in Annex 2 of this Appendix.

---

① The actual transverse section modulus of the hull girder of oil tankers calculated under paragraph 2.2.1(1) of this Appendix is not to be less than 90% of the required section modulus for new buildings specified in IACS Unified Requirements S7(C = 1.0 C_n is to be used for the purpose of this calculation.) or S11, whichever is the greater.

Annex 1
Calculation Criteria of Section Moduli of Midship Section of Hull Girder

1. When calculating the transverse section modulus of the ship's hull girder, the sectional area of all continuous longitudinal strength members is to be taken into account.
2. Large openings, i.e. openings exceeding 2.5 m in length (along ship's length) or 1.2 m in breadth and scallops, where scallop welding is applied, are always to be deducted from the sectional areas used in the section modulus calculation.
3. Smaller openings (manholes, lightening holes, single scallops in way of seams, etc.) need not be deducted provided that the sum of their breadths or shadow area breadths in one transverse section does not reduce the section modulus at deck or bottom by more than 3% and provided that the height of lightening holes, draining holes and single scallops in way of seams in longitudinals or longitudinal girders does not exceed 25% of the web depth, for scallops maximum 75 mm.
4. A deduction-free sum of smaller opening breadths in one transverse section in the bottom or deck area of 0.06 ($B - \sum b$) (where B = breadth of ship, $\sum b$ = total breadth of large openings) may be considered equivalent to the above reduction in sectional modulus.
5. The shadow area will be obtained by drawing two tangent lines with an opening angle of 30°.
6. The deck modulus is related to the moulded strength deck line at side.
7. The bottom modulus is related to the base line.
8. Continuous trunks and longitudinal hatch coamings are to be included in the longitudinal sectional area provided they are effectively supported by longitudinal bulkheads or deep girders. The deck modulus is then to be calculated by dividing the moment of inertia by the following distance, provided this is greater than the distance from neutral axis to the deck line at side:

$$y_t = y\left(0.9 + 0.2\frac{x}{B}\right)$$

where:

y = distance from neutral axis to top of continuous strength member,
x = distance from top of continuous strength member to centreline of the ship.
x and y to be measured to the point giving the largest value of y_t.

9. Longitudinal girders between multi-hatchways will be considered by special calculations.

Annex 2
Diminution Limit of Minimum Longitudinal Strength of Oil Tankers in Service

1 The diminution limit of the minimum section modulus (Z_{mc}) of oil tankers in service is given by the following formula:

$$Z_{mc} = cL^2B(C_b + 0.7)k \quad \text{cm}^3$$

where: L = Length of ships. L is the distance, in m, on the summer load waterline from the fore side of stem to the after side of the rudder post, or the centre of the rudder stock if there is no rudder post. L is not to be less than 96%, and need not be greater than 97%, of the extreme length on the summer load waterline. In ships with unusual stern and bow arrangement the length L may be specially considered;

B = Greatest moulded breadth in metres;

C_b = Moulded block coefficient at draught d corresponding to summer load waterline, based on L and B. C_b is not to be taken less than 0.60:

$$C_b = \frac{\text{moulded displacement (m}^3\text{) at draught } d}{LBd}$$

$$C = 0.9\, c_n$$

$$c_n = 10.75 - \left(\frac{300 - L}{100}\right)^{1.5} \quad \text{for } 130 \text{ m} \le L \le 300 \text{ m}$$

c_n = 10.75, for 300 m < L < 350 m

$$c_n = 10.75 - \left(\frac{L - 350}{150}\right)^{1.5} \quad \text{for } 350 \text{ m} \le L \le 500 \text{ m};$$

k = material factor, e.g.:
k = 1.0 for mild steel with yield stress of 235 N/mm^2 and over;
k = 0.78 for high tensile steel with yield stress of 315 N/mm^2 and over;
k = 0.72 for high tensile steel with yield stress of 355 N/mm^2 and over.

2 Scantlings of all continuous longitudinal members of the ship's hull girder based on the section modulus requirement in 1 above are to be maintained within 0.4L amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the end of 0.4L part, bearing in mind the desire not to inhibit the ship's loading flexibility.

3 However, the above standard may not be applicable to ships of unusual type or design, e.g. for ships of unusual main proportions and/or weight distributions.

Annex 3
Sampling Method of Thickness Measurements for Longitudinal Strength Evaluation and Repair Methods

1 Extent of longitudinal strength evaluation
1.1 Longitudinal strength is to be evaluated within 0.4L amidships for the extent of the hull girder length that contains tanks therein and within 0.5L amidships for adjacent tanks which may extend beyond 0.4L amidships.
1.2 The tanks in this Annex mean ballast tanks and cargo tanks.

2 Sampling method of thickness measurement
2.1 Pursuant to the requirements of 5.6.4.4 of this Chapter, transverse sections are to be chosen such that thickness measurements can be taken for as many different tanks in corrosive environments as possible, e.g. ballast tanks sharing a common plane boundary with cargo tanks fitted with heating coils, other ballast tanks, cargo tanks permitted to be filled with seawater and other cargo tanks. Ballast tanks sharing a common plane boundary with cargo tanks fitted with heating coils and cargo tanks permitted to be filled with seawater are to be selected where present.
2.2 The minimum number of transverse sections to be sampled is to be in accordance with Table 5.6.4.4(1) of this Chapter. The transverse sections are to be located where the largest thickness reductions are suspected to occur or are revealed from deck and bottom plating measurements and are to be clear of areas which have been locally renewed or reinforced.
2.3 At least two points are to be measured on each deck plate and/or bottom shell plate required to be measured within the cargo area in accordance with the requirements of Table 5.6.4.4(1) of this Chapter.
2.4 Within 0.1D (where D is the ship's moulded depth) of the deck and bottom at each transverse section to be measured in accordance with the requirements of Table 5.6.4.4(1) of this Chapter, every longitudinal and girder are to be measured on the web and face plate, and every plate is to be measured at one point between longitudinals.
2.5 For longitudinal members other than those specified in 2.4 to be measured at each transverse section in accordance with the requirements of Table 5.6.4.4(1) of this Chapter, every longitudinal and girder are to be measured on the web and face plate, and every plate is to be measured at least in one point per strake.
The thickness of each component is to be determined by averaging all of the measurements taken in way of the transverse section on each component.

3 Additional measurements where the longitudinal strength is deficient
3.1 Where one or more of the transverse sections are found to be deficient in respect of the longitudinal strength requirements given in this annex, the number of transverse sections for thickness measurement is to be increased such that each tank within the 0.5L amidships region has been sampled.
3.2 Additional thickness measurements are also to be performed on one transverse section forward and one aft of each repaired area to the extent necessary to ensure that the areas bordering the repaired section also comply with the requirements of Section 6 of this Chapter.

4 Effective repair methods
4.1 The extent of renewal or reinforcement carried out to comply with this Annex is to be in accordance with 4.2.

4.2 The minimum continuous length of a renewed or reinforced structural member is to be not less than twice the spacing of the primary members in way. In addition, the thickness diminution in way of the butt joint of each joining member forward and aft of the replaced member (plates, stiffeners, girder webs and flanges, etc.) is not to be within the substantial corrosion range (75% of the allowable diminution associated with each particular member). Where differences in thickness at the butt joint exceed 15% of the lower thickness, a transition taper is to be provided.

4.3 Alternative repair methods involving the fitting of straps or structural member modification are to be subject to special consideration. In considering the fitting of straps, it is to be limited to the following conditions:

(1) to restore and/or increase longitudinal strength;

(2) the thickness diminution of the deck or bottom plating to be reinforced is not to be within the substantial corrosion range (75% of the allowable diminution associated with the deck plating);

(3) the alignment and arrangement, including the termination of the straps, is in accordance with a standard recognized by CCS;

(4) the straps are continuous over the entire 0.5*L* amidships length; and

(5) continuous fillet welding and full penetration welds are used at butt welding and, depending on the width of the strap, slot welds. The welding procedures applied are to be acceptable to CCS.

4.4 The existing structure adjacent to replacement areas and in conjunction with the fitted straps, etc., is to be capable of withstanding the applied loads, taking into account the buckling resistance and the condition of welds between the longitudinal members and hull envelope plating.

Appendix 3 GUIDELINES FOR MEASURING SCANTLINGS OF THE TRANSVERSE WATERTIGHT VERTICALLY CORRUGATED BULKHEAD BETWEEN CARGO HOLDS NOS.1 AND 2 OF BULK CARRIERS

1 For verification that UR S19 is complied with, measurement is necessary to determine the general condition of the structure and the scope of possible repairs and/or reinforcement of transverse watertight vertically corrugated bulkheads.

2 In UR S19, the applicable buckling pattern is taken into account for evaluation of bulkhead strength and this is to determine the thickness reduction under the standard critical condition shown in Figure 2(1) and Figure 2(2).

3 The horizontal lines defined below are to be measured. The scantlings of each separate vertical corrugation, corrugation flange, web, shedder plate and gusset plate within each horizontal line given below are to be measured and properly evaluated.

— Horizontal line *a* without bottom stool, see Figure 2(1):

Location:

(1) half of the width of the corrugation flange approx. 200 mm above shedder plate line;
(2) center of gusset plate between corrugation flanges, if fitted;
(3) center of shedder plate;
(4) half of the center of the corrugation web approx. 200 mm above shedder plate line.

— Horizontal line *b* with bottom stool, see Figure 2(2):

Location:

(1) half of the width of the corrugation flange approx. 200 mm above shedder plate line;
(2) center of gusset plate between corrugation flanges, if fitted;
(3) center of shedder plate;
(4) half of the center of the corrugation web approx. 200 mm above shedder plate line.

— Horizontal line *c* with or without bottom stool, see Figure 2(1) and Figure 2(2):

Location:

(1) half of the width of the corrugation web and corrugation flange approx. in way of half height of corrugation.

4 Where thickness of plates along the horizontal line is different, the thinner ones are to be measured.

5 Steel renewal and/or reinforcement is to be in compliance with the requirements in UR S19.

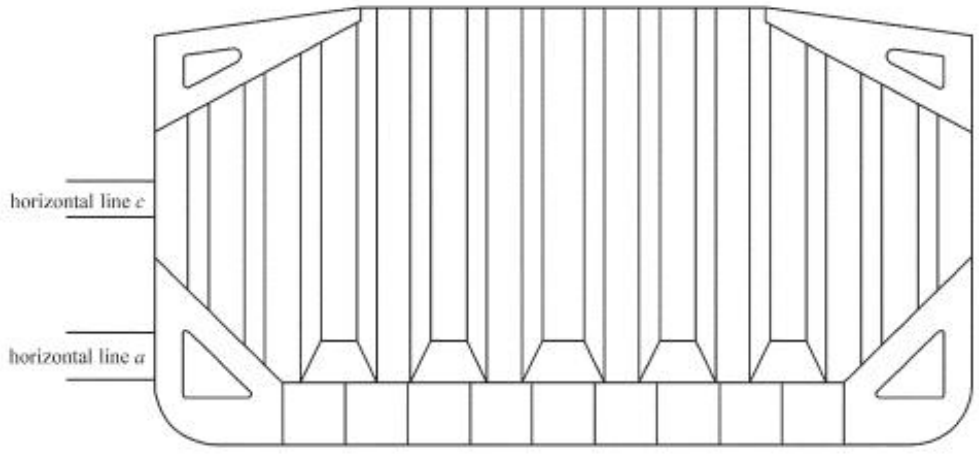


Figure 2(1)

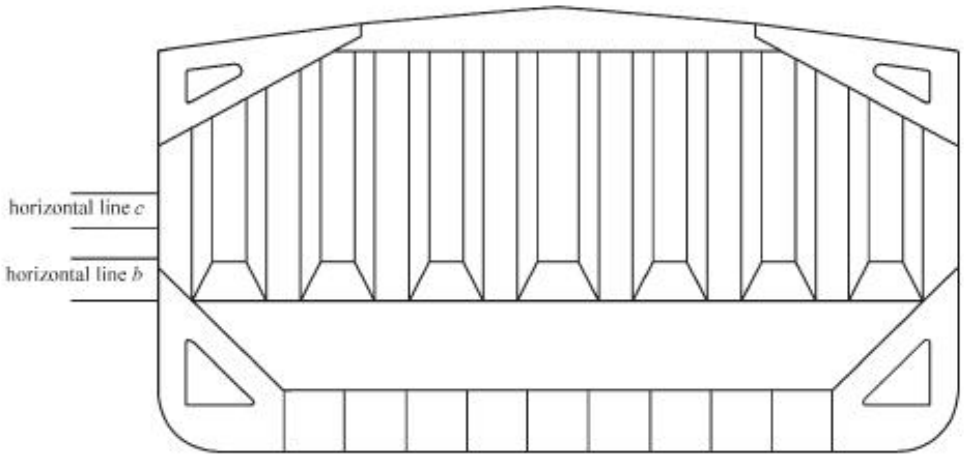


Figure 2(2)

Appendix 4 RUDDER BEARING WEAR CLEARANCE

The following values of rudder bearing wear clearance are provided for reference to owners for the purpose of facilitating their repairs.

Wear Clearance Limit for Lower Bearings of Double Bearing Rudders (mm)

Diameter of rudder stock	Rudder bearings made of copper or bearing alloy	Rudder bearings made of lignum vitae or compreg	Rudder bearings made of synthetic resin ①
≤ 80	3.00	3.50	3.00
> 80 ~ 120	4.00	4.50	4.00
> 120 ~ 180	5.00	6.00	5.00
> 180 ~ 250	6.00	7.00	6.00
> 250 ~ 315	7.00	7.50	7.00
> 315 ~ 400	7.50	8.00	8.00
> 400 ~ 500	8.00	9.00	9.00
> 500 ~ 630	9.00	10.00	10.00
> 630 ~ 800	10.00	11.00	11.00

Notes: ① Nylon or equivalent material, excluding saran.

② For wear clearance limit relating to renewal of rudders made of saran, refer to manufacturers' instructions. Where no such instructions are available, refer to the requirements for rudders made of lignum vitae or compreg.

③ Wear clearance limit of lower bearing of spade rudders is to be 70% of the value shown in the above table.

Wear Clearance Limit for Upper Pintle Bearings of Double Bearing Rudders (mm)

Diameter of rudder pintle	Pintle bearings made of copper or bearing alloy	Pintle bearings made of lignum vitae or compreg	Pintle bearings made of synthetic resin
≤ 80	3.00	3.50	3.00
> 80 ~ 120	4.00	4.50	4.00
> 120 ~ 180	5.00	5.50	5.00
> 180 ~ 250	6.00	6.50	6.00
> 250 ~ 315	7.00	7.50	6.50
> 315 ~ 400	7.50	8.00	7.00
> 400 ~ 500	8.00	9.00	8.00

Wear Clearance Limit for Pintle Bearings of Multi-pintle Rudders (mm)

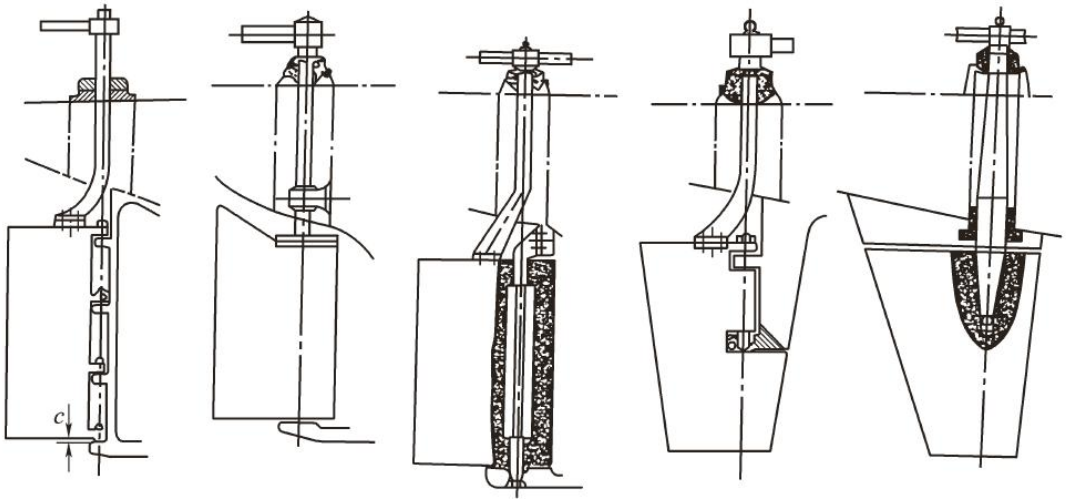
Diameter of rudder pintle	Pintle bearings made of copper or bearing alloy	Pintle bearings made of lignum vitae or compreg	Pintle bearings made of synthetic resin
≤ 50	4.00	4.50	4.20
> 50 ~ 80	5.00	5.50	5.24
> 80 ~ 120	6.00	6.50	7.35
> 120 ~ 180	7.00	7.50	7.35
> 180 ~ 250	8.00	8.50	8.40
> 250 ~ 315	8.50	9.00	8.43
> 315 ~ 400	9.00	9.50	9.45
> 400 ~ 500	10.00	10.50	10.50

Wear Clearance Limit for Pintle Bearings of Semi-Spade Rudders with Two Heel Pintles (mm)

Diameter of rudder pintle	Pintle bearings made of copper or bearing alloy	Rudder bearings made of lignum vitae or compreg	Rudder bearings made of synthetic resin
≤ 50	3.50	4.00	4.00
> 50 ~ 80	4.00	4.50	4.50
> 80 ~ 120	5.00	5.50	5.50
> 120 ~ 180	6.00	6.50	6.50
> 180 ~ 250	7.00	7.50	7.50
> 250 ~ 315	8.00	8.50	8.50
> 315 ~ 400	9.00	9.50	9.50
> 400 ~ 500	10.00	10.00	10.00

Wear Clearance Limit for Bearings of Rudders with Shaft (mm)

Diameter of rudder stock	Rudder bearings made of copper or bearing alloy	Rudder bearings made of lignum vitae or compreg	Rudder bearings made of synthetic resin
≤ 80	3.50	4.00	3.75
> 80 ~ 120	4.00	5.00	4.50
> 120 ~ 180	5.00	6.00	5.50
> 180 ~ 250	6.50	7.00	6.75
> 250 ~ 315	7.50	8.00	7.75
> 315 ~ 400	8.50	9.00	8.75
> 400 ~ 500	9.50	10.00	9.75



Multi-pintle rudder | Double bearing rudder | Rudder with shaft | Semi-spade rudder with two heel pintles | Spade rudder

Appendix 5 WEAR CLEARANCE OF BEARINGS OF PROPELLER SHAFTS OR TUBE SHAFTS

The wear clearance of bearings of propeller shafts or tube shafts is generally not to be more than that as given in the following Table.

Shaft diameter *d*	Clearance limit (mm)			
	Bearing made of white metal	Bearing made of lignum vitae	Plate-reinforced rubber bearing	Block-cast rubber bearing
≤ 100	1.80	3.50	3.50	3.50
> 100 ~ 120	2.00	4.00	4.00	4.00
> 120 ~ 150	2.20	4.50	4.50	5.00
> 150 ~ 180	2.40	5.00	5.00	–
> 180 ~ 220	2.60	5.50	5.50	–
> 220 ~ 260	2.80	6.00	6.00	–
> 260 ~ 310	3.00	6.60	6.50	–
> 310 ~ 360	3.20	7.30	7.20	–
> 360 ~ 440	3.50	8.00	7.80	–
> 440 ~ 500	3.80	8.70	8.50	–
> 500 ~ 600	4.10	9.50	9.00	–
> 600 ~ 700	4.50	10.50	10.00	–

Note: ① For low-speed shafting (n < 150 r/min), wear clearance limit for white metal bearings is to be 20% more than the value shown in the above table.

Appendix 6 GUIDELINES FOR THE GAUGING OF SIDE SHELL FRAMES AND BRACKETS IN SINGLE SIDE SKIN BULK CARRIERS REQUIRED TO COMPLY WITH UR S31

1 General

Gauging is necessary to determine the general condition of the structure and to define the extent of possible steel renewals or other measures for the webs and flanges of side shell frames and brackets for verification of the compliance with UR S31.

2 Zones of side shell frames and brackets

For the purpose of steel renewal, sand blasting and coating, four zones A, B, C and D are defined, as shown in Figure 2. Zones A & B are considered to be the most critical zones.

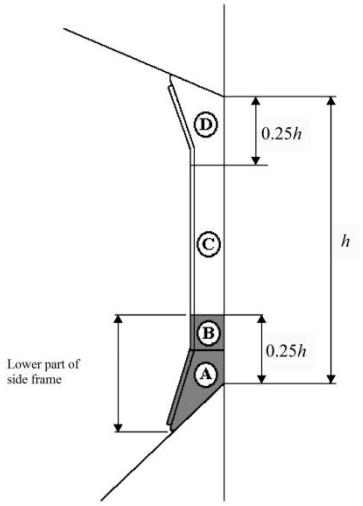


Figure 2 Zones of Side Shell Frames and Brackets

3 Pitting and grooving

—— Pits can grow in a variety of shapes, some of which would need to be ground before assessment.

—— Pitting corrosion may be found under coating blisters, which must be removed before inspection.

—— To measure the remaining thickness of pits or grooving, the normal ultrasonic transducer (generally 10 mm diameter) will not suffice. A miniature transducer (3 to 5 mm diameter) must be used. Alternatively the gauging firm must use a pit gauge to measure the depth of the pits and grooving and calculate the remaining thickness.

3.1 Assessment based upon area

This is the method specified in S31.2.5 and is based upon the intensity determined from Figure 3.1.

If pitting intensity is higher than 15% in an area (see Figure 2), then thickness measurements are to be taken to check the extent of the pitting corrosion. The 15% is based upon pitting or grooving on only one side of the web.

In cases where pitting is evident as defined above (exceeding 15%), then an area of 300 mm diameter or more (or, where this is impracticable on the frame flange or the side shell, hopper tank plating or topside tank plating attached to the side frame, an equivalent rectangular area), at the most pitted part, is to be cleaned to bare metal, and the thickness measured in way of the five deepest pits within the cleaned area. The least thickness measured in way of any of these pits is to be taken as the thickness to be recorded.

The minimum acceptable remaining thickness in any pit or groove is equal to:

—— 75% of the as-built thickness, for pitting or grooving in the cargo hold side frame webs and flanges;

—— 70% of the as-built thickness, for pitting or grooving in the side shell, hopper tank and topside tank plating attached to the cargo hold side frame, over a width up to 30 mm from each side of it.

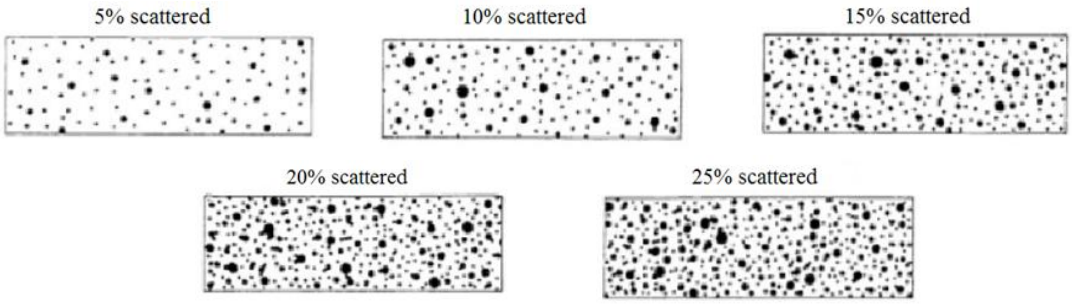


Figure 3.1 Pitting Intensity Diagrams (from 5% to 25% intensity)

4 Gauging methodology

Numbers of side frames to be measured are equivalent to those of special survey or intermediate survey corresponding to the ship's age. Representative thickness measurements are to be taken for each zone as specified below.

Special consideration to the extent of the thickness measurements may be given by CCS, if the structural members show no thickness diminution with respect to the as built thicknesses and the coating is found in "as-new" condition (i.e., without breakdown or rusting).

Where gauging readings close to the criteria are found, the number of hold frames to be measured is to be increased.

If renewal or other measures according to S31 are to be applied on individual frames in a hold, then all frames in that hold are to be gauged.

There is a variety of construction methods used for side shell frames in bulk carriers. Some have faceplates (T sections) on the side shell frames, some have flanged plates and some have bulb plates. The use of faceplates and flanged sections is considered similar for gauging purposes in that both the web and faceplate or web and flange plate are to be gauged. If bulb plate has been used, then web of the bulb plate is to be gauged in the normal manner and the sectional modulus has to be specially considered if required.

4.1 Gaugings for zones A, B & D

Web plating: The gauging pattern for zones A, B & D is to be a 5-point pattern. See Figure 4.1. The 5-point pattern is to be over the depth of the web and the same area vertically. The gauging report is to reflect the average reading.

4.2 Gaugings for zone C

Web plating: Depending upon the condition of the web in way of zone C, the web may be measured by taking 3 readings over the length of zone C and averaging them. The average reading is to be compared with the allowable thickness. If the web plating has general corrosion, then this pattern is to be expanded to a 5-point pattern as noted above.

4.3 Gaugings for sections a) and b) (flanges and side shell plating)

Where the lower bracket length or depth does not meet the requirements in UR S12(Rev. 3), gaugings are to be taken at sections a) and b) to calculate the actual section modulus required in UR S31.3.4. See Figure 4.3. At least 2 readings on the flange/faceplate are to be taken in way of each section. At least one reading of the attached shell plating is to be taken on each side of the frame (i.e. fore and aft) in way of sections a) and section b).

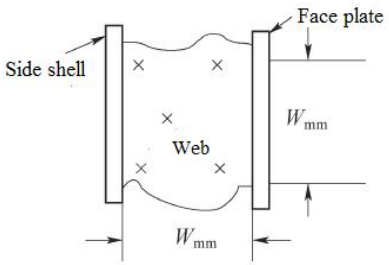


Figure 4.1 Typical 5-point pattern on the web plate

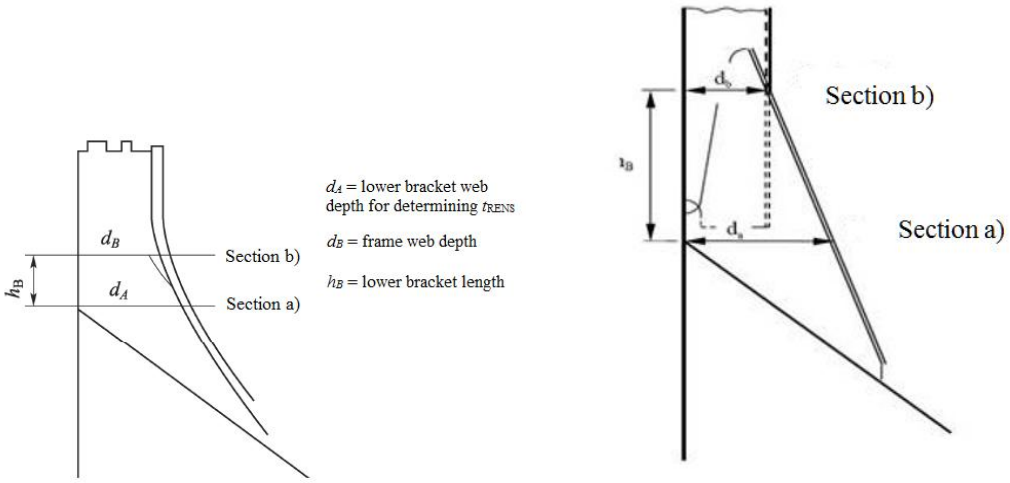


Figure 4.3 Sections a) and b)

5 Report on thickness measurement of cargo hold side shell frames

TM7-BC S31 Report on Thickness Measurement of Cargo Hold Side Shell Frames

Ship's name..... Class identity No. ..... Report No. .....

CARGO HOLD NO.: Side: (Port / stb.)

FRAME NO	ZONE A						ZONE B						ZONE C						ZONE D					
	Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution		Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution		Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution		Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution	
	mm	mm	mm	mm	mm	%	mm	mm	mm	mm	mm	%	mm	mm	mm	mm	mm	%	mm	mm	mm	mm	mm	%

Operators signature: .....

Appendix 7 GUIDELINES FOR THE SURVEY OF VOYAGE REPAIRS

1 Purpose

1.1 The purpose of these notes is to provide guidance to CCS field Surveyors in dealing with voyage repairs, including repairs during voyage. These notes form part of the surveys after construction as specified in Chapter 5 of this PART

2. General requirements

2.1 Where repairs to hull, machinery or equipment, which affect or may affect classification, are to be carried out by a riding crew during a voyage, such repairs are to be planned in advance. A complete repair procedure including the extent of proposed repair and the need for Surveyor's attendance during the voyage is to be submitted to and agreed by CCS reasonably in advance.

2.2 Failure to notify CCS, in advance of the repairs, may result in suspension of the ship's class until such time as the repair is redone or evidence submitted to satisfy the Surveyor that the repair was properly carried out.

2.3 Where in any emergency circumstance, emergency repairs are to be effected immediately, the repairs should be documented in the ship's log and submitted thereafter to CCS for use in determining further survey requirements.

2.4 The above is not intended to include maintenance and overhaul to hull, machinery and equipment in accordance with manufacturer's recommended procedures and established marine practice and which does not require CCS approval. However, any repair as a result of such maintenance and overhauls which affects or may affect classification is to be noted in the ship's log and submitted to the attending Surveyor for use in determining further survey requirements.

3. Requirements for commencement of repairs

3.1 A meeting is to be held with the owner prior to commencement of hull repairs during a ship's voyage to discuss and confirm the following:

(1) extent of intended repairs. All repairs to be based on CCS recommendations and/or concurrence;

(2) availability of pertinent drawings;

(3) verification of new materials regarding certification, grade and scantlings. Verified mill sheets to remain on board and to be provided to the attending Surveyor examining completed repairs;

(4) verification of welding consumables regarding certification and suitability for materials involved. Check on availability of drying ovens, holding containers, etc.;

(5) verification of the qualification of welders and supervisory personnel, qualification records to remain on board and to be provided to the attending Surveyor examining completed repairs;

(6) review of intended repair;

(7) review of the intended provisions to facilitate sound weldments, i.e. cleaning, preheating (if applicable) adherence to welding sequence principles;

(8) further, it might be necessary to restrict welding to certain positions and prohibit welding in more difficult positions when the ship's motions might influence the quality of the welding;

(9) review of the application of repair coating, as appropriate;

(10) review of intended working conditions, i.e. staging, lighting, ventilation, etc.;

(11) review of intended supervision and quality control;

(12) completed repairs are to be examined and tested as required to the satisfaction of the attending Surveyor.

3.2 All details and results of subject meeting to be covered by a memorandum. A copy of this memorandum is to be placed on board and to be provided to the attending Surveyor examining repairs. In addition, a copy is to be sent/faxed to the arrival port where completed repairs will be examined.

4. Repairs to hull structures and survey

4.1 Any contemplated repairs to primary hull structures, i.e. main longitudinal and transverse members and their attachments, are to be submitted to CCS for review prior to commencing voyage repairs.

4.2 Riding repairs to primary hull structures are not to be permitted except in extreme circumstances.

4.3 Any repairs to primary hull structures are to require attendance by a Surveyor riding-ship survey or at regular intervals to confirm fit-up, alignment, general workmanship and compliance with

recommendations.

4.4 NDT of completed repairs to primary structures is to be carried out to the attending Surveyor's satisfaction.

4.5 Repairs to other hull structural parts may be accepted based on examination upon completion of repairs.

4.6 No hull repairs carried out by a riding crew are to be accepted unless:

(1) the initial meeting had been carried out and conditions found satisfactory;

(2) a final satisfactory examination upon completion was carried out.

Appendix 8 PROCEDURAL REQUIREMENTS FOR SERVICE SUPPLIERS

1. General requirements

1.1 To approve firms providing services, such as measurements, tests or maintenance of safety systems and equipment, CCS is to apply procedures in this unified requirement and relevant Annex 1.

2. Objective

2.1 The objective of this procedure is to set minimum requirements for approval and certification of service suppliers and is applicable to both initial and renewal audits.

3. Definitions

3.1 Manufacturer: A company that manufactures equipment required to be periodically serviced and/or maintained.

3.2 Service supplier (A service supplier or category of service supplier may be referred to here after simply as 'supplier'): A person or company, not employed by an IACS Member, who at the request of an equipment manufacturer, shipyard, vessel's owner or other client acts in connection with inspection work and provides services for a ship or a mobile offshore unit such as measurements, tests or maintenance of safety systems and equipment, the results of which are used by surveyors in making decisions affecting classification or statutory certification and services.

3.3 Agent: A person or company authorized to act for or to represent a manufacturer or approved / recognized service supplier.

3.4 Subsidiary: A company partly or wholly owned by a manufacturer or approved / recognized service supplier.

3.5 Subcontractor: A person or company providing services to a manufacturer or approved / recognized service supplier, with a formal contract defining the assumption of the obligations of the service supplier.

4. Application

4.1 This procedure applies to the approval of the following categories of service suppliers:

4.1.1 Statutory services

(1) Firms engaged in servicing inflatable liferafts, inflatable lifejackets, hydrostatic release units and marine evacuation systems

(2) Firms engaged in inspections and testing of radio communication equipment

(3) Firms engaged in inspections and maintenance of self-contained breathing apparatus

(4) Firms engaged in annual performance testing of voyage data recorders (VDRs) and simplified voyage data recorders (S-VDRs)

(5) Firms engaged in sound pressure level measurements of public address and general alarm systems on board ships

(6) Firms engaged in inspections of low location lighting systems using photo luminescent materials and evacuation guidance systems used as an alternative to low-location lighting systems

(7) Firms engaged in maintenance, thorough examination, operational testing, overhaul and repair of lifeboats and rescue boats, launching appliances and release gear.

(8) Firms engaged in inspection, performance testing and maintenance of Automatic Identification Systems (AIS)

(9) Firms engaged in Commissioning Testing of Ballast Water Management System (BWMS).

4.1.2 Classification and/or statutory services

(1) Firms engaged in thickness measurements on ships or mobile offshore units except:

① non-ESP ships less than 500 gross tonnage, and

② all fishing vessels.

(2) Firms carrying out in-water survey on ships and mobile offshore units by diver or Remotely Operated Vehicle (ROV)

(3) Firms engaged in inspections and maintenance of fire extinguishing equipment and systems

(4) Firms engaged in tightness testing of closing appliances such as hatches, doors etc., with ultrasonic equipment

(5) Firms engaged in measurements of noise level on board ships

(6) Firms engaged in examination of ro-ro ship's bow, stern, side and inner doors

(7) Firms engaged in testing of coating systems in accordance with IMO resolution MSC.215(82), as

amended, and IACS UI SC223 and/or resolution MSC.288(87), as amended
(8) Firms engaged in tightness testing of primary and secondary barriers of gas carriers with membrane cargo containment systems for vessels in service
(9) Firms engaged in survey using Remote Inspection Techniques (RIT) as an alternative means for Close-up Survey of the structure of ships and mobile offshore units
(10) Firms engaged in Cable Transit Seal Systems inspection on ships and Mobile Offshore Units.
4.1.3 Where CCS accepts work of a third party (e.g. service supplier) approved by itself, CCS is to verify the performance of such services. For statutory service, the flag State may increase the scope of verification to be applied to these services. The process is to be defined within CCS quality management system. For the purpose of accountability to the flag State, the work performed by the third party (e.g. service supplier) constitutes the work of CCS and is to be subject to the requirements incumbent upon CCS under the RO Code, IMO resolutions MSC.349(92) and MEPC.237(65).
4.2 Where the results of the following service providers are used by a Surveyor of CCS in making decisions affecting classification services then that service provider must be approved (including single approval) and verified by CCS.
— Firms engaged in thickness measurements on ships or mobile offshore units except:
(1) non-ESP ships less than 500 gross tonnage, and
(2) all fishing vessels.
— Firms carrying out in-water survey on ships and mobile offshore units by diver or Remotely Operated Vehicle (ROV).
— Firms engaged in tightness testing of closing appliances such as hatches, doors etc., with ultrasonic equipment.
— Firms engaged in survey using Remote Inspection Techniques (RIT) as an alternative means for Close-up Survey of the structure of ships and mobile offshore units.
4.3 Where such services are used by Surveyors in making decisions affecting statutory certification service, the firms are subject to approval and verification by CCS where CCS is so authorized by the relevant flag State Administration (i.e. the flag of the ship on which the servicing is to be done or the service equipment is to be used). For such services CCS may accept approvals done by:
i. the flag State Administration itself,
ii. duly authorized organizations acting on behalf of the flag State Administration, or
iii. other organizations those are acceptable to the flag State Administration (e.g. other governments, etc.).
4.4 Use of the approved service suppliers is not mandatory for the following services, unless instructed otherwise by the flag State Administration with respect to statutory certification:
— Firms engaged in inspections of low location lighting systems using photo luminescent materials and evacuation guidance systems used as an alternative to low-location lighting systems.
— Firms engaged in sound pressure level measurements of public address and general alarm systems on board ships.
— Firms engaged in measurements of noise level onboard ships.
— Firms engaged in testing of coating systems in accordance with IMO resolution MSC.215(82), as amended and IACS UI SC223 and/or MSC.288(87), as amended.
— Firms engaged in examination of ro-ro ships' bow, stern, side and inner doors.
4.5 Detailed requirements specific to the various categories of suppliers are given in Annex 1. National and/or international requirements may give additional requirements. References to such national and/or international requirements are given in Annex 1.

5. Procedure for approval and certification

5.1 Submission of documents
5.1.1 The following documents are to be submitted to CCS for review. General requirements concerning suppliers are given in 5.2, and specific requirements as relevant, in Annex 1:
— Outline of company, e.g. organization and management structure, including subsidiaries to be included in the approval/certification;
— List of nominated agents, subsidiaries and subcontractors;
— Experience of the company in the specific service area;
— For categories of service suppliers that require certification from manufacturers, manufacturer's documentary evidence that the service supplier has been certified or licensed to service the particular makes and models of equipment for which approval is sought are to be provided;
— List of operators/technicians/inspectors documenting training and experience within the relevant service area, and qualifications according to recognized national, international or industry standards, as

relevant;
— Description of equipment used for the particular service for which approval is sought;
— A guide for operators of such equipment;
— Training programmes for operators/technicians/inspectors;
— Check lists and record formats for recording results of the services referred to in Annex 1;
— Quality Manual and/or documented procedures covering requirements in 5.5;
— Documented procedures for communication with the crew prior to commencing work, so that it is safe to decommission the equipment being maintained, and to provide a safe system of work in place;
— Evidence of approval/acceptance by other bodies, if any;
— Information on the other activities which may present a conflict of interest;
— Record of customer claims and of corrective actions requested by certification bodies;
— Operators/technicians/inspectors documentation they have acknowledged the code of conduct.

5.2 General requirements

5.2.1 Extent of approval – The supplier is to demonstrate, as required by 5.2.2 to 5.2.11, that it has the competence and control needed to perform the services for which approval is sought.

5.2.2 Training of personnel – The supplier is responsible for the qualification and training of its personnel to a recognized national, international or industry standard as applicable. Where such standards do not exist, the supplier is to define standards for the training and qualification of its personnel relevant to the functions each is authorized to perform. The personnel are also to have adequate experience and to be familiar with the operation of any necessary equipment. Operators/technicians/inspectors are to have had a minimum of one year tutored on-the-job training. Where it is not possible to perform internal training, a program of external training may be considered as acceptable.

5.2.3 Supervision – The supplier is to provide supervision for all services provided. The responsible supervisor is to have had a minimum of two years of experience as an operator/technician/inspector within the activity for which the supplier is approved. For a supplier consisting of one person, that person is to meet the requirements of a supervisor.

5.2.4 Personnel records – The supplier is to keep records of the approved operators / technicians / inspectors. The record is to contain information on age, formal education, training and experience for the services for which they are approved.

5.2.5 Equipment and facilities – The supplier is to have the necessary equipment and facilities for the service to be supplied. A record of the equipment used is to be kept and available. The record is to contain information on maintenance and results of calibration and verifications. CCS is to assess and record the validity of previous measuring results when the equipment is found not to conform to requirements. CCS is to take appropriate action on the equipment affected.

5.2.6 Control of data

When computers are used for the acquisition, processing, recording, reporting, storage, measurement assessment and monitoring of data, the ability of computer software to satisfy the intended application is to be documented and confirmed by the service supplier. This is to be undertaken prior to initial use and reconfirmed as necessary.

Note: Commercial off-the-shelf software (e.g. word processing, database and statistical programmes) in general use within their designed application range may be considered to be sufficiently validated and do not require any subsequent confirmation.

5.2.7 Where several servicing stations are owned by a given company, each station is to be assessed and approved except as specified in 5.5.3

5.2.8 Procedures – The supplier is to have documented work procedures covering all services supplied.

5.2.9 Subcontractors – The supplier is to give information of agreements and arrangements if any parts of the services provided are subcontracted. Particular emphasis is to be given to quality management by the supplier in following-up such subcontracts. Subcontractors providing the services of the approved service supplier are also to meet the requirements of sections 5.

5.2.10 Verification – The supplier is to verify that the services provided are carried out in accordance with approved procedures.

5.2.11 Reporting – The report is to be prepared in a form acceptable to CCS. The report should detail the results of inspections, measurements, tests, maintenance and/or repairs carried out. Special guidelines may be given in Annex 1. The report is to include a copy of the certificate of approval.

5.2.12 Documented procedures and instructions should be available for the recording of damages and defects found during inspections, servicing and repair work. This documentation is to be made available upon request.

5.3 Auditing of the Supplier – Upon reviewing the submitted documents with satisfactory result, the supplier is audited in order to ascertain that the supplier is duly organised and managed in accordance with

the submitted documents, and that it is considered capable of conducting the services for which approval/certification is sought.

5.4 Certification is conditional on a practical demonstration of the performance of the specific service as well as satisfactory reporting being carried out. At initial audits, when the service supplier is already certified by other QSCS certified Society according to the provision of this Appendix, this may be verified through documentary review that a practical demonstration has already been carried out. At renewal audits, verification by documentary review of jobs undertaken since the previous audit and that have been accepted by a QSCS certified Society is acceptable and is sufficient to satisfy this requirement.

5.5 Quality system

5.5.1 The supplier is to have a documented system covering at least the following:

— code of conduct for the relevant activity;
— maintenance and calibration of equipment;
— training programmes for operators/technicians/inspectors;
— supervision and verification to ensure compliance with operational procedures;
— recording and reporting of information;
— quality management of subsidiaries, agents and subcontractors;
— job preparation;
— periodic review of work process procedures, complaints, corrective actions, and issuance, maintenance and control of documents.

5.5.2 A documented quality system complying with the most current version of ISO 9000 series and including the above items, would be considered acceptable.

5.5.3 If a manufacturer of equipment (and/or its service supplier) applies to CCS for inclusion of its nominated agents and/or subsidiaries (excluding any subcontractor), in the approval, then it must have implemented a quality system certified in accordance with the most current version of ISO 9000 series. The quality system must contain effective controls of the manufacturer's (and/or service supplier's) agents and/or subsidiaries. The nominated agents/subsidiaries must also have in place an equally effective quality system complying with the most current version of ISO 9000 series. Such approvals are to be based upon an evaluation of the quality system implemented by the parent company against the most current version of ISO 9000 series. CCS may require follow-up audits on such agents or subsidiaries against the most current version of ISO 9000 series to confirm adherence to this quality system.

5.6 Service supplier's relations with the equipment manufacturer

5.6.1 A company which works as a service station for manufacturer(s) of equipment (and as a service supplier in this field), is to be assessed by the manufacturer(s) and nominated as their agent. The manufacturer is to ensure that appropriate instruction manuals, material etc. are available for the agent as well as proper training of the agent's technicians. Such suppliers are to be approved either on a case by case basis, or in accordance with 5.5.3.

6. Certification

6.1 Upon satisfactory completion of both the audit of the supplier and the demonstration test, as applicable, CCS may issue a certificate of approval stating that the supplier's service operation system has been found to be satisfactory and that the results of services performed in accordance with that system may be accepted and utilised by CCS Surveyors in making decisions affecting classification or statutory certification, as relevant. The certificate is to clearly state the type and scope of services and any limitations or restrictions imposed including type of equipment and/or names of manufacturers of equipment where this is a limiting restraint. The supplier may also be included in CCS record of approved service suppliers.

6.2 Renewal or endorsement of the certificate is to be made at intervals not exceeding five (5) years by verification through audits that approved conditions are maintained or, where applicable, on expiry of the supplier's approval received from an equipment manufacturer, whichever comes first. In the latter case, CCS is to be informed in due course by the service supplier. CCS may require renewal or endorsement of the certificate at intervals shorter than five (5) years and may require intermediate audits. For firms engaged in thickness measurements, renewal/endorsement of the certificate is to be made at intervals not exceeding 3 years by verification that original conditions are maintained.

7. Information regarding alterations to the certified service operating system

7.1 When any alteration to the certified service operating system of the supplier is made, such alteration is to be immediately informed to CCS. Re-audit may be required when deemed necessary by CCS.

8. Cancellation of approval

8.1 CCS reserves the right to cancel the approval and to inform the IACS Members accordingly (For

Firms engaged in thickness measurements refer to PR 23).
8.2 Approval may be cancelled in the following cases:
8.2.1 Where the service was improperly carried out or the results were improperly reported.
8.2.2 Where a Surveyor finds deficiencies in the approval service operating system of the supplier and appropriate corrective action is not taken.
8.2.3 Where alterations have been made to the company's quality system relevant to the service supplier certificates, without written notification to CCS.
8.2.4 Where the intermediate audit, if requested as per 6.2, has not been carried out.
8.2.5 Where wilful acts or omissions are ascertained.
8.2.6 Where any deliberate misrepresentation has been made by the service supplier.
8.3 A supplier whose approval was cancelled, may apply for re-approval provided it has corrected the non-conformities which resulted in cancellation, and CCS is able to confirm it has effectively implemented the corrective action.
8.4 Expiration or cancellation of the Supplier's parent company approval automatically invalidates approval of all agents and subsidiaries if these are certified according to 5.5.3

9. Existing Approvals
Approvals for the categories of service suppliers granted before the date of implementation of this Appendix by CCS may remain valid as stated in the respective certificates for a period up to but not exceeding 3 years. Renewals of such certificates must be carried out in accordance with this Appendix.

Annex 1
Special Requirements for Various Categories of Service Suppliers

1. Firms engaged in thickness measurements on ships or mobile offshore units
1.1 Extent of engagement – Thickness measurement of structural material of ships or mobile offshore units except:
(1) non-ESP ships less than 500 gross tonnage, and
(2) all fishing vessels.
1.2 Supervisor – The responsible supervisor is to be qualified according to a recognized national or international industrial NDT standard (e.g. EN 473 level II as amended or ISO 9712 level II as amended).
1.3 Operators – The operators carrying out the measurements are to be certified to a recognized national or international industrial standard (e.g. EN 473 level I as amended or ISO 9712 level I as amended) and to have adequate knowledge of ship structures sufficient to elect a representative position for each measurement.
1.4 Equipment – On coated surfaces, instruments using pulsed echo technique (either with oscilloscope or digital instruments using multiple echoes, single crystal technique) are required. Single echo instruments may be used on uncoated surfaces, which have been cleaned and ground.
1.5 Procedures – Documented work procedures are at least to contain information on inspection preparation, selection and identification of test locations, surface preparation, protective coating preservation, calibration checks, and report preparation and content.
1.6 Reporting – The report is to be based on the guidelines given in UR Z7, UR Z7.1, UR Z7.2, Z10.1, Z10.2, Z10.3, Z10.4 and Z10.5, as relevant.
1.7 Verification – The supplier must have the Surveyor's verification of each separate job, documented in the report by the attending Surveyor(s) signature.

2. Firms engaged in tightness testing of closing appliances such as hatches, doors, etc., with ultrasonic equipment
2.1 Extent of engagement – Ultrasonic tightness testing of closing appliances such as hatches, doors, etc.
2.2 Operators – The operator is to have the following qualifications:
— have knowledge of different closing appliances such as hatches, doors etc. including their design, functioning and sealing features;
— have experience with the operation and maintenance of different closing appliances such as hatches, doors etc.;
— be able to document theoretical and practical training onboard in using the ultrasonic equipment specified.
2.3 It is to be demonstrated to the Surveyor that the ultrasonic equipment is fit for the purpose of detecting leakages in closing appliances.

2.4 Procedures – The supplier is to have documented work procedures which are to include the manual for the ultrasonic equipment specified, its adjustment, its maintenance, its operation and approval criteria.

3. Firms carrying out an in-water survey on ships and mobile offshore units by diver or Remotely Operated Vehicle (ROV)

3.1 Extent of engagement – In-water survey in lieu of a docking survey and/or the internal hull survey of compartments filled with water on ships and mobile offshore units by diver or Remotely Operated Vehicle (ROV).

3.2 Training of personnel – The supplier is responsible for the qualification of its divers, Remotely Operated Vehicle (ROV) operators and supervisors and for their training in the use of the equipment utilised when carrying out inspection. Knowledge of the following is to be documented:

— ship's underwater structure and appendages, propeller shaft, propeller, rudder and its bearings, etc.;
— non-destructive testing in accordance with a recognized national or international industrial NDT standard. This requirement only applies if an in-water survey company performs non-destructive testing;
— certification as a thickness measurement firm when conducting thickness measurements under water;
— bearing clearance measurements on rudders and propeller shaft;
— under-water video monitoring with TV-monitors on deck, as well as still picture work;
— operation of under-water communication system;
— any special equipment necessary for the work carried out.

3.3 A plan for training of personnel in the reporting system, minimum rules requirements for relevant ship or unit types, ship's or unit's underwater structure, measuring of bearing clearances, the recognition of corrosion damage, buckling and deteriorated coatings, etc. is to be included.

3.4 Supervisor

3.4.1 Diving Supervisor – Diving supervisor is to be qualified according to the supplier's general requirements and is to have a minimum of two years' experience as a diver carrying out inspection.

3.4.2 ROV Supervisor – ROV supervisor is to have a minimum of two (2) years of experience conducting inspections with ROVs.

3.5 Diver and Operators

3.5.1 Divers carrying out inspection – The diver carrying out the inspection is to have had at least one year experience as an assistant diver carrying out inspection (including participation in a minimum of 10 different assignments).

3.5.2 ROV operators- ROV operators are to have at least one year of experience working with ROVs conducting inspections on vessels.

3.6 Equipment

3.6.1 The following is to be available:

— closed circuit colour television with sufficient illumination equipment;
— two-way communication between diver and surface staff;
— video recording device connected to the closed circuit television;
— still photography camera;
— equipment for carrying out thickness gauging, non-destructive testing and measurements, e.g. clearances, indents, etc., as relevant to the work to be performed;
— equipment for cleaning of the hull.

3.6.2 In addition to above 3.6.1, the following is to be available for firms carrying out survey by ROV:

— Remote Operated Vehicle;
– Adequate controls or programming for the ROV functions required.

3.7 Procedures and guidelines

3.7.1 The supplier is to have documented operational procedures and guidelines for how to carry out the inspection and how to handle the equipment. These are to include:

— two-way communication between diver and surface;
— video recording and closed circuit television operation;
— guidance of the diver along the hull to provide complete coverage of the parts to be inspected.

3.7.2 In addition to above 3.7.1, documented operational procedures and guidelines for firms carrying out in-water survey by ROV are also to include:

— guidance for the operation and maintenance of the Remotely Operated Vehicle, if applicable;
— methods and equipment to ensure the ROV operator can determine the ROV's location and orientation in relation to the vessel.

3.8 Verification – The supplier must have the Surveyor's verification of each separate job, documented in the report by the attending Surveyor(s) signature.

4. Firms engaged in inspection and maintenance of fire extinguishing equipment and systems

4.1 Extent of engagement – Inspections and maintenance of fire-extinguishing equipment and systems such as fixed fire extinguishing systems, portable fire extinguishers and fire detection and alarm systems.

4.2 Extent of approval

— Service suppliers are to have professional knowledge of fire theory, fire-fighting and fire-extinguishing appliances sufficient to carry out the maintenance and/or inspections, and to make the necessary evaluations of the condition of the equipment.
— In demonstrating professional knowledge, service suppliers are to have an understanding of the various types of fires and the extinguishing media to be used on them.
— For fixed fire-extinguishing systems, service suppliers are to demonstrate an understanding of the principles involved with gas, foam, deluge, sprinkler and water-mist systems, as relevant for the approval being sought.

4.3 Procedures

— Service suppliers are to have documented procedures and instructions on how to carry out the servicing of the equipment and/or system. These are to either contain or make reference to the manufacturer's servicing manuals, servicing bulletins, instructions and training manuals, as appropriate, and to international requirements.
— Additionally. they are to make reference to any requirements (e.g. what markings should be appended to the equipment/system).

4.4 Reference documents − The service supplier is to have access to the following documents:

— manufacturer's servicing manuals, servicing bulletins, instructions and training manuals, as appropriate;
— type approval certificates showing any conditions that may be appropriate during the servicing and/or maintenance of fire-extinguishing equipment and systems;
— SOLAS, MSC.1/Circular.1318/Rev.1 (Revised Guidelines for the Maintenance and Inspections of Fixed Carbon Dioxide Fire-Extinguishing Systems), International Code for Fire Safety Systems (FSS Code), ISO 6406 (Periodic inspection and testing of seamless steel gas cylinders), and any documentation specified in the authorization or license from the equipment manufacturer;
— MSC/Circ.670 (Guidelines for the Performance and Testing Criteria and Surveys of High Expansion Foam Concentrates for Fixed Fire-Extinguishing Systems);
— MSC/Circ.798 (Guidelines for the Performance and Testing Criteria and Surveys of Medium Expansion Foam Concentrates for Fixed Fire-Extinguishing Systems);
— MSC.1/Circ.1312 (Revised Guidelines for the Performance and Testing Criteria and Surveys of Foam Concentrates for Fixed Fire-Extinguishing Systems as corrected by MSC/Circ.1312/Corr.1);
— MSC.1/Circ.1432 (Revised Guidelines for the Maintenance and Inspection of Fire Protection Systems and Appliances, as amended by MSC.1/Circ.1516);
— IMO resolution A. 951(23) – Improved Guidelines for Marine Portable Fire Extinguishers;
— MSC.1/Circ.1370 – Guidelines for the Design, Construction and Testing of Fixed Hydrocarbon Gas Detection Systems;
— Guidelines adopted by IMO for fire extinguishing equipment and systems specifically intended for service by service suppliers.

4.5 Equipment and facilities

4.5.1 General requirements

— If service suppliers undertake shore-based inspecting and maintenance, they should maintain and implement procedures for workshop cleanliness, ventilation and arrangement, with due cognisance of the spares and extinguishing media being stored, to ensure safe and effective working procedures.
— Service suppliers undertaking inspecting and maintenance of equipment and systems onboard are to provide the appropriate facilities to either complete the work onboard or remove the necessary items to their workshops.

4.5.2 Equipment

Sufficient and appropriate spares and tools are to be available as applicable, which should include:

— various scales to weigh items;
— means to hydrostatically pressure test components/systems/storage bottles;
— liquid/gas, flow meters, as appropriate;
— pressure gauges or manometers;
— in the cases of foam concentrates and portable fire-extinguishers, chemical analysis equipment and a testing bay, respectively;
— specific equipment/spares as may be specified by manufacturers;
— level measuring equipment for bottles; and
— recharging facilities for pressurized bottles, extinguishers and cartridges.

5. Firms engaged in servicing inflatable liferafts, inflatable lifejackets, hydrostatic release units and marine evacuation systems

5.1 Extent of engagement:

— servicing of inflatable liferafts, inflatable lifejackets, hydrostatic release units;

— servicing of marine evacuation systems.

5.2 Equipment and facilities – IMO resolution A.761(18), as amended by resolution MSC.55(66) and by MSC.388(94) gives recommendations on conditions for the approval of servicing stations for inflatable liferafts which are to be observed as relevant. Where inflatable liferafts are subject to extended service intervals, MSC.1/Circ.1328 should also be followed.

5.3 Procedures and instructions – The supplier is to have documented procedures and instructions for how to carry out service of equipment. Where inflatable liferafts are subject to extended service intervals in accordance with the requirements of SOLAS regulation III/20.8.3, MSC.1/Circ.1328 should be followed in addition to resolution A.761(18), as amended by resolution MSC.55(66) and by MSC.388(94).

5.4 The supplier is to provide evidence that it has been authorized or licensed to service the particular makes and models of equipment for which approval is sought by the equipment's manufacturer.

5.5 Reference documents − The service supplier is to have access to the following documents:

— IMO resolution A.761(18) − Recommendation on Conditions for the Approval of Servicing Stations for Inflatable Liferafts (adopted on 4 November 1993), as amended by resolution MSC.55(66) and by MSC.388(94);

— IMO resolution MSC.55(66);

— IMO resolution MSC.388(94);

— IMO MSC.1/Circ.1328 – Guidelines for the Approval of Inflatable Liferafts Subject to Extended Service Intervals Not Exceeding 30 Months;

— Manufacturer's servicing manuals, servicing bulletins, instructions and training manuals, as appropriate;

— Type approval certificates, showing any conditions that may be appropriate during the servicing and/or maintenance of inflatable liferafts, inflatable lifejackets, and hydrostatic release units;

— LSA Code/Chapter IV, 1995 SOLAS Conference Resolution 4 regarding marine evacuation systems.

6. Firms engaged in inspections and testing of radio communication equipment

6.1 Extent of engagement:

— surveys, inspection, testing, and/or measurement of radio equipment aboard ships or mobile offshore units for compliance with SOLAS regulations;

— annual testing of 406 MHz satellite EPIRBs for compliance with SOLAS regulation IV/15.9;

— the principles of this section also apply to service suppliers involved in inspection, performance testing and maintenance of Automatic Identification Systems (AIS). The service supplier is to be familiar with the equipment with which it will be involved, such as being a service agent for the equipment manufacturer.

6.2 Reference documents – The supplier is to have access to the following documents:

— SOLAS, 1974, as amended;

— IMO resolution A.789(19) − Specification on the survey and certification functions of recognized organizations acting on behalf of the Administration;

— MSC/Circ.1040/Rev.1 – Guidelines on Annual Testing of 406 MHz Satellite EPIRBs;

— MSC.1/Circ.1252 – Guidelines on Annual Testing of the Automatic Identification System (AIS);

— SN/Circ.227, SN/Circ.227/Corr.1 and 245 – Guidelines for the Installation of a Shipborne Automatic Identification System (AIS) and amendments thereto;

— ITU Radio Regulations;

— IMO Performance Standards for the equipment for which the service supplier is approved;

— Flag State Administration requirements;

— Relevant parts, if any, of CCS Rules and Guidelines.

6.3 Supervisor – The supervisor is to have a minimum two years education from a technical school, experience as inspector, and should preferably hold a general operator's certificate (GOC) or a GMDSS radioelectronic certificate (REC), recognized by the ITU, to operate or test radio transmitters. He should be aware of any local conditions for radio signal propagation, of regional radio stations and their facilities, and of the GMDSS infrastructure.

6.4 Radio inspector – The inspector carrying out the inspection is to have passed the internal training of the supplier in radiotelephony, GMDSS, and initial and renewal surveys, as applicable. The inspector is also to have at least one year technical school training or as alternative hold evidence that he followed a technical course approved by the relevant Administration, at least one year experience as an assistant radio

inspector and should preferably hold an appropriate national radio operators certificate, recognized by the ITU, such as a GMDSS general operator's certificate (GOC) or a GMDSS radioelectronic certificate (REC). He should be aware of any local conditions for radio signal propagation, of regional radio stations and their facilities, and of the GMDSS infrastructure.

6.5 Equipment and facilities

6.5.1 The supplier is to have the major and auxiliary equipment required for correctly performing the inspection. A record of the equipment used is to be kept. The record is to contain information on manufacturer and type of equipment, and a log of maintenance and calibrations.

6.5.2 A standard which is relevant to the radio equipment to be tested is to be available for the equipment and to be cited in the inspection report.

6.5.3 For equipment employing software in conjunction with the testing/examination, this software is to be fully described and verified.

6.6 Minimum required instruments:

— equipment for measuring frequency, voltage, current and resistance;
— equipment for measuring output and reflect effect on VHF and MF/HF;
— equipment for measuring modulation on MF/HF and VHF (AM, FM, PM);
— acid tester for checking specific gravity of lead batteries;
— tester for checking of correct output from Free-Float Satellite EPIRB;
— equipment for testing the performance of Automatic Identification Systems (AIS).

6.7 Procedures and instructions – The supplier is to have documented procedures and instructions for how to carry out testing and examination of radio equipment. Procedures and instructions for operating each item of the testing/inspection equipment are also to be kept and to be available at all times.

7. Firms engaged in inspections and maintenance of self-contained breathing apparatus

7.1 Extent of engagement − inspections and maintenance of self-contained breathing apparatus, emergency escape breathing devices (EEBD)

7.2 Extent of approval

— The supplier is to document and demonstrate that it has knowledge of the equipment and systems sufficient to carry out the inspections and testing of self-contained breathing apparatus to identify standards and to make the necessary evaluation of the condition of the equipment.
— In demonstrating professional knowledge, service suppliers are to have an understanding of the operational requirements involved with self-contained breathing apparatus and how these are to be maintained.
— Additionally, service suppliers are to demonstrate the necessary safety requirements applicable to such equipment.

7.3 Procedures

— Service suppliers are to have documented procedures and instructions on how to carry out the servicing of the equipment and/or system. These are to either contain or make reference to the manufacturer's servicing manuals, servicing bulletins, instructions and training manuals, as appropriate.
— Additionally, they are to make reference to any requirements (e.g. what markings should be appended to the equipment/system) and how they should be applied.

7.4 Reference documents − The service supplier is to have access to the following documents:

— manufacturers' servicing manuals, servicing bulletins, instructions and training manuals, as appropriate;
— type approval certificates showing any conditions which may be appropriate during the servicing and/or maintenance of self-contained breathing apparatus.

7.5 Equipment and facilities

7.5.1 General requirements

— If service suppliers undertake shore-based inspecting and maintenance, they are to maintain and implement procedures for workshop cleanliness, ventilation and arrangement, with due cognisance of the spares and pressurised bottles being stored, to ensure safe and effective working procedures.
— Service suppliers undertaking inspecting and maintenance of equipment and systems onboard are to provide the appropriate facilities to either complete the work onboard or remove the necessary items to their workshops.

7.5.2 Equipment

— Sufficient and appropriate spares and tools are to be available for repair, maintenance and servicing of self-contained breathing apparatus in accordance with the requirements of the manufacturers.
— These are to include, as required by the self-contained breathing apparatus equipment and/or systems as follows:
  — various scales to weigh items;

— means to hydrostatically pressure test components/systems/storage bottles;
— flow meters;
— pressure gauges or manometers;
— equipment for checking air quality;
— recharging facilities for breathing apparatus.

8. Firms engaged in examination of ro-ro ships bow, stern, side and inner doors

8.1 Extent of engagement − inspection of securing and locking devices, hydraulic operating system, electric control system for the hydraulics, electric indicator systems, and supporting, securing and locking devices and tightness testing.

8.2 The supplier is to be certified to the most current version of ISO 9000 series.

8.3 Supervision − In addition to 5.2.3, the requirement to have had a minimum of two years' experience as operator/technician/inspector within the activity, a supervisor is to have a minimum two years related education from a technical school.

8.4 Training of personnel - Operators carrying out non-destructive test (NDT) are to be qualified to a recognized national or international standard for the methods used.

8.5 Reference documents − The supplier is to have access to the following reference documents:

— IMO International Convention on the Safety of Life at Sea (SOLAS, 1974), as amended;
— ISO 9002:1994 − Quality systems − Model for quality assurance in production, installation and servicing;
— UR Z24 − Survey Requirements for Shell and Inner Doors of Ro-Ro ships, or its equivalent, by CCS.

8.6 Required equipment

8.6.1 For inspection of supporting securing and locking devices, hinges and bearings:

— equipment for measuring clearances (i.e. feeler gauges, vernier calipers, micrometers);
— non-destructive test (i.e. dye penetrant, magnetic particle inspection).

8.6.2 For tightness testing:

— ultrasonic leak detector or equivalent.

8.6.3 For inspection of hydraulic operating system:

— pressure gauges;
— particle counter for analysing the quality of hydraulic fluid.

8.6.4 For inspection of electric control system and indication system:

— digital multi-meter;
— earth fault detector.

8.7 Procedures and instructions

8.7.1 The supplier is to have access to drawings and documents, including the operating and inspection manual.

8.7.2 The supplier is to have access to the service history of the doors.

8.7.3 The supplier should use, complete and sign a checklist which has been found acceptable by CCS.

9. Firms engaged in annual performance testing of voyage data recorders (VDRs) and simplified voyage data recorders (S-VDRs)

9.1 Extent of engagement – Testing and servicing of voyage data recorders (VDRs) and simplified voyage data recorders (S-VDRs) in accordance with SOLAS regulation V/18.8 and IMO MSC.1/Circular 1222/Rev.1 − Guidelines on Annual Testing of Voyage Data Recorders (VDRs) and Simplified Voyage Data Recorders (S-VDRs), as applicable.

9.2 Extent of approval

9.2.1 The supplier is to provide evidence that he has been authorized or licensed by the equipment's manufacturer to service the particular makes and models of equipment for which approval is sought.

9.2.2 Where the service supplier is also the manufacturer of the voyage data recorder (VDR) or simplified voyage data recorder (S-VDR) and has elected to apply IMO MSC.1/Circular 1222/Rev.1 − Guidelines on Annual Testing of Voyage Data Recorders (VDRs) and Simplified Voyage Data Recorders (S-VDRs) in its entirety for the purpose of acting as a service supplier engaged in annual performance testing, the following are to apply:

— The manufacturer is responsible for appointing manufacturer's authorized service stations to carry out annual performance testing.
— The manufacturer is required to be an approved service supplier and is to satisfy the requirements for service suppliers engaged in annual performance testing of voyage data recorders (VDRs) and simplified voyage data recorders (S-VDRs), as applicable.
— The manufacturer's authorized service station is not required to be an approved service supplier.

— The manufacturer is to demonstrate that IMO MSC.1/Circular 1222/Rev.1 − Guidelines on Annual Testing of Voyage Data Recorders (VDRs) and Simplified Voyage Data Recorders (S-VDRs) is applied in its entirety.

9.3 Procedures

9.3.1 The service supplier is to have documented procedures and instructions.

9.3.2 Where the service supplier is also the manufacturer of the voyage data recorder (VDR) or simplified voyage data recorder (S-VDR) and has selected to apply IMO MSC.1/Circular 1222/Rev.1 − Guidelines on Annual Testing of Voyage Data Recorders (VDRs) and Simplified Voyage Data Recorders (S-VDRs) in its entirety for the purpose of acting as a service supplier engaged in annual performance testing, the following are to apply:

— The manufacturer is to have documented procedures for the assessment and authorization of manufacturer's authorized service stations who carry out annual performance testing.

— The manufacturer is to have documented procedures for the review of manufacturer's authorized service stations annual performance test reports, analysis of the voyage data recorder (VDR) and simplified voyage data recorder (S-VDR) 12 hour log and the issue of annual performance test certificates to the owner/operator.

— The manufacturer is to maintain a list of manufacturer's authorized service stations that can be accessed (by any available means, e.g. via a nominated contact point or from the manufacturer's website) upon request.

9.4 Reference documents

9.4.1 The service supplier is to have access to the following documents:

— IMO International Convention on the Safety of Life at Sea (SOLAS 74/78), regulation V/18.8 – Approval, surveys and performance standards of navigational systems and equipment and voyage data recorder;

— IMO MSC.1/Circular 1222/Rev.1 − Guidelines on Annual Testing of Voyage Data Recorders (VDRs) and Simplified Voyage Data Recorders (S-VDRs) (11 December 2006);

— IMO resolution A.861(20) (adopted on 27 November 1997), as amended by IMO resolution MSC.214(81) and resolution MSC.333(90) − Performance Standards for Shipborne Voyage Data Recorders (VDRs);

— IMO resolution MSC.163(78) − Performance Standards for Shipborne Simplified Voyage Data Recorders (S-VDRs) (adopted on 17 May 2004), as amended by IMO resolution 214(81).

9.4.2 The service supplier is to have access to applicable industry performance standards, e.g.:

— IEC 61996 − Maritime navigation and radiocommunication equipment and systems − Shipborne voyage data recorder (VDR);

— IEC 61996-2 − Maritime navigation and radiocommunication equipment and systems –Shipborne voyage data recorder (VDR) – Part 2: Simplified voyage data recorder (S-VDR) – Performance requirements, method of testing and required test results.

9.4.3 The service supplier is also to have access to any documentation specified in the authorization or license from the equipment manufacturer.

9.5 Equipment and facilities − In addition, the service supplier is to have equipment as specified in the authorization or license from the equipment manufacturer.

9.6 Reporting − test report

9.6.1 The service supplier is to issue a certificate of compliance as specified in regulation V/18.8 of the International Convention on the Safety of Life at Sea (SOLAS, 1974), as amended.

9.6.2 Annual performance test of VDR and S-VDR should be recorded in the form of the model test report given in the Appendix to MSC.1/Circular 1222/Rev.1, signed and stamped by the service supplier and attached to the annual performance test certificate.

9.6.3 Where the service supplier is also the manufacturer of the voyage data recorder (VDR) or simplified voyage data recorder (S-VDR) and has selected to apply IMO MSC.1/Circular 1222/Rev.1 − Guidelines on Annual Testing of Voyage Data Recorders (VDRs) and Simplified Voyage Data Recorders (S-VDRs) in its entirety for the purpose of acting as a service supplier engaged in annual performance testing, the manufacturer is to make arrangements for the following:

— review of the manufacturer's authorized service station annual performance test report;

— analysis of the recorder's 12 hour log;

— checking of the master record/database for the recorder.

9.6.4 Issue of the annual performance test certificate to the owner/operator within 45 days of completion of the annual performance test.

10. Firms engaged in inspections of low location lighting systems using photo luminescent materials

and evacuation guidance systems used as an alternative to low-location lighting systems

10.1 Extent of engagement – Luminance measurements on board ships of low location lighting systems using photo luminescent materials.

10.2 Operators – The operator is to have the following qualifications:

— have adequate knowledge of the applicable international requirements (namely SOLAS regulation II-2/13.3.2.5, IMO resolution A.752(18) − Guidelines for the Evaluation, Testing and Application of Low-Location Lighting on Passenger Ships, ISO 15370-2010, FSS Code Chapter 11);

— be able to document theoretical and practical training onboard in using equipment specified.

10.3 Equipment – The measuring instrument is to incorporate a fast-response photometer head with CIE (International Commission on Illumination) photopic correction and have a measurement range of at least 10^{-4} cd/m^2 to 10 cd/m^2.

10.4 Procedures – Documented work procedures are at least to contain information on inspection preparation, selection and identification of test locations.

10.5 Reporting – The report is to conform to Annex C of ISO 15370-2010.

10.6 Verification – The supplier must have the Surveyor's verification of each separate job, documented in the report by the attending Surveyor's signature.

10.7 Reference documents

The service supplier is to have access to the following documents:

— IMO International Convention on the Safety of Life at Sea (SOLAS 74/78), regulation II-2/13.3.2.5 – Marking of escape routes;

— IMO Fire Safety Systems (FSS Code), Chapter 11 – Low-location lighting systems;

— IMO resolution A.752(18) − Guidelines for the Evaluation, Testing and Application of Low-Location Lighting on Passenger Ships (adopted on 4 November 1993);

— ISO 15370:2010 − Ships and marine technology − Low-location lighting on passenger ships – Arrangement;

— MSC/Circ.1168 – Interim guidelines for the testing, approval and maintenance of evacuation guidance systems used as an alternative to low-location lighting systems.

11. Firms engaged in sound pressure level measurements of public address and general alarm systems on board ships

11.1 Extent of engagement – Sound pressure level measurements of public address and general alarm systems on board ships.

11.2 Operators – The operator is to have the following qualifications:

— have adequate knowledge of the applicable international requirements (SOLAS regulations III/4 and 6, LSA Code/Chapter VII/7.2, IMO Code on Alarms and Indicators, 1995, as amended);

— be able to document theoretical and practical training onboard in using equipment specified.

11.3 Equipment – The measuring instrument is to be an integrating sound level meter with frequency analyser capabilities complying with IEC (International Electrotechnical Commission) 60651 and IEC 61672, type 1 precision class with, at least an A-weighting frequency response curve and 1/3 octave and 1 octave band filters, complying to IEC 61260, as appropriate for the measurements to be carried out. In addition microphones are to be of the random incidence type, complying with IEC 60651.

11.4 Procedures – Documented work procedures are at least to contain information on inspection preparation, calibration, selection and identification of test locations.

11.5 Reporting – The report is to describe, as a minimum, the environmental conditions of the tests and, for each test location, the ambient noise level or the speech interference level, as appropriate for the measurements to be carried out. The report is to conform to any other specific requirement of CCS.

11.6 Verification – The supplier must have the Surveyor's verification of each separate job, documented in the report by his signature.

11.7 Reference documents

The service supplier is to have access to the following documents:

— SOLAS 74/78, regulation III/4 – Evaluation, testing and approval of life-saving appliances and arrangements;

— SOLAS 74/78, regulation III/6 – Communications;

— International Life-Saving Appliance (LSA) Code, Chapter VII/7.2 – General alarm and public address system;

— IMO Code on Alarms and Indicators, 1995, as amended;

— IEC 60651 (2001-10) − Sound level meters;

— IEC 61672 − Electroacoustics − Sound level meters;

— IEC 61260 − Electroacoustics − Octave-band and fractional-octave-band filters.

12. Firms engaged in testing of coating systems in accordance with IMO resolution MSC.215(82), as amended and IACS UI SC223 and/or resolution MSC.288(87), as amended

12.1 Laboratories

12.1.1 Extent of engagement − Testing of coatings systems according to IMO resolution MSC.215(82), as corrected by IMO MSC.1/Circ.1381 and amended by IMO resolution 341(91) and IACS UI SC223 and/or MSC.288(87), as corrected by IMO MSC.1/Circ.1381 and amended by IMO resolution 341(91).

12.1.2 The laboratory is to provide to CCS the following information:

— A detailed list of the Laboratory test equipment for the coating approval according to the IMO resolution MSC.215(82), as amended and/or MSC.288(87), as amended.

— A detailed list of reference documents comprising a minimum those referred to in IMO resolution MSC.215(82), as amended and/or MSC.288(87), as amended for the coating approval.

— Details of test panel preparation, procedure of test panel identification, coating application, test procedures and a sample test report.

— Details of exposure method and site for weathering primed test panels.

— A sample daily or weekly log/form for recording test conditions and observations including unforeseen interruption of the exposure cycle with corrective actions.

— Details of any sub-contracting agreements (if applicable).

— Comparison test report with an approved coating system or laboratory if available.

12.1.3 Reporting – Reference is made to the following IACS Recommendations:

— Rec.101: IACS Model Report for IMO resolution MSC.215(82) Annex 1 “Test Procedures for Coating Qualification”;

— Rec.102: IACS Model Report for IMO resolution MSC.215(82) Annex 1 “Test Procedures for Coating Qualification”, Section 1.7 – Crossover Test.

12.1.4 Audit of the test laboratory is to be based on this procedure and the standards listed in the IMO resolution MSC.215(82), as amended and/or MSC.288(87), as amended for the coating approval.

13. Firms engaged in maintenance, thorough examination, operational testing, overhaul and repair of lifeboats and rescue boats, launching appliances and release gear

13.1 Extent of engagement – Maintenance, thorough examination, operational testing, overhaul and repair of:

.1 lifeboats (including free-fall lifeboats), all rescue boats (including inflated rescue boats and fast rescue boats); and

.2 launching appliances and on-load and off-load release gear for lifeboats (including primary and secondary means of launching appliances for free-fall lifeboats), rescue boats, fast rescue boats and davit-launched liferafts.

13.2 Extent of approval

13.2.1 The contents of this procedure apply equally to manufacturers or ship’s operator when they are acting as service suppliers.

13.2.2 Any service supplier engaged in maintenance, thorough examination, operational testing, overhaul and repair of lifeboats and rescue boats, launching appliances and release gear carried out in accordance with SOLAS regulation III/20 shall be approved for these operations for each make and type of equipment for which they provide the service in accordance with IMO Resolution MSC.402(96)/Corr.1 (annex, section 7).

Such approval shall include, as a minimum:

- employment and documentation of personnel certified in accordance with a recognized national, international or industry standard as applicable, or an equipment manufacturer’s established certification program. In either case, the certification program shall be based on the paragraph 13.3 for each make and type of equipment for which service is to be provided; and,
- compliance with provisions of paragraphs 13.4, 13.5 and 13.6.

13.2.3 In cases where an equipment manufacturer is no longer in business or no longer provides technical support, service suppliers may be approved for the equipment on the basis of prior approval for the equipment and/or long term experience and demonstrated expertise as an authorized service provider.

13.3 Certification of personnel

13.3.1 Personnel for the work specified in 13.1 shall be certified by the manufacturer or the Service Supplier for each make and type of the equipment to be worked on. Approved Service Supplier is allowed to certify its own personnel (i.e. employed by the same service supplier) only.

13.3.2 The education for initial certification of personnel should be documented and address, as a minimum:

— causes of lifeboat and rescue boat accidents;
— relevant rules and regulations, including International Conventions;
— design and construction of lifeboats (including free-fall lifeboats), rescue boats and fast rescue boats, including on load release gear and launching appliances;
— education and practical training in the procedures specified in section 6 of annex to IMO Resolution MSC.402(96)/Corr.1 for which certification is sought;
— detailed procedures for thorough examination, operational testing, repair and overhaul of lifeboats(including free-fall lifeboats), rescue boats and fast rescue boats, launching appliances and on load release gear, as applicable;
— procedures for issuing a report of service and statement of fitness for purpose based on IMO Resolution MSC.402(96)/Corr.1 (annex, paragraph 5.3); and
− Work, health and safety issues while conducting activities on board.

13.3.3 The education and training for the personnel shall include practical technical training on thorough examination, operational testing, maintenance, repair and overhaul techniques for which the personnel are to be certified. The technical training shall include disassembly, reassembly, correct operation and adjustment of the equipment. Classroom training shall be supplemented by field experience in the operations for which certification is sought, under the supervision of a certified person.

13.3.4 Prior to issuance of personnel certification, a competency assessment shall be satisfactorily completed, using the equipment for which the personnel are to be certified.

13.3.5 Upon completion of training and competency assessment, a certificate shall be issued defining the level of qualification and the scope of the certification (i.e. makes and types of equipment and specifically state which activities (annual thorough examination and operational tests; 5-year thorough examination, overhaul; overload operational tests; repairs) are covered by the certification). The expiry date shall clearly be written on the certificate and shall be three years from the date of issue. The validity of any certificate shall be suspended in the event of any shortfall in performance and only revalidated after a further competency assessment.

13.3.6 A competency assessment shall be conducted to renew the certification. In cases where refresher training is found necessary a further assessment shall be carried out after completion.

13.4 Reference Documents − The service supplier is to have access to the following documents:
— IMO resolution MSC.402(96)/Corr.1 Requirements for Maintenance, Thorough Examination, Operational Testing, Overhaul and Repair of Lifeboats and Rescue Boats, Launching Appliances and Release Gear;
— IMO resolution A.689(17), recommendation on testing of life-saving appliances and, for life-saving appliances installed on board on or after 1 July 1999;
— IMO resolution MSC.81(70), as amended, revised recommendation on testing of life-saving appliances;
— Manufacturer’s instructions (including updates, amendments and safety notices) for repair work involving disassembly or adjustment of on-load release mechanisms and davit winches;
— type approval certificate showing any conditions that may be appropriate during the servicing and/or maintenance of lifeboats, launching appliances and on-load release gear.

13.5 Equipment and facilities − The service supplier is to have access to the following:
— sufficient tools, and in particular any specialized tools specified in the equipment manufacturer’s instructions, including portable tools as needed for work to be carried out on board ship;
— access to appropriate parts and accessories as specified by the equipment manufacturer for maintenance and repair;
— for servicing and repair work involving disassembly or adjustment of on-load release mechanisms, availability of genuine replacement parts as specified or supplied by the equipment manufacturer.

13.6 Reporting − The report shall conform to the requirements of IMO Resolution MSC.402(96)/Corr.1 (annex, paragraph 5.3). When repairs, thorough examinations and annual servicing are completed, a statement confirming that the lifeboat arrangements remain fit for purpose should be promptly issued by the service supplier that conducted the work. A copy of valid documents of certification and authorization as appropriate shall be included with the statement.

14. Firms engaged in measurements of noise level onboard ships

14.1 Extent of engagement

Sound pressure level measurements onboard Ship.

14.2 Supervisor

The supervisor is to have a minimum of 2 years of experience as an operator in sound pressure level measurements.

14.3 Operators

The operator is to have the following qualifications:
— knowledge in the field of noise, sound measurements and handling of measurement equipment;
— adequate knowledge of the applicable international requirements (SOLAS regulation II-1/3-12, as amended, and IMO Code on Noise Levels on Board Ships, as amended);
— at least one year experience, including participation in a minimum of 5 measurement campaigns as an assistant operator;
— training concerning the procedures specified in IMO Code on Noise Levels on Board Ships;
— be able to document theoretical and practical training onboard in using a sound level meter.

14.4 Equipment

14.4.1 Sound level meters

Measurement of sound pressure levels is to be carried out using precision integrating sound level meters. Such meters are to be manufactured to IEC 61672-1(2002-05)1, as amended, type/class[1] standard as applicable, or to an equivalent standard acceptable to the Administration[2].

[1] Recommendation for sound level meters.

[2] Sound level meters class/type 1 manufactured according to IEC 651/IEC 804 may be used until 1 July 2016.

14.4.2 Octave filter set

When used alone, or in conjunction with a sound level meter, as appropriate, an octave filter set is to conform to IEC 61260 (1995)[3], as amended, or an equivalent standard acceptable to the Administration.

[3] Octave-band and fractional-octave-band filters.

14.4.3 Sound Calibrator

Sound calibrators are to comply with the standard IEC 60942(2003-01), as amended, and to be approved by the manufacturer of the sound level meter used.

14.4.4 Calibration

Sound Calibrator and sound level meter are to be verified at least every two years by a national Standard laboratory or a competent laboratory accredited according to ISO/IEC 17025:2017, as amended. A record with a complete description of the equipment used is to be kept, including a calibration log.

14.4.5 Microphone wind screen

A microphone wind screen is to be used when taking readings outside, e.g. on navigating bridge wings or on deck, and below deck where there is any substantial air movement. The wind screen should not affect the measurement level of similar sounds by more than 0.5 dB(A) in "no wind" conditions.

14.5 Procedures and instructions

14.5.1 The supplier is to have documented procedures and instructions to carry out service of the equipment.

Documented work procedures are at least to contain information on inspection preparation, selection and identification of sound level measurement locations, calibration checks and report preparation.

14.5.2 The supplier is to have access to the following documents:
— SOLAS, 1988, as amended (Reg.II-1/3-12);
— IMO resolution A.468(XII) and resolution MSC.337(91) Code on Noise Levels on Board Ships;
— IMO resolution A.343(IX) Recommendation on methods of measuring noise levels at listening posts;
— CCS Rules and Guidelines.

14.6 Reporting

A noise inspection report is to be made for each ship. The report is to comprise information on the noise levels in the various spaces on board. The report is to show the reading at each specified measuring point. The points are to be marked on a general arrangement plan, or on accommodation drawings attached to the report, or to otherwise be identified.

The format for noise inspection reports is set out in appendix 1 of IMO Code on Noise Levels on Board Ships and may conform to any other specific requirement of CCS (refer to IMO resolution MSC.337(91)).

14.7 Verification

The supplier must have the Surveyor’s verification of each separate job, documented in the report by his signature.

15. Firms engaged in tightness testing of primary and secondary barriers of gas carriers with membrane cargo containment systems for vessels in service

15.1 Extent of engagement

Firms carrying out the following:
— global vacuum testing of primary and secondary barriers;
— acoustic emission (AE) testing;
— thermographic testing.

15.2 Requirements for firms engaged in global testing of primary and secondary barriers

15.2.1 Testing Procedures – Testing is to be carried out in accordance with cargo containment system designer's procedures as approved by CCS.
15.2.2 Authorization − The supplier is to be authorized by the system designer to carry out the testing.
15.2.3 Equipment – Equipment is to be maintained and calibrated in accordance with recognized national or international industrial standards.
15.2.4 Reporting – The report is to contain the following:
— date of testing;
— identity of test personnel;
— vacuum decay data for each tank;
— summary of test results.
15.3 Requirements for firms engaged in acoustic emission (AE) testing
15.3.1 Testing procedures – The supplier is to have documented procedures based upon recognized national or international industrial standards to perform ultrasonic leak test using AE sensors for the secondary barrier of membrane cargo containment systems. The procedures are to include details of personnel responsibilities and qualification, instrumentation, test preparation, test method, signal processing, evaluation and reporting.
Note: The differential pressure during testing should not exceed the containment system designer's limitations.
15.3.2 Supervisor – The responsible supervisor is to be certified to a recognized national or international industrial standard (e.g. Level II, ISO-9712, as amended or SNT-TC-1A, as amended) and have one year experience at Level II.
15.3.3 Operators – The operators carrying out the acoustic emission (AE) testing are to be certified to a recognized national or international industrial standard (e.g. Level I, ISO-9712, as amended or SNT-TC-1A, as amended) and to have adequate knowledge of ship structures sufficient to determine sensor placement.
15.3.4 Equipment – Equipment is to be maintained and calibrated in accordance with recognized national or international industrial standards or equipment manufacturer's recommendations.
15.3.5 Evaluation of acoustic emission (AE) testing – Must be carried out by the supervisor or individuals certified to a recognized national or international industrial standard (e.g. Level II, ISO-9712, as amended or SNT-TC-1A, as amended) and have one year experience at Level II.
15.3.6 Reporting – The report is to contain the following:
— date of testing;
— supervisor and operator(s) certifications;
— description of time and pressure of each cycle of test;
— list and sketch detailing location of possible defects.
15.4 Requirements for firms engaged in thermographic testing
15.4.1 Testing Procedures – Testing is to be carried out in accordance with the cargo containment system designer's procedures as approved by CCS.
15.4.2 Authorization − The supplier is to be authorized by the system designer to carry out the testing.
15.4.3 Supervisor – The responsible supervisor is to be certified to a recognized national or international industrial standard (e.g. Level II, ISO-9712, as amended or SNT-TC-1A, as amended) with additional certification in infrared/thermal testing. SNT-TC-1A certified personnel must provide evidence that training on Level II or above has been administered by an independent training body centrally certified to ASNT or a comparable nationally recognized certification scheme.
15.4.4 Operators – The operators carrying out the imaging are to be certified to a recognized national or international industrial standard (e.g. Level I, ISO-9712, as amended or SNT-TC-1A, as amended) with additional certification in infrared/thermal testing and to have adequate knowledge of ship structures sufficient to determine position for each identified image, and of the containment system to understand the basis of the testing. SNT-TC-1A certified personnel must provide evidence that training on Level I or above has been administered by an independent training body centrally certified to ASNT or a comparable nationally recognized certification scheme.
15.4.5 Equipment – Thermal cameras and sensors are to be in accordance with the system designer's procedures with regards to sensitivity, accuracy and resolution.
Equipment are to be in accordance with recognized standard (IEC, etc.) with regards their safety characteristics for the use in hazardous areas (in gas explosive atmosphere), maintained and calibrated in accordance with the maker's recommendations.
15.4.6 Evaluation of thermographic images – Must be carried out by the supervisor or individuals certified to a recognized national or international industrial standard (e.g. Level II, ISO-9712, as amended or SNT-TC-1A, as amended) with additional certification in infrared/thermal testing. SNT-TC-1A certified personnel must provide evidence that training on Level II or above has been administered by an independent training body centrally certified to ASNT or a comparable nationally recognized certification

scheme.
15.4.7 Reporting – The report is to contain the following:
— date of testing;
— supervisor and operator(s) certifications;
— differential pressures of all phases;
— list and sketch detailing location of thermal indications;
— thermographic images of all phases of testing for thermal indications;
— evaluation of thermal images indicating possible leaks.

16. Firms engaged in survey using Remote Inspection Techniques (RIT) as an alternative means for Close-up Survey of the structure of ships and mobile offshore units

16.1 Definitions:
— Close-Up Survey: A Close-Up Survey is a survey where the details of structural components are within the close visual inspection range of the surveyor i.e. normally within reach of hand.
— Remote Inspection Techniques (RIT): RIT is a means of survey that enables examination of any part of the structure without the need for direct physical access of the surveyor (refer to IACS Rec.42). Remote inspection techniques may include the use of:
- Unmanned Aerial Vehicles (UAV)
- Drones
- Unmanned robot arm
- Remotely Operated Vehicles (ROV)
- Climbers
- Other means acceptable to CCS

16.2 Extent of engagement – Close-up Survey of ships' structure and mobile offshore units' structure by remote inspection techniques. For in-water close-up survey of the internal compartments by Remotely Operated Vehicle (ROV), suppliers are also to hold separate approval as a "Firm carrying out an in-water survey on ships and mobile offshore units by diver or Remotely Operated Vehicle (ROV)" (see Annex 1, Section 3).
16.3 Training and qualification of operators – The supplier is responsible for the training and qualification of its operators to undertake the remote inspections. UAV Pilots are to be qualified and licenced in accordance with applicable national requirements or an equivalent industrial standard acceptable to the society.
Knowledge of the following is to be documented:
- Marine and/or offshore nomenclatures.
- The structural configuration of relevant ships types and MOUs, including internal structure.
- The remote inspection equipment and its operation.
- Survey plans for examination of hull spaces of various configurations, including appropriate flight plans if using a UAV.
- Thickness measurement (TM) and non-destructive test (NDT) in accordance with a recognised National or International Industrial NDT Standard when these are part of the service. Suppliers undertaking TMs are to hold separate approval as a'Firm engaged in thickness measurements on ships' (see Annex 1, Section 1).

16.4 Training Plan – the supplier is to maintain a documented training plan for personnel. The plan is to include requirements for training in the minimum Rule requirements for the structure of relevant ships types and MOUs, the recognition of structural deterioration (including corrosion, buckling, cracking and deteriorated coatings) and use of the reporting system.
16.5 Supervisor – The supervisor is to be certified according to the recognized national requirements or an equivalent industrial standard (e.g. XXX Level) and is to have a minimum of two years' experience in the inspection of ship's and/or MOU's structure.
16.6 Operators – The operator carrying out the inspection is to be certified according to the recognized national requirements or an equivalent industrial standard (e.g. YYY Level) and have had at least one year's experience as an assistant carrying out inspections of ship's and/or MOU's structure (including participation in a minimum of five different assignments). The operators of those RIT which require, according to the international and national legislations, to be licensed for their use are to hold valid documentation issued by the appropriate Bodies (e.g. UAV Pilots are to be qualified and licenced in accordance with applicable national requirements).
16.7 Equipment – The following is to be available:

- Remotely operated platform with data capture devices capable of operation within an enclosed space.
- Means of powering the platforms with sufficient capacity to complete the required inspections, including spare batteries if applicable.
- Data collection devices which may include cameras capable of capturing in high definition both video images and still images.
- Illumination equipment.
- High definition display screen with live high definition feed from inspection cameras. (When this is part of the RIT).
- Means of communication.
- Data recording devices, as applicable.
- Equipment for carrying out thickness gauging and/or non-destructive testing, as relevant to the work to be performed (when this is part of the service).

16.8 Procedures and guidelines – The supplier is to have documented operational procedures and guidelines for how to plan, carry out and report inspections; how to handle/operate the equipment; collection and storage of data. These shall include:

- Requirements for preparation of inspection plans when UAV are part of the equipment flight plans shall be included.
- Operation of the remotely operated platforms.
- Operation of lighting.
- Calibration of the data collection equipment.
- Operation of the data collection equipment.
- Two-way communication between the operator, platform, Surveyor, other personnel such as support staff and ships officers and crew.
- Guidance of the operator to provide complete coverage of the structure to be inspected.
- Guidance for the maintenance of the remotely operated platforms, data capture and storage devices and display screens, as applicable.
- Requirements for the collection and validation of data.
- If data is to be stored, then requirements for location attribution (geo-tagging), validation and storage of data.
- Requirements for the reporting of inspections, including the recording of damages and defects found during inspection and repair work.

16.9 Documentation and records - The supplier is to maintain the following:

- Records of training.
- Operator statutory and regulatory certificates and licences.
- Equipment register for UAVs, Robots, data collection devices, data analysis devices and any associated equipment necessary to perform inspections.
- Equipment maintenance manuals and records / logbook.
- Records of calibration.
- UAV / Robot operation logbook.

16.10 Verification – The supplier must have the Surveyor’s verification of each separate job, documented in the report by the attending Surveyor(s) signature.

17. Firms engaged in Watertight Cable Transit Seal Systems Inspection on Ships and Mobile Offshore Units

17.1 Extent of engagement

17.1.1 Inspection of the Watertight Cable Transit Seal Systems for compliance with the relevant approval certificates and product installation manuals, (types of penetrating cables, dimensions, fill ratio and insulation details, as applicable).

17.2 Extent of Approval

17.2.1 The contents of this procedure apply equally to manufacturers or shipyards when they are acting as Service Suppliers.

17.2.2 Any Service Supplier engaged in the inspections of watertight cable transit seal systems shall be qualified in these inspections for each make and type of equipment for which they provide the inspection, and provide manufacturers documentary evidence that they have been so authorized or they are certified in accordance with an established system for training and authorization.

Such qualification shall include, as a minimum:

(1) Employment and documentation of personnel certified in accordance with a recognized national, international or industry standard as applicable, or an equipment manufacturer's established certification program. In either case, the certification program shall be based on the paragraph 17.3 for each make and type of equipment for which inspection is to be provided, and
(2) Compliance with provisions of paragraphs 17.4, 17.5 and 17.6.
17.2.3 In cases where an equipment manufacturer is no longer in business or no longer provides technical support, Service Suppliers may be authorised for the equipment on the basis of prior authorization for the equipment and/or long term experience and demonstrated expertise as an authorized service provider.
17.3 Qualifications and Training of Personnel
17.3.1 Personnel for the work specified in 17.1.1 shall be trained and qualified in the inspection for which they are authorised, for each make and type of equipment for which they provide the inspection.
17.3.2 The education for initial certification of personnel shall be documented and addressed, as a minimum:
(1) Procedures and instructions for the inspection of the watertight cable transit seal systems
(2) Common problems found with the initial installation and in-service inspections of watertight cable transit seal systems
(3) Relevant rules and regulations, including International Conventions
(4) Procedures for reporting on initial installation and in-service inspections of watertight cable transit seal systems in the Cable Transit Seal Systems Register.
17.3.3 The education and training for the personnel shall include practical technical training on actual inspection using the watertight cable transit seal systems for which the personnel are to be certified. The technical training shall include disassembly, reassembly and adjustment of the equipment. Classroom training shall be supplemented by field experience in the inspections for which certification is sought, under the supervision of an experienced senior certified person.
17.3.4 At the time of initial certification and at each renewal of certification, the service supplier shall provide documentation to verify personnel's satisfactory completion of a competency assessment using the equipment for which the personnel are certified.
17.3.5 The Service Supplier shall require refresher training as appropriate to renew the certification.
17.4 Reference Documents
The Service Supplier is to have access to the following documents:
17.4.1 Manufacturer's servicing manuals, servicing bulletins, instructions and training manuals as appropriate.
17.4.2 Type Approval certificate showing any conditions that may be appropriate during the installation or maintenance of the watertight cable transit seal system.
17.5 Equipment and Facilities
The Service Supplier is to have access to the following:
17.5.1 Sufficient tools, and in particular any specialized tools specified in the equipment manufacturer's instructions, including portable tools as needed for work to be carried out on board ship.
17.6 Reporting
17.6.1 On completion of inspection, the Service Supplier will issue a report confirming the condition of the Watertight Cable Transit Seal System. They will also record the results of their inspection in the Cable Transit Seal System Register.

18. Firms engaged in Commissioning Testing of Ballast Water Management Systems (BWMS)

18.1 Extent of engagement - Sampling and Analysis of ballast water and Verification of the self-monitoring equipment during Commissioning Testing of Ballast Water Management Systems (BWMS), for Statutory purposes.
18.2 Procedure
18.2.1 Service suppliers are to have documented procedures including:
— Procedures for sampling collection and handling, analysis, assessment of BWMS correct operations and documenting and reporting. The procedures are to outline how the ballast water sampling and analysis is conducted with respect to each size class of organisms;
— Operating procedures for the ballast water test equipment specified including calibration, adjustment and maintenance.
18.2.2 Service Suppliers are to be familiar with the BWMS operation including features and limits of each treatment technology, and self-monitoring parameters.
18.2.3 Service Suppliers are to be independent of the BWMS manufacturer or supplier including shipyards.
18.3 Operators – Service Suppliers are expected to be able to perform both the biological sampling and

assessment of self-monitoring parameters and has responsibility for document that the requirements to the operator are satisfied. Therefore, operators who conduct commissioning testing are to:
— demonstrate knowledge in the use of different ballast water testing equipment for the purpose of assessing biological efficacy;
— have documented evidence of sufficient engineering and biological knowledge to conduct the commissioning testing;
— have knowledge of IMO BWM.2/Circ.70/Rev.1, as may be amended - 'Guidance for the Commissioning Testing of Ballast Water Management Systems' and IMO BWM.2/Circ.42/Rev.2 - 'Guidance on Ballast Water Sampling and Analysis for Trial Use in accordance with the BWM Convention and Guidelines (G2)', as may be amended;
— (*) be trained in the proper use of portable indicative analysis equipment. Review of training records and/or interviews should be conducted to confirm the equipment will be properly used during testing;
— (*) be trained in the proper use of detailed analysis methods and equipment in case the Service Supplier offers detailed analysis. Review of training records and/or interviews should be conducted to confirm the equipment will be properly used during testing;
— (*) be familiar with and understand the design concepts of the Guidelines G2 sampling devices installed on the vessel's water ballast system. Personnel shall understand the need to maintain the G2 sampling devices clean and free of contaminants and the importance of controlling the ballast water sample flow rates from the G2 device (to avoid organism mortality in the sample);
— (*) be familiar with the technologies utilized by the indicative sampling equipment and understand water quality issues that are both conducive to successful use of the equipment and circumstances that could challenge the use of the equipment;
— (*) be trained in the proper disposal procedures for water samples following testing.
— (Δ) have knowledge of the system design limitations of the BWMS (as stated in the BWMS type approval certificate) and knowledge of the BWMS self-monitoring parameters, such as flow rate, pressure, TRO concentration, UV transmittance/intensity, etc, and how the BWMS notifies the operator in case he operates BWMS outside its system design limitations. This knowledge is relevant for evaluating whether the self-monitoring equipment of the BWMS indicates correct operation of the BWMS. In case Service Supplier are not present during ballasting operations, the Service Supplier shall have knowledge of how to access the BWMS log to evaluate that the BWMS operated correctly during ballasting operations;
— (Δ) have the procedures and knowledge to be able to assess the applicable selfmonitoring parameters (e.g., flow rate, pressure, TRO, UV intensity, etc.) of the BWMS, taking into account the System Design Limitations of the BWMS;

Notes:
(1) the points marked with (*) are qualifications for operators performing sampling and analysis of ballast water;
(2) the points marked with (Δ) are the qualifications for operators performing verification of the self-monitoring equipment ;
(3) the points above without symbol are the common qualifications for service supplier.

18.4 Equipment and facilities

Equipment, procedures and methods for detailed analysis, where applicable, are to be in accordance with relevant International standard and/or accepted Industry standards. Testing should be conducted using indicative analysis equipment accepted by Society. Information and reference to the acceptance documents for the equipment used should be submitted to the Society in the report which includes the results from the commissioning test as per IMO BWM.2/Circ.70/Rev.1, as may be amended. In case the indicative analysis equipment used has not been previously accepted by the Society, the following information is to be submitted to the Society:
• Equipment information - type, model, technology used, evidence of calibration, detection range, Organism type/size classes that can be analyzed.
• Test results conduct for the verification of accuracy, detection range and repeatability.
• Certificate of standards, if available.
For indicative analysis equipment planned to be used, the equipment OEM instruction manuals shall be available. The manuals shall include, at least, clear guidance for the proper storage, handling, operation, maintenance, repair, and calibration.
Note: Each Service Supplier applicant will present the Surveyor their confidential internal procedures for conducting the indicative testing. Not all the equipment listed in the references will be used. For all equipment planned to be used, the instruction manuals shall be available.
The Service Supplier will need to use specialty devices (e.g., sieves, screens, etc.) to separate the different organism sizes classes (i.e., ≥ 10 μm to < 50 μm, and ≥ 50 μm, and indicator microbes) to support analysis of each size class.
Equipment used for the analysis of other physical-chemical water parameters is to be suitable for the

intended use. Indicative analysis equipment should be properly stored or transported to avoid damage and disturbance to calibrations, etc. when transporting from the Service Suppliers facilities to the vessels.

18.5 Sampling and Analysis

Service Suppliers are to follow relevant guidelines on sampling of ballast water. A standard operating procedure is to be defined for sampling of uptake water. Discharge sampling shall follow the IMO's 'Guidelines for Ballast Water Sampling (G2)'. The representative samples shall be analyzed as a minimum for the two size classes of organisms, namely ≥ 50 μm and ≥ 10 μm to < 50 μm, specified in IMO Circular BWM.2/ Circ.70/Rev.1 - Guidance for the Commissioning Testing of Ballast Water Management Systems using indicative analysis methods. Detailed analysis of all organism type/size classes or combination of detail and indicative analysis can also be performed. Service Suppliers shall maintain a record of:

• Operation of the BWMS during test period, including any recorded data or operator observations associated with the performance deviations, alarms or abnormal/unexpected operations.

• Applicable self-monitoring parameters.

In case the commissioning testing requires the Service Supplier's personnel to work in hazardous areas (e.g., pump room for tankers, etc.), the Service Supplier shall have equipment certified for use in such spaces.

18.6 Reporting

Service Suppliers are to provide reports detailing the results of sampling and analysis of ballast water and assessment of self-monitoring parameters during commissioning testing. The format is to be acceptable to CCS. The report, as a minimum, will contain the following:

• Manufacturer's name;

• Model name;

• BWMS Technology limiting operating conditions and system design limitations;

• BWMS treatment mode of operation, e.g., high power, low power, single pass, IMO mode, USCG Mode, etc.;

• Treatment rated capacity (TRC) in m^3/h;

• Relevant performance parameters (e.g. TRO, UV dose, UVI, flow rate or other relevant performance parameter);

• Alarms developed during operation;

• Type Approval issued by and Certificate No.;

• Results of sample analysis;

• Pump and ballast tanks used for the commissioning test, including the flow rates and volumes of the ballasting and deballasting operations;

• Comments/Options: Filter and other major components, Process measurements.

18.7 Reference Documents

The Service Supplier is to have access to the following documents, as may be amended:

• IMO Resolution MEPC.300(72) — Code for Approval of Ballast Water Management Systems (BWMS Code);

• IMO Resolution MEPC.173(58) — Guidelines for Ballast Water Sampling (G2);

• IMO Circular BWM.2/Circ.42/Rev. 2 — Guidance on Ballast Water Sampling and Analysis for Trial Use in accordance with the BWM Convention and Guidelines (G2);

• IMO Circular BWM.2/Circ.70/Rev.1 - Guidance for the Commissioning Testing of Ballast Water Management Systems;

• IMO Circular BWM.2/Circ.61 - Guidance on Methodologies that may be used for Enumerating Viable Organisms for Type Approval of Ballast Water Management Systems;

• IMO Circular BWM.2/Circ.69 - Guidance on System Design Limitations of Ballast Water Management Systems and their Monitoring;

• IMO Resolution A.1156(32) – Survey Guidelines under the Harmonized System of Survey and Certification (HSSC), as amended (for BWMS that were Type Approved to the 2016 G8).

Appendix 9 CALIBRATION OF MEASURING EQUIPMENT

1. General requirements

1.1 Inspection, measuring and test equipment, which CCS Surveyors rely on to make decisions affecting classification or statutory certification, are to be individually identified and calibrated to a recognized national or international standard.

2. Simple measuring equipment

2.1 Simple measuring equipment means rulers, measuring tapes, weld gauges, micrometers, etc.

2.2 The Surveyor may accept simple measuring equipment without individual identification or confirmation of calibration, provided they are of standard commercial design approved by the State metrology service, properly maintained and periodically compared with other similar equipment or test pieces.

3. Shipboard equipment

3.1 The Surveyor may accept equipment fitted on board a ship and used in examination of shipboard equipment (e.g. pressure, temperature or rpm gauges and meters) based either on calibration records or comparison of readings with multiple instruments.

4. Other equipment

4.1 The Surveyor is to satisfy himself that other equipment (e.g. tensile test machines, ultrasonic thickness measurement equipment, etc.) is calibrated to a recognized national or international standard.

Appendix 10 PROCEDURES FOR CERTIFICATION OF FIRMS ENGAGED IN THICKNESS MEASUREMENT OF HULL STRUCTURES

1. Application

1.1 Appendix 8 of this Chapter and this guidance apply to certification of the firms which intend to engage in the thickness measurement of hull structures of the ships.

2. Procedures for certification

2.1 Submission of documents

2.1.1 The following documents are to be submitted to CCS for approval:

a. outline of firms, e.g. organization and management structure;

b. experiences of the firms on thickness measurement inter alia of hull structures of the ships;

c. technicians' careers, i.e. experiences of technicians as thickness measurement operators, technical knowledge of hull structure etc. Operators are to be qualified according to a recognized industrial NDT Standard;

d. equipment used for thickness measurement such as ultra-sonic testing machines and its maintenance/calibration procedures;

e. a guide for thickness measurement operators;

f. training programmes of technicians for thickness measurement.

2.1.2 Auditing of the firms: Upon reviewing the documents submitted with satisfactory results, the firm is to be audited on site by CCS in order to ascertain that the firm is duly organized and managed in accordance with the documents submitted, and eventually is capable of conducting thickness measurement of the hull construction of the ships.

2.1.3 Assessment of thickness measurement operation: Certification is to be made by CCS on an onboard demonstration at thickness measurements as well as satisfactory reporting.

3. Certification

3.1 Upon satisfactory results of both the audit of the firm in 2.1.2 and the demonstration tests in 2.1.3 above, CCS will issue a certificate of approval as well as a notice to the effect that the thickness measurement operation system of the firm has been certified by CCS.

3.2 Renewal/endorsement of the certificate is to be made at intervals not exceeding 3 years by verification that original conditions are maintained.

4. Control of any alteration to the certified thickness measurement operation system

4.1 In case where any alteration to the certified thickness measurement operation system of the firm is made, such an alteration is to be immediately informed to CCS. Re-audit is made where deemed necessary by CCS.

5. Cancellation of approval

5.1 Approval will be cancelled in the following cases:

(1) where the measurements were improperly carried out or the results were improperly reported;

(2) where CCS Surveyor found any deficiencies in the approved thickness measurement operation systems of the firm;

(3) where the firm failed to inform any alteration in 4 above to CCS.

Appendix 11 ESP SURVEY REPORTING PRINCIPLES

As a principle, for ships which are subject to the enhanced survey programme (ESP) of Appendix 2, Chapter 2 of this PART, the Surveyor is to include the following content in his report for survey of hull structure and piping systems, as relevant for the survey.

1. General

1.1 A survey report is to be generated in the following cases:

(1) in connection with commencement, continuation and/or completion of periodical hull surveys, i.e. annual, intermediate and special surveys, as relevant;

(2) when structural damages/defects have been found;

(3) when repairs, renewals or modifications have been carried out;

(4) when condition of class has been imposed or deleted.

1.2 The purpose of reporting is to provide:

(1) evidence that prescribed surveys have been carried out in accordance with applicable classification rules;

(2) documentation of surveys carried out with findings, repairs carried out and condition of class imposed or deleted;

(3) survey records, including actions taken, which are to form an auditable documentary trail. Survey reports are to be kept in the survey report file required to be on board;

(4) information for planning of future surveys;

(5) information which may be used as input for maintenance of classification rules and instructions.

1.3 When a survey is split between different survey stations, a report is to be made for each portion of the survey. A list of items inspected and/or tested (pressure test, thickness measurement, etc.) and an indication of whether the item has been credited is to be made available to the next attending Surveyor, prior to continuing or completing the survey. Thickness measurement and tank testing carried out is also to be listed for the next Surveyor.

2. Extent of the survey

2.1 Identification of compartments where an overall survey has been carried out.

2.2 Identification of locations, in each tank (for oil tanker and chemical carrier)/ballast tank and cargo hold (for bulk carrier) including hatch covers and coamings, where a close-up survey has been carried out, together with information of the means of access used.

2.3 Identification of locations, in each tank (for oil tanker and chemical carrier)/ballast tank and cargo hold (for bulk carrier) including hatch covers and coamings, where thickness measurement has been carried out.

Note: As a minimum, the identification of location of close-up survey and thickness measurement is to include a confirmation with description of individual structural members corresponding to the extent of requirements stipulated in Sections 6, 7 and 8 of this Chapter based on type of periodical survey and the ship's age.

Where only partial survey is required, i.e. one web frame ring/one deck transverse (for oil tankers), 25% of shell frames, one transverse web and two selected cargo hold transverse bulkheads (for bulk carriers), the identification is to include location within each tank (for oil tanker and chemical carrier)/ballast tank and cargo hold (for bulk carrier) by reference to frame numbers.

2.4 For areas in where protective coating is found to be in GOOD condition within a tank (for oil tanker and chemical carrier)/ballast tank and cargo hold (for bulk carrier) and the extent of close-up survey and/or thickness measurement has been specially considered, structures subject to special consideration are to be identified.

2.5 Identification of tanks subject to tank testing.

2.6 Identification of piping systems on deck, including crude oil washing (COW) piping for oil tankers, and within cargo holds, ballast tanks, pipe tunnels, cofferdams and void spaces where:

(1) examination including internal examination of piping with valves and fittings and thickness measurement, as relevant, has been carried out;

(2) operational test to working pressure has been carried out.

3. Result of the survey

3.1 Type, extent and condition of protective coating in each tank, as relevant (rated GOOD, FAIR or POOR) including identification of tanks fitted with anodes.

3.2 Structural condition of each compartment with information on the following, as relevant:

(1) Identification of findings, such as:
— corrosion with description of location, type and extent;
— areas with substantial corrosion;
— cracks/fractures with description of location and extent;
— buckling with description of location and extent;
— indents with description of location and extent.
(2) Identification of compartments where no structural damages/defects are found.
(3) The report may be supplemented by sketches/photos.
3.3 Thickness measurement report is to be verified and signed by the Surveyor controlling the measurements on board.
3.4 Evaluation result of longitudinal strength of the hull girder of oil tankers of 130 m in length and upwards and over 10 years of age. The following data is to be included, as relevant:
(1) measured and as-built transverse sectional areas of deck and bottom flanges;
(2) diminution of transverse sectional areas of deck and bottom flanges;
(3) details of renewals or reinforcements carried out, as relevant (as per 4.2).

4. Actions taken with respect to findings
4.1 Whenever the attending Surveyor is of the opinion that repairs are required, each item to be repaired is to be identified in the survey report. Whenever repairs are carried out, details of the repairs effected are to be reported by making specific reference to relevant items in the the survey report.
4.2 Repairs carried out are to be reported with identification of:
(1) compartment;
(2) structural member;
(3) repair method (i.e. renewal or modification);
① steel grades and scantlings (if different from the original);
② sketches/photos, as appropriate;
(4) repair extent;
(5) NDT/tests.
4.3 For repairs not completed at the time of survey, condition of class is to be imposed with a specific time limit for the repairs. In order to provide correct and proper information to the Surveyor attending for survey of the repairs, condition of class is to be sufficiently detailed with identification of each item to be repaired. For identification of extensive repairs, reference may be given to the survey report.

Report 1
EXECUTIVE HULL SUMMARY FOR OIL TANKER/CHEMICAL TANKER
(Issued upon Completion of Special Survey)

General particulars

Ship's name		Class identify number	
Port of registry		IMO identify number	
Deadweight (t)		National flag	
Date of build		Gross tonnage	
Date of major conversion		Classification notation	
Type of conversion		Owner	

a) The survey reports and documents listed below have been reviewed by the undersigned and found to be satisfactory.
b) A summary of the survey is attached herewith on sheet 2.
c) The hull special survey has been completed in accordance with the Rules on [date].

Executive Summary Report completed by:	Name: Signature:	Title:
OFFICE	DATE	
Executive Summary Report verified by:	Name: Signature:	Title:
OFFICE	DATE	

Attached reports and documents:
1)
2)
3)
4)
5)
6)

EXECUTIVE HULL SUMMARY

A) General particulars:	– Refer to previous page
B) Report review:	– Where and how survey was done
C) Close-up survey:	– Extent (which tanks)
D) Cargo & ballast piping system	– Examined
	– Operationally tested
E) Thickness measurements:	– Reference to thickness measurement report
	– Summary of where measured
	– Separate form indicating the tanks/areas with substantial corrosion, and corresponding
	* Thickness diminution
	* Corrosion pattern
F) Tank protection	Separate form indicating:
	– Location of coating
	– Condition of coating (if applicable)
G) Repairs:	– Identification of tanks/areas
H) Condition of class:	
I) Memoranda:	– Acceptable defects
	– Any points of attention for future surveys, e.g. for suspect areas
	– Examination of ballast tanks at annual surveys due to coating breakdown

J) Evaluation results of the ship's longitudinal strength (for oil tankers of 130 m in length and upwards and of over 10 years of age)

K) Conclusion	– Statement on evaluation/verification of survey report

EXTRACT OF THICKNESS MEASUREMENTS (NON-CSR SHIPS)

(Reference is made to the thickness measurements report)

1) Positions of substantially corroded tanks/areas or areas with deep pitting	Thickness diminution [%]	2) Corrosion pattern	Remarks: e.g. ref. attached sketches

Remarks:

1) Substantial corrosion, i.e. 75% to 100% of acceptable margins wasted.

2) P = Pitting;

C = Corrosion in general.

Any bottom plating with a pitting intensity of 20% or more, with wastage in the substantial corrosion range or having an average depth of pitting of 1/3 or more of actual plate thickness is to be noted.

EXTRACT OF THICKNESS MEASUREMENTS (CSR SHIPS)

(Reference is made to the thickness measurements report)

1) Positions of substantially corroded tanks/areas or areas with deep pitting	$t_m - t_{ren}$ (mm)	2) Corrosion pattern	Remarks: e.g. ref. attached sketches

Remarks:

1) Substantial corrosion, an extent of corrosion such that the assessment of the corrosion pattern indicates a measured thickness between t_{ren} + 0.5mm and t_{ren}.

2) P = Pitting C = Corrosion in general

Areas with deep pitting assessed according to 5.1.17, Chapter 5 of this PART are to be recorded in this column.

TANK PROTECTION

1) Tank Nos.	2) Tank protection	3) Coating condition	Remarks

Remarks:
1) All segregated ballast tanks and combined cargo/ballast tanks to be listed.
2) C = Coating; NP = No Protection.
3) Coating condition according to the following standard:
GOOD condition with only minor spot rusting;
FAIR condition with local breakdown at edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for POOR condition;
POOR condition with general breakdown of coating over 20% or more of areas or hard scale at 10% or more of areas under consideration.

For ballast tanks, if coating condition less than "GOOD" is given, tanks are to be examined at annual surveys. This is to be noted in part I) of the Executive Hull Summary.

Evaluation result of longitudinal strength of the hull girder of oil tankers of 130 m in length and upwards and of over 10 years of age
(Of sections 1, 2 and 3 below, only one applicable section is to be completed)

1 This section applies to ships regardless of the date of construction: Transverse sectional areas of deck flange (deck plating and deck longitudinals) and bottom flange (bottom shell plating and bottom longitudinals) of the ship's hull girder have been calculated by using the thickness measured, renewed or reinforced, as appropriate, during the special survey most recently conducted after the ship reached 10 years of age, and found that the diminution of the transverse sectional area does not exceed 10% of the as-built area, as shown in Table 1:

Transverse Sectional Area of Hull Girder Flange **Table 1**

		Measured	As-built	Diminution
Transverse section 1	Deck flange	cm^2	cm^2	cm^2 (%)
	Bottom flange	cm^2	cm^2	cm^2 (%)
Transverse section 2	Deck flange	cm^2	cm^2	cm^2 (%)
	Bottom flange	cm^2	cm^2	cm^2 (%)
Transverse section 3	Deck flange	cm^2	cm^2	cm^2 (%)
	Bottom flange	cm^2	cm^2	cm^2 (%)

2 This section applies to ships constructed on or after 1 July 2002: Section moduli of transverse section of the ship's hull girder have been calculated by using the thickness of structural members measured, renewed or reinforced, as appropriate, during the special survey most recently conducted after the ship reached 10 years of age in accordance with the provisions of 2.2.1(1) of Appendix 2 of this Chapter, and are found to be within their diminution limits determined by CCS①, as shown in Table 2:

Transverse Section Modulus of Hull Girder **Table 2**

		Z_{act} (cm^3) (1)	Z_{req} (cm^3) (2)	Remarks
Transverse section 1	Upper deck			
	Bottom			
Transverse section 2	Upper deck			
	Bottom			
Transverse section 3	Upper deck			
	Bottom			

Notes: (1) Z_{act} means the actual section moduli of the transverse section of the ship's hull girder calculated by using the thickness of structural members measured, renewed or reinforced, as appropriate, during the special survey, in accordance with the provisions of 2.2.1(1) of Appendix 2 of this Chapter.
(2) Z_{req} means diminution limit of the longitudinal bending strength of ships, as calculated in accordance with the provisions of 2.2.1(1) of Appendix 2 of this Chapter. The calculation sheets for Zact are to be attached to this report.

3 This section applies to ships constructed before 1 July 2002: Section moduli of transverse section of the ship's hull girder have been calculated by using the thickness of structural members measured, renewed or reinforced, as appropriate, during the special survey most recently conducted after the ship reached 10 years of age in accordance with the provisions of 2.2.1(2) of Appendix 2 of this Chapter, and found to meet the criteria required by CCS and that Z_{act} is not less than Z_{mc} (defined in note 2 of Table 3) as specified in Annex 2 to Appendix 2 of this PART, as shown in Table 3. Describe the criteria for acceptance of the minimum section moduli of the ship's hull girder for ships in service required by CCS.

Transverse Section Modulus of Hull Girder **Table 3**

		Z_{act} (cm^3) (1)	Z_{mc} (cm^3) (2)	Remarks
Transverse section 1	Upper deck			
	Bottom			
Transverse section 2	Upper deck			
	Bottom			
Transverse section 3	Upper deck			
	Bottom			

Notes: (1) As defined in note *1 of Table 2.
(2) Z_{mc} means the diminution limit of minimum section modulus calculated in accordance with provisions of 2.2.1(2) of Appendix 2 of this Chapter.

---

① The actual transverse section modulus of the hull girder of oil tankers calculated under 2.2.1(1) of Appendix 2 of this Chapter is not to be less than 90% of the required section modulus for new buildings specified in IACS Unified Requirements S7 (C = 1.0 C_n is to be used for the purpose of this calculation.) or S11, whichever is the greater.

Report 2
EXECUTIVE HULL SUMMARY FOR BULK CARRIER
(Issued upon Completion of Special Survey)

General particulars

Ship's name		Class identify number	
Port of registry		Imo identify number	
Deadweight (t)		National flag	
Date of build		Gross tonnage	
Date of major conversion		Classification notation	
Type of conversion		Owner	

a) The survey reports and documents listed below have been reviewed by the undersigned and found to be satisfactory.
b) A summary of the survey is attached herewith on sheet 2.
c) The hull special survey has been completed in accordance with the Rules on [date].

Executive Summary Report completed by:	Name: Signature:	Title:
OFFICE	DATE	
Executive Summary Report verified by:	Name: Signature:	Title:
OFFICE	DATE	

Attached reports and documents:
1)
2)
3)
4)
5)
6)

EXECUTIVE HULL SUMMARY

A) General particulars:	– Refer to previous page
B) Report review:	– Where and how survey was done
C) Close-up survey:	– Extent (which tanks)
D) Thickness measurements:	– Reference to thickness measurement report
	– Summary of where measured
	– Separate form indicating the tanks/areas with substantial corrosion, and corresponding
	* Thickness diminution
	* Corrosion pattern
E) Tank/hold/double-side skin void space Protection	Separate form indicating: – Location of coating
	– Condition of coating (if applicable)
F) Repairs:	– Identification of tanks/areas
G) Condition of class:	
H) Memoranda:	– Acceptable defects
	– Any points of attention for future surveys, e.g. for suspect areas
	– Examination of ballast tanks and double-side skin void spaces at annual surveys due to coating breakdown
I) Conclusion	– Statement on evaluation/verification of survey report

EXTRACT OF THICKNESS MEASUREMENTS (NON-CSR SHIPS)

(Reference is made to the thickness measurements report)

1) Positions of substantially corroded tanks/areas or areas with deep pitting	Thickness diminution [%]	2) Corrosion pattern	Remarks: e.g. ref. attached sketches

Remarks:

1) Substantial corrosion, i.e. 75% to 100% of acceptable margins wasted.

2) P = Pitting

C = Corrosion in general

Any bottom plating with a pitting intensity of 20% or more, with wastage in the substantial corrosion range or having an average depth of pitting of 1/3 or more of actual plate thickness is to be noted.

EXTRACT OF THICKNESS MEASUREMENTS (CSR SHIPS)

(Reference is made to the thickness measurements report)

1) Positions of substantially corroded tanks/areas or areas with deep pitting	$t_m - t_{ren}$ (mm)	2) Corrosion pattern	Remarks: e.g. ref. attached sketches

Remarks:

1) Substantial corrosion, an extent of corrosion such that the assessment of the corrosion pattern indicates a measured thickness between t_{ren} + 0.5mm and t_{ren}.

2) P = Pitting
   C = Corrosion in general

Areas with deep pitting assessed according to 5.1.17, Chapter 5 of this PART are to be recorded in this column.

SPACE PROTECTION

1) Tank/hold/void Nos.	2) Tank/hold/void protection	3) Coating condition	Remarks

Remarks:
1) All ballast tanks, cargo holds and double-side skin void spaces to be listed.
2) C = Coating; NP = No Protection
3) Coating condition according to the following standard:

GOOD condition with only minor spot rusting;
FAIR condition with local breakdown at edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for POOR condition;
POOR condition with general breakdown of coating over 20% or more of areas or hard scale at 10% or more of areas under consideration.

For ballast tanks, if coating condition less than "GOOD" is given, tanks are to be examined at annual surveys. This is to be noted in part H) of the Executive Hull Summary.
For double-side skin void spaces on bulk carriers exceeding 20 years of age and of 150 m in length and upwards, if coating condition POOR is given, those voids are to be examined at annual surveys. This is to be noted in part H of Executive Hull Summary.

Appendix 11A SURVEY PROGRAMME

Basic information and particulars

Name of ship:
IMO number:
Flag State:
Port of registry:
Gross tonnage:
Deadweight (t):
Length between perpendiculars (m):
Shipbuilder:
Hull number:
Classification society:
Class ID:
Date of delivery of the ship:
Owner:
Thickness measurement company:

1 Preamble

1.1 Scope

(1) The present survey programme covers the minimum extent of overall surveys, close-up surveys, thickness measurements and pressure testing within the cargo (length) area, cargo holds, ballast tanks, including fore and aft peak tanks, required by Sections 6 to 8 of this Chapter.

(2) The arrangements and safety aspects of the survey should be acceptable to the attending Surveyor(s).

1.2 Documentation

All documents used in the development of the survey programme should be available onboard during the survey as required by 5.1.7 of this Chapter.

2 Arrangement of cargo holds, tanks and spaces

This section of the survey programme should provide information (either in the form of plans or text) on the arrangement of cargo holds, tanks and spaces that fall within the scope of the survey.

3 List of cargo holds, tanks and spaces with information on their use, extent of coatings and corrosion protection system

This section of the survey programme should indicate any changes relating to (and should update) the information on the use of the holds and tanks of the ship, the extent of coatings and the corrosion protective system provided in the Survey Planning Questionnaire set out in Appendix 11B of this Chapter.

4 Conditions for survey

This section of the survey programme should provide information on the conditions for survey, e.g. information regarding cargo hold and tank cleaning, gas freeing, ventilation, lighting, etc.

5 Provisions and method of access to structures

This section of the survey programme should indicate any changes relating to (and should update) the information on the provisions and methods of access to structures provided in the Survey Planning Questionnaire set out in Appendix 11B of this Chapter.

6 List of equipment for survey

This section of the survey programme should identify and list the equipment that will be made available for carrying out the survey and the required thickness measurements.

7 Survey requirements

7.1 Overall survey

This section of the survey programme should identify and list the spaces that should undergo an overall survey for this ship in accordance with Sections 6 to 8 of this Chapter.

7.2 Close-up survey

This section of the survey programme should identify and list the hull structures that should undergo a close-up survey for this ship in accordance with Sections 6 to 8 of this Chapter.

8 Identification of tanks for tank testing

This section of the survey programme should identify and list the cargo holds and tanks that should undergo tank testing for this ship in accordance with Sections 6 to 8 of this Chapter.

9 Identification of areas and sections for thickness measurements

This section of the survey programme should identify and list the areas and sections where thickness measurements should be taken in accordance with Sections 6 to 8 of this Chapter.

10 Minimum thickness of hull structures

This section of the survey programme should specify the minimum thickness for hull structures of this ship that are subject to survey, (indicate either (1) or preferably (2), if such information is available):

(1) determined from the attached wastage allowance table and the original thickness to the hull structure plans of the ship;

(2) given in the following Table(s):

Area or location	Applicable ship type			Original as-built thickness (mm)	Minimum thickness (mm)	Substantial corrosion thickness (mm)
	B	**O**	**C**			
Deck	X	X	X			
Plating	X	X	X			
Longitudinals	X	X	X			
Longitudinal girders	X	X	X			
Cross deck plating	X					
Cross deck stiffeners	X					
Bottom	X	X	X			
Plating	X	X	X			
Longitudinals	X	X	X			
Longitudinal girders	X	X	X			
Ship side		X	X			
Plating		X	X			
Longitudinals		X	X			
Longitudinal girders		X	X			
Inner bottom	X	X	X			
Plating	X	X	X			
Longitudinals	X	X	X			
Longitudinal girders	X	X	X			
Floors	X					
Ship side in way of topside tanks	X					
Plating	X					
Longitudinals	X					
Ship side in way of hopper side tanks	X					
Plating	X					
Longitudinals	X					
Ship side in way of tanks	X_p					
Plating	X					
Longitudinals or ordinary	X					

Area or location	Applicable ship type			Original as-built thickness (mm)	Minimum thickness (mm)	Substantial corrosion thickness (mm)
	B	**O**	**C**			
transverse frames						
Longitudinal stringers	X					
Ship side in way of cargo holds	X					
Plating	X					
Side frames webs	X					
Side frames flanges	X					
Upper brackets webs	X					
Upper brackets flanges	X					
Lower brackets webs	X					
Lower brackets flanges	X					
Longitudinal bulkhead	X_p	X	X			
Plating	X	X	X			
Longitudinals	X_p	X	X			
Longitudinal girders	X_p	X	X			
Transverse bulkheads	X	X	X			
Plating	X	X	X			
Stiffeners	X_p	X	X			
Upper stool plating	X					
Upper stool stiffeners	X					
Lower stool plating	X					
Lower stool stiffeners	X					
Transverse web frames in topside tanks	X					
Plating	X					
Flanges	X					
Stiffeners	X					
Transverse web frames in hopper tanks	X					
Plating	X					
Flanges	X					
Stiffeners	X					
Hatch Covers	X					
Plating	X					
Stiffeners	X					
Hatch Coamings	X					
Plating	X					
Stiffeners	X					
Transverse web frames, floors and stringers and (for chemical tankers) diaphragms		X	X			
Plating		X	X			
Flanges		X	X			
Stiffeners		X	X			
Cross ties		X				
Flanges		X				
Webs		X				

Notes: The wastage allowance tables are to be attached to the survey programme.

X – applicable; X_p – if applicable; B – bulk carrier; O – oil tanker; C – chemical tanker.

For CSR ships, the renewal thickness of the hull structure elements is to be indicated in the appropriate drawings.

11 Thickness measurement company

This section of the survey programme should identify changes, if any, relating to the information on the thickness measurement company provided in the Survey Planning Questionnaire.

12 Damage experience related to the ship

This section of the survey programme should, using the tables provided below, provide details of the hull damages for at least the last three years in way of the cargo holds, ballast tanks and void spaces within the cargo length area. These damages are subject to survey.

Hull Damages Sorted by Location for This Ship

Cargo hold, tank or space number or area	Possible cause, if known	Description of the damages	Location	Repair	Date of repair

Hull Damages for Sister or Similar Ships (if available) in the Case of Design Related Damage

Cargo hold, tank or space number or area	Possible cause, if known	Description of the damages	Location	Repair	Date of repair

13 Areas identified with substantial corrosion from previous surveys

This section of the survey programme should identify and list the areas of substantial corrosion from previous surveys.

14 Critical structural areas and suspect areas

This section of the survey programme should identify and list the critical structural areas and the suspect areas, when such information is available.

15 Other relevant comments and information

This section of the survey programme should provide any other comments and information relevant to the survey.

Appendices

Appendix 1 − List of plans

5.1.6.5(3) of this Chapter requires that main structural plans of cargo holds and ballast tanks (scantling drawings), including information regarding use of high tensile steel (HTS), clad steel and stainless steel should be available.

This Appendix of the survey programme should identify and list the main structural plans which form part of the survey programme.

Appendix 2 − Survey Planning Questionnaire

The Survey Planning Questionnaire (Appendix 11B of this Chapter), which has been submitted by the

owner, should be appended to the survey programme.

Appendix 3 − Other documentation

This part of the survey programme should identify and list any other documentation that forms part of the plan.

Prepared by the owner in co-operation with CCS for compliance with 5.1.6.5(3) of this Chapter:
Date: ..... (name and signature of authorized owner's representative)
Date: ..... (name and signature of CCS Surveyor).

Appendix 11B SURVEY PLANNING QUESTIONNAIRE

(Bulk Carriers/Oil Tankers/Chemical tankers)

1 The following information will enable the owner in co-operation with CCS to develop a survey programme complying with the requirements of this Chapter. It is essential that the owner provides, when completing the present questionnaire, up-to-date information. The present questionnaire, when completed, is to provide all information and material required by this Chapter.

Particulars

Ship's name:
IMO number:
Flag State:
Port of registry:
Owner:
Classification society:
Class ID:
Gross tonnage:
Deadweight (t):
Date of build:

Information on access provision for close-up surveys and thickness measurement

2 The owner is to indicate, in the table below, the means of access to the structures subject to close-up survey and thickness measurement.

Hold/ Tank No.	Structure	①C (Cargo)/B (ballast tank)	Permanent means of access	Temporary means of access	Rafts	Ladders	Direct access	Other means (please specify)
F.P. (oil tankers/ bulk carriers/ chemical tankers)	Fore peak							
A.P. (oil tankers/ bulk carriers/ chemical tankers)	Aft peak							
Cargo holds (bulk carriers)	Hatch side coamings							
	Topside sloping plate							
	Upper stool plating							
	Cross deck							
	Side shell, frames & brackets							
	Transverse bulkhead							
	Hopper tank platting							
	Lower stool							
	Tank top plating							
Wing tanks (oil tankers/ chemical tankers)	Under deck							
	Side shell							
	Bottom transverse							
	Longitudinal							
	Transverse							
Center tanks (oil tankers/	Under deck							
	Bottom							

Hold/ Tank No.	Structure	①C (Cargo)/B (ballast tank)	Permanent means of access	Temporary means of access	Rafts	Ladders	Direct access	Other means (please specify)
chemical tankers)	transverse							
	Transverse							
Topside tanks (bulk carriers)	Underdeck structure							
	Side shell & structure							
	Sloping plate & structure							
	Webs & bulkheads							
Double side skin tanks (double skin bulk carriers)	Side shell & structure							
	Inner skin & structure							
	Webs and bulkheads							
Hopper tanks (bulk carriers)	Hopper sloping plate & structure							
	Side shell & structure							
	Bottom structure							
	Webs & bulkheads							
	Double bottom structure (bulk carriers)							
	Upper stool internal structure (bulk carriers)							
	Lower stool internal structure (bulk carriers)							
Wing tanks of ore carriers	Underdeck & structure							
	Side shell & structure							
	Side shell vertical web & structure							
	Longitudinal bulkhead & structure							
	Longitudinal bulkhead web & structure							
	Bottom plating & structure							
	Cross ties/stringers							

History of cargoes②

① Applicable to oil tankers.

② For bulk carriers, history of bulk cargoes of a corrosive nature (e.g. high sulphur content) for bulk carriers;
For oil tankers, history of cargo with H_2S content or heated cargo for the last 3 months together with indication as to whether cargo was heated and, where available, Marine Safety Data Sheets (MSDS)*;
For chemical tankers, history of heated cargo for the last 3 years together with indication as to whether cargo was heated.

* Refer to resolution MSC.150(77) on Recommendation for Material Safety Data Sheets for MARPOL Annex I Cargoes and Marine Fuel Oils.

Owner's inspections

3 Using a format similar to that of the table below (which is given as an example), the owner is to provide details of the results of their inspections for the last 3 years on all cargo and ballast tanks and void spaces within the cargo area in accordance with the requirements of this Chapter.

Tank/Hold No.	Corrosion protection (1)	Coating extent (2)	Coating condition (3)	Structural deterioration (4)	Hold and tank history (5)
Cargo holds (bulk carriers)					
Cargo centre tanks (oil tankers/ chemical tankers)					
Cargo wing tanks (oil tankers/ chemical tankers)					
Slop tanks (oil tankers)					
Topside tanks (bulk carriers)					
Hopper tanks (bulk carriers)					
Double side skin tanks (bulk carriers)					
Double bottom tanks (bulk carriers)					
Upper stools (bulk carriers)					
Lower stools (bulk carriers)					
Wing tanks (ore carriers)					
Ballast tanks (oil tankers/ chemical tankers)					
Fore peak (oil tankers/bulk carriers/ chemical tankers)					
Aft peak (oil tankers/bulk carriers/ chemical tankers)					
Miscellaneous other spaces (oil tankers/ bulk carriers/ chemical tankers)					

Note: Indicate tanks which are used for oil/ballast.

1) HC = hard coating; SC = soft coating; SH = semi-hard coating; NP = no protection
2) U = upper part; M = middle part; L = lower part; C = complete
3) G = good; F = fair; P = poor; RC = recoated (during the last 3 years)
4) N = no findings recorded; Y = findings recorded (Description of findings is to be attached to this questionnaire)
5) DR = Damage & Repair; L = Leakages; CV = Conversion (Description to be attached to this questionnaire)

Name of owner's representative:

Signature:

Date:

Reports of Port State Control inspections

List the reports of Port State Control inspections containing hull structural related deficiencies and relevant information on rectification of the deficiencies:

Safety Management System

List non-conformities related to hull maintenance, including the associated corrective actions:

Name and address of the approved thickness measurement company:

Appendix 12 GUIDELINES FOR TECHNICAL ASSESSMENT IN CONJUNCTION WITH PLANNING FOR ENHANCED SURVEYS AND OWNER'S INSPECTION REPORT

1 Guidelines for technical assessment in conjunction with planning for enhanced surveys

1.1 Introduction

These guidelines contain information and suggestions concerning technical assessments, which may be of use in conjunction with the planning of enhanced special surveys of oil tankers, bulk carriers and chemical tankers. See 5.1.6.5(5) of this Chapter①.The guidelines are a recommended tool which may be invoked at the discretion of CCS, when considered necessary and appropriate, in conjunction with the preparation of the required survey programme.

1.2 Purpose and principles

1.2.1 The purpose of the technical assessments described in these guidelines is to assist in identifying critical structural areas, nominating suspect areas and in focusing attention on structural elements or areas of structural elements which may be particularly susceptible to, or evidence a history of, wastage or damage. This information may be useful in nominating locations, areas, holds and tanks for thickness measurement, close-up survey and tank testing.

1.2.2 These guidelines may not be used to reduce the requirements pertaining to thickness measurement, close-up survey and tank testing contained in Sections 6, 7 and 8, Chapter 5 of this PART, which are, in all cases, to be complied with as a minimum.

1.2.3 As with other aspects of survey planning, the technical assessments described in these guidelines should be worked out by the owner or operator in cooperation with CCS well in advance of the commencement of the special survey, i.e. prior to commencing the survey and normally at least 12 to 15 months before the survey's completion due date.

1.2.4 Aspects to be considered

1.2.4.1 Technical assessments, which may include quantitative or qualitative evaluation of relative risks of possible deterioration of the following aspects of a particular ship, may be used as a basis for the nomination of holds, tanks and areas for survey:

(1) design features such as stress levels on various structural elements, design details and extent of use of high tensile steel;

(2) former history with respect to corrosion, cracking, buckling, indents and repairs for the particular ship as well as similar ships, where available;

(3) information with respect to types of cargo carried, use of different holds/tanks for cargo/ballast, protection of holds and tanks and condition of coating, if any.

1.2.4.2 Technical assessments of the relative risks of susceptibility to damage or deterioration of various structural elements and areas are to be judged and decided on the basis of recognized principles and practices, such as may be found in publications of Tanker Structure Cooperative Forum (TSCF), (Refs.2 and 3)② and Bulk Carriers-Guidelines for Surveys, Assessment and Repair of Hull Structure (IACS), (Ref. 4).

1.3 Technical assessment

1.3.1 General requirements

1.3.1.1 There are three basic types of possible failure, which may be the subject of technical assessment in connection with planning of surveys: corrosion, cracks and buckling. Contact damages are not normally covered by the survey planning since indents are usually noted in memoranda and assumed to be dealt with as a normal routine by Surveyors.

1.3.1.2 Technical assessments performed in conjunction with the survey planning process are, in principle,

---

① Ref.1: For hull survey of chemical tankers, see Section 8 of this Chapter. For hull survey of oil tankers and bulk carriers, see TSCF Guidance Manual for the Inspection and Condition Assessment of Tanker Structures (1986). For hull survey of double hull oil tankers, see IACS Rec 96 Double Hull Oil Tankers – Guidelines for Surveys, Assessment and Repair of Hull Structures, 2019. For hull survey of double-side skin bulk carriers, see IACS Rec 76 IACS Guidelines for Surveys, Assessment and Repair of Hull Structure – Bulk Carriers, 2007.

② Ref.2: For hull survey of oil tankers and bulk carriers, see TSCF Condition Evaluation and Maintenance of Tanker Structures (1992). For hull survey of chemical tankers, double hull oil tankers and double-side skin bulk carriers, see TSCF Guidelines for the Inspection and Maintenance of Double Hull Tanker Structures (1995); Ref.3: For hull survey of chemical tankers, double hull oil tankers and double-side skin bulk carriers, see TSCF Guidance Manual for Tanker Structures (1997). For hull survey of bulk carriers, see IACS Rec 76 IACS Guidelines for Surveys, Assessment and Repair of Hull Structure – Bulk Carriers, 2007.

to be as shown schematically in Figure 1.3.1.2, which indicates how to perform technical assessments in conjunction with the survey planning process.
The approach is basically an evaluation of the risk based on the knowledge and experience related to design and corrosion.
The design is to be considered with respect to structural details, which may be susceptible to buckling or cracking as a result of vibration, high stress levels or fatigue.
Corrosion is related to the ageing process, and is closely connected with the quality of corrosion prevention systems fitted at newbuilding, and subsequent maintenance during the service life. Corrosion may also lead to cracking and/or buckling.

1.3.2 Methods

1.3.2.1 Design details

Damage experience related to the ship in question and sister and similar ships, where available, is the main source of information to be used in the process of planning. In addition, a selection of structural details from the design drawings is to be included.
Typical damage experience to be considered will consist of:
— number, extent, location and frequency of cracks;
— location of buckles.
This information may be found in the survey reports and/or the owner's files, including the results of the owner's own inspections. The defects are to be analyzed, noted and marked on sketches.
In addition, general experience is to be utilized. For example, reference is to be made to TSCF's two publications (Refs.2 and 3) and IACS's "Bulk Carriers: Guidelines for Survey, Assessment and Repair of Hull Structures" (Ref. 4) which contains a catalogue of typical damages and proposed repair methods for various structural details of tankers and bulk carriers.
Such figures are to be used together with a review of the main drawings, in order to compare with the actual structure and search for similar details that may be susceptible to damage. Reference is made to examples in Figures 1.3.2.1(1) to (3). In particular, Chapter 3 of Ref. 2 deals with various aspects specific to double hull tankers, such as stress concentration locations, misalignment during construction, corrosion trends, fatigue considerations and areas requiring special attention, which are to be considered in working out the survey planning.
The review of the main structural drawings, in addition to using the above-mentioned figures, is to include checking for typical design details where cracking has been experienced. The factors contributing to damage are to be carefully considered.
The use of high tensile steel (HTS) is an important factor. Details showing good service experience where ordinary, mild steel has been used may be more susceptible to damage when HTS, and its higher associated stresses, are utilized. There is extensive and, in general, good experience, with the use of HTS for longitudinal material in deck and bottom structures. Experience in other locations, where the dynamic stresses may be higher, is less favourable, e.g. side structures.
In this respect, stress calculations of typical and important components and details, in accordance with the latest Rules or other relevant methods may prove useful and are to be considered.
The selected areas of the structure identified during this process should be recorded and marked on the structural drawings to be included in the survey programme.

1.3.2.2 Corrosion

In order to evaluate relative corrosion risks, the following information is generally to be considered:
— usage of tanks, holds and spaces;
— condition of coatings;
— cleaning procedures;
— previous corrosion damage;
— ballast use and time for oil cargo holds/cargo holds;
— planning of risk of corrosion (referring to Ref. 3). Special attention is to be given to the areas where the double hull tanker is particularly exposed to corrosion. To this end, the specific aspects addressing corrosion in double hull tankers indicated in 3.4 (Corrosion trends) of Ref. 2 are to be taken into account;
— location of heated tanks.
Ref. 3 gives definitive examples which can be used for judging and describing coating condition, using typical pictures of conditions.
The evaluation of corrosion risks is to be based on information in Ref.3, together with relevant information on the anticipated condition of the ship as derived from the information collected in order to prepare the survey programme and the age of the ship.
The various holds, tanks and spaces are to be listed with the corrosion risks nominated accordingly.

1.3.2.3 Locations for close-up survey and thickness measurement

On the basis of the table of corrosion risks and the evaluation of design experience, the locations for initial close-up survey and thickness measurement (areas and sections) may be nominated.

The sections subject to thickness measurement are to normally be nominated in tanks, holds and spaces where corrosion risk is judged to be the highest.

The nomination of tanks, holds and spaces for close-up survey is to, initially, be based on highest corrosion risk, and is to always include ballast tanks. The principle for the selection is to be that the extent is increased by age or where information is insufficient or unreliable.

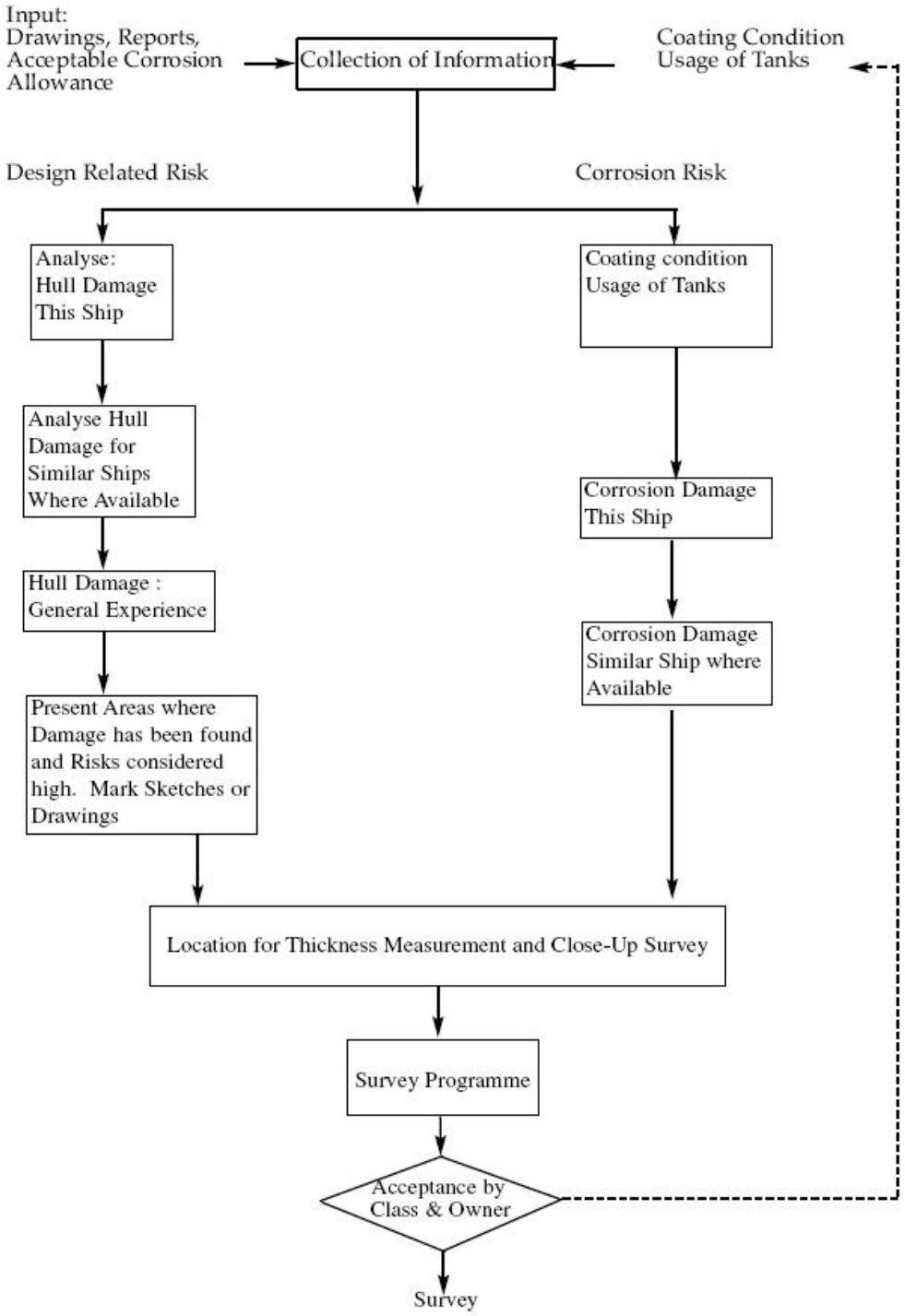
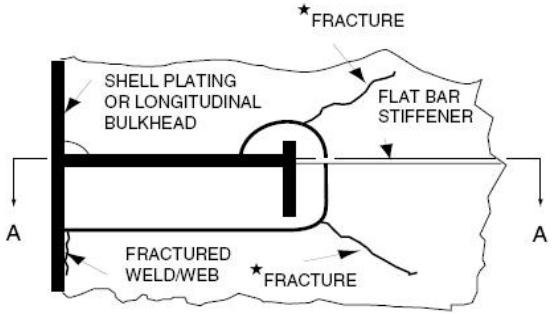
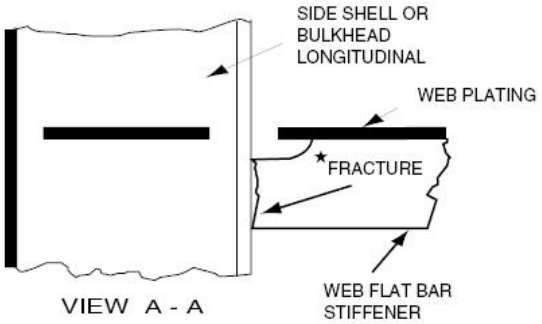


Figure 1.3.1.2 Technical Assessment & the Survey Planning Process

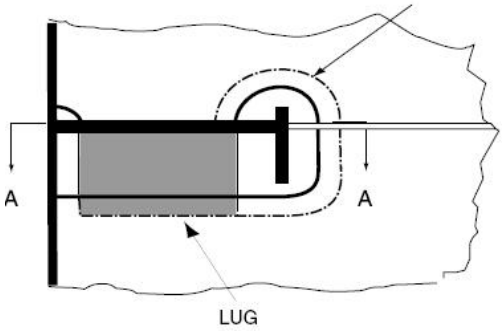
Location: Connection of longitudinals to transverse webs Example No.1 : Web and flat bar fractures at cut-outs for longitudinal stiffener connections	
Typical Damage	Proposed Repair

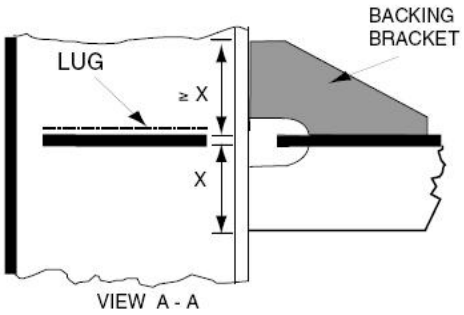




Note: One or more fractures may occur

Full collar if fractures in web plate are small and are repaired by welding





Web and flat bar cropped and part renewed or alternatively welded

Factors contributing to damage:

1. Asymmetrical connection of flat bar stiffener resulting in high peak stresses at the heel of the stiffener under fatigue loading.
2. Insufficient area of connection of longitudinal to web plate.
3. Defective weld at return around the plate thickness.
4. High localized corrosion at areas of stress concentration such as flat bar stiffener connections, corners of cut-out for the longitudinal and connection of web to shell at cut-outs.
5. High stress in the web of the transverse.
6. Dynamic sea way load/ship motions.

Figure 1.3.2.1(1) Typical Damage and Repair Example (Tanker) (Reproduced From Ref.2)

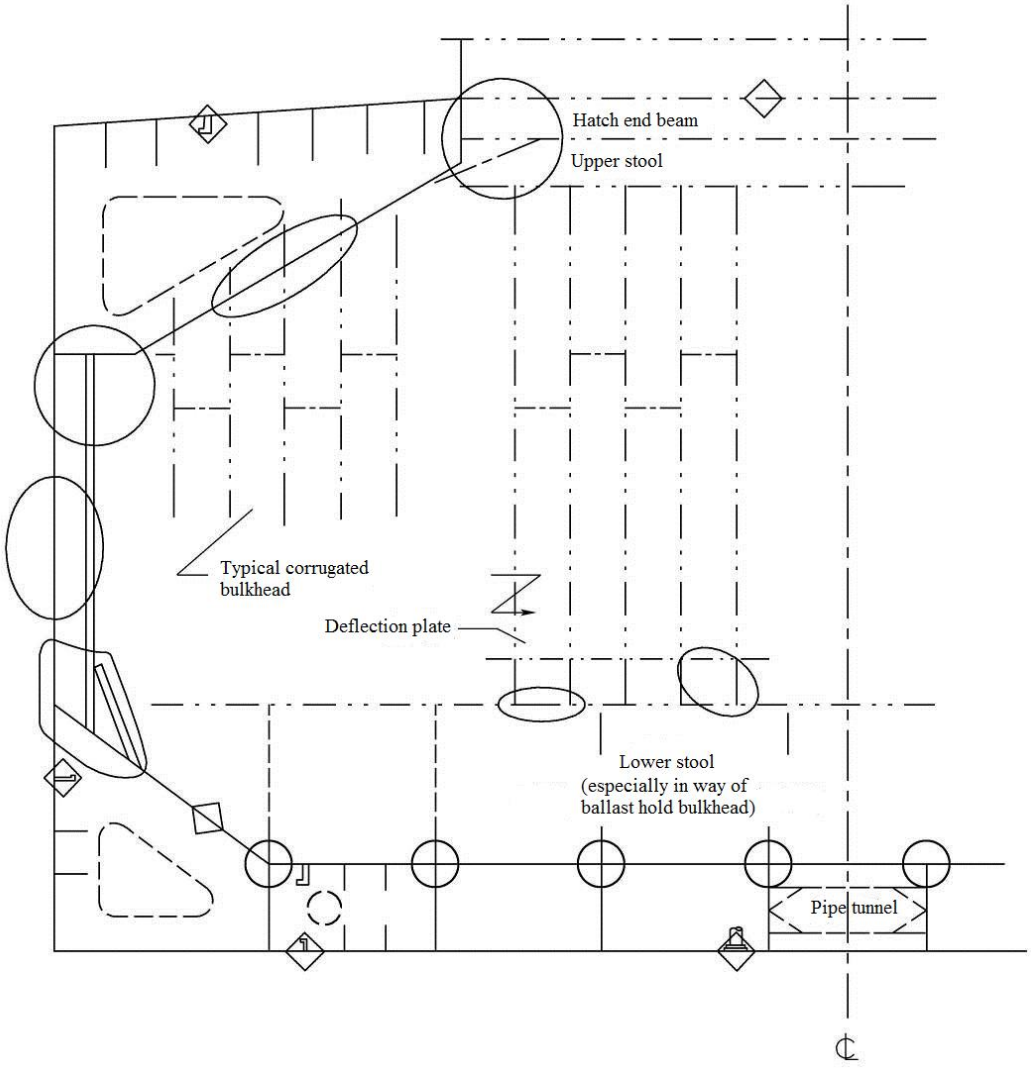
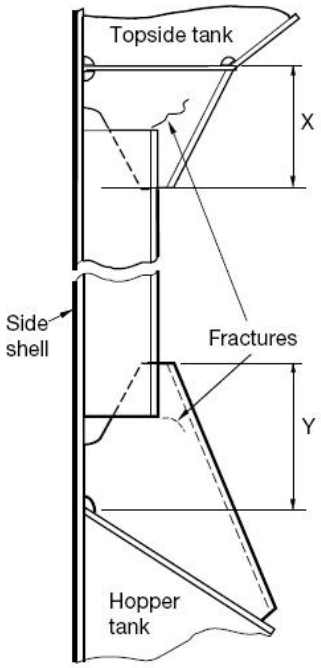
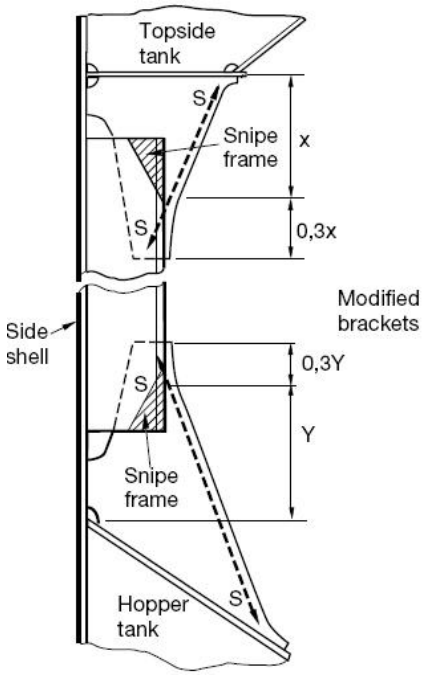


Figure 1.3.2.1(2) Typical Locations Susceptible to Structural Damage or Corrosion (Bulk Carrier)

<table>
<tr><td>Area 1</td><td>Structural item</td><td>Side shell frames and end brackets (separate bracket configuration)</td><td>Example 1</td></tr>
<tr><td colspan="2">Detail of damage</td><td colspan="2">Fractures in brackets at termination of frame</td></tr>
<tr><td colspan="2">Sketch of damage
 

Separate bracket configuration</td><td colspan="2">Sketch of repair
 

S = Sniped end</td></tr>
<tr><td colspan="2">Notes on possible cause of damage:
This type of damage is due to stress concentration.</td><td colspan="2">Notes on repairs:
1. For small fractures e.g. hairline fractures, the fracture can be ‘veed’ out, welded up, ground and examined by NDT for fractures.
2. For large/significant fractures, consideration is to be given to cropping and partly renewing/renewing the frame brackets. If renewing the brackets, end of frames can be sniped to soften them.
3. If felt prudent, soft toes are to be incorporated at the boundaries of the bracket to the wing tanks.
4. Attention to be given to the structure in wing tanks in way of the extended bracket arm, i.e. reinforcement provided in line with the bracket arm</td></tr>
</table>

Note: The above Refs.2 and 3 are both from Tanker Structure Cooperative Forum (TSCF), and Ref.4 from Bulk Carriers-Guidelines for Surveys, Assessment and Repair of Hull Structure (IACS).

Figure 1.3.2.1(3) Typical Damage and Repair Example (Bulk Carrier) (Reproduced from Ref.4)

2 Owner's inspection report

Owner's Inspection Report – Structural Condition

Ship name:_____ For tank/hold No:_____

Grade of steel: Deck:_____ Side:_____
Bottom:_____ Long. bhd_____

Elements	Cracks	Buckles	Corrosion	Coating condition	Pitting	Mod. /Rep.	Other

Deck:

Bottom:

Side:

Longitudinal bulkheads:

Transverse bulkheads:

Repairs carried out due to①:

Thickness measurements carried out, dates:
Results in general:

Overdue surveys:
Outstanding conditions of class:

Comments:

① Repairs carried out is to be surveyed by CCS Surveyor

Date of Inspection:_____

Inspected by:_____

Signature:_____

Appendix 13 RECOMMENDED PROCEDURES FOR THICKNESS MEASUREMENTS①

13.1A RECOMMENDED PROCEDURES FOR THICKNESS MEASUREMENTS OF SHIPS

1 Notes

1.1 This document is to be used for recording thickness measurements for all ships as required by Section 4, Chapter 5 of this PART.

1.2 Reporting forms TM1-G, TM2-G (i) and (ii), TM3-G, TM4-G, TM5-G (sheets 4 to 9) are to be used for recording thickness measurements and the maximum allowable diminution is to be stated. The maximum allowable diminution is to be stated in an attached document.

GENERAL PARTICULARS

Ship's name:
IMO number:
Class identity number:
Port of registry:
Gross tons:
Deadweight:
Date of build:
Classification society:

Name of Company performing thickness measurement:
Thickness measurement company certified by:
Certificate No:
Certificate valid from.....to.....
Place of measurement:
First date of measurement:
Last date of measurement:
Special survey/intermediate survey due:*
Details of measurement equipment:
Qualification of operators:

Report number: consisting of Sheets

Name of operator:	Name of surveyor:
Signature of operator:	Signature of surveyor:
Company official stamp:	Classification society official stamp:

① This Appendix is recommendatory. For ESP ships, IMO No. is to be marked in the general particulars.

* Delete as appropriate.

Sheet 4

TM1-G **Report on Thickness Measurement of All Deck Plating, All Bottom Shell Plating or Side Shell Plating***

(*delete as appropriate)

Ship's name..... Class identity No. ..... Report No. .....

STRAKE POSITION																	
PLATE POSITION	No. or Letter	Org. Thk. mm	Forward Reading						Aft Reading						Mean Diminution %		Maximum Allowable Diminution
			Gauged		Diminution *P*		Diminution *S*		Gauged		Diminution *P*		Diminution *S*				
			P	*S*	mm	%	mm	%	*P*	*S*	mm	%	mm	%	*P*	*S*	mm
12th forward																	
11th																	
10th																	
9th																	
8th																	
7th																	
6th																	
5th																	
4th																	
3rd																	
2nd																	
1st																	
Amidships																	
1st aft																	
2nd																	
3rd																	
4th																	
5th																	
6th																	
7th																	
8th																	
9th																	
10th																	
11th																	
12th																	

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   A – All strength deck plating within the cargo length area.
   B – All keel, bottom shell plating and bilge plating within the cargo length area.
   C – Side shell plating that is all wind and water strakes within the cargo length area.
   D – Side shell plating that is selected wind and water strakes outside the cargo length area.
2. The strake position is to be clearly indicated as follows:
   2.1 For strength deck indicate the number of the strake of plating inboard from the stringer plate.
   2.2 For bottom plating indicate the number of the strake of plating outboard from the keel plate.
   2.3 For side shell plating give number of the strake of plating below sheer strake and letter as shown on shell expansion.
3. Only the deck plating strakes outside line of openings are to be recorded.
4. Measurements are to be taken at the forward and aft areas of all plates, and the single measurements recorded are to represent the average of multiple measurements.
5. The maximum allowable diminution could be stated in an attached document.

Sheet 5

TM2-G(i) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class identity No. ..... Report No. .....

STRENGTH DECK AND SHEERSTRAKE PLATING																											
	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER										THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRAKE POSITION	No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution *P*		Diminution *S*		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution *P*		Diminution *S*		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution *P*		Diminution *S*	
		mm	mm	*P*	*S*	mm	%	mm	%		mm	mm	*P*	*S*	mm	%	mm	%		mm	mm	*P*	*S*	mm	%	mm	%
Stringer Plate																											
1st strake inboard																											
2nd																											
3rd																											
4th																											
5th																											
6th																											
7th																											
8th																											
9th																											
10th																											
11th																											
12th																											
13th																											
14th																											
Centre strake																											
Sheer strake																											
TOPSIDE TOTAL																											

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Strength deck plating and sheer strake plating transverse sections:
   Two or three sections within the cargo length area, comprising of the structural items.
2. Only the deck plating strakes outside the line of openings are to be recorded.
3. The topside area comprises deck plating, stringer plate and sheerstrake (including rounded gunwales).
4. The exact frame station of measurement is to be stated.
5. The single measurements recorded are to represent the average of multiple measurements.
6. The maximum allowable diminution could be stated in an attached document.

Sheet 6

TM2-G(ii) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class identity No. ..... Report No. .....

SHELL PLATING																													
	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER										
STRAKE POSITION	No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution *P*		Diminution *S*		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution *P*		Diminution *S*		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution *P*		Diminution *S*			
		mm	mm	*P*	*S*	mm	%	mm	%		mm	mm	*P*	*S*	mm	%	mm	%		mm	mm	*P*	*S*	mm	%	mm	%		
1st below Sheer strake																													
2nd																													
3rd																													
4th																													
5th																													
6th																													
7th																													
8th																													
9th																													
10th																													
11th																													
12th																													
13th																													
14th																													
15th																													
16th																													
17th																													
18th																													
19th																													
20th																													
Keel strake																													
BOTTOM TOTAL																													

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Shell plating transverse sections:
   Two or three sections within the cargo length area, comprising of the structural items.
2. The bottom area comprises keel, bottom and bilge plating.
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The maximum allowable diminution could be stated in an attached document.

Sheet 7

TM3-G **Report on Thickness Measurement of Longitudinal Members (one, two or three transverse sections)**

Ship's name..... Class identity No. ..... Report No. .....

	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER										THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRUCTURAL MEMBER	No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution *P*		Diminution *S*		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution *P*		Diminution *S*		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution *P*		Diminution *S*	
		mm	mm	*P*	*S*	mm	%	mm	%		mm	mm	*P*	*S*	mm	%	mm	%		mm	mm	*P*	*S*	mm	%	mm	%

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Longitudinal members at transverse sections:
   Two or three sections within the cargo length area, comprising of the appropriate structural items.
2. The exact frame station of measurement is to be stated.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 8
TM4-G **Report on Thickness Measurement of Transverse Bulkheads**

Ship's name..... Class identity No. ..... Report No. .....

LOCATION OF STRUCTURE:						FRAME NO.:		
STRUCTURAL COMPONENT (PLATING/STIFFENER)								
	Original Thickness mm	Max. Alwb. Dim.mm	Gauged		Diminution *P*		Diminution *S*	
			Port	Starboard	mm	%	mm	%

Operators signature: .....

Notes:
1. This report is to be used for recording the thickness measurement of cargo hold transverse bulkheads.
2. The single measurements recorded are to represent the average of multiple measurements.
3. The maximum allowable diminution could be stated in an attached document.

Sheet 9

TM5-G Report on Thickness Measurement of Miscellaneous Structural Members

Ship's name..... Class identity No. ..... Report No. .....

STRUCTURAL MEMBER:									SKETCH
LOCATION OF STRUCTURE:									
Description	Org. Thk. mm	Max. Alwb. Dim. mm	Gauged		Diminution *P*		Diminution *S*		
			P	*S*	mm	%	mm	%	

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of miscellaneous structural members.
2. The single measurements recorded are to represent the average of multiple measurements.
3. The maximum allowable diminution could be stated in an attached document.

13.1B RECOMMENDED PROCEDURES FOR THICKNESS MEASUREMENTS OF SHIPS BUILT ACCORDING TO THE NET SCANTLING APPROACH①

Notes:
1. This document is to be used for recording thickness measurements of ships built according to the net scantling approach as required by Section 4, Chapter 5 of this PART.
2. Reporting forms TM1-G(NSD), TM2-G(NSD) (i) and (ii), TM3-G(NSD), TM4-G(NSD), TM5-G(NSD) (sheets 4 to 9) are to be used for recording thickness measurements. The as-built thickness, the voluntary thickness addition and renewal thickness (minimum allowable thickness) are to be stated in the said forms.

GENERAL PARTICULARS

Ships name:
IMO number:
Class identity number:
Port of registry:
Gross tons:
Deadweight:
Date of build:
Classification society:

Name of Company performing thickness measurement:
Thickness measurement company certified by:
Certificate No:
Certificate valid from.....to.....
Place of measurement:
First date of measurement:
Last date of measurement:
Special survey/intermediate survey due:*
Details of measurement equipment:
Qualification of operators:

Report Number:	consisting of Sheets
Names of operator:.....	Name of surveyor:.....
Signature of operator:.....	Signature of surveyor:.....
Company official stamp:	Classification society official stamp:

① This Appendix is recommendatory.
* Delete as appropriate.

Sheet 4

TM1-G(NSD) Report on Thickness Measurement of All Deck Plating, All Bottom Plating or Side Shell Plating*

(* delete as appropriate)

Ship's name..... Class identity No. ..... Report No. .....

STRAKE POSITION																		
PLATE POSITION	No. or Letter	As Built Thk. mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Forward Reading						Aft Reading						Mean Remaining Corr. Addition, mm [(c1)+(c2)]/2	
					Gauged Thk. mm (b1)		Remaining Corr. Addition, mm (c1)=(b1)-(a)				Gauged Thk. mm (b2)		Remaining Corr. Addition, mm (c2)=(b2)-(a)					
					P	*S*	*P*		*S*		*P*	*S*	*P*		*S*		*P*	*S*
12th																		
11th																		
10th																		
9th																		
8th																		
7th																		
6th																		
5th																		
4th																		
3rd																		
2nd																		
1st forward																		
Amidships																		
1st aft																		
2nd																		
3rd																		
4th																		
5th																		
6th																		
7th																		
8th																		
9th																		
10th																		
11th																		
12th																		

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   A − All strength deck plating within the cargo length area.
   B − All keel, bottom shell plating and bilge plating within the cargo length area.
   C − Side shell plating that is all wind and water strakes within the cargo length area.
   D − Side shell plating that is selected wind and water strakes outside the cargo length area.
2. The strake position is to be clearly indicated as follows:
   2.1 For strength deck indicate the number of the strake of plating inboard from the stringer plate.
   2.2 For bottom plating indicate the number of the strake of plating outboard from the keel plate.
   2.3 For side shell plating give number of the strake of plating sheer strake and letter as shown on shell expansion.
3. Only the deck plating strakes outside line of openings are to be recorded.
4. Measurements are to be taken at the forward and aft areas of all plates and the single measurements recorded are to represent the average of multiple measurements.
5. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and substantial corrosion allowable limits, the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 5

TM2-G(NSD)(i) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class identity No. ..... Report No. .....

STRENGTH DECK AND SHEERSTRAKE PLATING																								
	FIRST TRANSVERSE SECTION AT FRAME NUMBER								SECOND TRANSVERSE SECTION AT FRAME NUMBER								THIRD TRANSVERSE SECTION AT FRAME NUMBER							
STRAKE POSITION	No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)		No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)		No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)	
					P	*S*	*P*	*S*					*P*	*S*	*P*	*S*					*P*	*S*	*P*	*S*
Stringer plate																								
1st strake inboard																								
2nd																								
3rd																								
4th																								
5th																								
6th																								
7th																								
8th																								
9th																								
10th																								
11th																								
12th																								
13th																								
14th																								
Centre strake																								
Sheer strake																								
TOPSIDE TOTAL																								

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Strength deck plating and sheer strake plating transverse sections:
   One, two or three sections within the cargo length area, comprising of the structural items.
2. Only the deck plating strakes outside the line of openings are to be recorded.
3. The topside area comprises deck plating, stringer plate and sheer strake (including rounded gunwales).
4. The exact frame station of measurement is to be stated.
5. The single measurements recorded are to represent the average of multiple measurements.
6. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and substantial corrosion allowable limits, the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 6

TM2-G(NSD)(ii) **Report on Thickness Measurement of Shell Plating (one, two or three transverse sections)**

Ship's name..... Class identity No. ..... Report No. .....

SHELL PLATING																															
	FIRST TRANSVERSE SECTION AT FRAME NUMBER										SECOND TRANSVERSE SECTION AT FRAME NUMBER										THIRD TRANSVERSE SECTION AT FRAME NUMBER									
STRAKE POSITION	No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)			
					P	*S*	*P*		*S*						*P*	*S*	*P*		*S*						*P*	*S*	*P*		*S*	
1st below sheer strake																														
2nd																														
3rd																														
4th																														
5th																														
6th																														
7th																														
8th																														
9th																														
10th																														
11th																														
12th																														
13th																														
14th																														
15th																														
16th																														
17th																														
18th																														
19th																														
20th																														
Keel strake																														
BOTTOM TOTAL																														

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Shell plating transverse sections:
   One, two or three sections within the cargo length area, comprising of the structural items.
2. The bottom area comprises keel, bottom and bilge plating.
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and substantial corrosion allowable limits, the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 7

TM3-G(NSD) **Report on Thickness Measurement of Longitudinal Members (one, two or three transverse sections)**

Ship's name..... Class identity No. ..... Report No. .....

	FIRST TRANSVERSE SECTION AT FRAME NUMBER								SECOND TRANSVERSE SECTION AT FRAME NUMBER								THIRD TRANSVERSE SECTION AT FRAME NUMBER							
STRUCTURAL MEMBER	Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)		Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)		Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)	
					P	*S*	*P*	*S*					*P*	*S*	*P*	*S*					*P*	*S*	*P*	*S*

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Longitudinal Members at transverse sections:
   One, two or three sections within the cargo length area, comprising of the appropriate structural items.
2. The exact frame station of measurement is to be stated.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and substantial corrosion allowable limits, the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 8
TM4-G(NSD) Report on Thickness Measurement of Transverse Bulkheads

Ship's name..... Class identity No. ..... Report No. .....

LOCATION OF STRUCTURE:						FRAME NO.:			
STRUCTURAL COMPONENT (PLATING/STIFFENER)									
STRUCTURAL COMPONENT (PLATING/STIFFENER)	As Built Thickness mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)			
				P	*S*	*P*		*S*	

Operators signature: .....

Notes:
1. This report is to be used for recording the thickness measurement of cargo hold transverse bulkheads.
2. The single measurements recorded are to represent the average of multiple measurements.
3. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and substantial corrosion allowable limits, the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 9
TM5-G(NSD) Report on Thickness Measurement of Miscellaneous Structural Members

Ship's name..... Class identity No. ..... Report No. .....

STRUCTURAL COMPONENT:										SKETCH
LOCATION OF STRUCTURE:										
Description	As Built Thk. mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)				
				P	*S*	*P*		*S*		

Operators signature: .....

Notes:
1. This report is to be used for recording the thickness measurement of miscellaneous structural members.
2. The single measurements recorded are to represent the average of multiple measurements.
3. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and substantial corrosion allowable limits, the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

13.1 Recommended Procedures for Thickness Measurements of Oil Tankers, Ore/Oil Ships, etc.①

1. Notes

1.1 This document is to be used for recording thickness measurements for oil tanks as required by Section 6, Chapter 5 of this PART.

1.2 Sheets TM1-T, TM2-T, TM3-T, TM4-T, TM5-T and TM6-T (sheets 4 to 10) are to be used for recording thickness measurements and the maximum allowable diminution is to be stated.
The maximum allowable diminution could be stated in an attached document.

1.3 The remaining sheets 11 to 15 are guidance diagrams and notes relating to the reporting format and the procedure for the thickness measurements.

GENERAL PARTICULARS

Ship's name:
IMO number:
Class identity number
Port of registry:
Gross tons:
Deadweight:
Date of build:
Classification society:

Name of company performing thickness measurement:
Thickness measurement company certified by:
Certificate No.
Certificate valid from _____ to _____
Place of measurement:
First date of measurement:
Last date of measurement:
Special survey/intermediate survey due*:
Details of measurement equipment:
Qualification of operator:

Report number: consisting of Sheets

Name of operator: _____
Signature of operator: _____
Company official stamp: _____

Name of surveyor: _____
Signature of surveyor: _____
Classification society
Official Stamp: _____

① The Recommended Procedures for Thickness Measurements are also applicable to chemical tankers.
* Delete as appropriate.

Sheet 4

TM1-T

Report on Thickness Measurement of All Deck Plating, All Bottom Shell Plating or Side Shell Plating*

(*delete as appropriate)

Ship's name..... Class Identity No. ..... Report No. .....

STRAKE POSITION																	
PLATE POSITION	No. or Letter	Org. Thk. mm	Forward Reading						Aft Reading						Mean Diminution %		Maximum Allowable Diminution
			Gauged		Diminution P		Diminution S		Gauged		Diminution P		Diminution S				
			P	S	mm	%	mm	%	P	S	mm	%	mm	%	P	S	mm
12th forward																	
11th																	
10th																	
9th																	
8th																	
7th																	
6th																	
5th																	
4th																	
3rd																	
2nd																	
1st																	
Amidships																	
1st aft																	
2nd																	
3rd																	
4th																	
5th																	
6th																	
7th																	
8th																	
9th																	
10th																	
11th																	
12th																	

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   A – All strength deck plating within the cargo area.
   B – All keel, bottom shell plating and bilge plating within the cargo area.
   C – Side shell plating including selected wind and water strakes outside cargo area.
   D – All wind and water strakes within cargo area.
2. The strake position is to be clearly indicated as follows:
   2.1 For strength deck indicate the number of the strake of plating inboard from the stringer plate.
   2.2 For bottom plating indicate the number of the strake of plating outboard from the keel plate.
   2.3 For side shell plating give number of the strake of plating below sheer strake and letter as shown on shell expansion.
3. For oil tankers all deck plating strakes are to be recorded, for ore/oil ships only the deck plating strakes outside line of openings are to be recorded.
4. Measurements are to be taken at the forward and aft areas of all and where plates cross ballast/cargo tank boundaries separate measurements for the area of plating in way of each type of tank are to be recorded.
5. The single measurements recorded are to represent the average of multiple measurements.
6. The maximum allowable diminution could be stated in an attached document.

Sheet 5

TM2-T(i) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class identity No. ..... Report No. .....

STRENGTH DECK AND SHEERSTRAKE PLATING																											
	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRAKE POSITION	No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%
Stringer Plate																											
1st strake inboard																											
2nd																											
3rd																											
4th																											
5th																											
6th																											
7th																											
8th																											
9th																											
10th																											
11th																											
12th																											
13th																											
14th																											
centre strake																											
sheer strake																											
TOPSIDE TOTAL																											

Operators signature: .....

Notes:

1. This report form is to be used for recording the thickness measurements of:
   Strength deck plating and sheer strake plating transverse sections:
   One, two or three sections within the cargo area comprising of the structural items (1), (2) and (3) as shown on the diagrams of typical transverse sections.
2. For oil tankers all deck plating strakes are to be recorded and for ore/oil ships only the deck plating strakes outside the line of openings are to be recorded.
3. The topside area comprises deck plating, stringer plate and sheer strake (including rounded gunwales).
4. The exact frame station of measurement is to be stated.
5. The single measurements recorded are to represent the average of multiple measurements.
6. The maximum allowable diminution could be stated in an attached document.

Sheet 6

TM2-T(ii) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class Identity No. ..... Report No. .....

SHELL PLATING																											
	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRAKE POSITION	No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%
1st below sheer strake																											
2nd																											
3rd																											
4th																											
5th																											
6th																											
7th																											
8th																											
9th																											
10th																											
11th																											
12th																											
13th																											
14th																											
15th																											
16th																											
17th																											
18th																											
19th																											
20th																											
keel strake																											
BOTTOM TOTAL																											

Operators signature: .....

Notes:

1. This report form is to be used for recording the thickness measurements of:
   Shell plating transverse sections:
   One, two or three sections within the cargo area comprising of the structural items (4), (5) and (6) and (7) as shown on the diagrams of typical transverse sections.
2. The bottom area comprises keel, bottom and bilge plating.
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The maximum allowable diminution could be stated in an attached document.

Sheet 7
TM3-T **Report on Thickness Measurement of Longitudinal Members (one, two or three transverse sections)**

Ship's name..... Class identity No. ..... Report No. .....

	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRUCTURAL MEMBER	Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurements of:
   Longitudinal members at transverse sections:
   One, two or three sections within the cargo area comprising of the appropriate structural items (8) to (20) as shown on the diagrams of typical transverse sections.
2. The exact frame station of measurement is to be stated.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 8
TM4-T

Report on Thickness Measurement of Transverse Structural Members
In the cargo oil and water ballast tanks within the cargo tank length

Ship's name..... Class identity No. ..... Report No. .....

TANK DESCRIPTION:									
LOCATION OF STRUCTURE:									
STRUCTURAL MEMBER	ITEM	Original Thickness mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S	
				P	S	mm	%	mm	%

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurements of transverse structural members, comprising of the appropriate structural items (25) to (33) as shown on diagrams of typical transverse section.
2. Guidance for areas of measurement is indicated on Sheet 15 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 9
TM5-T

Report on Thickness of W.T./O.T. Transverse Bulkheads

Within the cargo tank or cargo hold spaces

Ship's name..... Class Identity No. ..... Report No. .....

TANK/HOLD DESCRIPTION:

LOCATION OF STRUCTURE: FRAME NO.:

STRUCTURAL COMPONENT (PLATING/STIFFENER)	Original Thickness mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S	
			Port	Starboard	mm	%	mm	%

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of W.T./O.T. transverse bulkheads.
2. Guidance for areas of measurement is indicated on Sheet 15 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 10
TM6-T

Report on Thickness measurement of Miscellaneous Structural Members

Ship's name..... Class Identity No. ..... Report No. .....

STRUCTURAL MEMBER:									SKETCH
LOCATION OF STRUCTURE:									
Description	Org. Thk. mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S		
			P	S	mm	%	mm	%	

Operators signature: .....

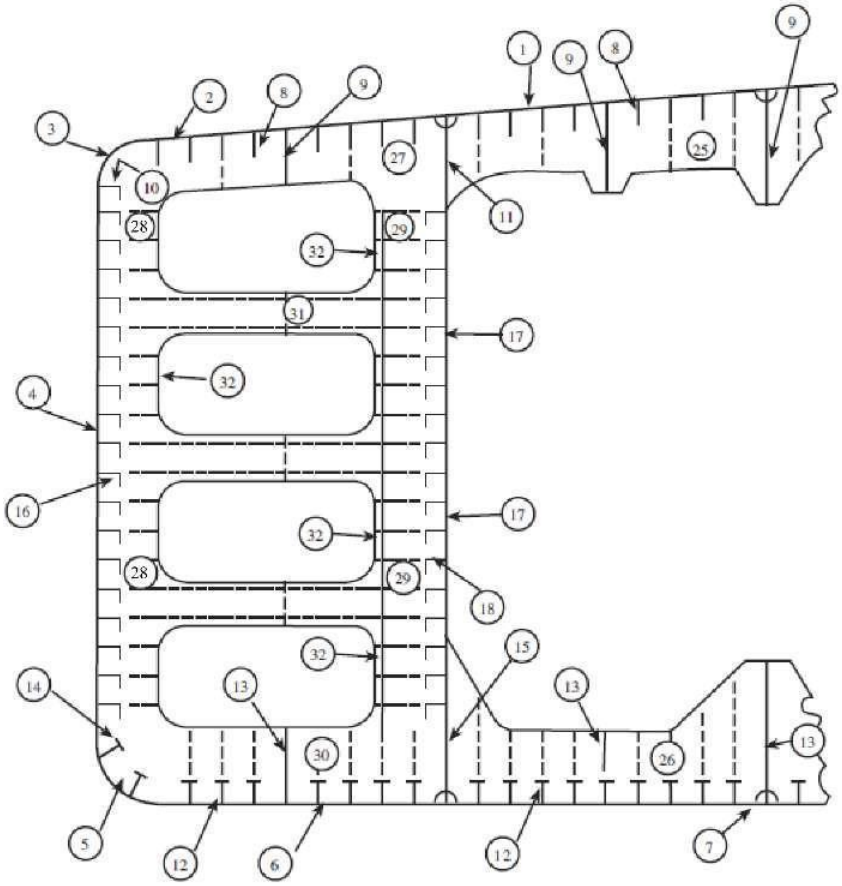
Notes:

1. This report is to be used for recording the thickness measurement of miscellaneous structural members including the structural items (36), (37) and (38).
2. The single measurements recorded are to represent the average of multiple measurements.
3. The maximum allowable diminution could be stated in an attached document.

Sheet 11

Thickness Measurement - Oil Tankers, Ore/Oil Ships and etc.

Oil Tanker - Typical Transverse Section Indicating Longitudinal and Transverse Members

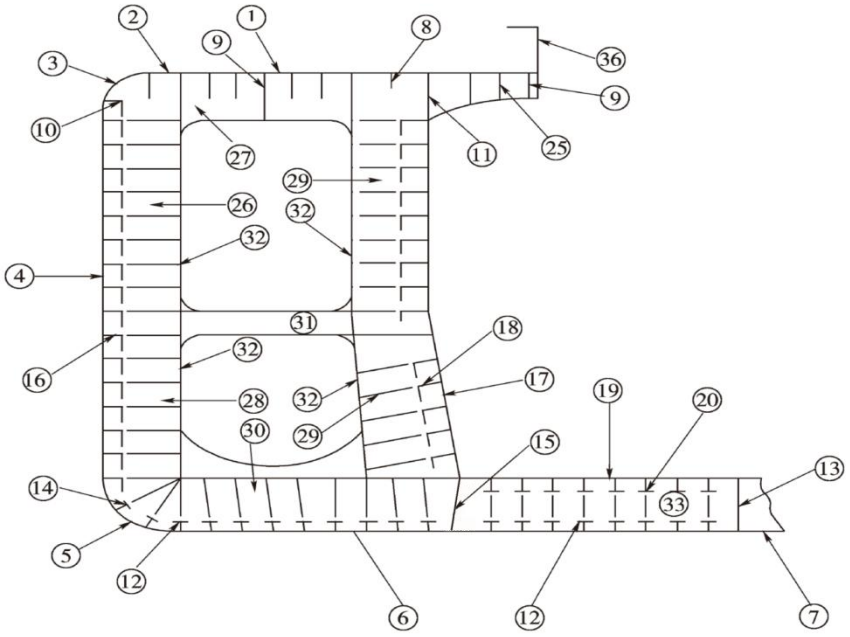


Report on TM2-T(1) & (2)	Report on TM3-T	Report on TM4-T
1. Strength deck plating 2. Stringer plate 3. Sheer strake 4. Side shell plating 5. Bilge plating 6. Bottom shell plating 7. Keel plate	8. Deck longitudinals 9. Deck girders 10. Sheer strake longitudinals 11. Longitudinal bulkhead top strake 12. Bottom longitudinals 13. Bottom girders 14. Bilge longitudinals 15. Longitudinal bulkhead lower strake 16. Side shell longitudinals 17. Longitudinal bulkhead plating (remainder) 18. Longitudinal bulkhead longitudinals 19. Inner bottom plating 20. Inner bottom longitudinals 21. 22. 23. 24.	25. Deck transverse centre tank 26. Bottom transverse centre tank 27. Deck transverse wing tank 28. Side shell vertical web 29. Longitudinal bulkhead vertical web 30. Bottom transverse wing tank 31. Struts 32. Transverse web face plate 33. D.B.Floors 34. 35.
		Report on TM6-T
		36. Hatch coamings 37. Deck plating between hatches 38. Hatch covers 39. 40.

Sheet 12

Thickness Measurement - Oil Tankers, Ore/Oil Ships and etc.

Oil/Ore Ship - Typical Transverse Section Indicating Longitudinal and Transverse Members

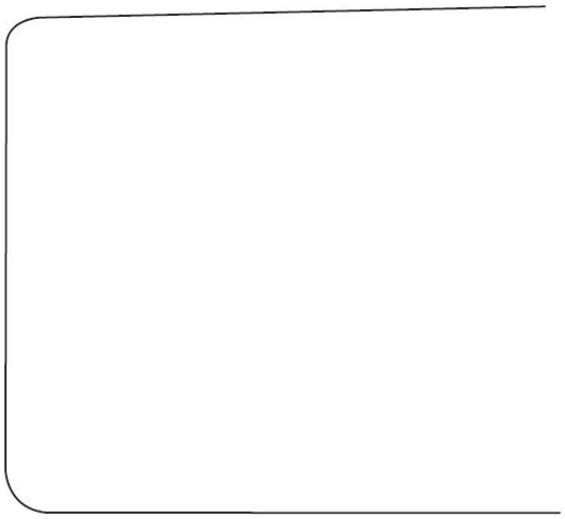


Report on TM2-T(1) & (2)	Report on TM3-T	Report on TM4-T
1. Strength deck plating 2. Stringer plate 3. Sheer strake 4. Side shell plating 5. Bilge plating 6. Bottom shell plating 7. Keel plate	8. Deck longitudinals 9. Deck girders 10. Sheer strake longitudinals 11. Longitudinal bulkhead top strake 12. Bottom longitudinals 13. Bottom girders 14. Bilge longitudinals 15. Longitudinal bulkhead lower strake 16. Side shell longitudinals 17. Longitudinal bulkhead plating (remainder) 18. Longitudinal bulkhead longitudinals 19. Inner bottom plating 20. Inner bottom longitudinals 21. 22. 23. 24.	25. Deck transverse centre tank 26. Bottom transverse centre tank 27. Deck transverse wing tank 28. Side shell vertical web 29. Longitudinal bulkhead vertical web 30. Bottom transverse wing tank 31. Struts 32. Transverse web face plate 33. D.B.Floors 34. 35.
		Report on TM6-T
		36. Hatch coamings 37. Deck plating between hatches 38. Hatch covers 39. 40.

Sheet 13

Thickness Measurement - Oil Tankers, Ore/Oil Ships and etc.
Transverse Section Outline

To be used for longitudinal and transverse members where typical oil tanker or oil/ore ship sections are not applicable

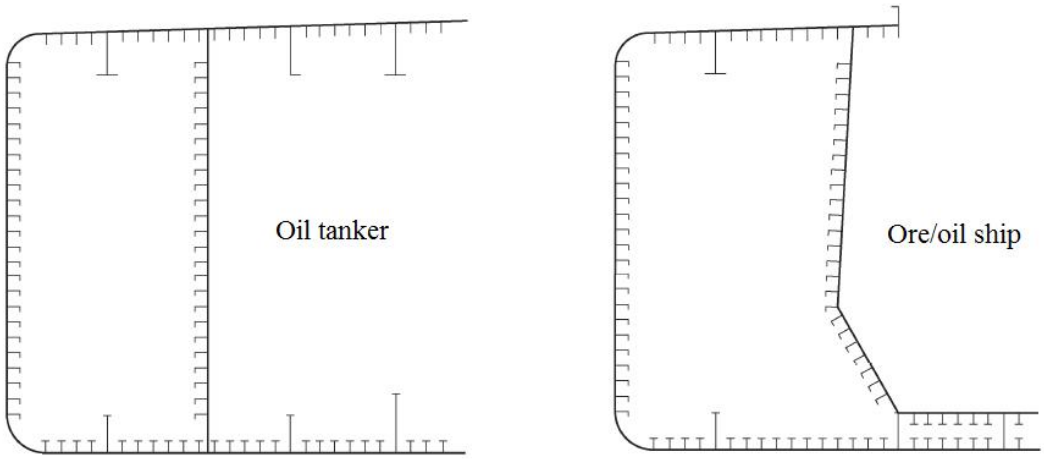


Report on TM2-T(1) & (2)	Report on TM3-T	Report on TM4-T
1. Strength deck plating 2. Stringer plate 3. Sheer strake 4. Side shell plating 5. Bilge plating 6. Bottom shell plating 7. Keel plate	8. Deck longitudinals 9. Deck girders 10. Sheer strake longitudinals 11. Longitudinal bulkhead top strake 12. Bottom longitudinals 13. Bottom girders 14. Bilge longitudinals 15. Longitudinal bulkhead lower strake 16. Side shell longitudinals 17. Longitudinal bulkhead plating (remainder) 18. Longitudinal bulkhead longitudinals 19. Inner bottom plating 20. Inner bottom longitudinals 21. 22. 23. 24.	25. Deck transverse centre tank 26. Bottom transverse centre tank 27. Deck transverse wing tank 28. Side shell vertical web 29. Longitudinal bulkhead vertical web 30. Bottom transverse wing tank 31. Struts 32. Transverse web face plate 33. D.B. floors 34. 35.
		Report on TM6-T
		36. Hatch coamings 37. Deck plating between hatches 38. Hatch covers 39. 40.

Sheet 14

Thickness Measurement - Oil Tankers, Ore/Oil Ships and etc.

Typical Transverse Section Showing All Longitudinal Members to be Reported on TM2-T and TM3-T

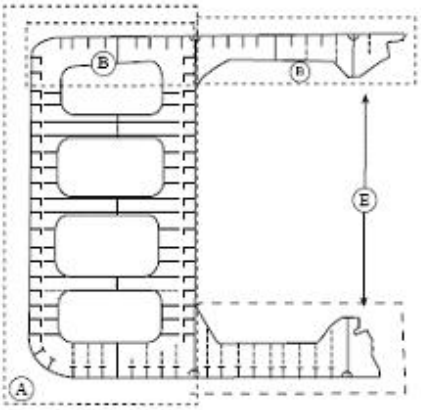


Sheet 15

Thickness Measurement - Oil Tankers, Ore/Oil Ships and etc.

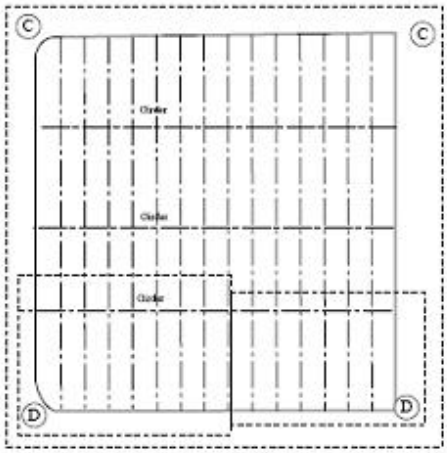
Close-up Survey Requirements

Oil Tanker
Typical transverse section close-up survey



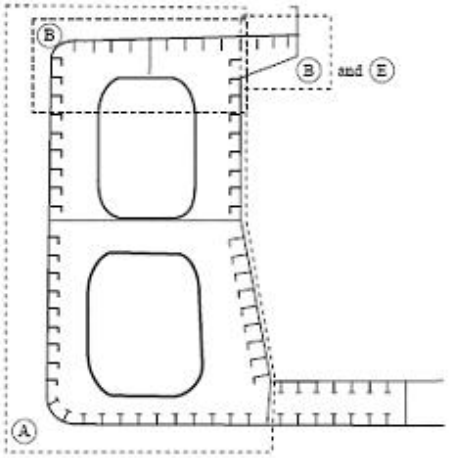
Thickness to be reported on
TM3-T and TM4-T as appropriate

Oil Tanker
Typical transverse bulkhead



Thickness to be reported on TM5-T

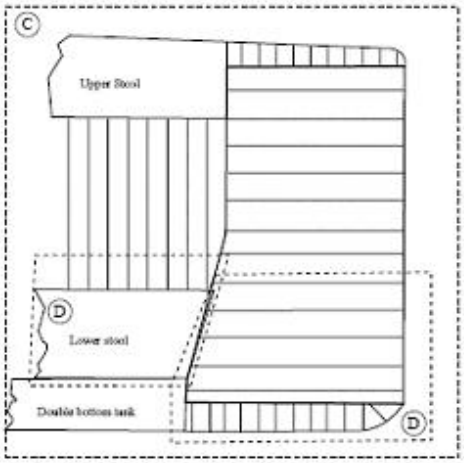
Oil/Ore ship
Typical transverse section close-up survey



Thickness to be reported on
TM3-T and TM4-T as appropriate

Close-up survey area

Oil/Ore ship
Typical transverse bulkhead



Thickness to be reported on TM5-T

13.2A Recommended Procedures for Thickness Measurements of Bulk Carriers

Notes:
1. This document is to be used for recording thickness measurements of single side skin bulk carriers as required by Section 7, Chapter 5 of this PART.

2. Reporting forms TM1-BC, TM2-BC, TM3-BC, TM4-BC, TM5-BC, TM6-BC and TM7-BC (Sheets 4 to 11) are to be used for recording thickness measurements and the minimum allowable diminution is to be stated.
The minimum allowable diminution could be stated in an attached document.

3. The remaining Sheets 12 to 14 are guidance diagrams and notes relating to the reporting forms and the IACS Unified Requirements for thickness measurement.

4. The reporting forms are where appropriate, to be supplemented by data presented on structural sketches.

GENERAL PARTICULARS

Ship's name:
IMO number:
Class identity number:
Port of registry:
Gross tons:
Deadweight:
Date of build:
Classification society:

Name of company performing thickness measurement:
Thickness measurement company certified by:
Certificate No:
Certificate valid from _____ to _____
Place of measurement:
First date of measurement:
Last date of measurement:
Special survey/intermediate survey due①:
Details of measurement equipment:
Qualification of operators:

Report number: consisting of Sheets

Name of operator: _____
Signature of operator: _____
Company official stamp: _____

Name of surveyor: _____
Signature of surveyor: _____
Classification society
Official Stamp: _____

① Delete as appropriate.

Sheet 4

TM1-BC **Report on Thickness Measurement of All Deck Plating, All Bottom Shell Plating or Side Shell Plating***

(*delete as appropriate)

Ship's name..... Class Identity No. ..... Report No. .....

STRAKE POSITION																	
PLATE POSITION	No. or Letter	Org. Thk. mm	Forward Reading						Aft Reading						Mean Diminution %		Maximum Allowable Diminution
			Gauged		Diminution P		Diminution S		Gauged		Diminution P		Diminution S				
			P	S	mm	%	mm	%	P	S	mm	%	mm	%	P	S	mm
12th forward																	
11th																	
10th																	
9th																	
8th																	
7th																	
6th																	
5th																	
4th																	
3rd																	
2nd																	
1st																	
Amidships																	
1st aft																	
2nd																	
3rd																	
4th																	
5th																	
6th																	
7th																	
8th																	
9th																	
10th																	
11th																	
12th																	

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   A – All strength deck plating within cargo length area.
   B – Keel, bottom shell plating and bilge plating within the cargo length area.
   C – Side shell plating that is selected wind and water strakes within the cargo length area.
   D – Side shell plating that is all wind and water strakes outside the cargo length area.
2. The strake position is to be clearly indicated as follows:
   2.1 For strength deck indicate the number of the strake of plating inboard from the stringer plate.
   2.2 For bottom plating indicate the number of the strake of plating outboard from the keel plate.
   2.3 For side shell plating give number of the strake of plating sheer strake and letter as shown on shell expansion.
3. Only the deck plating strakes outside line of openings are to be recorded.
4. Measurements are to be taken at the forward and aft areas of all plates and the single measurements recorded are to represent the average of multiple measurements.
5. The maximum allowable diminution could be stated in an attached document.

Sheet 5

TM2-BC(i) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class Identity No. ..... Report No. .....

STRENGTH DECK AND SHEERSTRAKE PLATING																											
	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRAKE POSITION	No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%
Stringer Plate																											
1st strake inboard																											
2nd																											
3rd																											
4th																											
5th																											
6th																											
7th																											
8th																											
9th																											
10th																											
11th																											
12th																											
13th																											
14th																											
centre strake																											
sheer strake																											
TOPSIDE TOTAL																											

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Strength deck plating and sheer strake plating transverse sections:
   Two or three sections within the cargo length area, comprising of the structural items (1), (2) and (3) as shown on the diagram of typical transverse section.
2. Only the deck plating strakes outside the line of openings are to be recorded.
3. The topside area comprises deck plating, stringer plate and sheer strake (including rounded gunwales).
4. The exact frame station of measurement is to be stated.
5. The single measurements recorded are to represent the average of multiple measurements.
6. The maximum allowable diminution could be stated in an attached document.

Sheet 6

TM2-BC(ii) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class Identity No. ..... Report No. .....

SHELL PLATING																										
	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER							
STRAKE POSITION	No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%
1st below sheer strake																										
2nd																										
3rd																										
4th																										
5th																										
6th																										
7th																										
8th																										
9th																										
10th																										
11th																										
12th																										
13th																										
14th																										
15th																										
16th																										
17th																										
18th																										
19th																										
20th																										
keel strake																										
BOTTOM TOTAL																										

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Shell plating transverse sections:
   Two or three sections within cargo length area comprising of the structural (4), (5), (6) and (7) as shown on the diagram of typical transverse section.
2. The bottom area comprises keel, bottom and bilge plating.
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The maximum allowable diminution could be stated in an attached document.

Sheet 7

TM3-BC **Report on Thickness Measurement of Longitudinal Members (one, two or three transverse sections)**

Ship's name..... Class Identity No. ..... Report No. .....

	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRUCTURAL MEMBER	Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Longitudinal members at transverse sections:
   One, two or three sections within the cargo length area, comprising of the appropriate structural items (8) to (20) as shown on diagram of typical transverse section.
2. The exact frame station of measurement is to be stated.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 8
TM4-BC

Report on Thickness Measurement of Transverse Structural Members
In the double bottom, hopper side and topside water ballast tanks

Ship's name..... Class Identity No. ..... Report No. .....

TANK DESCRIPTION:									
LOCATION OF STRUCTURE:									
STRUCTURAL MEMBER	ITEM	Original Thickness mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S	
				P	S	mm	%	mm	%

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of transverse structural members, comprising of the appropriate structural items (23) to (25) as shown on diagram of typical transverse section, Sheet 12 of this document.
2. Guidance for areas if measurement is indicated on the diagrams shown on Sheet 14 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 9
TM5-BC

Report on Thickness of Cargo Hold Transverse Bulkheads

Ship's name..... Class Identity No. ..... Report No. .....

LOCATION OF STRUCTURE:					FRAME NO.:			
STRUCTURAL COMPONENT (PLATING/STIFFENER)								
	Original Thickness mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S	
			Port	Starboard	mm	%	mm	%

Operators signature: .....

Notes:

1. This report form is to be used for recording the thickness measurement of cargo hold transverse bulkheads.
2. Guidance for areas of measurement is indicated on the diagrams shown on Sheet 14 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 10
TM6-BC

Report on Thickness Measurement of Miscellaneous Structural Members

Ship's name..... Class Identity No. ..... Report No. .....

STRUCTURAL MEMBER:									SKETCH
LOCATION OF STRUCTURE:									
Description	Org. Thk. mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S		
			P	S	mm	%	mm	%	

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of miscellaneous structural members including the structural items (28), (29) and (30) as shown on diagram of typical transverse section, Sheet 12 of this document.
2. Guidance for areas of measurement is indicated on Sheet 14 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 11
TM7-BC

Report on Thickness Measurement of Cargo Hold Transverse Frames

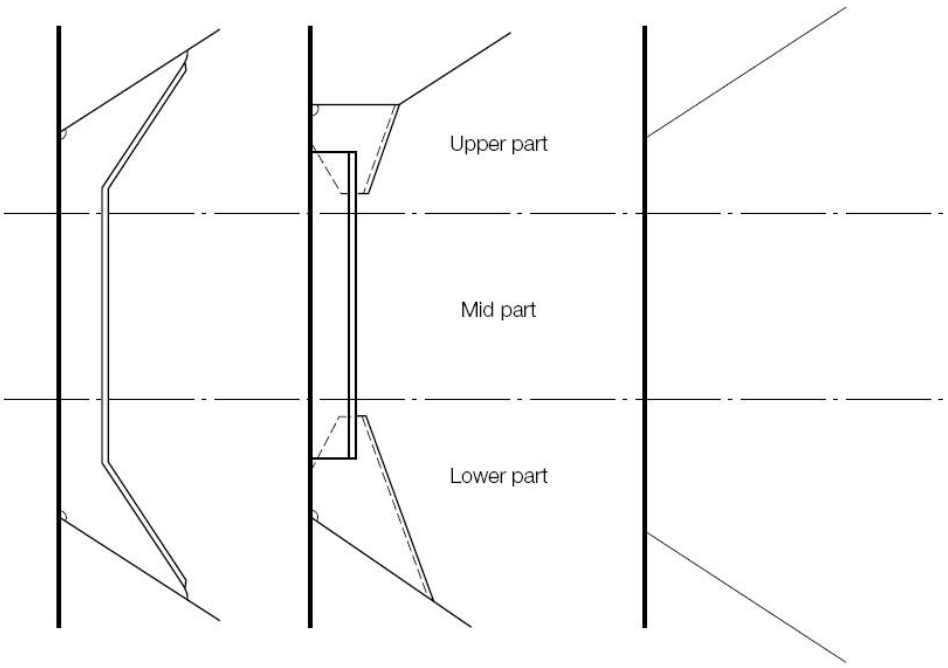
Ship's name..... Class Identity No. ..... Report No. .....

CARGO HOLD NO.																								
	UPPER PART								MID PART								LOWER PART							
FRAME NUMBER	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
	mm	mm	P	S	mm	%	mm	%	mm	mm	P	S	mm	%	mm	%	mm	mm	P	S	mm	%	mm	%

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Cargo hold transverse frames;
   Structural item number (34) as shown on the diagram of typical transverse section, Sheet 12 of this document.
2. Guidance for areas of measurement is indicated on the diagrams shown on Sheet 14 of this document.
   The single measurements recorded are to represent the average of multiple measurements.
3. The location and pattern of measurements is to be indicated on the sketches of hold frames shown below.
4. The maximum allowable diminution could be stated in an attached document.



Typical transverse frames in cargo hold
Thickness gauging area (A)

Non-typical transverse frames in cargo hold
Thickness gauging area (A)

Sheet 11(1)
TM7-BC S31

Report on Thickness Measurement of Cargo Hold Side Shell Frames

Ship's name..... Class Identity No. ..... Report No. .....

CARGO HOLD NO.: Side: (Port / stb.)

FRAME NO	ZONE A						ZONE B						ZONE C						ZONE D					
	Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution		Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution		Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution		Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution	
	mm	mm	mm	mm	mm	%	mm	mm	mm	mm	mm	%	mm	mm	mm	mm	mm	%	mm	mm	mm	mm	mm	%

Operators signature: .....

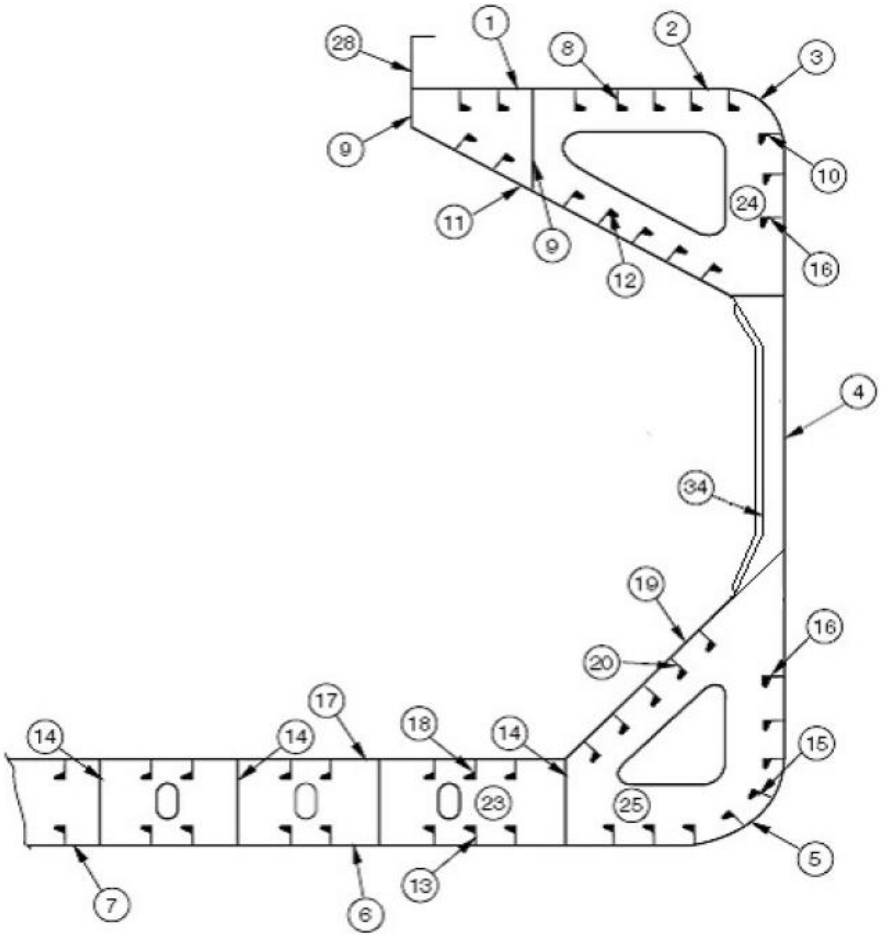
Notes:

1. This report is to be used for recording the thickness measurement of:
   Cargo hold transverse frames for application of UR S31.
2. Guidance for areas of measurement is provided in Appendix 6 to this Chapter.
3. The maximum allowable diminution could be stated in an attached document.

Sheet 12

Thickness measurement – Bulk Carriers

Typical Transverse Section Indicating Longitudinal and Transverse Members

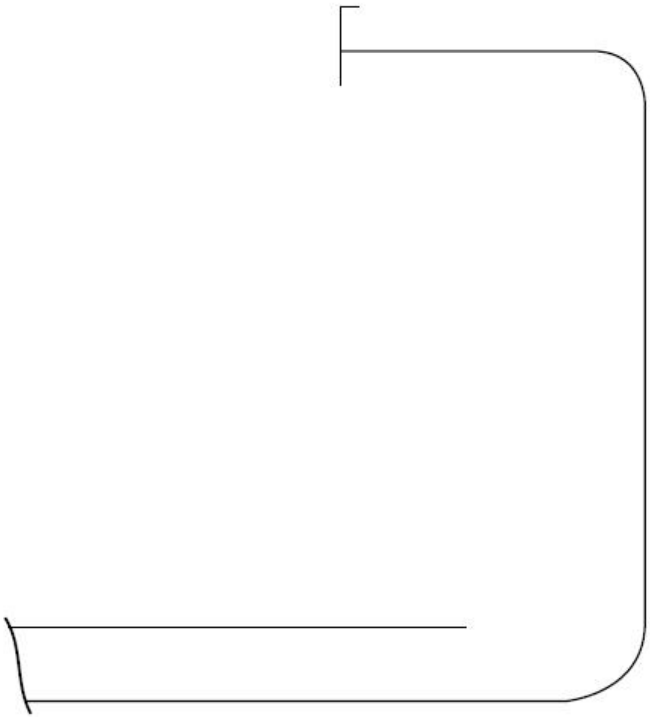


Report on TM2-BC	Report on TM3-BC	Report on TM4-BC
1. Strength deck plating 2. Stringer plate 3. Sheer strake 4. Side shell plating 5. Bilge plating 6. Bottom shell plating 7. Keel plate	8. Deck longitudinals 9. Deck girders 10. Sheer strake longitudinals 11. Topside tank sloping plating 12. Topside tank sloping plating longitudinals 13. Bottom longitudinals 14. Bilge girders 15. Bilge longitudinals 16. Side shell longitudinals 17. Inner bottom plating 18. Inner botom longitudinals 19. Hopper side plating 20. Hopper side longitudinals 21. 22.	23. Double bottom tank floors 24. Topside tank transverses 25. Hopper side tank transverses 26. 27.
Report on TM7-BC		**Report on TM6-BC**
34. Hold frames or diaphragms		28. Hatch coamings 29. Deck plating between hatches 30. Hatch covers 31. 32. 33.

Sheet 13

Thickness Measurement – Bulk Carriers: Typical Transverse Section Outline

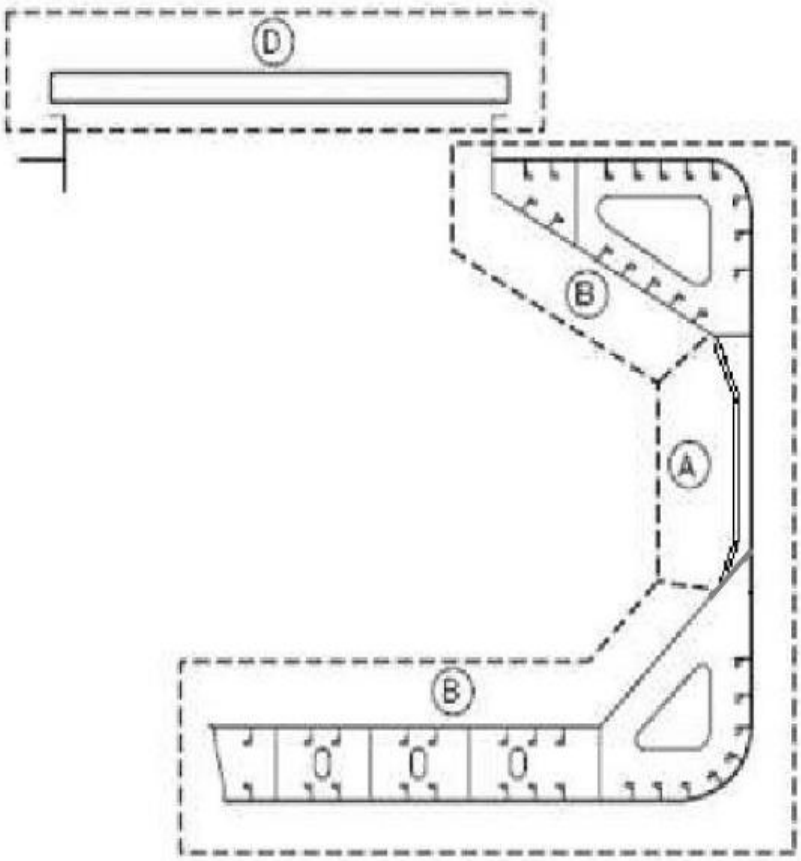
To be used for longitudinal and transverse members where the typical bulk carrier section is not applicable



Report on TM2-BC	Report on TM3-BC	Report on TM4-BC
1. Strength deck plating 2. Stringer plate 3. Sheer strake 4. Side shell plating 5. Bilge plating 6. Bottom shell plating 7. Keel plate	8. Deck longitudinals 9. Deck girders 10. Sheer strake longitudinals 11. Topside tank sloping plating 12. Topside tank sloping plating longitudinals 13. Bottom longitudinals 14. Bilge girders 15. Bilge longitudinals 16. Side shell longitudinals 17. Inner bottom plating 18. Inner botom longitudinals 19. Hopper side plating 20. Hopper side longitudinals 21. 22.	23. Double bottom tank floors 24. Topside tank transverses 25. Hopper side tank transverses 26. 27.
Report on TM7-BC		**Report on TM6-BC**
34. Hold frames or diaphragms		28. Hatch coamings 29. Deck plating between hatches 30. Hatch covers 31. Inner bulkhead plating 32. 33.

Sheet 14

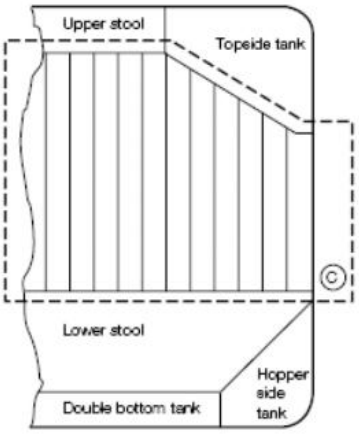
Close-up Survey and Thickness Measurement Areas



Thickness to be reported on TM3-BC, TM4-BC, TM6-BC and TM7-BC as appropriate

A cargo hold, transverse bulkhead

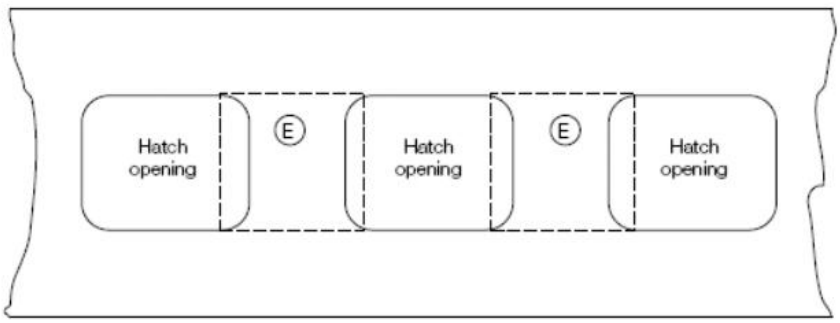
Area Ⓒ



Thickness to be reported on TM5-BC

Typical areas of deck plating inside line
of hatch openings between cargo hold hatches

Area Ⓔ



Thickness to be reported on TM6-BC

13.2B Recommended Procedures for Thickness Measurements of Bulk Carriers Built under Common Structural Rules①

Notes:

1. This document is to be used for recording thickness measurements of bulk carriers built under Common Structural Rules① as required by 5.1.9.3, Section 1, Chapter 5 of this PART.

2. Reporting forms TM1-BC(CSR), TM2-BC(CSR) (i) and (ii), TM3-BC(CSR), TM4-BC(CSR), TM5-BC(CSR), TM6-BC(CSR) and TM7-BC(CSR) (Sheets 4 to 11) are to be used for recording thickness measurements. The as-built thickness, the voluntary thickness addition and the renewal thickness (minimum allowable thickness) are to be stated in the said forms.

3. The remaining Sheets 12 to 14 are guidance diagrams and notes relating to the reporting forms and the procedure for the thickness measurement.

GENERAL PARTICULARS

Ship's name:
IMO number:
Class identity number
Port of registry:
Gross tons:
Deadweight:

---

① PART TEN of the Rules (2012 version) and its 2013 and 2014 amendments or PART NINE of the Rules (2015 version) and its subsequent versions (including amendments).

Date of build:
Classification society:

Name of Company performing thickness measurement:
Thickness measurement company certified by:
Certificate No.
Certificate valid from …… to ……
Place of measurement:
First date of measurement:
Last date of measurement:
Special survey/intermediate survey due:①
Details of measurement equipment:
Qualification of operators:

Report number: consisting of Sheets

Name of operator:	……	Name of surveyor:	……
Signature of operator:	……	Signature of surveyor:	……
Company		Classification society	
Official stamp:		Official Stamp:	

① Delete as appropriate.

Sheet 4

TM1-BC(CSR) **Report on Thickness Measurement of All Deck Plating, All Bottom Plating or Side Shell Plating***

(*delete as appropriate)

Ship's name..... Class Identity No..... Report No.....

STRAKE POSITION																		
PLATE POSITION	No. or Letter	As Built Thk. mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Forward Reading						Aft Reading						Mean Remaining Corr. Addition, mm [(c1)+(c2)]/2	
					Gauged Thk. mm (b1)		Remaining Corr. Addition, mm (c1)=(b1)-(a)				Gauged Thk. mm (b2)		Remaining Corr. Addition, mm (c2)=(b2)-(a)					
					P	S	P		S		P	S	P		S		P	S
12th																		
11th																		
10th																		
9th																		
8th																		
7th																		
6th																		
5th																		
4th																		
3rd																		
2nd																		
1st forward																		
Amidships																		
1st aft																		
2nd																		
3rd																		
4th																		
5th																		
6th																		
7th																		
8th																		
9th																		
10th																		
11th																		
12th																		

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   A – All strength deck plating within cargo length area.
   B – Keel, bottom shell plating and bilge plating within the cargo length area.
   C – Side shell plating that is all wind and water strakes within the cargo length area.
   D – Side shell plating that is selected wind and water strakes outside the cargo length area.
2. The strake position is to be clearly indicated as follows:
   2.1 For strength deck indicate the number of the strake of plating inboard from the stringer plate.
   2.2 For bottom plating indicate the number of the strake of plating outboard from the keel plate.
   2.3 For side shell plating give number of the strake of plating sheer strake and letter as shown on shell expansion.
3. Only the deck plating strakes outside the line of openings are to be recorded.
4. Measurements are to be taken at the forward and aft areas of all plates and the single measurements recorded are to represent the average of multiple measurements.
5. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 5

TM2-BC(CSR)(i) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class Identity No. ..... Report No. .....

STRENGTH DECK AND SHEERSTRAKE PLATING																															
	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRAKE POSITION	No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)			
					P	S	P		S						P	S	P		S						P	S	P		S	
Stringer Plate																															
1st strake inboard																															
2nd																															
3rd																															
4th																															
5th																															
6th																															
7th																															
8th																															
9th																															
10th																															
11th																															
12th																															
13th																															
14th																															
centre strake																															
sheer strake																															
TOPSIDE TOTAL																															

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   Strength deck plating and sheer strake plating transverse sections:
   One, two or three sections within the cargo length area, comprising the structural items (1), (2) and (3) as shown on the diagram of typical transverse sections.
2. Only the deck plating strakes outside the line of openings are to be recorded.
3. The topside area comprises deck plating, stringer plate and sheer strake (including rounded gunwales).
4. The exact frame station of measurement is to be stated.
5. The single measurements recorded are to represent the average of multiple measurements.
6. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 6

TM2-BC(CSR)(ii) **Report on Thickness Measurement of Shell Plating (one, two or three transverse sections)**

Ship's name..... Class Identity No. ..... Report No. .....

SHELL PLATING																													
	FIRST TRANSVERSE SECTION AT FRAME NUMBER										SECOND TRANSVERSE SECTION AT FRAME NUMBER										THIRD TRANSVERSE SECTION AT FRAME NUMBER									
STRAKE POSITION	No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)			
					P	S	P		S						P	S	P		S						P	S	P		S	
1st below sheer strake																													
2nd																													
3rd																													
4th																													
5th																													
6th																													
7th																													
8th																													
9th																													
10th																													
11th																													
12th																													
13th																													
14th																													
15th																													
16th																													
17th																													
18th																													
19th																													
20th																													
Keel strake																													
BOTTOM TOTAL																													

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   Shell plating transverse sections:
   One, two or three sections within the cargo length area, comprising the structural items (4), (5), (6) and (7) as shown on the diagram of typical transverse sections.
2. The bottom area comprises keel, bottom and bilge plating.
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 7

TM3-BC(CSR) **Report on Thickness Measurement of Longitudinal Members (one, two or three transverse sections)**

Ship's name..... Class Identity No. ..... Report No. .....

	FIRST TRANSVERSE SECTION AT FRAME NUMBER										SECOND TRANSVERSE SECTION AT FRAME NUMBER										THIRD TRANSVERSE SECTION AT FRAME NUMBER									
STRUCTURAL MEMBER	Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)			
					P	S	P		S						P	S	P		S						P	S	P		S	

Notes:

1. This report is to be used for recording the thickness measurement of:
   Longitudinal members at transverse sections:
   One, two or three sections within the cargo length area, comprising the appropriate structural items (8) to (20) as shown on the diagram of typical transverse sections.
2. The exact frame station of measurement is to be stated.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 8
TM4-BC(CSR)

Report on Thickness Measurement of Transverse Structural Members in Double Bottom, Hopper Side and Topside Water Ballast Tanks

Ship's name..... Class Identity No. ..... Report No. .....

TANK DESCRIPTION:										
LOCATION OF STRUCTURE										
STRUCTURAL MEMBER	ITEM	As Built Thickness mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)			
					P	S	P		S	

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of transverse structural members, comprising the appropriate structural items (23) to (25) as shown on the diagram of typical transverse sections.
2. Guidance for areas of measurement is indicated on the diagrams shown on Sheet 14 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 9

TM5-BC(CSR) **Report on Thickness Measurement of Cargo Hold Transverse Bulkheads**

Ship's name..... Class Identity No. ..... Report No. .....

HOLD DESCRIPTION:

LOCATION OF STRUCTURE: FRAME NO.:

STRUCTURAL COMPONENT (PLATING/STIFFENER)	As Built Thickness mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)			
				P	S	P		S	

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of cargo hold transverse bulkheads.
2. Guidance for areas of measurement is indicated on the diagrams shown on Sheet 14 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 10

TM6-BC(CSR) **Report on Thickness Measurement of Miscellaneous Structural Members**

Ship's name..... Class Identity No. ..... Report No. .....

STRUCTURAL MEMBER:											SKETCH
LOCATION OF STRUCTURE:											
Description	As Built Thk. mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)					
				P	S	P		S			

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of miscellaneous structural members including the structural item (28), (29) and (30) as shown on the diagram of typical transverse sections, sheet 12 of this document.
2. Guidance for areas of measurement is indicated on the diagrams shown on Sheet 14 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

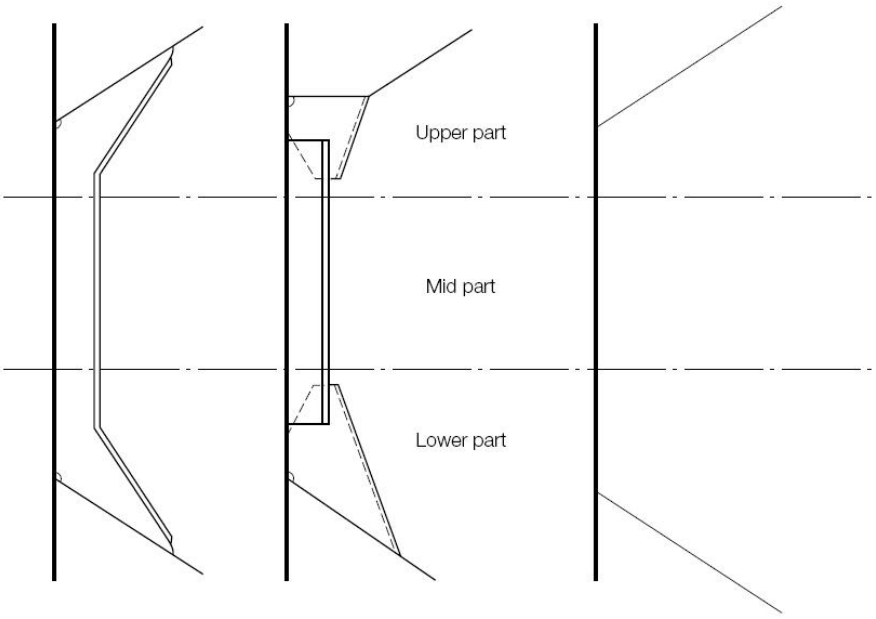
Sheet 11
TM7-BC(CSR) **Report on Thickness Measurement of Cargo Hold Transverse Frames**

Ship's name..... Class Identity No. ..... Report No. .....

CARGO HOLD NO.																															
	UPPER PART										MID PART										LOWER PART										
FRAME NUMBER	As Built Thk mm	Volun. Thk. Add. mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)				As Built Thk mm	Volun. Thk. Add. mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)				As Built Thk mm	Volun. Thk. Add. mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)						
				P	S	P		S					P	S	P		S							P	S	P		S			

Notes:

1. This report is to be used for recording the thickness measurement of:
   Cargo hold transverse frames,
   Structural item number (34) as shown on the diagram of typical transverse sections.
2. Guidance for areas of measurement is indicated on the diagrams shown on Sheet 14 of this document.
   The single measurements recorded are to represent the average of multiple measurements.
3 The location and pattern of measurements is to be indicated on the sketches of hold frames shown below.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.



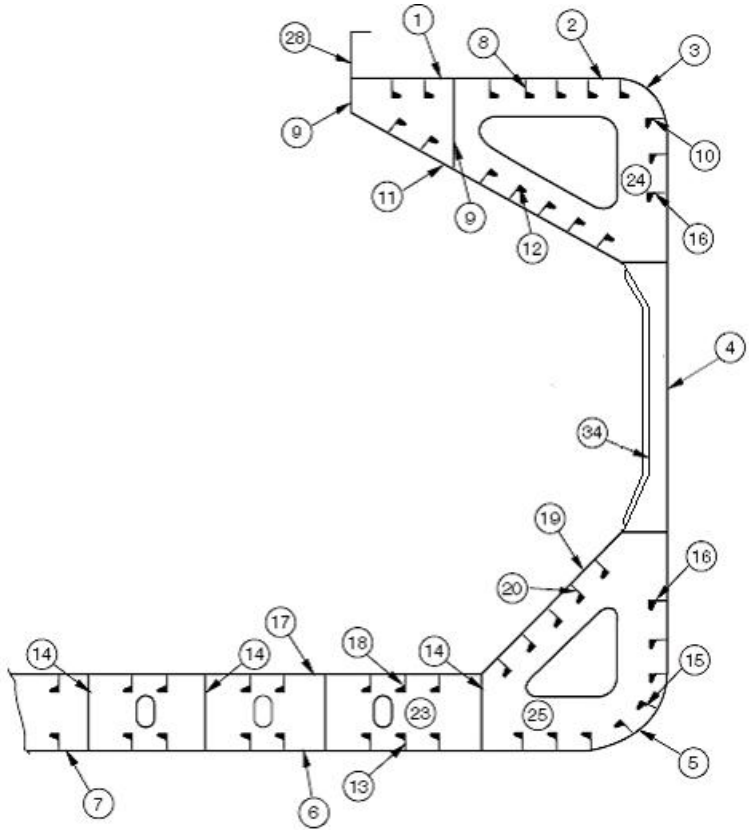
Typical transverse frames in cargo hold
Thickness gauging area (A)

Non-typical transverse frames in cargo hold
Thickness gauging area (A)

Sheet 12

Thickness Measurement – Bulk Carriers

Typical Transverse Section Indicating Longitudinal and Transverse Members

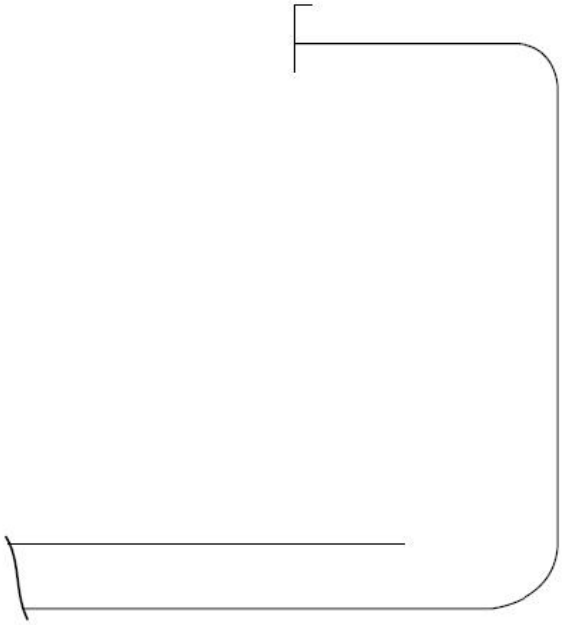


Report on TM2-BC(CSR) (i) & (ii)	Report on TM3-BC(CSR)		Report on TM6-BC(CSR)
1. Strength deck plating	8. Deck longitudinals	17. Inner bottom plating	28. Hatch coamings
2. Stringer plate	9. Deck girders	18. Inner bottom longitudinals	29. Deck plating between hatches
3. Sheerstrake	10. Sheerstrake longitudinals	19. Hopper plating	30. Hatch covers
4. Side shell plating	11. Topside tank sloping plating	20. Hopper longitudinals	31.
5. Bilge plating	12. Topside tank sloping plating longitudinals	21.	32.
6. Bottom plating	13. Bottom longitudinals	22.	33.
7. Keel plate	14. Bottom girders	**Report on TM4-BC(CSR)**	
	15. Bilge longitudinals	23. Double bottom tank floors	
	16. Side shell longitudinals, if any	24. Top side tank transverses	
		25. Hopper side tank transverses	**Report on TM7-BC(CSR)**
		26.	34.Cargo hold frames
		27.	

Sheet 13

Thickness Measurement – Bulk Carriers

Transverse section outline: The diagram may be used for those ships where the diagrams on Sheet 12 are not suitable.



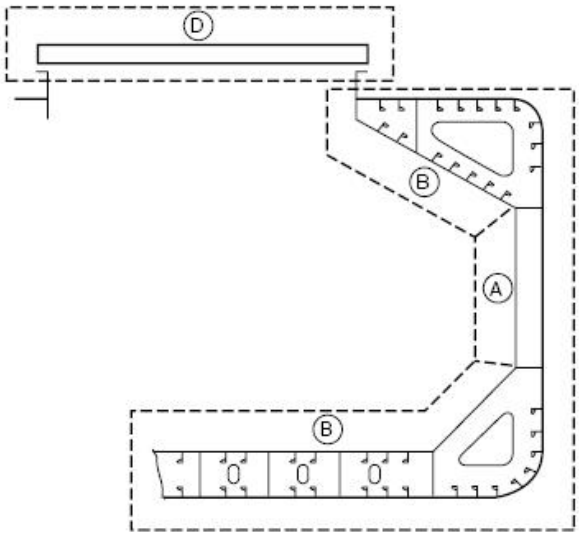
Report on TM2-BC(CSR) (i) & (ii)	Report on TM3-BC(CSR)		Report on TM6-BC(CSR)
1. Strength deck plating	8. Deck longitudinals	17. Inner bottom plating	28. Hatch coamings
2. Stringer plate	9. Deck girders	18. Inner bottom longitudinals	29. Deck plating between hatches
3. Sheerstrake	10. Sheerstrake longitudinals	19. Hopper plating	30. Hatch covers
4. Side shell plating	11. Topside tank sloping plating	20. Hopper longitudinals	31.
5. Bilge plating	12. Topside tank sloping plating longitudinals	21.	32.
6. Bottom plating	13. Bottom longitudinals	22.	33.
7. Keel plate	14. Bottom girders	**Report on TM4-BC(CSR)**	
	15. Bilge longitudinals	23. Double bottom tank floors	
	16. Side shell longitudinals, if any	24. Top side tank transverses	
		25. Hopper side tank transverses	**Report on TM7-BC(CSR)**
		26.	34.Cargo hold frames
		27.	

Sheet 14

Close-up Survey and Thickness Measurement Areas

Typical transverse section

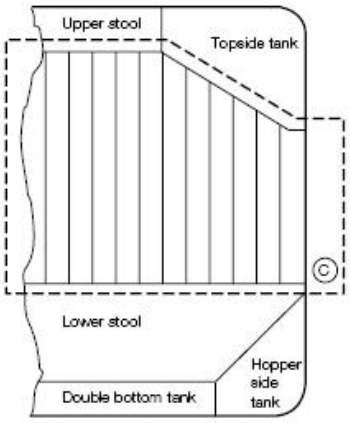
Areas (A), (B) and (D)



Thickness to be reportedd on TM3-BC, TM4-BC, TM6-BC and TM7-BC as appropriate

A cargo hold, transverse bulkhead

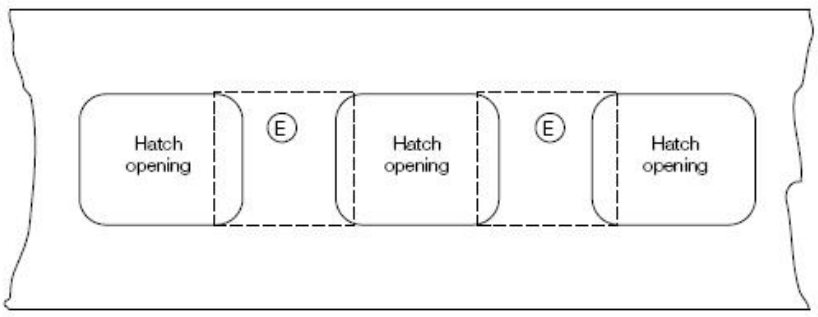
Area (C)



Thickness to be reported on TM5-BC

Typical areas of deck plating inside line of hatch openings between cargo hold hatches

Area (E)



Thickness to be reported on TM6-BC

13.3A Recommended Procedures for Thickness Measurements of Double Hull Oil Tankers

1. This document is to be used for recording thickness measurements as required by Section 6, Chapter 5 of this PART.
2. Reporting forms TM1-DHT, TM2-DHT, TM3-DHT, TM4-DHT, TM5-DHT and TM6-DHT (Sheets 4 to 10) are to be used for recording thickness measurements and the maximum allowable diminution is to be stated.
The maximum allowable diminution could be stated in an attached document.
3. The remaining Sheets 11 to 15 are guidance diagrams and notes relating to the reporting forma and the procedure for the thickness measurements.

GENERAL PARTICULARS

Ship's name:
IMO number:
Class identity number:
Port of registry:
Gross tons:
Deadweight:
Date of build:
Classification society:

Name of company performing thickness measurement:
Thickness measurement company certified by:
Certificate No:
Certificate valid from _____ to _____
Place of measurement:
First date of measurement:
Last date of measurement:
Special survey/intermediate survey due①:
Details of measurement equipment:
Qualification of operators:

Report number: consisting of Sheets

Name of operator: _____
Signature of operator: _____
Company official stamp: _____

Name of surveyor: _____
Signature of surveyor: _____
Classification society
Official Stamp: _____

① Delete as appropriate.

Sheet 4

TM1-DHT **Report on Thickness Measurement of All Deck Plating, All Bottom Shell Plating or Side Shell Plating***

(*delete as appropriate)

Ship's name..... Class Identity No. ..... Report No. .....

STRAKE POSITION																		
PLATE POSITION	No. or Letter	Org. Thk. mm	Forward Reading						Aft Reading						Mean Diminution %		Maximum Allowable Diminution
			Gauged		Diminution P		Diminution S		Gauged		Diminution P		Diminution S				
			P	S	mm	%	mm	%	P	S	mm	%	mm	%	P	S	mm
12th forward																	
11th																	
10th																	
9th																	
8th																	
7th																	
6th																	
5th																	
4th																	
3rd																	
2nd																	
1st																	
Amidships																	
1st aft																	
2nd																	
3rd																	
4th																	
5th																	
6th																	
7th																	
8th																	
9th																	
10th																	
11th																	
12th																	

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   1.1 All strength deck plating within the cargo area.
   1.2 All keel, bottom shell plating and bilge plating within the cargo area.
   1.3 Side shell plating including selected wind and water strakes outside cargo area.
   1.4 All wind and water strakes within cargo area.
2. The strake position is to be clearly indicated as follows:
   2.1 For strength deck indicate the number of the strake of plating inboard from the stringer plate.
   2.2 For bottom plating indicate the number of the strake of plating outboard from the keel plate.
   2.3 For side shell plating give number of the strake of plating below sheer strake and letter as shown on shell expansion.
3. Measurements are to be taken at the forward and aft areas of all and where plates cross ballast/cargo tank boundaries separate measurements for the area of plating in way of each type of tank are to be recorded.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The maximum allowable diminution could be stated in an attached document.

Sheet 5

TM2-DHT(i) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class Identity No. ..... Report No. .....

STRENGTH DECK AND SHEERSTRAKE PLATING																											
	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRAKE POSITION	No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%
Stringer Plate																											
1st strake inboard																											
2nd																											
3rd																											
4th																											
5th																											
6th																											
7th																											
8th																											
9th																											
10th																											
11th																											
12th																											
13th																											
14th																											
centre strake																											
sheer strake																											
TOPSIDE TOTAL																											

Operators signature: ……

Notes:

1. This report form is to be used for recording the thickness measurements of:
   Strength deck plating and sheer strake plating transverse sections:
   One, two or three sections within the cargo area comprising of the structural items (0), (1) and (2) as shown on the diagrams of typical transverse sections illustrated on Sheets 11 and 12 of this document.
2. The topside area comprises deck plating, stringer plate and sheer strake (including rounded gunwales).
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The maximum allowable diminution could be stated in an attached document.

Sheet 6

TM2-DHT(ii) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class Identity No. ..... Report No. .....

SHELL PLATING																											
	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRAKE POSITION	No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%
1st below sheer strake																											
2nd																											
3rd																											
4th																											
5th																											
6th																											
7th																											
8th																											
9th																											
10th																											
11th																											
12th																											
13th																											
14th																											
15th																											
16th																											
17th																											
18th																											
19th																											
20th																											
keel strake																											
BOTTOM TOTAL																											

Operators signature: ……

Notes:

1. This report form is to be used for recording the thickness measurements of:
   Shell plating transverse sections:
   One, two or three sections within the cargo area comprising of the structural items (3), (4) and (5) and (6) as shown on the diagrams of typical transverse sections illustrated on Sheets 11 and 12 of this document.
2. The bottom area comprises keel, bottom and bilge plating.
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The maximum allowable diminution could be stated in an attached document.

Sheet 7

TM3-DHT **Report on Thickness Measurement of Longitudinal Members (one, two or three transverse sections)**

Ship's name..... Class Identity No. ..... Report No. .....

	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRUCTURAL MEMBER	Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurements of:
   Longitudinal members at transverse sections:
   One, two or three sections within the cargo area comprising of the appropriate structural items (10) to (29) as shown on the diagrams of typical transverse sections illustrated on Sheets 11 and 12 of this document.
2. The exact frame station of measurement is to be stated.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 8
TM4-DHT

Report on Thickness Measurement of Transverse Structural Members
In the cargo oil and water ballast tanks within the cargo tank length

Ship's name..... Class Identity No. ..... Report No. .....

TANK DESCRIPTION:									
LOCATION OF STRUCTURE:									
STRUCTURAL MEMBER	ITEM	Original Thickness mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S	
				P	S	mm	%	mm	%

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurements of:
   Transverse structural members, comprising of the appropriate structural items (30) to (36) as shown on diagrams of typical transverse sections illustrated on Sheets 11 and 12 of this document.
2. Guidance for areas of measurement is indicated on Sheets 14 and 15 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 9
TM5-DHT

Report on Thickness of W.T./O.T. Transverse Bulkheads
Within the cargo tank or cargo hold spaces

Ship's name..... Class Identity No. ..... Report No. .....

TANK/HOLD DESCRIPTION:								
LOCATION OF STRUCTURE:					FRAME NO.:			
STRUCTURAL COMPONENT (PLATING/STIFFENER)	Original Thickness mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S	
			Port	Starboard	mm	%	mm	%

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   W.T./O.T. transverse bulkheads.
2. Guidance for areas of measurement is indicated on Sheet 14 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 10
TM6-DHT **Report on Thickness Measurement of Miscellaneous Structural Members**

Ship's name..... Class Identity No. ..... Report No. .....

STRUCTURAL MEMBER:									SKETCH
LOCATION OF STRUCTURE:									
Description	Org. Thk. mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S		
			P	S	mm	%	mm	%	

Operators signature: .....

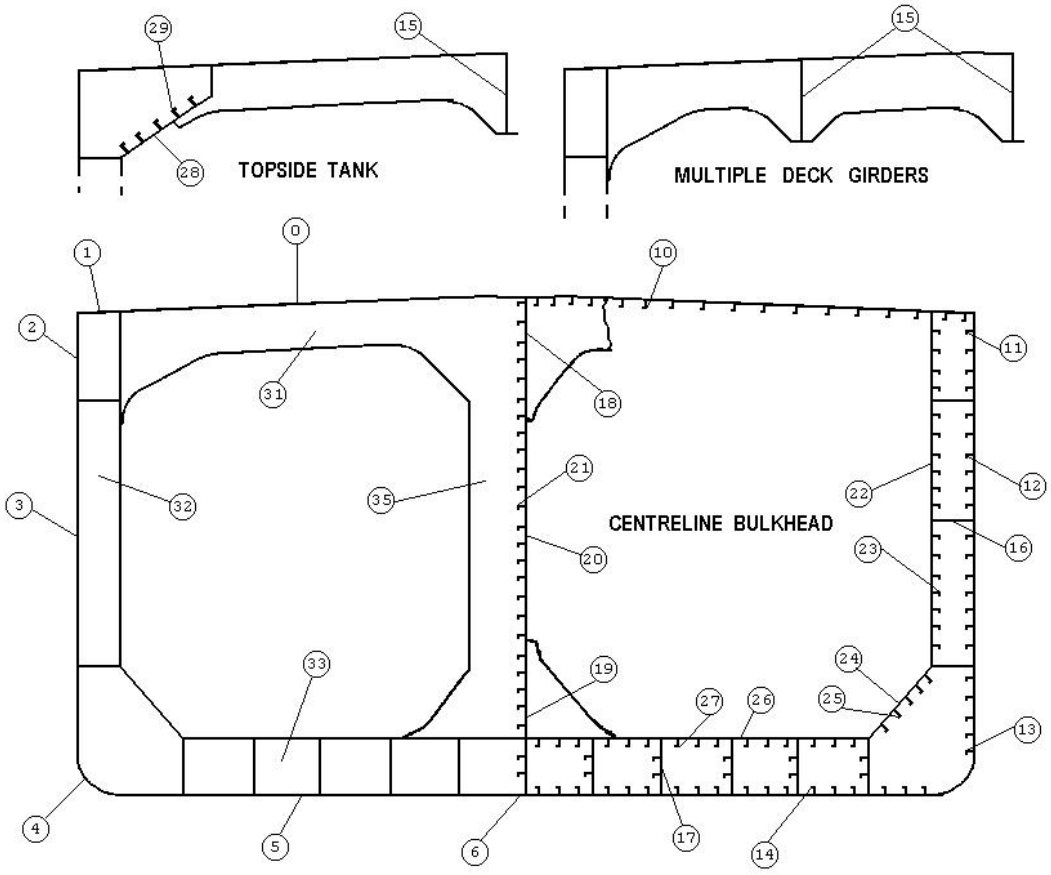
Notes:

1. This report is to be used for recording the thickness measurement of:
   Miscellaneous structural members.
2. The single measurements recorded are to represent the average of multiple measurements.
3. The maximum allowable diminution could be stated in an attached document.

Sheet 11

Thickness Measurement – Double Hull Oil Tankers

Typical Transverse Section of a Double Hull Tanker up to 150,000 dwt with Indication of Longitudinal and Transverse Members

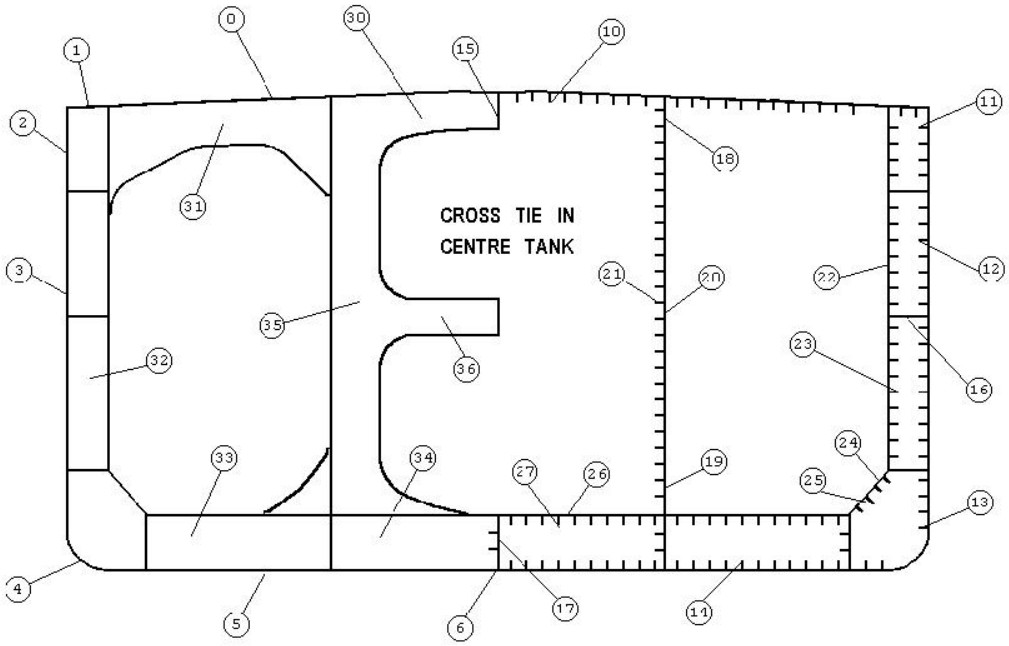


Report on TM2-DHT (i) & (ii)	Report on TM3-DHT		Report on TM4-DHT
0. Strength deck plating	10. Deck longitudinals	20. Longitudinal bulkhead plating (remainder)	30. Deck transverse (centre tank)
1. Stringer plate	11. Sheer strake longitudinals	21. Longitudinal bulkhead longitudinals	31. Deck transverse (wing tank)
2. Sheer strake	12. Side shell longitudinals	22. Inner side plating	32. Vertical web in wing ballast tank
3. Side shell plating	13. Bilge longitudinals	23. Inner side longitudinals	33. Double bottom floor – wing tank
4. Bilge plating	14. Bottom longitudinals	24. Hopper plating	34. Double bottom floor – centre tank
5. Bottom shell plating	15. Deck girders	25. Hopper longitudinals	35. Longitudinal bulkhead vertical web
6. Keel plate	16. Horizontal girders in wing ballast tanks	26. Inner bottom plating	36. Cross ties
	17. Bottom girders	27. Inner bottom longitudinals	
	18. Longitudinal bulkhead top strake	28. Topside tank plating	
	19. Longitudinal bulkhead bottom strake	29. Topside tank longitudinals	

Sheet 12

Thickness Measurement – Double Hull Oil Tankers

Typical Transverse Section of a Double Hull Tanker above 150,000 dwt with Indication of Longitudinal and Transverse Members



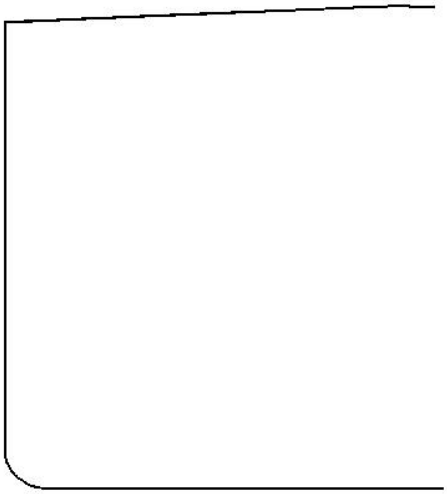
Report on TM2-DHT (i) & (ii)	Report on TM3-DHT		Report on TM4-DHT
0. Strength deck plating	10. Deck longitudinals	20. Longitudinal bulkhead plating (remainder)	30. Deck transverse (centre tank)
1. Stringer plate	11. Sheer strake longitudinals	21. Longitudinal bulkhead longitudinals	31. Deck transverse (wing tank)
2. Sheer strake	12. Side shell longitudinals	22. Inner side plating	32. Vertical web in wing ballast tank
3. Side shell plating	13. Bilge longitudinals	23. Inner side longitudinals	33. Double bottom floor – wing tank
4. Bilge plating	14. Bottom longitudinals	24. Hopper plating	34. Double bottom floor – centre tank
5. Bottom shell plating	15. Deck girders	25. Hopper longitudinals	35. Longitudinal bulkhead vertical web
6. Keel plate	16. Horizontal girders in wing ballast tanks	26. Inner bottom plating	36. Cross ties
	17. Bottom girders	27. Inner bottom longitudinals	
	18. Longitudinal bulkhead top strake	28. Topside tank plating	
	19. Longitudinal bulkhead bottom strake	29. Topside tank longitudinals	

Sheet 13

Thickness Measurement – Double Hull Oil Tankers

Transverse Section Outline

The diagram may be used for those ships where the diagrams on Sheets 11 and 12 are not suitable.

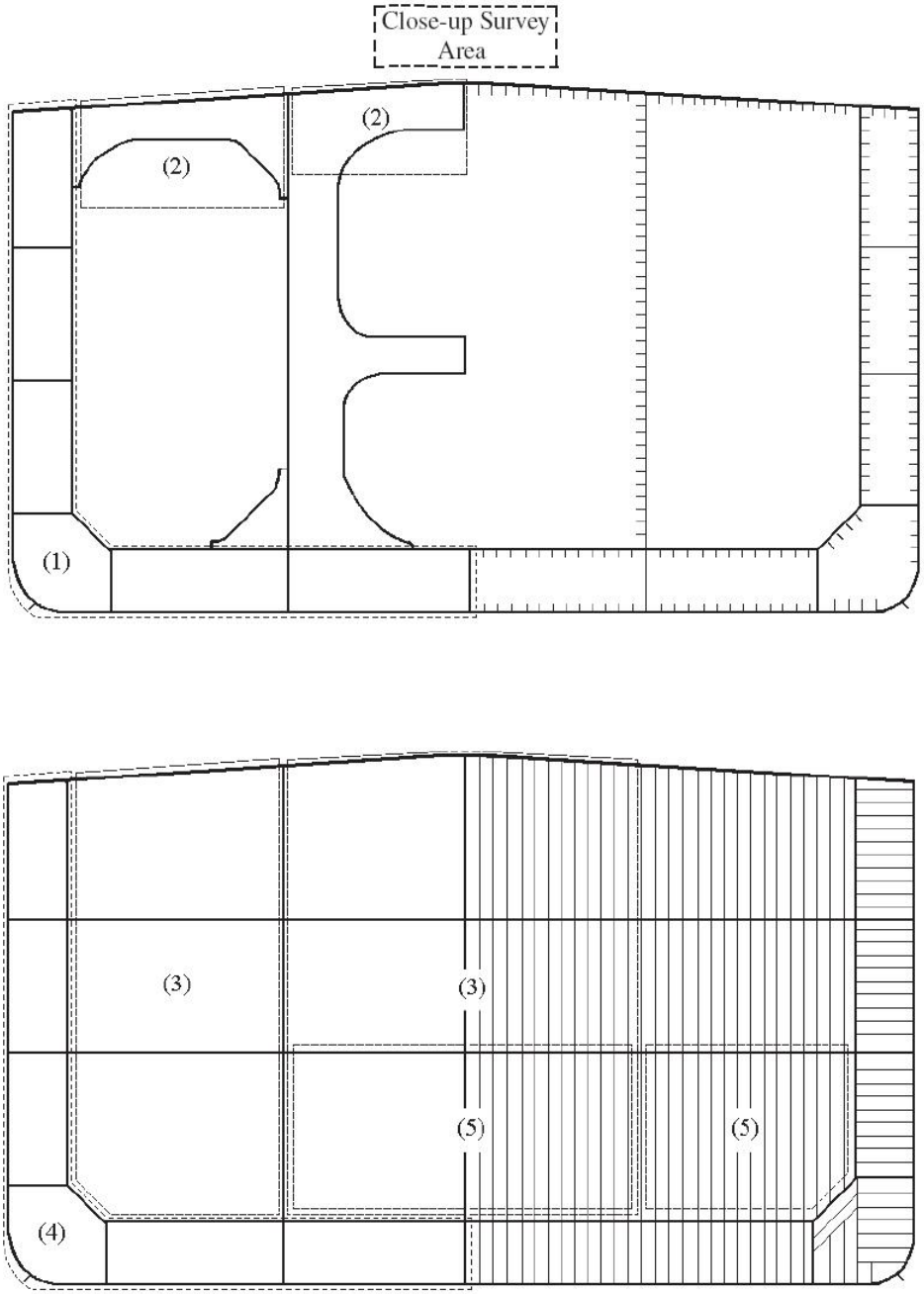


Report on TM2-DHT (i) & (ii)	Report on TM3-DHT		Report on TM4-DHT
0. Strength deck plating	10. Deck longitudinals	20. Longitudinal bulkhead plating (remainder)	30. Deck transverse (centre tank)
1. Stringer plate	11. Sheer strake longitudinals	21. Longitudinal bulkhead longitudinals	31. Deck transverse (wing tank)
2. Sheer strake	12. Side shell longitudinals	22. Inner side plating	32. Vertical web in wing ballast tank
3. Side shell plating	13. Bilge longitudinals	23. Inner side longitudinals	33. Double bottom floor – wing tank
4. Bilge plating	14. Bottom longitudinals	24. Hopper plating	34. Double bottom floor – centre tank
5. Bottom shell plating	15. Deck girders	25. Hopper longitudinals	35. Longitudinal bulkhead vertical web
6. Keel plate	16. Horizontal girders in wing ballast tanks	26. Inner bottom plating	36. Cross ties
	17. Bottom girders	27. Inner bottom longitudinals	
	18. Longitudinal bulkhead top strake	28. Topside tank plating	
	19. Longitudinal bulkhead bottom strake	29. Topside tank longitudinals	

Sheet 14

Thickness Measurement – Double Hull Oil Tankers

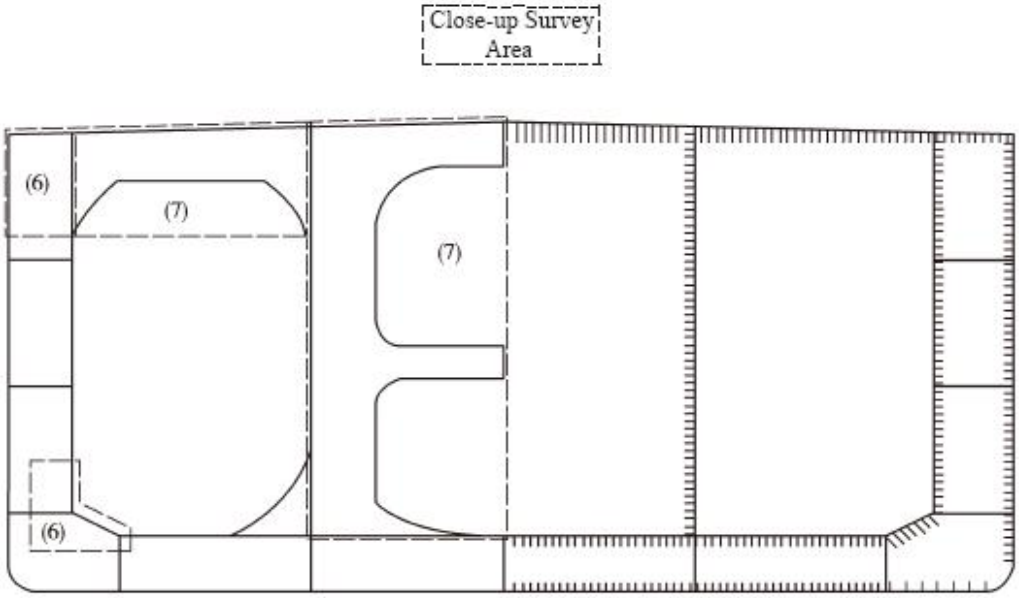
Areas subject to close-up survey and thickness measurements - Thickness to be reported on TM3-DHT, TM4-DHT and TM5-DHT as appropriate



Sheet 15

Thickness Measurement – Double Hull Oil Tankers

Areas subject to close-up survey and thickness measurements - Thickness to be reported on TM3-DHT and TM4-DHT as appropriate



13.3B Recommended Procedures for Thickness Measurements of Double Hull Oil Tankers Built under Common Structural Rules①

Notes:
1. This document is to be used for recording thickness measurements of double hull oil tankers built under Common Structural Rules① as required by 5.1.9.3, Section 1, Chapter 5 of this PART.

2. Reporting forms TM1-DHT(CSR), TM2-DHT(CSR)(i) and (ii), TM3-DHT(CSR), TM4-DHT(CSR), TM5-DHT(CSR) and TM6-DHT(CSR) (Sheets 4 to 10) are to be used for recording thickness measurements. The as-built thickness, the voluntary thickness addition and the renewal thickness (minimum allowable thickness) are to be stated in the said forms.

3. The remaining Sheets 11 to 15 are guidance diagrams and notes relating to the reporting forms and the procedure for the thickness measurement.

GENERAL PARTICULARS

Ship's name:
IMO number:
Class identity number
Port of registry:
Gross tons:
Deadweight:
Date of build:
Classification society:

Name of Company performing thickness measurement:
Thickness measurement company certified by:
Certificate No.
Certificate valid from …… to ……
Place of measurement:
First date of measurement:
Last date of measurement:
Special survey/intermediate survey due:②
Details of measurement equipment:
Qualification of operators:

Report number: consisting of Sheets

Name of operator:	……	Name of surveyor:	……
Signature of operator:	……	Signature of surveyor:	……
Company		Classification society	
Official stamp:		Official Stamp:	

① PART NINE of the Rules (2012 version) and its 2013 and 2014 amendments or PART NINE of the Rules (2015 version) and its subsequent versions (including amendments).
② Delete as appropriate.

Sheet 4

TM1-DHT(CSR) **Report on Thickness Measurement of All Deck Plating, All Bottom Plating or Side Shell Plating***

(*delete as appropriate)

Ship's name..... Class Identity No..... Report No.....

STRAKE POSITION																		
PLATE POSITION	No. or Letter	As Built Thk. mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Forward Reading						Aft Reading						Mean Remaining Corr. Addition, mm [(c1)+(c2)]/2	
					Gauged Thk. mm (b1)		Remaining Corr. Addition, mm (c1)=(b1)-(a)				Gauged Thk. mm (b2)		Remaining Corr. Addition, mm (c2)=(b2)-(a)					
					P	S	P		S		P	S	P		S		P	S
12th																		
11th																		
10th																		
9th																		
8th																		
7th																		
6th																		
5th																		
4th																		
3rd																		
2nd																		
1st forward																		
Amidships																		
1st aft																		
2nd																		
3rd																		
4th																		
5th																		
6th																		
7th																		
8th																		
9th																		
10th																		
11th																		
12th																		

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   1.1 All strength deck plating within the cargo length area.
   1.2 All keel, bottom shell plating and bilge plating within the cargo length area.
   1.3 Side shell plating including selected wind and water strakes outside the cargo length area.
   1.4 All wind and water strakes within the cargo length area.
2. The strake position is to be clearly indicated as follows:
   2.1 For strength deck indicate the number of the strake of plating inboard from the stringer plate.
   2.2 For bottom plating indicate the number of the strake of plating outboard from the keel plate.
   2.3 For side shell plating give number of the strake of plating sheer strake and letter as shown on shell expansion.
3. Measurements are to be taken at the forward and aft areas of all plates cross ballast/cargo tank boundaries, separate measurements for the area of plating in way of each type of tank are to be recorded.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 5

TM2-DHT(CSR)(i) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class Identity No..... Report No.....

STRENGTH DECK AND SHEERSTRAKE PLATING																															
	FIRST TRANSVERSE SECTION AT FRAME NUMBER										SECOND TRANSVERSE SECTION AT FRAME NUMBER										THIRD TRANSVERSE SECTION AT FRAME NUMBER									
STRAKE POSITION	No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)			
					P	S	P		S						P	S	P		S						P	S	P		S	
Stringer Plate																														
1st strake inboard																														
2nd																														
3rd																														
4th																														
5th																														
6th																														
7th																														
8th																														
9th																														
10th																														
11th																														
12th																														
13th																														
14th																														
centre strake																														
sheer strake																														
TOPSIDE TOTAL																														

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   Strength deck plating and sheer strake plating transverse sections:
   One, two or three sections within the cargo length area, comprising the structural items (0), (1) and (2) as shown on the diagram of typical transverse sections, illustrated on Sheets 11 and 12 of this document.
2. The topside area comprises deck plating, stringer plate and sheer strake (including rounded gunwales).
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 6

TM2-DHT(CSR)(ii) **Report on Thickness Measurement of Shell Plating (one, two or three transverse sections)**

Ship's name..... Class Identity No..... Report No.....

SHELL PLATING																															
	FIRST TRANSVERSE SECTION AT FRAME NUMBER										SECOND TRANSVERSE SECTION AT FRAME NUMBER										THIRD TRANSVERSE SECTION AT FRAME NUMBER									
STRAKE POSITION	No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)			
					P	S	P		S						P	S	P		S						P	S	P		S	
1st below sheer strake																														
2nd																														
3rd																														
4th																														
5th																														
6th																														
7th																														
8th																														
9th																														
10th																														
11th																														
12th																														
13th																														
14th																														
15th																														
16th																														
17th																														
18th																														
19th																														
20th																														
Keel strake																														
BOTTOM TOTAL																														

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   Shell plating transverse sections:
   One, two or three sections within the cargo length area, comprising the structural items (3), (4), (5) and (6) as shown on the diagram of typical transverse sections, illustrated on Sheets 11 and 12 of this document.
2. The bottom area comprises keel, bottom and bilge plating.
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 7

TM3-DHT(CSR) **Report on Thickness Measurement of Longitudinal Members (one, two or three transverse sections)**

Ship's name..... Class Identity No..... Report No.....

	FIRST TRANSVERSE SECTION AT FRAME NUMBER										SECOND TRANSVERSE SECTION AT FRAME NUMBER										THIRD TRANSVERSE SECTION AT FRAME NUMBER									
STRUCTURAL MEMBER	Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)			
					P	S	P		S						P	S	P		S						P	S	P		S	

Notes:

1. This report is to be used for recording the thickness measurement of:
   Longitudinal members at transverse sections:
   One, two or three sections within the cargo length area, comprising the appropriate structural items (10) to (29) as shown on the diagram of typical transverse sections, illustrated on Sheets 11 and 12 of this document.
2. The exact frame station of measurement is to be stated.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 8
TM4-DHT(CSR)

Report on Thickness Measurement of Transverse Structural Members
In the Cargo Oil and Water Ballast Tanks within the Cargo Tank Length

Ship's name..... Class Identity No..... Report No.....

TANK DESCRIPTION:										
LOCATION OF STRUCTURE										
STRUCTURAL MEMBER	ITEM	As Built Thickness mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)			
					P	S	P		S	

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   Transverse structural members, comprising the appropriate structural items (30) to (36) as shown on the diagram of typical transverse sections, illustrated on Sheets 11 and 12 of this document.
2. Guidance for areas of measurement is indicated on the diagrams shown on Sheet 14 and 15 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 9
TM5-DHT(CSR)

Report on Thickness Measurement of W.T./O.T. Transverse Bulkheads Within the Cargo and Ballast Tanks

Ship's name..... Class Identity No..... Report No.....

TANK DESCRIPTION:									
LOCATION OF STRUCTURE:				FRAME NO.:					
STRUCTURAL COMPONENT (PLATING/STIFFENER)	As Built Thickness mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)			
				P	S	P		S	

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   W.T./O.T. transverse bulkheads.
2. Guidance for areas of measurement is indicated on the diagrams shown on Sheet 14 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 10

TM6-DHT(CSR) **Report on Thickness Measurement of Miscellaneous Structural Members**

Ship's name..... Class Identity No..... Report No.....

STRUCTURAL MEMBER:										SKETCH
LOCATION OF STRUCTURE:										
Description	As Built Thk. mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)				
				P	S	P		S		

Operators signature: ……

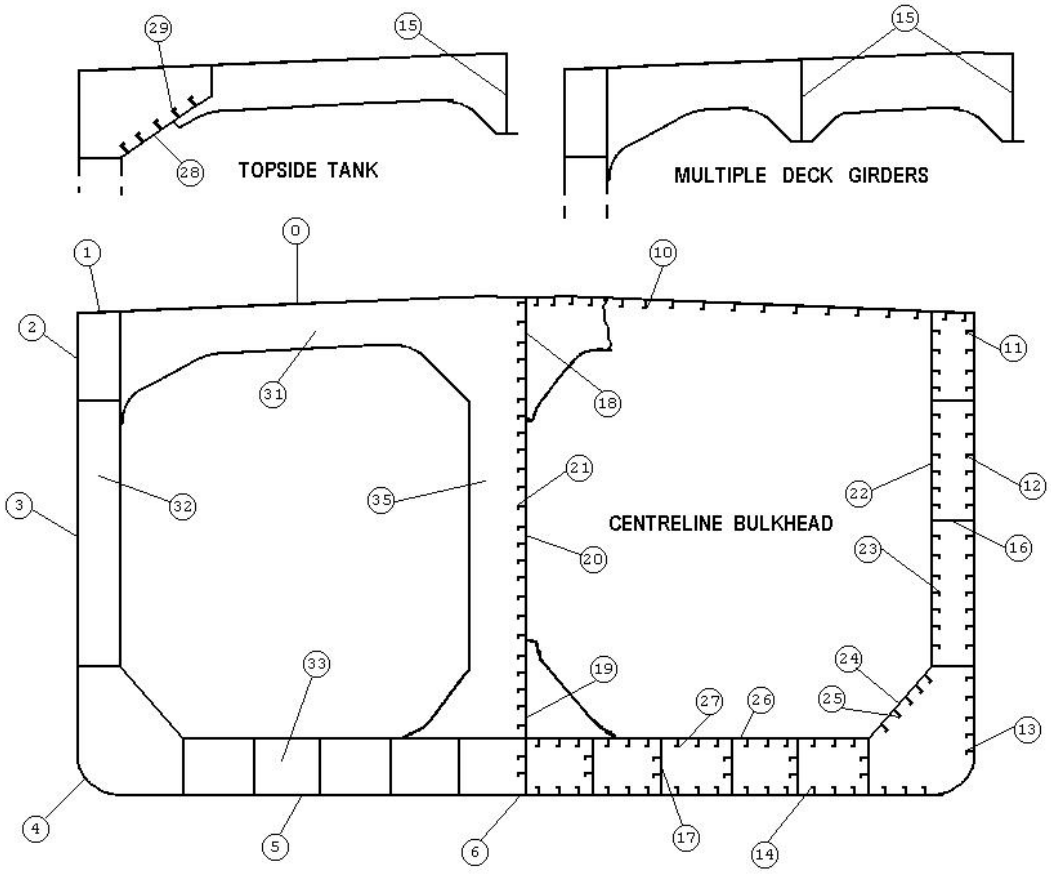
Notes:

1. This report is to be used for recording the thickness measurement of miscellaneous structural members.
2. The single measurements recorded are to represent the average of multiple measurements.
3. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 11

Thickness Measurement – Double Hull Oil Tankers

Typical Transverse Section of a Double Hull Oil Tanker Up to 150,000 dwt with Indication of Longitudinal and Transverse Members

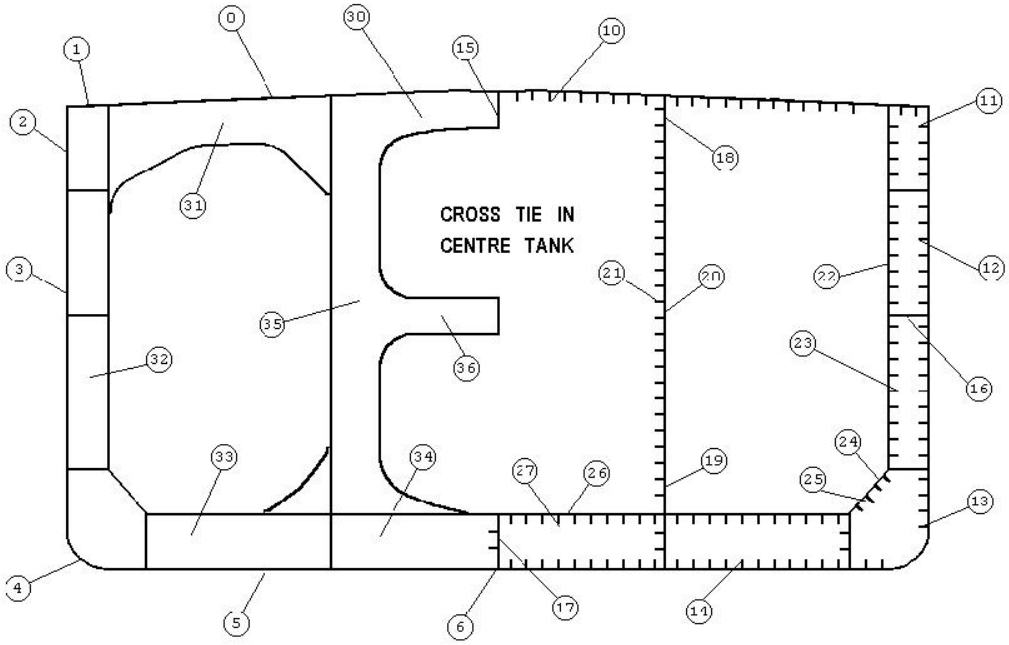


Report on TM2-DHT(CSR)(i) & (ii)	Report on TM3-DHT(CSR)		Report on TM4-DHT(CSR)
0. Strength deck plating	10. Deck longitudinals	20. Longitudinal bulkhead plating (remainder)	30. Deck transverse – centre tank
1. Stringer plate	11. Sheer strake longitudinals	21. Longitudinal bulkhead longitudinals	31. Deck transverse – wing tank
2. Sheer strake	12. Side shell longitudinals	22. Inner side plating	32. Vertical web in wing ballast tank
3. Side shell plating	13. Bilge longitudinals	23. Inner side longitudinal	33. Double bottom floor – wing tank
4. Bilge plating	14. Bottom longitudinals	24. Hopper plating	34. Double bottom floor – centre tank
5. Bottom shell plating	15. Deck girders	25. Hopper longitudinal	35. Longitudinal bulkhead vertical web
6. Keel plate	16. Horizontal girders in wing ballast tanks	26. Inner bottom plating	36. Cross ties
	17. Bottom girders	27. Inner bottom longitudinals	
	18. Longitudinal bulkhead top strake	28. Topside tank plating	
	19. Longitudinal bulkhead bottom strake	29. Topside tank longitudinals	

Sheet 12

Thickness Measurement – Double Hull Oil Tankers

Typical Transverse Section of a Double Hull Oil Tanker above 150,000 dwt with Indication of Longitudinal and Transverse Members



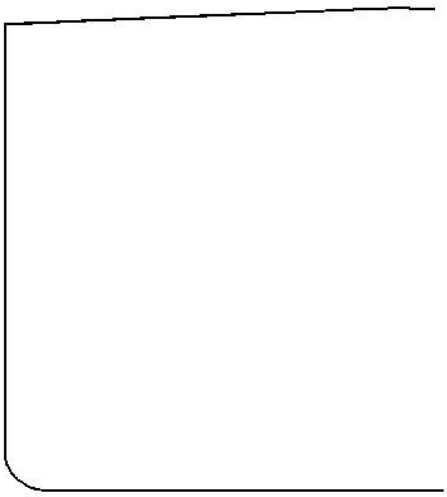
Report on TM2-DHT(CSR)(i) & (ii)	Report on TM3-DHT(CSR)		Report on TM4-DHT(CSR)
0. Strength deck plating	10. Deck longitudinals	20. Longitudinal bulkhead plating (remainder)	30. Deck transverse – centre tank
1. Stringer plate	11. Sheer strake longitudinals	21. Longitudinal bulkhead longitudinals	31. Deck transverse – wing tank
2. Sheer strake	12. Side shell longitudinals	22. Inner side plating	32. Vertical web in wing ballast tank
3. Side shell plating	13. Bilge longitudinals	23. Inner side longitudinal	33. Double bottom floor – wing tank
4. Bilge plating	14. Bottom longitudinals	24. Hopper plating	34. Double bottom floor – centre tank
5. Bottom shell plating	15. Deck girders	25. Hopper longitudinal	35. Longitudinal bulkhead vertical web
6. Keel plate	16. Horizontal girders in wing ballast tanks	26. Inner bottom plating	36. Cross ties
	17. Bottom girders	27. Inner bottom longitudinals	
	18. Longitudinal bulkhead top strake	28. Topside tank plating	
	19. Longitudinal bulkhead bottom strake	29. Topside tank longitudinals	

Sheet 13

Thickness Measurement – Double Hull Oil Tankers

Transverse Section Outline

The diagram may be used for those ships where the diagrams on Sheets 11 and 12 are not suitable.

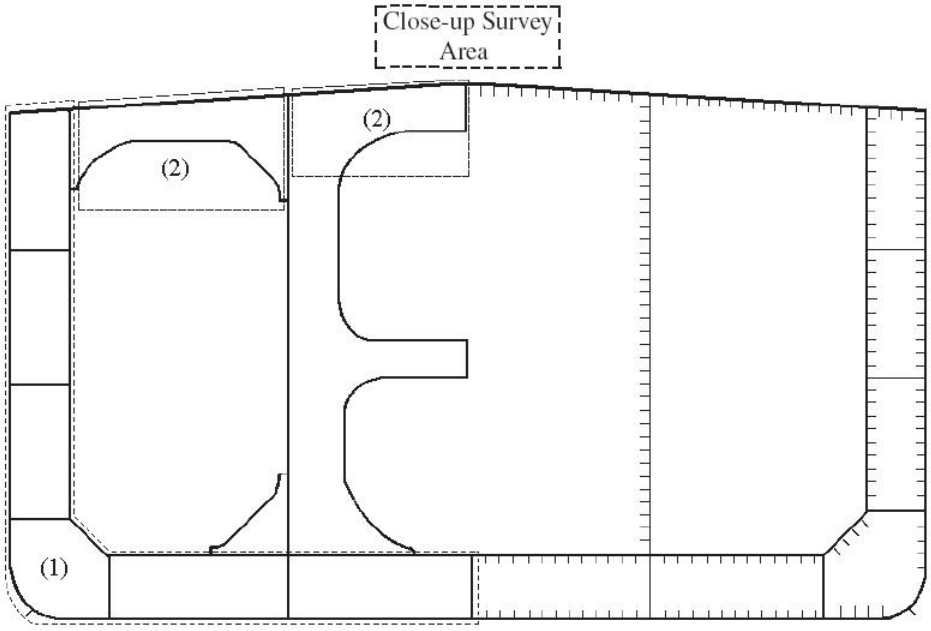


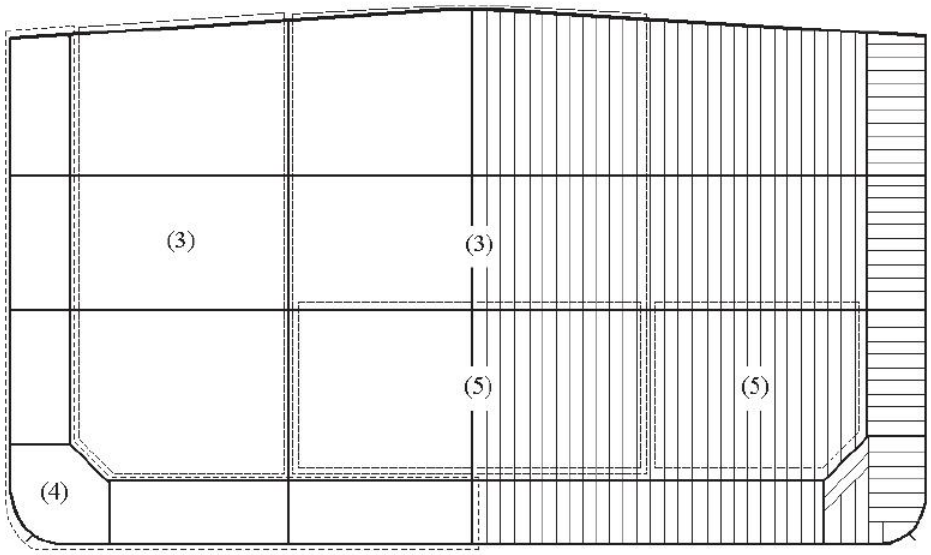
Report on TM2-DHT(CSR)(i) & (ii)	Report on TM3-DHT(CSR)		Report on TM4-DHT(CSR)
0. Strength deck plating	10. Deck longitudinals	20. Longitudinal bulkhead plating (remainder)	30. Deck transverse – centre tank
1. Stringer plate	11. Sheer strake longitudinals	21. Longitudinal bulkhead longitudinals	31. Deck transverse – wing tank
2. Sheer strake	12. Side shell longitudinals	22. Inner side plating	32. Vertical web in wing ballast tank
3. Side shell plating	13. Bilge longitudinals	23. Inner side longitudinal	33. Double bottom floor – wing tank
4. Bilge plating	14. Bottom longitudinals	24. Hopper plating	34. Double bottom floor – centre tank
5. Bottom shell plating	15. Deck girders	25. Hopper longitudinal	35. Longitudinal bulkhead vertical web
6. Keel plate	16. Horizontal girders in wing ballast tanks	26. Inner bottom plating	36. Cross ties
	17. Bottom girders	27. Inner bottom longitudinals	
	18. Longitudinal bulkhead top strake	28. Topside tank plating	
	19. Longitudinal bulkhead bottom strake	29. Topside tank longitudinals	

Sheet 14

Close-up Survey and Thickness Measurement Areas

Areas subject to close-up survey and thickness measurements – areas (1) to (5) as defined in Table 5.6.4.3(2)② of Section 6, Chapter 5 of this PART – Thickness to be reported on TM3-DHT(CSR), TM4-DHT(CSR) and TM5-DHT(CSR) as appropriate.

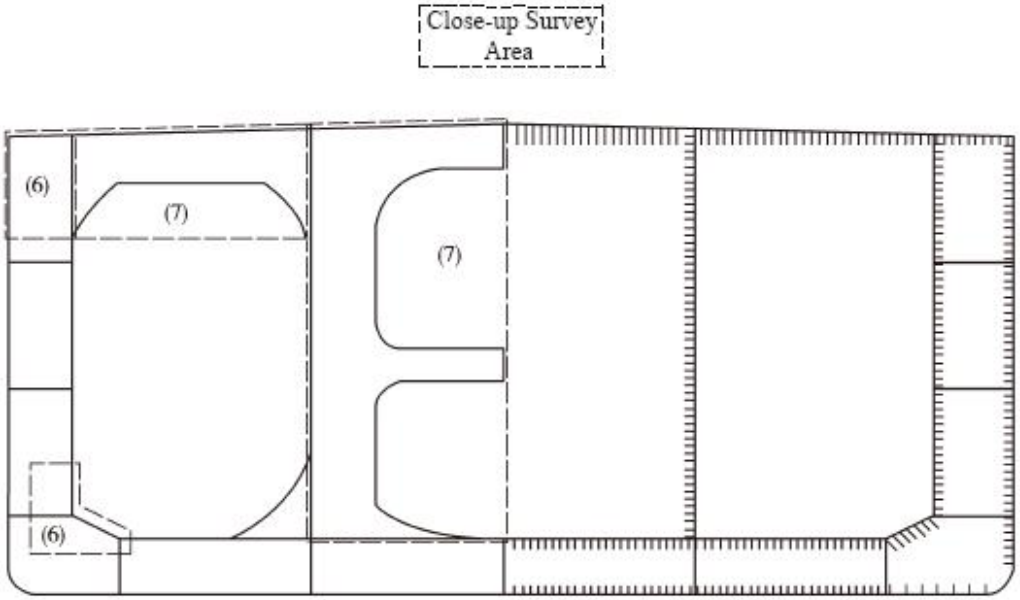




Sheet 15

Close-up Survey and Thickness Measurement Areas

Areas subject to close-up survey and thickness measurements – areas (6) to (7) as defined in Table 5.6.4.3(2)② of Section 6, Chapter 5 of this PART – Thickness to be reported on TM3-DHT(CSR) and TM4-DHT(CSR) as appropriate.



13.4A Recommended Procedures for Thickness Measurements of Double Skin Bulk Carriers

Notes:
1. This document is to be used for recording thickness measurements as required by Section 7, Chapter 5 of this Part.

2. Reporting forms TM1-DSBC, TM2-DSBC, TM3-DSBC, TM4-DSBC, TM5-DSBC and TM6-DSBC (Sheets 4 to 10) are to be used for recording thickness measurements and the maximum allowable diminution should be stated.
The maximum allowable diminution could be stated in an attached document.

3. The remaining Sheets 11 to 14 are guidance diagrams and notes relating to the reporting forms and the procedure for the thickness measurements as required by IACS Unified Requirement.

GENERAL PARTICULARS

Ship's name:
IMO number:
Class identity number:
Port of registry:
Gross tons:
Deadweight:
Date of build:
Classification society:

Name of company performing thickness measurement:
Thickness measurement company certified by:
Certificate No.
Certificate valid from _____ to _____
Place of measurement:
First date of measurement:
Last date of measurement:
Special survey/intermediate survey due*:
Details of measurement equipment:
Qualification of operator:

Report number: consisting of Sheets

Name of operator: _____
Signature of operator: _____
Company official stamp: _____

Name of surveyor: _____
Signature of surveyor: _____
Classification society
Official Stamp: _____

* Delete as appropriate.

Sheet 4

TM1-DSBC **Report on Thickness Measurement of All Deck Plating, All Bottom Shell Plating and Side Shell Plating***

(*delete as appropriate)

Ship's name..... Class Identity No. ..... Report No. .....

STRAKE POSITION																	
PLATE POSITION	No. or Letter	Org. Thk. mm	Forward Reading						Aft Reading						Mean Diminution %		Maximum Allowable Diminution
			Gauged		Diminution P		Diminution S		Gauged		Diminution P		Diminution S				
			P	S	mm	%	mm	%	P	S	mm	%	mm	%	P	S	mm
12th forward																	
11th																	
10th																	
9th																	
8th																	
7th																	
6th																	
5th																	
4th																	
3rd																	
2nd																	
1st																	
Amidships																	
1st aft																	
2nd																	
3rd																	
4th																	
5th																	
6th																	
7th																	
8th																	
9th																	
10th																	
11th																	
12th																	

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   1.1 All strength deck plating within cargo length area.
   1.2 All keel, bottom shell plating and bilge plating within the cargo length area.
   1.3 Side shell plating including selected wind and water strakes outside cargo length area.
   1.4 All wind and water strakes within cargo length area.
2. The strake position is to be clearly indicated as follows:
   2.1 For strength deck indicate the number of the strake of plating inboard from the stringer plate.
   2.2 For bottom plating indicate the number of the strake of plating outboard from the keel plate.
   2.3 For side shell plating give number of the strake of plating sheer strake and letter as shown on shell expansion.
3. Only the deck plating strakes outside line of openings are to be recorded.
4. Measurements are to be taken at the forward and aft areas of all plates and where plates cross ballast/cargo tank boundaries separate measurements for the area of plating in way of each type of tank are to be recorded.
5. The single measurements recorded are to represent the average of multiple measurements.
6. The maximum allowable diminution could be stated in an attached document.

Sheet 5

TM2-DSBC(i) **Report on Thickness Measurement of Shell and Deck Plating at Transverse Sections (one, two or three transverse sections)**

Ship's name..... Class identity No. ..... Report No. .....

STRENGTH DECK AND SHEERSTRAKE PLATING																											
	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRAKE POSITION	No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%
Stringer Plate																											
1st strake inboard																											
2nd																											
3rd																											
4th																											
5th																											
6th																											
7th																											
8th																											
9th																											
10th																											
11th																											
12th																											
13th																											
14th																											
centre strake																											
sheer strake																											
TOPSIDE TOTAL																											

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Strength deck plating and sheer strake plating transverse sections:
   One, two or three sections within the cargo length area, comprising the structural items (0), (1) and (2) as shown on the diagrams of typical transverse sections illustrated on Sheets 11, 12 and 13 of this document.
2. Only the deck plating strakes outside line of hatch openings are to be recorded.
3. The top side area comprises deck plating, stringer plate and sheer strake (including rounded gunwales).
4. The exact frame station of measurement is to be stated.
5. The single measurements recorded are to represent the average of multiple measurements.
6. The maximum allowable diminution could be stated in an attached document.

Sheet 6

TM2-DSBC (ii) **Report on Thickness Measurement of Shell and Deck Plating at Transverse Sections (one, two or three transverse sections)**

Ship's name..... Class identity No. ..... Report No. .....

SHELL PLATING																											
	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRAKE POSITION	No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%
1st below sheer strake																											
2nd																											
3rd																											
4th																											
5th																											
6th																											
7th																											
8th																											
9th																											
10th																											
11th																											
12th																											
13th																											
14th																											
15th																											
16th																											
17th																											
18th																											
19th																											
20th																											
keel strake																											
BOTTOM TOTAL																											

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Shell plating at transverse sections:
   One, two or three sections within the cargo length area, comprising the structural items (3), (4), (5) and (6) as shown on the diagrams of typical transverse sections illustrated on Sheets 11, 12 and 13 of this document.
2. The bottom area comprises keel, bottom and bilge plating.
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The maximum allowable diminution could be stated in an attached document.

Sheet 7

TM3-DSBC **Report on Thickness Measurement of Longitudinal Members at Transverse Sections (one, two or three transverse sections)**

Ship's name..... Class identity No. ..... Report No. .....

	FIRST TRANSVERSE SECTION AT FRAME NUMBER									SECOND TRANSVERSE SECTION AT FRAME NUMBER									THIRD TRANSVERSE SECTION AT FRAME NUMBER								
STRUCTURAL MEMBER	Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S		Item No.	Org. Thk.	Max. Alwb. Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Longitudinal members at transverse sections:
   One, two or three sections within the cargo length area comprising the appropriate structural items (10) to (25) as shown on diagrams of typical transverse sections illustrated on Sheets 11, 12 and 13 of this document.
2. The exact frame station of measurement is to be stated.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 8

TM4-DSBC

Report on Thickness Measurement of Transverse Structural Members

In the double bottom, hopper side and topside water ballast tanks

Ship's name..... Class identity No. ..... Report No. .....

TANK DESCRIPTION:									
LOCATION OF STRUCTURE:									
STRUCTURAL MEMBER	ITEM	Original Thickness mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S	
				P	S	mm	%	mm	%

Operators signature: .....

Notes:

1. This report is to be used for recording the thickness measurement of:
   Transverse structural members, comprising the appropriate structural items (30) to (34) as shown on diagrams of typical transverse sections illustrated on Sheets 11, 12 and 13 of this document.
2. Guidance for areas of measurements is indicated on Sheet 14 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 9
TM5-DSBC **Report on Thickness of Watertight Transverse Bulkheads in Cargo Holds**

Ship's name..... Class identity No. ..... Report No. .....

LOCATION OF STRUCTURE:					FRAME NO.:			
STRUCTURAL COMPONENT (PLATING/STIFFENER)								
	Original Thickness mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S	
			Port	Starboard	mm	%	mm	%

Operators signature: .....

Notes:

1. This report form is to be used for recording the thickness measurement of:
   W.T. transverse bulkheads in cargo holds.
2. Guidance for areas of measurements is indicated on Sheet 14 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 10
TM6-DSBC **Report on Thickness Measurement of Miscellaneous Structural Members**

Ship's name..... Class identity No. ..... Report No. .....

STRUCTURAL MEMBER:									SKETCH
LOCATION OF STRUCTURE:									
Description	Org. Thk. mm	Max. Alwb. Dim. mm	Gauged		Diminution P		Diminution S		
			P	S	mm	%	mm	%	

Operators signature: .....

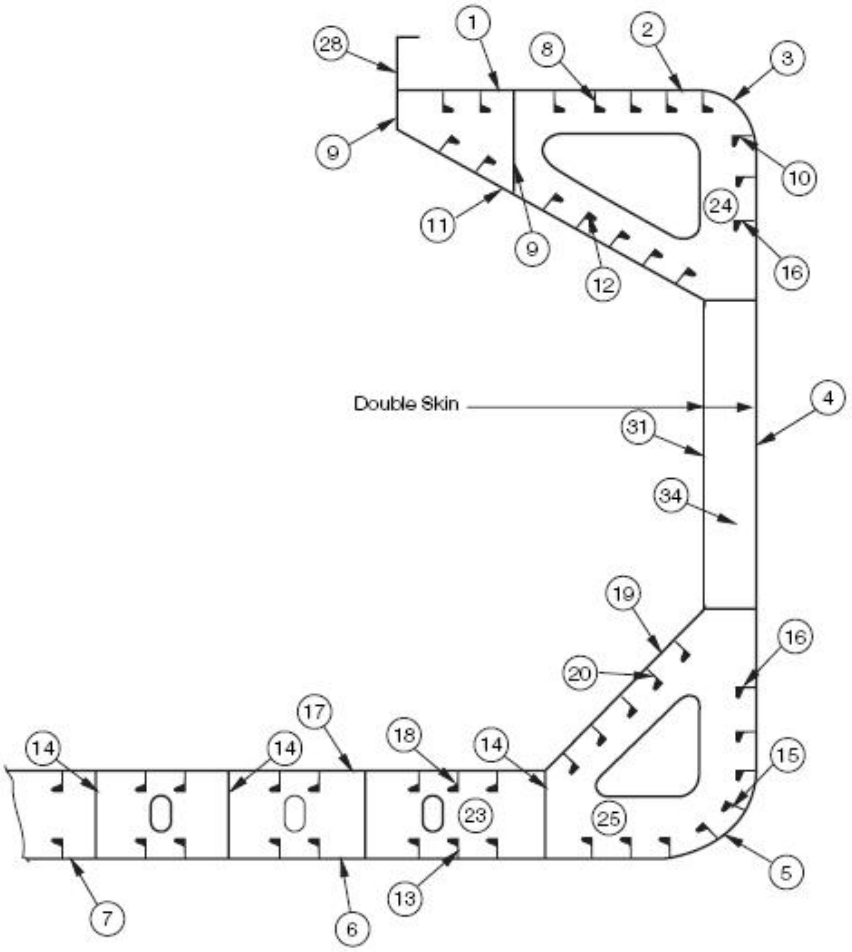
Notes:

1. This report is to be used for recording the thickness measurement of:
   Miscellaneous structural members including the structural items (40), (41) and (42) as shown on diagrams of typical transverse sections illustrated on Sheets 11, 12 and 13 of this document.
2. Guidance for areas of measurement is indicated on Sheet 14 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

Sheet 11

Thickness Measurement – Double Skin Bulk Carriers

Typical Transverse Section of a Double Skin Bulk Carrier with Indication of Longitudinal and Transverse Members

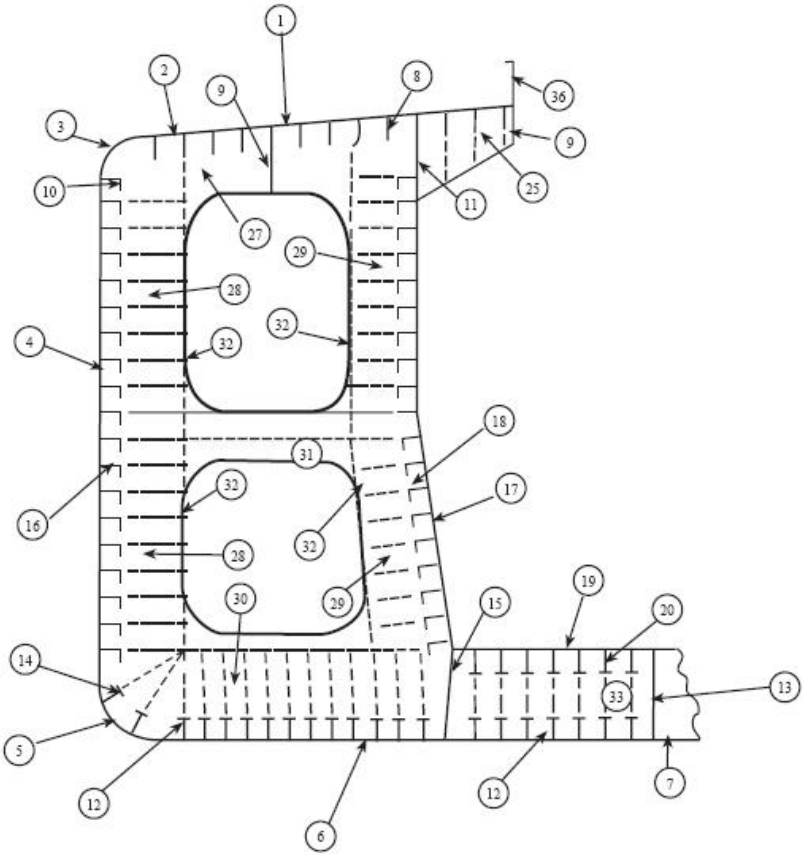


Report on TM2-DSBC(i) & (ii)	18. Inner bottom longitudinals
1. Strength deck plating	19. Hopper plating
2. Stringer plate	20. Hopper longitudinals
3. Sheer strake	31. Inner side plating
4. Side shell plating	– Inner side longitudinals, if any
5. Bilge plating	– Horizontal girders in wing ballast tanks
6. Bottom shell plating	
7. Keel plate	
	Report on TM4-DSBC
	23. Double bottom tank floors
Report on TM3-DSBC	25. Hopper side tank transverses
8. Deck longitudinals	34. Transverse web frame
9. Deck girders	– Topside tank transverses
10. Sheer strake longitudinals	
11. Topside tank sloping plating	
12. Topside tank sloping plating longitudinals	**Report on TM6-DSBC**
13. Bottom longitudinals	28. Hatch coamings
14. Bottom girders	– Deck plating between hatches
15. Bilge longitudinals	– Hatch covers
16. Side shell longitudinals, if any	
17. Inner bottom plating	

Sheet 12

Thickness Measurement – Ore Carriers

Typical Transverse Section of an Ore Carrier with Indication of Longitudinal and Transverse Members

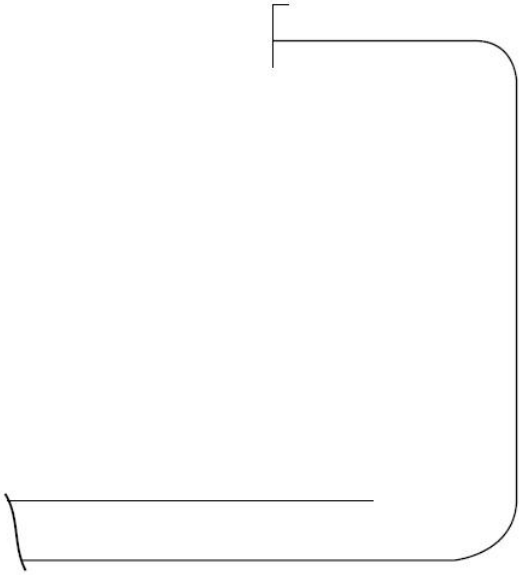


Report on TM2-DSBC(i) & (ii)	Report on TM4-DSBC
1. Strength deck plating 2. Stringer plate 3. Sheer strake 4. Side shell plating 5. Bilge plating 6. Bottom shell plating 7. Keel plate	25. Deck transverse (centre tank) 26. Bottom transverse (centre tank) 27. Deck transverse (wing tank) 28. Side shell vertical web 29. Longitudinal bulkhead vertical web 30. Bottom transverse (wing tank) 31. Struts 32. Transverse web face plate 33. D.B. floors 34. 35.
Report on TM3-DSBC	**Report on TM6-DSBC**
8. Deck longitudinals 9. Deck girders 10. Sheer strake longitudinals 11. Longitudinal bulkhead top strake 12. Bottom longitudinals 13. Bottom girders 14. Bilge longitudinals 15. Longitudinal bulkhead lower strake 16. Side shell longitudinals 17. Longitudinal bulkhead plating (remainder) 18. Longitudinal bulkhead longitudinals 19. Inner bottom plating 20. Inner bottom longitudinals 21. 22. 23. 24.	36. Hatch coamings 37. Deck plating between hatches 38. Hatch covers 39. 40.

Sheet 13

Thickness Measurement – Double Skin Bulk Carriers

Transverse section outline: The diagram may be used for those ships where the diagrams on Sheets 11 and 12 are not suitable.



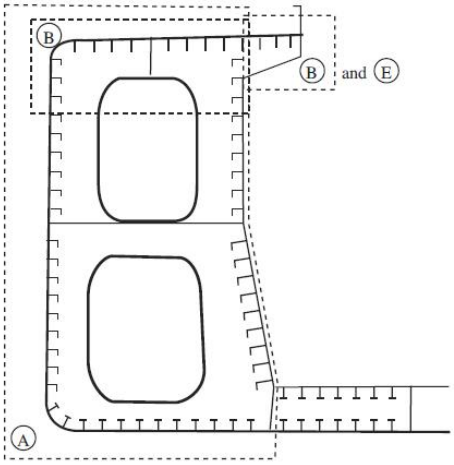
Report on TM2-DSBC(i) & (ii)	17. Inner bottom plating
1. Strength deck plating	18. Inner bottom longitudinals
2. Stringer plate	19. Hopper plating
3. Sheer strake	20. Hopper longitudinals
4. Side shell plating	31. Inner side plating
5. Bilge plating	– Inner side longitudinals, if any
6. Bottom shell plating	– Horizontal girders in wing ballast tanks
7. Keel plate	
	Report on TM4-DSBC
	23. Double bottom tank floors
	25. Hopper side tank transverses
Report on TM3-DSBC	34. Transverse web frame
8. Deck longitudinals	– Topside tank transverses
9. Deck girders	
10. Sheer strake longitudinals	
11. Topside tank sloping plating	**Report on TM6-DSBC**
12. Topside tank sloping plating longitudinals	28. Hatch coamings
13. Bottom longitudinals	– Deck plating between hatches
14. Bottom girders	– Hatch covers
15. Bilge longitudinals	
16. Side shell longitudinals, if any	

Sheet 14

Thickness Measurement – Ore Carriers

Areas Subject to Close up Survey and Thickness Measurements - Thickness to be Reported on TM3-DSBC, TM4-DSBC, TM5-DSBC and TM6-DSBC as appropriate

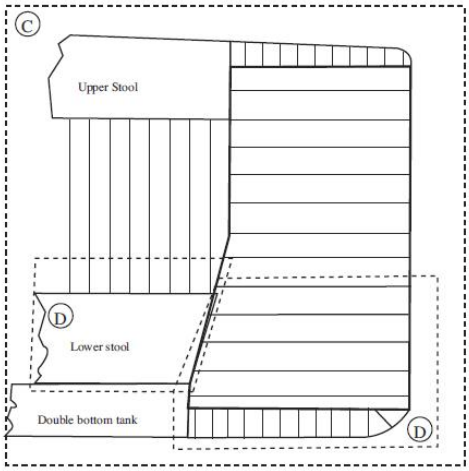
Typical transverse section close-up survey



Thickness to be reported on
TM3-DSBC and TM4-DSBC as appropriate

Close-up survey area

Typical transverse bulkhead



Thickness to be reported on TM5-DSBC

13.4B Recommended Procedures for Thickness Measurements of Double Skin Bulk Carriers Built under Common Structural Rules①

Notes:
1. This document is to be used for recording thickness measurements of double skin bulk carriers built under Common Structural Rules① as required by 5.1.9.3, Section 1, Chapter 5 of this PART.

2. Reporting forms TM1-DSBC(CSR), TM2-DSBC(CSR) (i) and (ii), TM3-DSBC(CSR), TM4-DSBC(CSR), TM5-DSBC(CSR) and TM6-DSBC(CSR) (Sheets 4 to 10) are to be used for recording thickness measurements. The as-built thickness, the voluntary thickness addition and the renewal thickness (minimum allowable thickness) are to be stated in the said forms.

3. The remaining Sheets 11 to 13 are guidance diagrams and notes relating to the reporting forms and the procedure for the thickness measurement.

GENERAL PARTICULARS

Ship's name:
IMO number:
Class identity number
Port of registry:
Gross tons:
Deadweight:
Date of build:
Classification society:

Name of Company performing thickness measurement:
Thickness measurement company certified by:
Certificate No.
Certificate valid from …… to ……
Place of measurement:
First date of measurement:
Last date of measurement:
Special survey/intermediate survey due:②
Details of measurement equipment:
Qualification of operators:

Report number: consisting of Sheets

Name of operator:	……	Name of surveyor:	……
Signature of operator:	……	Signature of surveyor:	……
Company		Classification society	
Official stamp:		Official Stamp:	

① PART TEN of the Rules (2012 version) and its 2013 and 2014 amendments or PART NINE of the Rules (2015 version) and its subsequent versions (including amendments).
② Delete as appropriate.

Sheet 4

TM1-DSBC(CSR) **Report on Thickness Measurement of All Deck Plating, All Bottom Plating or Side Shell Plating***

(*delete as appropriate)

Ship's name..... Class Identity No..... Report No.....

STRAKE POSITION																		
PLATE POSITION	No. or Letter	As Built Thk. mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Forward Reading						Aft Reading						Mean Remaining Corr. Addition, mm [(c1)+(c2)]/2	
					Gauged Thk. mm (b1)		Remaining Corr. Addition, mm (c1)=(b1)-(a)				Gauged Thk. mm (b2)		Remaining Corr. Addition, mm (c2)=(b2)-(a)					
					P	S	P		S		P	S	P		S		P	S
12th																		
11th																		
10th																		
9th																		
8th																		
7th																		
6th																		
5th																		
4th																		
3rd																		
2nd																		
1st forward																		
Amidships																		
1st aft																		
2nd																		
3rd																		
4th																		
5th																		
6th																		
7th																		
8th																		
9th																		
10th																		
11th																		
12th																		

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   1.1 All strength deck plating within the cargo length area.
   1.2 All keel, bottom shell plating and bilge plating within the cargo length area.
   1.3 Side shell plating including selected wind and water strakes outside the cargo length area.
   1.4 All wind and water strakes within the cargo length area.
2. The strake position is to be clearly indicated as follows:
   2.1 For strength deck indicate the number of the strake of plating inboard from the stringer plate.
   2.2 For bottom plating indicate the number of the strake of plating outboard from the keel plate.
   2.3 For side shell plating give number of the strake of plating sheer strake and letter as shown on shell expansion.
3. Only the deck plating strakes outside the line of openings are to be recorded.
4. Measurements are to be taken at the forward and aft areas of all plates and the single measurements recorded are to represent the average of multiple measurements.
5. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 5

TM2-DSBC(CSR)(i) **Report on Thickness Measurement of Shell and Deck Plating (one, two or three transverse sections)**

Ship's name..... Class Identity No..... Report No.....

STRENGTH DECK AND SHEERSTRAKE PLATING																															
	FIRST TRANSVERSE SECTION AT FRAME NUMBER										SECOND TRANSVERSE SECTION AT FRAME NUMBER										THIRD TRANSVERSE SECTION AT FRAME NUMBER									
STRAKE POSITION	No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)			
					P	S	P		S						P	S	P		S						P	S	P		S	
Stringer Plate																														
1st strake inboard																														
2nd																														
3rd																														
4th																														
5th																														
6th																														
7th																														
8th																														
9th																														
10th																														
11th																														
12th																														
13th																														
14th																														
centre strake																														
sheer strake																														
TOPSIDE TOTAL																														

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   Strength deck plating and sheer strake plating transverse sections:
   One, two or three sections within the cargo length area, comprising the structural items (1), (2) and (3) as shown on the diagram of typical transverse sections, illustrated on Sheets 11 and 12 of this document.
2. Only the deck plating strakes outside the line of openings are to be recorded.
3. The topside area comprises deck plating, stringer plate and sheer strake (including rounded gunwales).
4. The exact frame station of measurement is to be stated.
5. The single measurements recorded are to represent the average of multiple measurements.
6. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 6

TM2-DSBC(CSR)(ii) **Report on Thickness Measurement of Shell Plating (one, two or three transverse sections)**

Ship's name..... Class Identity No..... Report No.....

SHELL PLATING																															
	FIRST TRANSVERSE SECTION AT FRAME NUMBER										SECOND TRANSVERSE SECTION AT FRAME NUMBER										THIRD TRANSVERSE SECTION AT FRAME NUMBER									
STRAKE POSITION	No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				No. or Letter	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)			
					P	S	P		S						P	S	P		S						P	S	P		S	
1st below sheer strake																														
2nd																														
3rd																														
4th																														
5th																														
6th																														
7th																														
8th																														
9th																														
10th																														
11th																														
12th																														
13th																														
14th																														
15th																														
16th																														
17th																														
18th																														
19th																														
20th																														
Keel strake																														
BOTTOM TOTAL																														

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of:
   Shell plating at transverse sections:
   One, two or three sections within the cargo length area, comprising the structural items (4), (5), (6) and (7) as shown on the diagram of typical transverse sections, illustrated on Sheets 11 and 12 of this document.
2. The bottom area comprises keel, bottom and bilge plating.
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 7

TM3-DSBC(CSR) **Report on Thickness Measurement of Longitudinal Members (one, two or three transverse sections)**

Ship's name..... Class Identity No..... Report No.....

	FIRST TRANSVERSE SECTION AT FRAME NUMBER										SECOND TRANSVERSE SECTION AT FRAME NUMBER										THIRD TRANSVERSE SECTION AT FRAME NUMBER									
STRUCTURAL MEMBER	Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)				Item No.	As Built Thk. mm	Vol. Thk. Add. mm	Ren. Thk. mm (a)	Gauged Thk. mm (b)		Remaining Corr. Addition, mm (b)-(a)			
					P	S	P		S						P	S	P		S						P	S	P		S	

Notes:

1. This report is to be used for recording the thickness measurement of:
   Longitudinal members at transverse sections:
   One, two or three sections within the cargo length area, comprising the appropriate structural items (8) to (20) and (31) as shown on the diagram of typical transverse sections, illustrated on Sheets 11 and 12 of this document.
2. The exact frame station of measurement is to be stated.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 8

TM4-DSBC(CSR)

Report on Thickness Measurement of Transverse Structural Members
In Double Bottom, Hopper Side and Topside Water Ballast Tanks

Ship's name..... Class Identity No..... Report No.....

TANK DESCRIPTION:										
LOCATION OF STRUCTURE										
STRUCTURAL MEMBER	ITEM	As Built Thickness mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)			
					P	S	P		S	

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of transverse structural members, comprising the appropriate structural items (23) to (25) and (34) as shown on the diagram of typical transverse sections, illustrated on Sheets 11 and 12 of this document.
2. Guidance for areas of measurement is indicated on the diagrams shown on Sheet 13 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 9

TM5-DSBC(CSR) **Report on Thickness Measurement of Cargo Hold Transverse Bulkheads**

Ship's name..... Class Identity No..... Report No.....

HOLD DESCRIPTION:										
LOCATION OF STRUCTURE: FRAME NO.:										
STRUCTURAL COMPONENT (PLATING/STIFFENER)	As Built Thickness mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)			
				P	S	P		S	

Operators signature: ……

Notes:

1. This report is to be used for recording the thickness measurement of W.T. transverse bulkheads in cargo holds.
2. Guidance for areas of measurement is indicated on the diagrams shown on Sheet 13 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 10

TM6-DSBC(CSR) **Report on Thickness Measurement of Miscellaneous Structural Members**

Ship's name..... Class Identity No..... Report No.....

STRUCTURAL MEMBER:										SKETCH
LOCATION OF STRUCTURE:										
Description	As Built Thk. mm	Voluntary Thickness Addition mm	Renewal Thickness mm (a)	Gauged Thickness mm (b)		Remaining Corr. Addition mm (b)-(a)				
				P	S	P		S		

Operators signature: ……

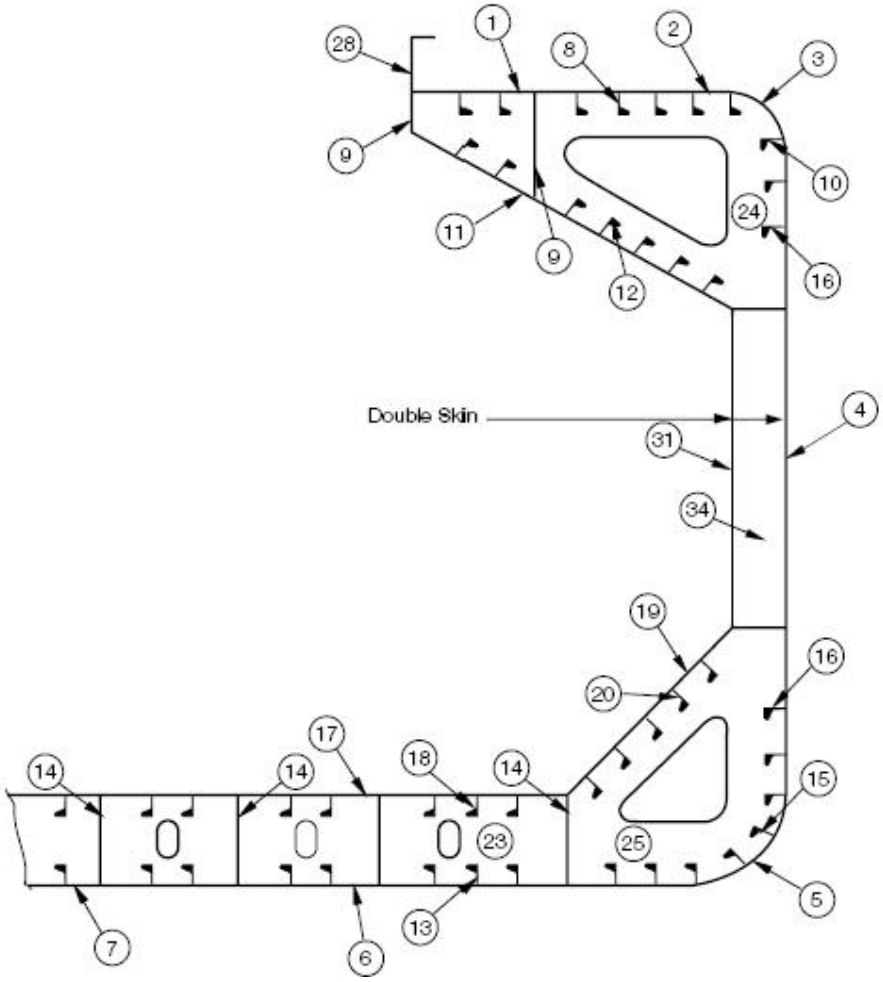
Notes:

1. This report is to be used for recording the thickness measurement of miscellaneous structural members including the structural items (28) as shown on the diagram of typical transverse sections, illustrated on Sheets 11 and 12 of this document.
2. Guidance for areas of measurement is indicated on the diagrams shown on Sheet 13 of this document.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The remaining corrosion addition is to be recorded with result of gauged thickness minus renewal thickness. If the result is negative, the structure in way is to be renewed, and the mark "*R*" is to be indicated in the right-hand column. If the result is between 0 and 0.5 mm (0 included), the structure in way is to be additionally gauged, and the mark "*S*" is to be indicated in the right-hand column.

Sheet 11

Thickness Measurement – Double Skin Bulk Carriers

Typical Transverse Section of a Double Skin Bulk Carrier with Indication of Longitudinal and Transverse Members



Report on TM2-DSBC(CSR)(i) & (ii)
1. Strength deck plating
2. Stringer plate
3. Sheerstrake
4. Side shell plating
5. Bilge plating
6. Bottom plating
7. Keel plate

Report on TM3-DSBC(CSR)	
8. Deck longitudinals	17. Inner bottom plating
9. Deck girders	18. Inner bottom longitudinals
10. Sheerstrake longitudinals	19. Hopper plating
11. Topside tank sloping plate	20. Hopper longitudinals
12. Topside tank sloping plate longitudinals	31. Inner side plating
13. Bottom longitudinals	– Inner side longitudinals, if any
14. Bottom girders	– Horizontal girders in wing ballast tanks
15. Bilge longitudinals	
16. Side shell longitudinals, if any	

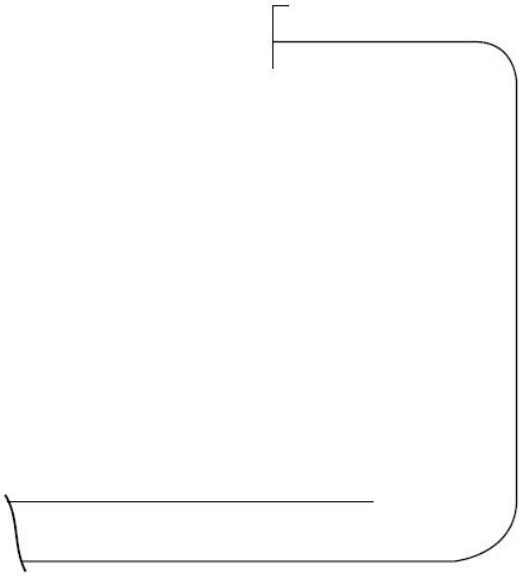
Report on TM4-DSBC(CSR)
23. Double bottom tank floors
24. Topside tank transverses
25. Hopper side tank transverses
34. Transverse web frame
– Ordinary transverse frame in double skin tank

Report on TM6-DSBC(CSR)
28. Hatch coamings
– Deck plating between hatches
– Hatch covers

Sheet 12

Thickness Measurement – Double Skin Bulk Carriers

Transverse section outline: This diagram may be used for those ships where the diagram on Sheet 11 is not suitable



Report on TM2-DSBC(CSR)(i) & (ii)
1. Strength deck plating 2. Stringer plate 3. Sheer strake 4. Side shell plating 5. Bilge plating 6. Bottom plating 7. Keel plate

Report on TM3-DSBC(CSR)	
8. Deck longitudinals 9. Deck girders 10. Sheer strake longitudinals 11. Topside tank sloping plating 12. Topside tank sloping plating longitudinals 13. Bottom longitudinals 14. Bottom girders 15. Bilge longitudinals 16. Side shell longitudinals, if any	17. Inner bottom plating 18. Inner bottom longitudinals 19. Hopper plating 20. Hopper longitudinals 31. Inner side plating – Inner side longitudinals, if any – Horizontal girders in wing ballast tanks

Report on TM4-DSBC(CSR)
23. Double bottom tank floors 24. Topside tank transverses 25. Hopper side tank transverses 34. Transverse web frame – Ordinary transverse frame in double skin tank

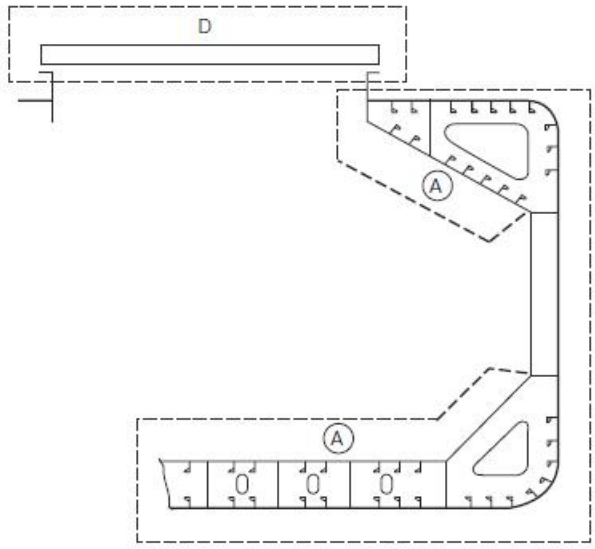
Report on TM6-DSBC(CSR)
28. Hatch coamings – Deck plating between hatches – Hatch covers

Sheet 13

Close-up Survey and Thickness Measurement Areas

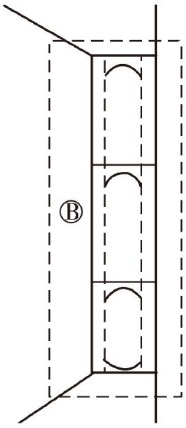
Typical transverse section

Areas (A) and (D)



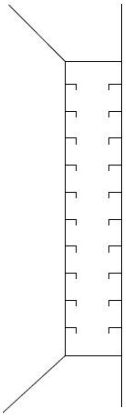
Thickness to be reported on TM3-DSBC(CSR), TM4-DSBC(CSR) and TM6-DSBC(CSR), as appropriate

Framing in double-side tanks
Area B



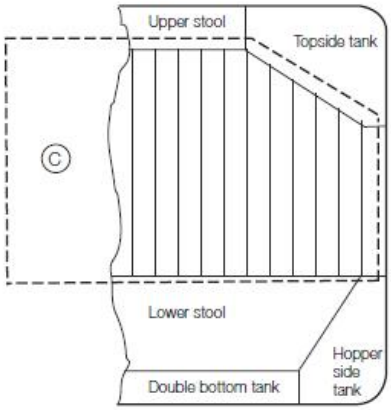
Ordinary transverse frame in double skin tank

Ordinary longitudinal structure in double skin tank



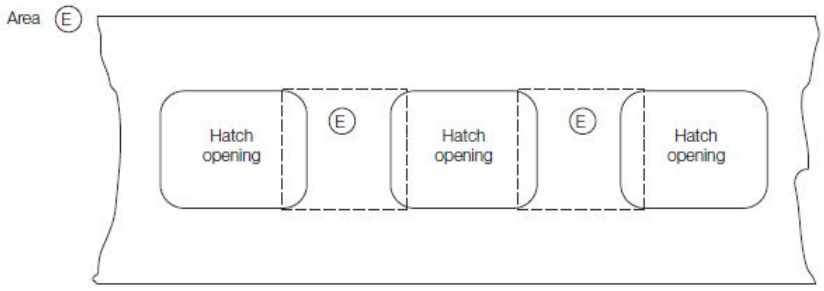
Thickness to be reported on TM4-DSBC(CSR)

A cargo hold, transverse bulkhead
Area C



Thickness to be reported on TM5-DSBC (CSR)

Typical areas of deck plating and underdeck structure inside line of hatch openings between cargo hold hatches



Thickness to be reported on TM6-DSBC(CSR)

Appendix 14 GUIDELINES FOR SCREWSHAFT CONDITION MONITORING SYSTEM

1 General Provisions

1.1 General requirements

1.1.1 Scope

1.1.1.1 These Guidelines apply to the ships applying for the class notation SCM.

1.1.1.2 These Guidelines apply also to rudder propellers (or called azimuth propulsion arrangements).

1.1.2 Application

1.1.2.1 Where the screwshaft condition monitoring (SCM) system is intended for a ship, the owner is to submit an application together with the following information to CCS for approval:

(1) Feasibility of condition monitoring (including approved shaft glands fitted and capable of being replaced without drawing the screwshaft, etc.);

(2) General arrangement of screwshaft and stern tube, including oil glands, shaft structure and fitting of shaft with propeller (if already provided, this may not be submitted).

1.1.2.2 One copy of the above-mentioned documentation is to be retained on board the ship.

1.1.3 Requirements for the analysis organization and its personnel

1.1.3.1 A lubricating oil analysis organization seeking the approval by CCS for carrying out the corresponding analysis work, is to make an application to CCS for certification of the organization and its personnel in accordance with the relevant requirements of Section 4 of these Guidelines.

1.1.3.2 Where an analysis organization and its personnel, of which the expenses are borne by the owner or shipyard, are not subject to the approval by CCS, the relevant requirements of Section 4 of these Guidelines are to be complied with.

1.1.3.3 A lubricating water analysis organization carrying out water-lubricated screwshaft condition monitoring system is to comply with International Standards for Laboratory Approval (e.g. ISO/IEC 17025) or equivalent standards accepted by CCS. The analysis organization is to submit qualification certificate to the ship owner.

1.2 Oil-lubricated screwshaft condition monitoring system

1.2.1 Role of condition monitoring system

1.2.1.1 The screwshaft condition monitoring system is to analyze various tests of the lubricating oil in use for the screwshaft so as to indicate the wear condition of bearings, determine the deterioration of lubricating oil and provide the basis for maintenance decision. Therefore, after the class notation SCM is assigned, the main engines are still to be operated within the required speed ranges to prevent shafting from being operated within the restricted speed ranges or speed ranges where vibration stress is great.

1.2.1.2 Within the interval between surveys, the screwshaft condition monitoring system may be used to replace drawing of screwshaft.

1.2.1.3 The condition monitoring system has the following characteristics:

(1) to save the maintenance expenses;

(2) to reduce the ship’s laid-up period;

(3) to avoid damaging the equipment twice;

(4) to increase the equipment usage and extend the service life of lubricating oil.

1.2.2 Technical methods used by condition monitoring system

1.2.2.1 The condition monitoring system uses three methods, i.e. physical and chemical analysis, atomic spectrum analysis and ferrographic analysis which have different characteristics respectively and complement each other.

1.2.3 The physical and chemical analysis is capable of:

1.2.3.1 measuring and assessing the change of quality of lubricating oil, e.g. chloride content in lubricating oil, oxidation and sulphidation of lubricating oil and deterioration of additives;

1.2.3.2 detecting the contaminants in lubricating oil, e.g. dust, diluted fuel and water;

1.2.3.3 detecting the change of physical performance of lubricating oil, e.g. viscosity, total acid number and total base number;

1.2.3.4 assessing the lubricating oil condition to indicate proper intervals for replacing oil and extend the service life of lubricating oil so far as practicable with the machinery friction pairs being well lubricated.

1.2.4 The atomic spectrum analysis is capable of:

1.2.4.1 judging the wear condition of machinery friction pairs and of lubricating oil by detecting the kinds,

concentration and variation trend of metallic and non-metallic elements in the lubricating oil.
1.2.5 The ferrographic analysis is capable of:
1.2.5.1 by analyzing the appearance (shape, surface texture, edges, colors, etc.) and concentration of the wear particles in the lubricating oil, further judging the wear condition of machinery friction pairs and determining the mechanism and positions of wear so as to provide the basis for early failure forecasts and maintenance decisions.

1.3 Water-lubricated screwshaft condition monitoring system

1.3.1 Role of condition monitoring system
1.3.1.1 Water-lubricated screwshaft condition monitoring system monitors quality, flow rate and temperature of screwshaft lubricating water as well as wear or protection condition of screwshaft and shaft liner so as to ensure indication of the wear condition of bearings and corrosion condition of shafts, determine quality condition of lubricating water and provide the basis for maintenance decision.
1.3.1.2 Within the interval between surveys, the screwshaft condition monitoring system may be used to replace drawing of screwshaft.
1.3.2 Technical requirements for condition monitoring system
1.3.2.1 The screwshaft is to either be made of corrosion resistant material or protected with a corrosion resistant protective liner or coating approved by CCS (i.e. shaft body is covered by paint between two bearing liners to prevent water corrosion). Where a protective liner and/or coating is used, the ship owner must submit measures for condition examination and evaluation (e.g. at stern tube opening or fitted with endoscope), which are to be approved by CCS.
1.3.2.2 Shaft glands are to be capable of being replaced without withdrawal of the screwshaft.
1.3.2.3 A maximum permitted weardown of the bearing and the weardown at which it is recommended to carry out an inspection and maintenance are to be established, and equipment measuring bearing clearance is to be fitted. When the ship is docking or subject to in-water survey, bearing weardown or clearance is to be measured and the conditions of wear of protective shaft liner and integrity of coating are to be examined. The results are to be recorded and retained on board.
1.3.2.4 For open water lubrication system, the ship is to be fitted with water supply processing system. The lubricating water supply is to be filtered, separated and purified, so as to ensure compliance with design requirements of the manufacturer. The water supply pump, filters and separators are to be duplicated and as a standby to each other, match the lubrication water flow required by the design and have sufficient redundancy to ensure that the lubrication water flow requirements can be met even when filters and separators are slightly clogged. The above equipment is to be easy for maintenance and replacement, and means are to be provided to prevent impurities such as suspended particles from entering the lubrication water of the stern tube during maintenance. The system is to be provided with sampling openings which are readily accessible, and the selected samples are to reflect the condition of processed water supply before entering stern tube. Samples are to be taken under service condition.
1.3.2.5 The ship owner is to establish sampling procedure, appoint special person to collect water supply samples regularly at intervals not exceeding six months. The analysis organization mentioned in 1.1.3.3 is to carry out water sample detection and analysis according to detection technology and water sample analysis index allowance provided by the manufacturer, and analysis records are to be kept on board ship. For open water lubrication system, sampling is to be carried out at least once every 6 months, and the size of suspending particles are to be detected each time as a minimum. In the absence of procedures for sampling or records for sampling and testing, equivalent means including but not limited to the followings may be taken:

① during the annual survey and tube shaft survey as a minimum, the supply water treatment system is to be inspected, the maintenance record and alarm record are to be checked, and the monitoring and alarm equipment is to be confirmedin a satisfactory working condition; or
② online monitoring of the diameter of the floating particles in the supply water, and providing the alarm function when standard is exceeded.

For closed water lubrication system, sampling is to be carried out at least once every 6 months, and chloride content, PH value as well as bearing material particles content are to be detected each time as a minimum.[①]
1.3.2.6 Two independent sensors are to be provided to monitor flow rate of water supply, one of which is to be near inlet of screwshaft lubricating water as far as possible. When the shaft is started and the flow rate of lubricating water is below specified value, audible and visual alarm is to be given, and engine room

① Refer to IACS Rec 143 Recommended procedure for the determination of contents of metals and other contaminants in a closed fresh water system lubricated stern tube.

monitoring and alarm system is to record such alarm.
1.3.2.7 Screwshaft interlock is to be provided to prevent starting screwshaft when normal flow rate of lubricating water is not established.
1.3.2.8 For closed water lubrication system, the ship owner is to adopt fresh water as circulating lubrication medium. Circulating water temperature sensor is to be provided at circulating water outlet of stern tube. When water temperature exceeds specified value recommended by the manufacturer, audible and visual alarm is to be given by temperature sensor, and engine room monitoring and alarm system is to record such alarm. The ship is to record daily consumption of circulating water.

2 Surveys

2.1 Initial survey

2.1.1 Examination of plans and documentation
2.1.1.1 For a ship with oil-lubricated screwshaft, when applying for SCM notation, the plans and documents listed in 1.1.2.1 are to be submitted for examination and approval, compliance of all systems with the requirements of these Guidelines is to be confirmed, and the following conditions are to be satisfied:
(1) the oil lubricating system of the propeller shaft is to be fitted with a device for taking samples representative of the oil in the system;
(2) the tube shaft is to be fitted with at least 2 sensors or other approved devices for measuring bearing temperature;
(3) the propeller shaft is to be fitted with a device for measuring bearing wastage;
(4) oil glands are capable of being replaced without withdrawal of the propeller shaft;
(5) the oil lubricating system of the propeller shaft is to be fitted with a device for indicating oil consumption.
2.1.1.2 For a ship with water-lubricated screwshaft, when applying for SCM notation, the plans and documents listed in 1.1.2.1 are to be submitted for examination and approval, and compliance of all systems with relevant technical requirements in 1.3.2 of the Guidelines is to be confirmed.
2.1.1.3 Initial survey for new construction
(1) All systems required by these Guidelines are to be examined and tested to confirm compliance with the approved plans and documentation.
(2) Verification that management documents related to condition monitoring, as required by these Guidelines, are provided on board.
2.1.1.4 Initial survey for existing ships
(1) All systems required by these Guidelines are to be examined and tested to confirm compliance with the approved plans and documentation.
(2) If the specified survey (drawing of the shaft) is due, the survey is to be carried out in conjunction with the initial survey in accordance with the rules; or
(3) At least the following records of screwshaft condition monitoring (SCM) showing satisfactory results in the last 3 years are to be submitted:

① stern bearing oil analysis records or lubricating water analysis records and qualification certificate of analysis organization;
② stern bearing oil consumption records or closed circulating lubricating water consumption records;
③ stern bearing temperature monitoring records (oil-lubricated screwshaft);
④ stern bearing clearance and tailshaft weardown measurement records;
⑤ alarm records (water-lubricated screwshaft).

2.2 Annual survey

2.2.1 The requirements for annual surveys are given in Section 12, Chapter 5 of this PART.

2.3 Miscellaneous

2.3.1 Availability of lubricating oil or lubricating water analysis information
2.3.1.1 The lubricating oil or lubricating water analysis information is to be kept on board the ship by the chief engineer for check by the attending Surveyor.
2.3.2 Cancellation of the class notation SCM
2.3.2.1 At the request of the owner or where the annual survey specified in 5.12.4, Section 12, Chapter 5 of this PART is not carried out on time, the SCM notation may be canceled and survey is to be carried out in accordance with relevant provisions of Section 12, Chapter 5 of this PART.

3 Oil-lubricated Screwshaft Condition Monitoring Procedures

3.1 Sampling procedure

3.1.1 Sampling personnel

3.1.1.1 All oil samples are to be taken by a designated person on board or the chief engineer, who is to fill in a sampling table and make an appropriate record which are to be kept on board for future examination. The sampling personnel are to be skilled at sampling.

3.1.2 Sampling period

3.1.2.1 For the screwshaft monitored by lubricating oil analysis, a sampling analysis of lubricating oil is to be carried out at least once every six months. Where the sampling frequency is increased by the owner, this is to be recorded for future examination.

3.1.2.2 Where the analysis can not be carried out on time when the sampling is due because the ship is in operation at sea, oil samples are still to be taken on time. However, the lubricating oil analysis is to be completed within three months.

3.1.2.3 According to lubricating oil analysis results and practical operation condition (e.g. replacing of lubricating oil or abrupt change of wear particle concentration), the Surveyor may require the sampling period to be reduced.

3.1.3 Sampling positions

3.1.3.1 For forced oil circulating lubrication systems, samples may be taken at the dump pump or the valve fitted in front of the filter and capable of sampling.

3.1.3.2 For gravity type lubrication systems, samples may be taken at oil outlet at the bottom of stern tube unit.

3.1.3.3 For permanent sampling valves and tubes fitted in the pipelines, oil of about twice the volume of residual oil is to be discharged prior to sampling to ensure that no oil sampled at the last time is left.

3.1.3.4 Where samples are taken at oil outlet, an amount of oil is to be discharged prior to sampling to wash away the sediments left there.

3.1.4 Sampling condition

3.1.4.1 Samples are to be taken in the normally stable operation condition of the screwshaft or immediately after stop of the operation.

3.1.4.2 Each time the samples are taken in the operation condition, the equipment is to be in the similar working conditions (e.g. rate of revolution, power).

3.1.5 Sampling precautions

3.1.5.1 Sampling tools (including sample bottles, samplers, tubes, etc.) are to be kept clean, non-fragile and protected from pollution.

3.1.5.2 Sample bottles are to be made of colorless and transparent plastic or glass.

3.1.5.3 The lubricating oil sample is to be taken for an amount of about 2/3 of the volume of a sample bottle, but not less than 150 ml.

3.2 Analysis of lubricating oil samples

3.2.1 General requirements

3.2.1.1 During the lubricating oil sample analysis, in general, the physical and chemical analysis and the spectrum analysis are to be carried out at first and then on this basis, the analysis by direct reading ferrogram may be carried out. Where it is considered necessary, qualitative analysis is to be carried out by an analytical ferrograph.

3.2.2 Items and methods of lubricating oil analysis for screwshaft

3.2.2.1 The lubricating oil analysis items:

Analysis items	Analysis means (or instruments)
Physical and chemical analysis	Physical and chemical analysis instruments (international standards)
Element content (mainly for metal) analysis	Spectrum analysis [atomic emission (or absorption) spectrograph]
Analysis of appearance and concentration of wear particles	Ferrographic analysis (ferrograph)

3.2.2.2 Physical and chemical analysis items (items marked with "*" are optional):

(1) viscosity;

(2) water;

(3) total acid number (TAN);

(4) total base number (TBN);

(5) content of insolubles;
(6) deterioration* (oxidation, nitrification, etc.);
(7) pollution* (contaminant pollution, etc.).

3.2.2.3 For the element content analysis, the content of the following elements is to be measured:

(1) elements relative to wear of metal (materials of shaft, bearings, gearing, etc.): chromium, lead, copper, nickel, iron, silicon, tin, molybdenum, etc.;
(2) elements relative to pollution: Magnesium, sodium, etc.;
(3) elements relative to additives: Barium, boron, calcium, magnesium, phosphor, zinc, lithium, etc.

The sources of various elements are to be correctly differentiated in accordance with the materials of friction pairs, additive components of lubricating oil, ambient working environment, etc.

3.2.2.4 Analysis of appearance and concentration wear particles:

(1) Where the appearance of wear particles is analyzed by analytical ferrograph, a classified description is to be made in accordance with the following types of wear particles:

a. rubbed wear particles;
b. cutting wear particles;
c. spherical wear particles;
d. fatigue wear particles in lumpy shape;
e. laminar wear particles;
f. severe sliding wear particles;
g. corroded wear particles;
h. red oxidic particles;
i. black oxidic particles;
j. non-metallic crystals;
k. pollutant particles.

(2) Where the quantitative analysis of concentration is carried out by direct-reading ferrograph, the reading values D_l (large particles) and D_S (small particles) are to be measured and recorded.

3.2.3 Determination of reference values for parameters of lubricating oil analysis

3.2.3.1 The allowable ranges of physical and chemical criteria required for the type of lubricating oil used by the owner are to be used in judging physical and chemical parameters of the lubricating oil.

3.2.3.2 The reference values for the quantitative spectrum or ferrographic analysis depend on values accumulated from practical tests and experience to a great extent. The reasonable criteria for judgment are to be determined by comparing the results of sampling tests of the specific monitored objects with the practical operation conditions. In the quantitative spectrum or ferrographic analysis, trend analysis is to be based mainly on the measured values.

3.2.3.3 In the quantitative spectrum or ferrographic analysis, the following interim criteria are to be used for reference:

Viscosity (at 40℃)	at least 70 m^2/s
Water	maximum 1%
Copper	maximum 50 ppm
Iron	maximum 30 ppm
Tin	maximum 10 ppm
Nickel	maximum 10 ppm
Chromium	maximum 10 ppm
Silicon	maximum 40 ppm
Sodium	maximum 80 ppm
Lead	maximum 10 ppm
Chlorine content in water	maximum 70ppm ((ingress of salt water)
Magnesium	maximum 30ppm

In addition, the gradient values of spectrum readings are to be controlled.

3.2.3.4 In the direct-reading ferrogram analysis, wear reference line and control line are to be made in accordance with direct reading values.

(1) It is recommended that the reference line be determined as follows.

The reference line (expressed as $\overline{WPC}$) is determined by wear particle concentration parameters (expressed as WPC) at normal wear stage:

$$\overline{WPC}=\frac{\sum_i^n (WPC_i)}{n}$$

where: i — sample number;
n — the total number of samples.

(2) It is recommended that the control line be determined as follows.
The control line is divided into warning line and dangerous line:

Warning line $= \overline{WPC} + 2S$

Dangerous line $= \overline{WPC} + 3S$

$$S = \sqrt{\frac{\sum WPC_i^2 - \frac{\left(\sum EPC_i\right)^2}{n}}{n-1}}$$

where: S — standard variance.

(3) When calculating the reference line and control line, it is impossible to include all *WPC* values in normal wear condition, and only a part of the latest *WPC* values are required to be taken into consideration, generally not less than five specimen values ($n \geq 5$).

3.2.3.5 Oil ageing

(1) Oxidation characteristics such as Total Acid Number (TAN), viscosity and oil appearance depend upon the type of oil used. Hence no recommended value is listed. Instead observation of any trends (such as viscosity and change in colour etc.) based on sequential analysis should be made. TAN is adversely influenced by oxidation for most typical oil lubricant types and also by hydrolysis in the case of unsaturated Environmentally Acceptable Lubricants (EALs). Observation of any trends on TAN should be made based on sequential analysis in conjunction with the limits defined by the oil maker for continued use in service.

3.2.4 All lubricating oil samples are to be sent to an analysis organization approved or accepted by CCS for analysis. The analysis organization is to complete the analysis in time, fill in the lubricating oil analysis record table carefully and correctly and submit an analysis report. Where the analysis results exceed the allowable ranges or any abnormality or uncertainty is found, the owner has the obligation to report this to CCS in time.

3.3 Condition monitoring record and analysis report

3.3.1 Measurement record by owner

3.3.1.1 The consumption of lubricating oil is to be measured once a month and recorded in the Lubricating Oil Consumption Record Table, refer to Table 3.3.1.1.

Lubricating Oil Consumption Record **Table 3.3.1.1**

Name of monitored ship: Type of lubricating oil:		Name of monitored objects:		
Measuring date	Volume of lub. oil (L)	Consumption of lub. oil (L)	Refilled volume of lub. oil (L)	Measuring personnel

3.3.1.2 The bearing temperature of screwshaft in normal operation condition is to be measured once a month and recorded in the Bearing Temperature Record Table, refer to Table 3.3.1.2.

Bearing Temperature Record **Table 3.3.1.2**

Name of monitored ship: Type of bearings:		Name of monitored objects:	
Measuring date	Bearing temperature	Service hours of bearing (h)	Measuring personnel

3.3.1.3 Each time samples are taken, sampling personnel are to fill in the Sampling Record Table accurately, refer to Table 3.3.2.1. A label showing name of the monitored ship and sampling date, etc. are to be affixed to the sample bottles. The completed Table together with the oil samples is to be sent to the analysis organization. Where the analysis organization is changed, the last analysis results are also to be sent to the new analysis organization.

3.3.2 Contents and formats of condition monitoring records and report

3.3.2.1 Sampling Record Table

The Sampling Record Table is to cover the basic parameters (static values) of the monitored objects and the working parameters (dynamic values) during sampling. The basic parameters include name of the monitored machinery, sampling position, measure units used, numbering, power, rate of revolution, type and volume of lubricating oil, etc. The working parameters include total operating hours of equipment, service time of lubricating oil, service hours of filter, bearing temperature, oil pressure, oil temperature, refilling of lubricating oil, operation site and sampling date, etc., refer to Table 3.3.2.1.

Sampling Record **Table 3.3.2.1**

Name of owner:	Name of monitored ship:
Name of monitored machinery:	Sampling method:
Sampling position:	Sampling date:
Sampling personnel:	Sample No.:
Bearing temperature:	Power of main engines:
Rate of revolution of screwshaft (r/min):	Service hours (h):
Type of lub. oil:	Volume of lub. oil (L):
Temperature of lub. oil:	Service hours of lub. oil (h):
Service hours of lub. oil filter (h):	Pressure of lub. oil (MPa):
Refilling quantity and period of lub. oil (L/frequency, h):	
Description:	

Sampled by: Signature of chief engineer:

3.3.2.2 Lubricating Oil Analysis Record Table

The Lubricating Oil Analysis Record Table is divided into three kinds: Physical and Chemical Analysis Record Table (including test and analysis of viscosity, water content, content of insolubles, total acid number, total base number, pollution and deterioration of lubricating oil), Spectrum Analysis Record Table (including test and analysis of content of elements, e.g. metallic particles worn from machinery friction pairs into lubricating oil, metallic particles and pollutants in lubricating oil additive), Ferrographic Analysis Record Table (including information and conclusions obtained from ferrographic analysis of samples, preparation data of samples, quantitative data of ferrogram, types and quantities of wear particles, etc.), refer to Tables 3.3.2.2(1), 3.3.2.2(2) and 3.3.2.2(3) respectively. The owner may add necessary items in these tables according to their own needs.

3.3.2.3 Condition Monitoring Analysis Report

The Analysis Report is a report sheet, which is to be completed by a lubricating oil analysis organization approved or accepted by CCS and is to be provided to the owner for guidance of his operation and maintenance, covering basic condition of the monitored objects, main data of lubricating oil analysis, analysis results, recommendation, etc., refer to Table 3.3.2.3.

3.3.3 Preservation of lubricating oil analysis documentation

3.3.3.1 All records and analysis reports for lubricating oil condition monitoring are to be prepared in triplicate, one is to be retained by the analysis organization for reference, one submitted to CCS for filing and one kept on board the ship.

Physical and Chemical Analysis Record

Owner: **Table 3.3.2.2(1)**

Sample No:		Type of lub. oil	
Name of monitored machinery		Sampling date	
Service hours of lub. oil (h)		Receiving date	
Analysis date			

Criteria for analysis	Viscosity	Water content	Content of insolubles	Total acid number	Total base number
Sample					
New oil					
Name of oil recommended by Shipyard					

Testing items	
Pollution	Deterioration

Description:

Analyzed by: Stamp of organization:

Spectrum Analysis Record

Owner: **Table 3.3.2.2(2)**

Sample No: Operating hours (h): Analysis date: Type of lub. oil:	Name of monitored ship: Sampling date: Receiving date:

Criteria for analysis	Fe	Cu	Al	Pb	Ni	Cr	Si	Mo	Ba
Sample analysis									
Last analysis									
Elements for analysis	Zn	Sn	Ca	Mg	Na	P	B		
Sample analysis									
Last analysis									

Description:

Analyzed by: Stamp of organization:

Ferrographic Analysis Record

Table 3.3.2.2(3)

1. Basic data

Ferrogram No:_____; Date of making ferrogram:_____;

Name of monitored ship:_____; Name of monitored machinery:_____;

Sampling position:_____; Sampling date:_____;

Operating hours:_____ h; Service hours of lub. oil:_____ h;

Type of lub. oil:_____; Volume of lub. oil:_____ L;

Volume of sample used to make ferrogram: Volume of solvent used to make ferrogram:

_____mL; _____mL;

Dilution of sample concentration:_____.

2. Quantitative data

Direct readings of ferrogram: D_l = _____; D_s = _____;

Size of the largest particle: _____μm.

3. Qualitative data

Types of particles	None	Few	Moderate	Massive	Remarks
Rubbed wear particles					
Cutting wear particles					
Fatigue wear particles in lumpy shape					
Spherical wear particles					
Severe sliding wear particles					
Laminar wear particles					
Red oxidic particles					
Black oxidic particles					
Corrosive wear particles					
Non-metallic crystals					
Pollutant particles					

4. Judgment of wear conditions: Normal Caution Warning

5. Description:

Analyzed by: Stamp of organization:

Lubricating Oil Analysis Report Sheet

Owner: **Table 3.3.2.3**

Sample No:		Name of monitored ship:
Name of monitored equipment:		Sampling date:
Ferrogram No:		Receiving date:
Lubricating oil analysis results	Physical and chemical analysis	
	Spectrum analysis	
	Ferrographic analysis	
Conclusions and recommendations		

Analyzed by: Date:

Reviewed by: Stamp of organization:

4 Requirements for Approval of Lubricating Oil Analysis Organizations and Their Personnel

4.1 General requirements

4.1.1 Scope

4.1.1.1 The requirements of this Section apply to the following three types of analysis organizations and their personnel:

(1) analysis organizations established by CCS and their personnel;

(2) analysis organizations and their personnel (subcontractors) applying for the approval by CCS;

(3) analysis organizations and their personnel who are not approved by CCS and whose expenses are borne by the owner.

4.1.2 General requirements

4.1.2.1 This Section has been prepared in accordance with the requirements of IACS QSCS.

4.1.2.2 The analysis organizations and their personnel applying for the approval by CCS are to pay the relative expenses in accordance with the provisions of CCS.

4.1.2.3 The instruments and equipment of an analysis organization may be purchased at its discretion or leased from other organizations.

4.1.2.4 It is recommended that the owner designate an analysis organization as a permanent partner.

4.2 Requirements for approved analysis organizations and their personnel

4.2.1 Requirements for approval of analysis organizations

4.2.1.1 The analysis organization is to have a complete set of quality assurance system for lubricating oil analysis condition monitoring, including work post responsibility, analysis result and report review, files management, instrumentation management and calibration, personnel training and assessment, etc.

4.2.1.2 The analysis organization is to be provided with at least three approved lubricating oil analysts (at least one for physical and chemical analysis, one for spectrum analysis and one for ferrographic analysis). The chief analyst is to be an engineer or have a more superior technical rank, familiar with the analysis technique, skilled at proper operation of instrumentation, and capable of working independently, giving guidance to other analysts and making a correct evaluation of the analysis results.

4.2.1.3 The analysis organization is to be provided with appropriate instrumentation and equipment certified by manufacturers and in addition, certified for effective calibration by the statutory metrology service or a metrology service accepted by CCS.

4.2.2 Requirements for approval of analysts

4.2.2.1 The chief analyst is to have at least college degree (or an equivalent education), and other analysts are to have at least a special secondary school degree (or an equivalent education).

4.2.2.2 Analysts are to have some basic knowledge of lubricating oil analysis technique.

4.2.2.3 Analysts are to be familiar with the basic principles and testing methods of analytical instruments.

4.2.2.4 Analysts are to hold an appropriate qualification certificate.

4.2.3 Approval procedure

4.2.3.1 An analysis organization and its personnel seeking the approval by CCS are to submit an application to a local Branch of CCS and upon satisfactory initial review, the application will be sent to the Headquarters of CCS for approval. The corresponding analysis work may be carried out only after the analysis organization and its personnel are approved and certified by CCS.

4.2.3.2 The analysis organization and its personnel approved for lubricating oil analysis are to guarantee the analysis quality in accordance with the requirements of these Guidelines for lubricating oil analysis and are responsible for their written analysis reports and conclusions.

4.2.3.3 An analysis organization applying for approval is to submit the following documentation:

(1) name and particulars of the organization;

(2) number, condition and qualification of the analysts to be approved;

(3) type, date of manufacture, name of manufacturer, manufacturer’s certificate, class of accuracy and (or) calibration certificate of analytical instruments;

(4) various management systems;

(5) fees to be charged for service.

4.2.3.4 The analysts applying for approval are to submit the following documentation:

(1) name, age, education background and health condition of the applicant;

(2) technical biography (i.e. experience of lubricating oil analysis) and certificates;

(3) recommendation by the organization and qualification documents.

4.2.3.5 Upon approval by CCS, appropriate certificates will be issued.

4.2.4 Maintenance of approval

4.2.4.1 The approval certificate of the analysis organization and its personnel is valid for five years. An

application for an overall examination is to be made three months before the expiry date of the certificate, and a new certificate will be issued upon satisfactory examination.

4.2.4.2 Within the period of validity of the certificate, the approved organization is in general to be re-examined once a year for the following:

(1) having a general idea of the testing work and management of the organization within the year;

(2) examining the service, maintenance, repair and calibration of analytical instruments and the period of validity of calibration certificates;

(3) the appropriate column of the approval certificate is to be endorsed by the re-examining Branch after the annual re-examination is satisfactorily carried out.

4.2.4.3 Where the re-examination is unsatisfactory, or major failures occur in the work of analysts, or testing data (reports) are false, the approval certificate of the analysis organization and its personnel will be suspended or canceled by CCS as appropriate.

4.2.4.4 The approved analysis organization is to report any changes of its personnel or instruments and equipment to the CCS Branch which has carried out the approval.

4.2.4.5 If considered necessary, the Surveyor is to take part in one of the lubricating oil sample analysis jobs.

4.3 Requirements for analysis organizations and their personnel not approved by CCS

4.3.1 General requirements

4.3.1.1 Where an analysis organization, of which the expenses are borne by the owner, does not apply for the approval by CCS, the lubricating oil analysis information and the related documentation provided by the owner will be regarded as the products supplied to CCS by the client (owner).

4.3.1.2 The lubricating oil analysis services by such analysis organizations and their personnel are to be delivered according to an arrangement agreed by CCS.

4.3.2 Availability of certificates

4.3.2.1 During the annual survey, the owner is to make available the relevant periodical sampling records and analysis reports and in addition, the qualification documents of the analysis organization and its personnel and valid documents of its instruments and equipment.

Appendix 15 GUIDELINES FOR LUBRICATING OIL CONDITION MONITORING SYSTEM OF DIESEL ENGINES

1 General Provisions

1.1 Scope

1.1.1 These Guidelines apply to lubricating oil condition monitoring systems of diesel engines on ships classed with CCS. The class notation for such systems is ECM.

1.2 Application

1.2.1 Where the lubricating oil condition monitoring system of diesel engines is intended for a ship, the owner is to submit an application in writing together with the following information:

(1) Relevant information of diesel engines, including technical parameters, intended type of lubricating oil and its physical and chemical criteria, name and material of parts of oil-lubricated friction pairs. The oil-lubricated friction pairs refer to all friction pairs the lubricating oil of which is supplied by the lubricating system of diesel engines, including those friction pairs the lubricating oil of which is supplied separately by cylinders in the case of crosshead type engines.

(2) Feasibility description, including a valve or an oil outlet which is fitted on the main lubricating oil pipeline between the main lubricating oil pump and the filter and capable of sampling in working condition of engines.

(3) General arrangement of engines, including arrangement of lubricating systems (if already provided, this may not be submitted).

(4) Reports and records of current status of engines to be monitored.

(5) Technical requirements specified by manufacturers of diesel engines and/or lubricating oils for operation, maintenance, monitoring, etc. of their respective products, if any.

1.2.2 One copy of the above-mentioned documentation is to be retained on board the ship.

1.3 Approval of the analysis organization and its personnel

1.3.1 A lubricating oil analysis organization seeking the approval by CCS for carrying out the analysis work, is to make an application to CCS for certification of the organization and its personnel in accordance with the relevant requirements of section 4 of these Guidelines.

1.3.2 Where the owner requires the lubricating oil analysis by a foreign analysis organization, prior agreement of CCS is to be sought.

1.4 Conditions of lubricating oil condition monitoring system of diesel engines

1.4.1 Sampling and analyzing of lubricating oil is to be carried out at an interval dependent on type, rate of revolution, working conditions, performance, etc. of engines. The analysis information is to be kept on board, covering at least the following items:

(1) physical and chemical criteria, including viscosity, water content, flashpoint, total acid number/total insoluble alkalis;

(2) content of elements contained in lubricating oil, including elements of wear metals, additives and contaminants.

1.4.2 Paragraph 1.4.1(1) of this section does not apply to analysis of cylinders of crosshead type diesel engines.

1.4.3 A valve or an oil outlet capable of sampling is to be fitted on the main lubricating oil pipeline between the main lubricating oil pump and the filter. However, the oil samples for physical and chemical analysis may also be taken at a position after the filter, taking into consideration the operability of taking samples in working condition of engines.

2 Surveys of Lubricating Oil Condition Monitoring System of Diesel Engines

2.1 General requirements

2.1.1 For ships having the class notation ECM, the survey of diesel engines is to comply with the relevant requirements of Chapter 5 of this PART and unless required otherwise by 2.1.2 of this section, only an verification examination and a general examination are to be carried out.

2.1.2 The survey of those items not covered by 2.1.3 of this Section is to be in accordance with the relevant requirements of Chapter 5 of this PART.

2.1.3 Survey items to be included in the lubricating oil analysis: Cylinders, pistons, piston rings, piston rods, piston pins, crossheads, crosshead pins, guides, crankshafts and all bearings, connecting rods, piston rod stuffing boxes.

2.2 Initial surveys

2.2.1 The application and documentation submitted by the owner are to be examined to confirm whether the ship has the service conditions for the class notation ECM.

2.2.2 For newbuildings, the periodical sampling analyses are to be carried out at the specified interval from the date of commissioning, as requested by the owner and approved by CCS.

2.2.3 For existing ships, the records and reports of at least three consecutive lubricating oil sampling analyses are to be submitted together with the application by the owner, and the following are to be complied with.

(1) All analysis items in 3.2.2.1 are to be included for the oil in the lubricating system, and 3.2.1.3 is to be complied with for the oil in cylinders.

(2) The time period between the latest sampling and the submission of application is not to exceed an interval between two consecutive samplings, and a verification examination is to be carried out according to 2.3 of this section.

(3) The class notation ECM will be assigned upon approval, and then the periodical sampling analyses are to be carried out at the specified interval from the date of the latest sampling for lubricating oil analysis.

(4) Where the last special survey of diesel engines was carried out 5 years ago, it is recommended that the engine lubricating oil condition monitoring be implemented after the due special survey.

2.2.4 For class-transferred ships which were originally subject to the survey of the engine lubricating oil condition monitoring system, where the owner requests to retain the system, the class notation ECM will be assigned upon a verification examination being satisfactorily carried out in accordance with 2.3 of this section. Subsequent periodical sampling analyses are to be carried out at the originally specified interval.

2.3 Verification examination

2.3.1 The verification examination of the engine lubricating oil condition monitoring system is to be carried out during the annual, intermediate and special surveys of machinery installations.

2.3.2 The verification examination is to be carried out to verify the following:

(1) Approval certificates or other qualification documentation of the lubricating oil analysis organization and its personnel (the lubricating oil analysis report is to be fed back together with copies of such certificates or documentation to the owner by the analysis organization).

(2) Sheets of lubricating oil analysis record and analysis report confirming that monitored parameters and trend analysis are within the normal ranges.

(3) Engine room logbook entries and maintenance records and other parameters recorded since last verification examination are to be checked, e.g. lubricating oil temperature, pressure, exhaust temperature, cooling water (oil) temperature.

2.4 General examination

2.4.1 At the special survey, a general examination is to be carried out in addition to the verification examination.

2.4.2 The general examination is to be carried out as follows.

(1) The maintenance records of diesel engines since last verification examination are to be examined.

(2) Other survey items not covered by lubricating oil analysis are to be examined to confirm whether they have been dealt with as required for the special survey.

2.5 Overhaul conditions

2.5.1 The overhaul of engine parts connected to the lubricating oil condition monitoring system is to be determined according to the lubricating oil analysis results and other performance parameters. Where the analysis results and other performance parameters are normal, the overhaul is not necessary. Where the analysis results and other performance parameters are abnormal, the Surveyor may require an overhaul depending on the actual condition.

2.5.2 Those parts not subject to an effective monitoring according to the engine lubricating oil condition monitoring procedures are to be overhauled according to the specified inspection regime.

2.5.3 Those parts, of which the owner requests to withdraw the lubricating oil condition monitoring, are to be overhauled according to the specified inspection regime.

2.6 Retention of lubricating oil analysis information

2.6.1 The following information is to be well retained on board for check by the attending Surveyor:
(1) the lubricating oil analysis information (to be kept by the chief engineer);
(2) copies of approval certificates or other valid qualification documentation of the lubricating oil analysis organization and its personnel provided to the owner by the analysis organization;
(3) relevant documents or information deemed necessary by the personnel on board or the Surveyor.

2.7 Cancellation of the class notation

2.7.1 At the request of the owner or where the lubricating oil sampling analysis is not carried out on time, the class notation ECM may be canceled and conventional survey is to be restored at the same time. A general overhaul is to be carried out at the next intermediate or special survey.

3 Engine Lubricating Oil Condition Monitoring Procedures

3.1 Sampling procedure

3.1.1 Sampling personnel

3.1.1.1 All oil samples are to be taken by a designated person on board or the chief engineer, who is to ensure that the samples are representative.

3.1.2 Sampling period

3.1.2.1 For diesel engines connected to a lubricating oil condition monitoring system, the sampling period for lubricating oil analysis is to be dependent on type, rate of revolution, working conditions, performance of engines.

In general, the sampling period is 300 to 500 hours or 60 days for medium and high speed diesel engines and 1,000 hours or 90 days for low speed diesel engines. For engines, of which the oil of lubricating system is required to be replaced regularly, the sampling period is not to exceed the oil-replacing period. The sampling period may be adjusted as appropriate, subject to confirmation by the Surveyor.

3.1.2.2 According to lubricating oil analysis results and practical operation condition (e.g. replacing of lubricating oil or abrupt change of wear particle concentration, metallic element content), the Surveyor may require the sampling period to be reduced. Where the sampling frequency is increased by the owner, this is to be recorded for future examination.

3.1.3 Sampling positions

3.1.3.1 Samples are to be taken through the sampling valve or oil outlet fitted on the main lubricating oil pipeline between the main lubricating oil pump and the filter so as to take representative samples. However, the oil samples for physical and chemical analysis may also be taken at a position after the filter.

3.1.3.2 For crosshead type diesel engines, separate samples are to be taken from cylinder oil, and the sampling position may be at the scavenger relief outlet or piston rod stuffing box of each cylinder.

3.1.3.3 For permanent sampling valves and tubes fitted in the pipelines, oil of about twice the volume of residual oil is to be discharged prior to sampling to ensure that no oil sampled at the last time is left.

3.1.3.4 Where samples are taken at oil outlet of the crankcase, an amount of oil is to be discharged prior to sampling to wash away the sediments left there.

3.1.3.5 The sampling positions are to be kept unchanged once they are set.

3.1.4 Sampling condition

3.1.4.1 Samples are to be taken in the normal operation condition of diesel engines.

3.1.5 Sampling record

3.1.5.1 Each time samples are taken, sampling personnel are to fill in the Sampling Record Table carefully and accurately, and affix a label showing sample No., name of the monitored ship, sampling date, service hours of engines and lubricating oil to the sample bottles. The completed Table together with the oil samples is to be sent to the analysis organization.

3.1.6 Sampling precautions

3.1.6.1 Sampling tools (including sample bottles, samplers, tubes, etc.) are to be kept clean, non-fragile and protected from pollution.

3.1.6.2 The quantity of oil samples is to be determined at the discretion of the analysis organization, at least sufficient samples are to be kept for re-testing.

3.1.6.3 Each sample is to be taken for two bottles, one of which is to be sent to the analysis organization and the other kept on board for future use or examination.

3.2 Analysis of lubricating oil samples

3.2.1 General requirements

3.2.1.1 During the lubricating oil sample analysis, in general, the physical and chemical analysis and the spectrum analysis are to be carried out at first and then on this basis, the analysis by direct reading

ferrogram may be carried out. Where it is considered necessary, qualitative analysis is to be carried out by an analytical ferrograph.

3.2.1.2 At the early stage of using the lubricating oil monitoring system, when it is difficult to develop criteria for distinguishing specific objects being monitored or make trend analysis due to insufficient analysis data, physical and chemical analysis, spectrum analysis and ferrographic analysis are to be carried out together.

3.2.1.3 Only spectrum analysis and ferrographic analysis are to be carried out for cylinder oil, and it is recommended that both analysis methods be applied together.

3.2.2 Diesel engine lubricating oil analysis

3.2.2.1 The items of diesel engine lubricating oil analysis are given in Table 3.2.2.1.

Table 3.2.2.1

Analysis items	Means (or tools) of analysis
Physical and chemical analysis	Physical and chemical analysis instrument
Analysis of element content (mainly metal content)	Spectrum analysis (spectrograph for oil analysis)
Analysis of appearance and concentration of wear particles	Ferrographic analysis (ferrograph)

3.2.2.2 Physical and chemical analysis items (items marked with "*" are optional):

(1) viscosity;

(2) water;

(3) flashpoint;

(4) total acid number (TAN)/Total base number (TBN);

(5) content of insolubles;

(6) deterioration* (oxidation, sulphidation, etc.);

(7) diluted fuel oil*.

3.2.2.3 Element content analysis (the owner may increase or reduce the elements listed in Table 3.3.1.2 at his discretion):

(1) Elements relative to material wear of friction pairs:

Cr Pb Cu Ni Fe Ag Ti Mn

Al Zn Si Sn V Mo W Sb

(2) Elements relative to pollution:

Si Na K B

(3) Elements relative to additives:

Ba B Ca Mg P Zn Li

The sources of various elements are to be correctly differentiated in accordance with the materials of friction pairs, additive components of lubricating oil, ambient working environment, etc.

3.2.2.4 Analysis of appearance and concentration wear particles:

(1) Where the appearance of wear particles is analyzed by analytical ferrograph, a classified description is to be made in accordance with the following types of wear particles:

① normal wear particles;

② cutting wear particles;

③ spherical wear particles;

④ fatigue wear particles in lumpy shape;

⑤ laminar wear particles;

⑥ severe sliding wear particles;

⑦ corroded wear particles;

⑧ nonferrous metallic wear particles;

⑨ red oxidic particles;

⑩ black oxidic particles;

⑪ non-metallic crystals;

⑫ carbon deposit;

⑬ rubbed polymer.

(2) Where the quantitative analysis of concentration is carried out by direct-reading ferrograph, the reading values D_l (large particles) and D_s (small particles) are to be measured and recorded.

3.2.3 Determination of criteria for analysis of parameters in lubricating oil analysis

3.2.3.1 Unless provided specially, the criteria of replacing oil as specified for the type of lubricating oil used by the owner, e.g. the relevant National standards, ministerial standards and control criteria of individual oil companies, are to be used in judging physical and chemical parameters of the lubricating oil.

3.2.3.2 The criteria for the quantitative spectrum or ferrographic analysis depend on values accumulated from practical tests and experience to a great extent. The reasonable criteria for judgment are to be determined by comparing the results of sampling tests of the specific monitored objects with the practical operation conditions. In the quantitative spectrum or ferrographic analysis, trend analysis is at present based mainly on the measured values.

Some criteria for spectrum analysis of diesel engine lubricating oil are given for reference in the Annex to these Guidelines.

3.2.4 Analysis of oil samples

3.2.4.1 All lubricating oil samples are to be sent to an analysis organization approved or accepted by CCS for analysis. The analysis organization is to complete the analysis in time and submit an analysis report. Where the analysis results exceed the allowable ranges or any abnormality or uncertainty is found, both the owner and the organization have the obligation to report this to CCS promptly.

3.3 Lubricating oil condition monitoring records, reports and formats

3.3.1 Lubricating oil condition monitoring records and analysis reports

3.3.1.1 Sampling Record Table

Table 3.3.1.1 is an example of the Sampling Record Table, covering the following:

(1) the basic parameters of the monitored object include name of the object, sampling position, measure units used, type of fuel oil, type and volume of lubricating oil, etc.;

(2) the working parameters during sampling include total operating hours of diesel engines, service time of lubricating oil, oil pressure, oil temperature, refilling date and sampling date of lubricating oil, etc.;

(3) the operation and maintenance condition since last sampling is to be entered into the description column of Table 3.3.1.1.

Sampling Record **Table 3.3.1.1**

Name of owner		Name of monitored ship	
Type of diesel engine		Sampling position /Cylinder No.	
Sample No.		Sampling date	
Type of fuel oil		Total operating hours of diesel engine (h)	
Type of lubricating oil		Volume of lubricating oil in use (L)	
Lubricating oil temperature (℃)		Service hours of lubricating oil (h)	
Lubricating oil pressure (MPa)		Volume (L) and time (h) of latest refilling of lubricating oil	
Description:			

Sampled by: Signature of chief engineer:

3.3.1.2 Lubricating Oil Analysis Report

Table 3.3.1.2 is an example of the Lubricating Oil Analysis Report, covering the analysis records and general report of lubricating oil analysis by the following three methods and the owner may add necessary test items into the Table at his discretion:

(1) physical and chemical analysis record, including viscosity, water content, flashpoint, content of insolubles, total acid number/total base number, deterioration and diluted fuel oil;

(2) spectrum analysis record, including test and analysis of content of elements, e.g. metallic particles worn from machinery friction pairs into lubricating oil, metallic particles and pollutants in lubricating oil additive;

(3) ferrographic analysis record, including D_l, D_s record of direct-reading ferrographic analysis.

Lubricating Oil Analysis Report **Table 3.3.1.2**

Ship's name: Owner:	Sample No: Type of diesel engine: Type of lubricating oil: Type of fuel oil: Ferrogram No:

Analysis date	Sampling date	Receiving date	Sampling position	Service hours of lubricating oil (h)	Total operating hours of diesel engine (h)

Physical and chemical analysis

Viscosity (cst)	Water content (%)	Flashpoint (℃)	TBN/TAN (mgKOH/g)	Insolubles (%)	Deterioration (oxidation, sulfidation)	Diluted fuel oil

Spectrum analysis (ppm)

Fe	Cu	Pb	Cr	Ni	Sn	Si	Ag	Zn	V	Na	Mg	Ba	Mo	Ca	W	Mn	P	B	Sb	Ti

Ferrographic analysis

Qualitative analysis (mark an appropriate box below with √ if deemed correct)

Kind of particles	Normal wear particles	Cutting particles	Spherical particles	Fatigue wear particles in lumpy shape	Laminar wear particles	Severe sliding wear particles	Corroded wear particles	Nonferrous metallic wear particles	Red oxidic particles	Black oxidic particles	Non-metallic crystals	Carbon deposit	Rubbed polymer
None													
Few													
Moderate													
Massive													

Quantitative analysis

D_l		D_s	

Description (additional pages may be attached):

Conclusion:

Analyzed by: Date:

Reviewed by: Stamp of organization:

3.3.1.3 Annual general report

The analysis organization is to prepare an annual general report separately for each diesel engine under lubricating oil condition monitoring, including a general analysis of the monitoring of each engine within the year.

3.3.2 Availability of lubricating oil analysis information

3.3.2.1 All records and analysis reports for lubricating oil condition monitoring are to be prepared in quadruplicate, one is to be retained by the analysis organization for reference, one submitted to CCS for filing, one sent to the owner and the original one kept on board the ship for future examination.

4 Requirements for Approval of Analysis Organizations and Their Personnel

4.1 General requirements

4.1.1 Scope

4.1.1.1 The requirements of this Section apply to the following two types of analysis organizations and their personnel:
(1) analysis organizations established by CCS and their personnel;
(2) analysis organizations and their personnel (subcontractors) applying for the approval by CCS.
4.1.2 General requirements
4.1.2.1 This Section has been prepared in accordance with the requirements of IACS QSCS.
4.1.2.2 The analysis organizations and their personnel applying for the approval by CCS are to pay the relative expenses in accordance with the provisions of CCS.
4.1.2.3 The instruments and equipment of an analysis organization may be purchased at its discretion or leased from other organizations.
4.1.2.4 It is recommended that the owner designate an analysis organization as a permanent partner.

4.2 Requirements for analysis organizations and their personnel applying for approval by CCS
4.2.1 Scope
4.2.1.1 This Section applies to the analysis organizations and their personnel covered by 4.1.1.1(1) and 4.1.1.1(2).
4.2.2 Requirements for approval of analysis organizations
4.2.2.1 The analysis organization is to have a complete set of quality assurance system or quality system for lubricating oil analysis condition monitoring, including:
(1) lubricating oil analysis procedure;
(2) work post responsibility;
(3) analysis result and report review;
(4) files management;
(5) instrumentation management and calibration;
(6) personnel training and assessment.
4.2.2.2 The analysis organization is to be manned according to its workload, with at least four approved lubricating oil analysts, one of whom is to be the chief analyst.
4.2.2.3 The analysis organization is to be provided with appropriate instrumentation and equipment certified by manufacturers and in addition, certified for effective calibration by the statutory metrology service or a metrology service accepted by CCS.
4.2.3 Requirements for approval of analysts
4.2.3.1 The chief analyst is to have at least college degree (or an equivalent education) and is also to be an engineer or have a more superior technical rank, familiar with the analysis technique, skilled at proper operation of instrumentation, and capable of working independently, giving guidance to other analysts and making a correct evaluation of the analysis results. And where the analysis results exceed the limits, he is to be capable of proposing key positions or parts for overhaul and predicting variation trend of lubricating oil against previous analysis reports.
4.2.3.2 Other analysts are to have at least a special secondary school degree (or an equivalent education) and some basic knowledge of lubricating oil analysis technique.
4.2.3.3 All analysts are to be familiar with the basic principles and testing methods of analytical instruments.
4.2.3.4 All analysts are to be trained in lubricating oil analysis technique by an organization approved by CCS and certified for satisfactory training.
4.2.4 Approval procedure
4.2.4.1 An analysis organization and its personnel seeking the approval by CCS are to submit an application to a local Branch of CCS according to relevant provisions and upon satisfactory initial review, the application will be sent to the Headquarters of CCS for approval. The corresponding analysis work may be carried out only after the analysis organization and its personnel are approved and certified by CCS.
4.2.4.2 The analysis organization and its personnel approved by CCS for lubricating oil analysis are to guarantee the analysis quality in accordance with the requirements of these Guidelines for lubricating oil analysis and are responsible for their written analysis reports and conclusions.
4.2.4.3 An analysis organization applying for approval is to submit the following documentation:
(1) name and particulars of the organization;
(2) number, condition and qualifications of the analysts to be approved;
(3) type, date of manufacture, name of manufacturer, manufacturer’s certificate, class of accuracy and (or) calibration certificate of analytical instruments;
(4) quality assurance system or quality system documents;
(5) fees to be charged for service.

4.2.4.4 The analysts applying for approval are to submit the following documentation:
(1) name, age, education background and health condition of the applicant;
(2) technical biography (i.e. experience of lubricating oil analysis) and certificates;
(3) recommendation by the organization and lubricating oil analysis training certificate.
4.2.4.5 Upon approval by CCS, appropriate certificates will be issued.
4.2.5 Maintenance of approval
4.2.5.1 The approval certificate of the analysis organization and its personnel is valid for five years. An application for an overall examination is to be made three months before the expiry date of the certificate, and a new certificate will be issued upon satisfactory examination.
4.2.5.2 Within the period of validity of the certificate, the approved organization is in general to be re-examined once a year for the following:
(1) Having a general idea of the testing work and management of the organization within the year;
(2) Examining the service, maintenance, repair and calibration of analytical instruments and the period of validity of calibration certificates;
(3) The appropriate column of the approval certificate is to be endorsed by the re-examining Branch after the annual re-examination is satisfactorily carried out.
4.2.5.3 Where the re-examination is unsatisfactory, or major failures occur in the work of analysts, or testing data (reports) are false, the approval certificate of the analysis organization and its personnel will be suspended or canceled by CCS as appropriate.
4.2.5.4 If considered necessary, the Surveyor is to take part in one of the lubricating oil sample analysis jobs.
4.2.5.5 The approved analysis organization is to report any changes of its personnel or instruments and equipment to the CCS Branch which has carried out the approval.

Annex Criteria for Spectrum Analysis of Diesel Engine Lubricating Oil

This Annex presents criteria for spectrum analysis of lubricating oil used for the following types of marine diesel engines for reference. The absolute values and abnormal trend values (increments within 10 hours) given in the Tables are to be considered together.

1 The criteria for spectrum analysis of MIL – L – 2104 lubricating oil used for EMD8 – 567 type marine diesel engines are given in Table 1.

Unit: ppm Table 1

	Fe	Ag	A1	Cu	Si	Sn	Pb
Normal	0 ~ 42	0 ~ 38	0 ~ 3	0 ~ 128	0 ~ 14	0 ~ 4	0 ~ 38
Critical	43 ~ 52	39 ~ 47	4	129 ~ 158	15 ~ 18	5 ~ 6	39 ~ 47
Max. limit	53 ~ 65	48 ~ 58	5	159 ~ 197	19 ~ 22	7	48 ~ 58
Abnormal	66 +	59 +	6 +	198 +	23 +	8 +	59 +
Abnormal trend	13	12	2	39	4	2	12

2 The criteria for spectrum analysis of lubricating oil used for FM38D – 8⅛ type marine diesel engines are given in Table 2.

Unit: ppm Table 2

	Fe	A1	Cr	Cu	Si	Pb
Normal	0 ~ 102	0 ~ 9	0 ~ 10	0 ~ 3l	0 ~ 17	0 ~ 19
Critical	103 ~ 126	10 ~ 11	11 ~ 13	32 ~ 48	18 ~ 2l	20 ~ 23
Max. limit	127 ~ 157	12 ~ 14	14 ~ 16	39 ~ 47	22 ~ 26	24 ~ 29
Abnormal	158 +	15 +	17 +	48 +	27 +	30 +
Abnormal trend	31	3	4	9	5	5

3 The criteria for spectrum analysis of lubricating oil used for Cummins VT400 type marine diesel engines are given in Table 3.

Unit: ppm Table 3

	Fe	Al	Cr	Cu	Si	Pb	Sn
Normal	0 ~ 43	0 ~ 9	0 ~ 19	0 ~ 23	0 ~ 21	0 ~ 9	0 ~ 3
Critical	44 ~ 53	10 ~ 11	20 ~ 24	24 ~ 28	22 ~ 26	10 ~ 12	4 ~ 5
Max. limit	54 ~ 67	12 ~ 14	25 ~ 30	29 ~ 36	27 ~ 33	13 ~ 15	6 ~ 7
Abnormal	68 +	15 +	31 +	37 +	34 +	16 +	8 +
Abnormal trend	11	3	7	8	6	2	2

4 The criteria for spectrum analysis of lubricating oil used for Detroit Diesel Allison 3080 type marine diesel engines are given in Table 4.

Unit: ppm Table 4

	Fe	A1	Cr	Cu	Si	Pb
Normal	0 ~ 100	0 ~ 5	0 ~ 10	0 ~ 26	0 ~ n	0 ~ 20
Critical	101 ~ 123	6 ~ 7	11 ~ 12	27 ~ 31	12 ~ 14	21 ~ 25
Max. limit	124 ~ 153	8	13 ~ 15	32 ~ 39	15 ~ 17	26 ~ 3l
Abnormal	154 +	9 +	16 +	40 +	18 +	32 +
Abnormal trend	31	2	4	8	4	6

5 The criteria for spectrum analysis of lubricating oil used for D399 type diesel engines of Caterpillar Company in USA are given in Table 5.

Unit: ppm Table 5

	Fe	A1	Cr	Cu	Si	Pb
Normal	<20	<6	<2	<6	<15	<25
Caution	20 ~ 30	6 ~ 9	2 ~ 6	6 ~ 9	15 ~ 20	25 ~ 40
Abnormal	31 ~ 40	10 ~ 12	7 ~ 10	10 ~ 12	21 ~ 30	41 ~ 75
Warning	>40	>12	>10		>30	>75

Appendix 16 GUIDELINES FOR SURVEY OF PLANNED MAINTENANCE SCHEME（PMS）FOR MACHINERY

1 General

1.1 Purpose

1.1.1 The Guidelines for Survey of Planned Maintenance Scheme (PMS) for Machinery may be regarded as guidance notes for CCS Surveyors, owners, ship management company and chief engineers in carrying out the PMS.

1.2 Scope

1.2.1 These Guidelines apply to the ships having the class notation PMS.

1.2.2 PMS may be regarded as an alternative to the continuous machinery survey (CMS) and the survey items and contents are to cover those of the related continuous survey.

1.2.3 PMS considers surveys to be carried out on the basis of intervals between overhauls recommended by manufacturers, documented operator's experience and a condition monitoring system, where fitted.

1.2.4 For a ship which is subject to survey of PMS, any other survey items necessary for maintaining its class is not to be canceled and changed, and the items not included in survey of PMS are to be surveyed in compliance with Chapter 5 of this PART.

1.3 Requirements for owner or ship management company

1.3.1 Organizational unit and personnel

(1) The owner or ship management company applying for implementation of survey of PMS is to establish a special organizational unit to manage the PMS. The department of machinery business may act as such unit or a specialized department may be set up. In all cases, a person in charge is to be assigned.

(2) The organizational unit is responsible for the PMS documentation and PMS daily management.

1.3.2 Plan formulation

(1) The PMS department of the owner or ship management company is to make a list of PMS equipment in accordance with the relevant requirements of the Rules and the specifications of manufacturers.

(2) The list of PMS equipment is to cover the items of special machinery survey or continuous machinery survey required by the Rules, and each maintenance interval is to be determined and detailed maintenance plan is to be made in accordance with the specifications of manufacturers and the actual operation of equipment on board; the items not required in the specifications of manufacturers are to be overhauled at least once within a five-year survey period of PMS.

(3) The computerized PMS management system is to be programmed in accordance with the above-mentioned documentation.

1.3.3 Maintenance intervals and examination items

(1) When the ship is subject to PMS survey, contents of preventive maintenance are to be included in the PMS schedule in accordance with the specifications of machinery and requirements of CCS Rules, and items subject to confirmatory examination each year and items to be overhauled within a five-year survey period specified as special survey items in the current CCS Rules are also to be included in PMS schedule.

(2) In general, the intervals between any two PMS surveys are not to exceed 5 years.

(3) For items which are subject to survey based on running hours, intervals exceeding 1 year may be accepted, but not to exceed 5 years.

(4) Items subject to confirmatory examination each year and items to be overhauled once within a five-year survey period are to be indicated by "F" and "H" respectively in Annex "Items for Survey of PMS" to this Appendix.

1.3.4 Requirements for PMS database system

(1) Documentation requirements

① software development unit is to be provided with business license for business entity and qualification certificates for developing relevant software;

② system specifications;

③ operation manual (instructions for use);

④ reports and plans for testing which have been carried out (all software functions in various operation modes, important function combinations, relevance are to be included);

⑤ instructions of system key algorithm (included in system specifications or provided individually);

⑥ other relevant technical specifications.

(2) Function requirements

① management of code: complete standard code management system (all PMS items may be covered and requirements of CCS Rules and guidelines are met);

② management of survey plan

a. each overhaul of the item are covered during the preparation of the plan and requirements of rules or specifications are complied with;

b. indication is to be provided that the item has entered the survey period when the planned date enters the windows (such as first three months) and automatic alarms will be given when the item is overdue;

c. the PMS survey plan of any intervals within a period may be inquired and printed;

d. the arranged PMS survey plan distribution in the system may be overviewed;

e. the planned completion time for each PMS item and allowable flexible range may be indicated;

f. when the completion time of one item is inputted, the subsequent plan grade and date may be generated automatically;

g. items within windows, overdue items and failed items in the survey plan may be clearly identified;

③ Management of working sheets

a. working sheets of any survey items may be inquired and printed;

④ Management of work report

a. survey reports may be generated automatically while the working contents are inputted;

b. survey items of any interval within a period may be inquired and printed (at least name of PMS equipment/standard code/planned time/completion time are to be included);

c. survey reports of any interval within a period may be inquired and printed;

d. the common format of testing report is considered to be included in the database;

⑤ Correction/self-checking function

a. software is to be capable of identifying normal faulty operation and correcting automatically;

b. software is to be capable of testing normal mistakes in database;

(3) Compatibility

① software is to be with good compatibility;

② requirements for hardware are to be with generality and not to be over demanding;

(4) Information security

① effective backup system and measures are to be provided;

② stable data synchronization scheme and correction and recovery capability in dealing with data conflict and document missing etc.;

③ modification of procedure/plan

a. specific level of modification permission is to be determined in order to prohibit illegal modification of procedures and plans;

b. records must be kept for change of the plan and are to be easy to inquire;

④ the system is to be with a certain anti-virus capabilities;

(5) software is easy and simple to operate;

(6) Only the software developer or personnel authorized by the developer is permitted to update and modify the documentation and information in database. Contents of update and modification are to be described when the company and ship are subject to the annual audit and are to be confirmed by the Surveyor to be valid;

(7) A Statement of Compliance of management system (software) of planned maintenance scheme for machinery issued by CCS is to be acquired for the above requirements. The period of validity of Statement of Compliance is 5 years and the renewal audit is to be carried out once every 5 years to ensure the effectiveness of the software after maintenance, upgrading or update.

1.3.5 Implementation of the plan

(1) The chief engineer is to complete the required items in time in accordance with the monthly maintenance plan generated automatically by computer and PMS management system installed on board.

(2) The ship is at least to report the monthly completion to the PMS department in accordance with the document requirements of the company and the PMS department is responsible for collecting the information, statistics and supervision of the completion and is to give feedback to the ship of the supervision comments or advise on the completion of PMS in time.

1.3.6 Reports
(1) The PMS department of the owner or ship management company is to submit PMS completion to CCS for confirmation when applying for CCS PMS survey.
(2) When the ship applies for the annual classification survey, the owner or ship management company is to submit an application for PMS annual audit simultaneously; the Surveyor is to carry out confirmatory examination on board (see items indicated by "F" in Annex "Items for Survey of PMS" to this Appendix); when the special classification survey is due, the owner or ship management company is also to submit an application for PMS annual audit simultaneously, and the Surveyor is to carry out confirmatory examination on board (see items indicated by "F" in Annex "Items for Survey of PMS" to this Appendix).
1.3.7 Responsibilities of chief engineer
(1) The chief engineer is responsible for implementation of PMS on board.
(2) The chief engineer is responsible for arranging maintenance of each PMS item. The maintenance is to be carried out in accordance with the requirements of preventive maintenance and techniques which have been inputted in PMS computer system and the necessary records of maintenance and measurement are to be kept. The relevant maintenance reports are to be examined or confirmed and signed by the chief engineer.
(3) In general, the chief engineer is to undertake PMS related trainings organized by CCS or ship company.
1.3.8 Where the shipping company or ship management company is changed and the class notation PMS of ship needs to be maintained, the new shipping company or new ship management company is to re-submit the changed parts to CCS for audit and confirmation in accordance with the requirements of 1.3.1 to 1.3.7.

1.4 Definitions
1.4.1 Ship repair and maintenance system (CWBT) combines the traditional onboard equipment management with the internationally used card-inserted type management to form a new, scientific and practical mode of onboard equipment management, including planning, management and guidance. Its abbreviation CWBT consists of the initials of Chinese phonetic letters for the four Chinese words Chuanbo (ship), Weixiu (repair) Baoyang (maintenance) and Tixi (system).
1.4.2 Planned maintenance scheme (PMS) means a detailed periodical maintenance plan for machinery (including electrical installations) onboard made by the owner or ship management company in accordance with the relevant requirements of the Rules and the specifications of manufacturers. Through the implementation on board, the machinery will be always kept in good technical condition. Such planned management of periodical maintenance for machinery is called planned maintenance scheme.
1.4.3 Planned maintenance system (PMS) for machinery survey means a system as an alternative to CMS for machinery (including electrical installations), which is applied for by the owner or ship management company and subject to approval by CCS.
1.4.4 Confirmatory audit means confirmation of validity of the class notation PMS. For the survey of PMS, an annual audit is to be made in accordance with the requirements of 3.2 of Section 3 when the annual/intermediate/special survey is carried out every year.
1.4.5 Implementation survey means the first confirmatory survey of PMS for the ship which applies for survey of PMS within one year of its trial.

1.5 Appendix
1.5.1 The Items for Survey of PMS in the Appendix of these Guidelines are only for reference for the owner or ship management company and PMS computer programming personnel in formulating the PMS and developing the programs.
1.5.2 CWBT code in the Items for Survey of PMS is recommended to be used where no international code system is available.

2 Procedural Requirements

2.1 Application
2.1.1 The owner of the ship or ship management company, for which PMS is intended, is to submit an application for the assignment of PMS notation to the Headquarters or a survey unit of CCS.
2.1.2 After the owner or ship management company is provided with PMS notation, application for PMS implementation of the ship is to be made on the completion of initial classification survey or special machinery survey or continuous machinery survey.
2.1.3 For the ship which is under continuous survey, where the owner or ship management company applies to CCS for PMS implementation, the items of the original continuous survey may be confirmed,

provided the survey of PMS items can be reasonably arranged, and the items for survey of PMS are to cover all those of the continuous survey. And it is to be ensured that the interval between the completion date of the original continuous survey and the next PMS maintenance date will not exceed 5 years.

2.1.4 For the ship which applies for PMS between two special surveys, where all items of special machinery survey can be reasonably arranged within the remaining special survey period (from the application date to the due date of this special survey), the survey of PMS implementation may also be carried out.

2.2 Approval documentation

2.2.1 While the owner or ship management company applies to CCS for assignment of PMS notation, the following written documentation or electronic file are to be submitted for approval:

(1) Organization chart identifying related posts (responsibilities);

(2) PMS documentation preparation procedure (or preparation instructions);

(3) List of PMS equipment;

(4) Description of identification of PMS equipment (or PMS number);

(5) Preventive maintenance items for each unit of PMS equipment;

(6) Maintenance plan for each unit of PMS equipment (for the equipment to be surveyed according to running hours, the hours of overhaul period are to be indicated in the plan and to be calibrated to be overhauled once every 5 years);

(7) Statement of Compliance of management system (software) of planned maintenance scheme for machinery issued by CCS.

2.2.2 For the series ships or sister ships, if PMS equipment of which are the same, documentation provided in accordance with 2.2.1 are to cover all the applicable ships.

2.3 Documentation to be kept on board

2.3.1 The following documentation are to be kept on board:

(1) All items of 2.2 above in an up-to-date version;

(2) Maintenance specifications of manufacturers and shipyard;

(3) Reference documents (trend analysis procedure, etc.);

(4) Records of maintenance, including repairs and renewals carried out.

2.4 Approval

2.4.1 After receipt of the application and documentation submitted by the owner or ship management company, CCS is to examine the documentation in time. Upon satisfactory examination, CCS will arrange the audit of the PMS Department established by the owner or ship management company in accordance with the relevant requirements of 1.3.

2.4.2 When the owner or ship management company has the ships which have been assigned with PMS notation or have been PMS surveyed, requirement of 2.4.1 for audit of the PMS department may be exempted.

2.5 Assignment of class notation

2.5.1 The ship which has been approved to implement the PMS is to apply for an occasional machinery survey to:

(1) confirm that the documentation specified in 2.3 are complete and meet the requirements;

(2) confirm that the PMS survey plan covers all items of the continuous machinery survey.

2.5.2 After the confirmation, the survey unit may issue an interim classification certificate to the ship and assign the PMS notation.

2.5.3 For the ship which is assigned the class notation PMS for the first time, a class memorandum is to be given and Implementation Survey is to be carried out by CCS Surveyor within one year since the approval date of PMS.

3 Survey Requirements

3.1 Implementation survey

3.1.1 For the ship which begins to carry out the PMS, trial is to be completed before implementation of the survey. After the trial is finished, the owner or ship management company is to apply to CCS for an implementation survey.

3.1.2 The Surveyor is to confirm the following:

(1) PMS has been implemented according to the approved documentation and the PMS computer

management procedures on board are suitable for the onboard equipment and system.
(2) The documentation necessary for the PMS annual audit and surveys/test necessary for maintaining the ship's class are provided.
(3) Engineers are familiar with PMS procedures.
3.1.3 When this survey is carried out and the implementation is found in order, a report describing the implementation of PMS is to be submitted to CCS survey unit by the owner or ship management company. The approved PMS may replace CMS.

3.2 Annual Audit①

3.2.1 A confirmatory audit is to be carried out during annual/intermediate survey every year for the ship under PMS, and it is preferably to be carried out concurrently with the annual/intermediate survey.
3.2.2 During the annual confirmatory audit, the surveyor is to review the detailed record or verify that it has been reviewed by CCS. The detailed record is to include at least the information required in 2.2.1(3) and (5) as well as any change to other paragraphs of 2.2.1.
3.2.3 During the annual audit, the Surveyor is to examine the following items when reviewing the detailed record submitted by the owner or ship management company.
(1) The confirmation examination is to be carried out for PMS computer management system. Verifying that PMS is being correctly and effectively implemented and that the machinery has been functioning satisfactorily since the previous annual audit, together with a general examination of the relevant PMS preventive maintenance items and completion of plans.
(2) The performance and maintenance records are to be examined to verify that the machinery has functioned satisfactorily since the previous annual audit or action has been taken in response to machinery operating parameters exceeding acceptable tolerances and the overhaul intervals have been maintained according to the requirements of the Rules and manufactures.
(3) Examining written details of breakdown or malfunction.
(4) The description of repairs carried out is to be examined. Any damaged machinery part, which has been replaced by a spare one, is to be retained on board – where possible – until examined by the Surveyor; where necessary, the chief engineer is to take photographs for such examination. For the renewed essential parts required by the Rules, the relevant product certificate is to be provided.
(5) When the Surveyor deems, in examining maintenance records, that the measured data are not correct or that the data exceed acceptable tolerances with no renewal being made and that the machinery malfunction is not properly handled, he may require the chief engineer to open the equipment for further survey.
(6) General examination is to be carried out for items indicated by "F" in Annex "Items for Survey of PMS" to this Appendix, and all items indicated by "H" which have been completed form the previous annual audit to this annual audit are to be verified and visual examination to be carried out.
(7) For the items indicated by "F" in Annex "Items for Survey of PMS" to this Appendix, when the overhaul time coincides with the time of annul audit, confirmatory examination is to be carried out under the surveyor's supervision; for the items indicated by "H" in Annex "Items for Survey of PMS" to this Appendix, when the overhaul and test time coincides with the time of annul audit, overhaul and test are to be carried out under the surveyor's supervision.
(8) According to the audit and examination results, the Surveyor is to issue an appropriate audit report and the PMS notation is to be retained.

3.3 PMS audit during special class survey

3.3.1 When the special class survey is due, the owner or ship management company is to apply for special survey and PMS annual audit.
3.3.2 The detailed record of PMS implementation to be submitted by the owner or ship management company and the survey requirements of the Surveyor are the same as 3.2.2 and 3.2.3 above.
3.3.3 The Surveyor is to verify that the examination of items indicated by "H" in Annex "Items for Survey of PMS" to this Appendix has been completed or the maintenance and function test completed by the ship's engineer at least once within the period of 5 years.
3.3.4 For the items indicated by "F" in Annex "Items for Survey of PMS" to this Appendix, when the overhaul time coincides with the time of special class survey, confirmatory examination is to be carried out under the surveyor's supervision; for the items indicated by "H" in Annex "Items for Survey of PMS" to this Appendix, when the overhaul and test time coincides with the time of special class survey, overhaul and test are to be carried out under the surveyor's supervision.

---

① The term audit, in this context, is not related to ISM audit, the implementation of surveys is to be completed prior to the commencement of the audit.

3.3.5 Where the special class survey is due and cannot be completed due to other reasons, the owner or ship management company may apply for extension. Where found satisfactory①, an extension not exceeding 3 months may be granted for the special class survey and PMS annual audit. Such survey and audit are to be carried out in accordance with the requirements of 3.3.1 to 3.3.3 by the end of the extension.

3.4 Damage and repair survey

3.4.1 The damage of PMS equipment (including components) is to be applied for to CCS for occasional class survey. The repairs of such components/machinery are to be carried out to the satisfaction of the Surveyor.

3.4.2 Any repair and corrective action regarding machinery under PMS are to be recorded in the engine logbook and the result of the repair of the machinery is to be verified by the Surveyor at the annual audit.

3.4.3 In the case of overdue conditions of class or a record of unrepaired damage which would affect the PMS, the relevant items are to be kept out of the PMS, i.e. subject to the inspection by the Surveyor until such conditions of class are fulfilled.

3.5 Change of plan

3.5.1 In general, the maintenance interval of items indicated by "H" of PMS items are to be implemented in accordance with the requirements of 1.3.3 of these Guidelines.

3.5.2 The maintenance plan may be properly adjusted by the owner or ship management company or chief engineer according to the maintenance of equipment and the operation of ship, however, the maximum interval between two maintenances for items indicated by "H" of PMS items is not to exceed that required in 1.3.3, i.e. not to exceed 5 years.

3.5.3 Where the chief engineer has completed the maintenance of a certain PMS item indicated by "H" in advance, the interval between the completion date and the next maintenance date is to comply with that specified in 1.3.3, i.e. not exceeding 5 years.

3.6 Withdrawal and cancellation

3.6.1 The owner or ship management company may apply for the withdrawal of PMS in writing to restore the special or continuous machinery survey.

(1) Where application for the withdrawal of class notation PMS and assignment of class notation CMS is made during special class survey, the survey unit is to examine all PMS items according to the equipment maintenance plan of PMS to confirm that the continuous survey may be restored directly after all due items for survey of PMS have been completed. The continuous machinery survey (CMS) scheme is to be prepared by the attending Surveyor in conjunction with the completion date of PMS survey items of a five-year period.

(2) When applying for the withdrawal of class notation PMS and assignment of class notation CMS during the second to the fourth PMS annual audits, the survey unit is to examine all PMS items according to the equipment maintenance plan of PMS to confirm that all due PMS items before applying for the withdrawal of class notation PMS have been completed. Items indicated by "H" among PMS items to be completed until the expiry date of the special survey are to be prepared into the continuous machinery survey (CMS) scheme and these continuous survey items are to be completed within the period between the date on the continuous machinery survey (CMS) scheme and expiry date of special survey.

(3) Where application for the withdrawal of class notation PMS and application for special class survey are made during special class survey, the survey unit is to examine all PMS items according to the equipment maintenance plan of PMS. After confirming that all due PMS survey items have been completed, items other than those indicated by "H" among PMS items completed within 15 months prior to the expiry date of the special survey period are to be overhauled to the satisfaction of the Surveyor, and the special survey may be restored.

(4) Where application for the withdrawal of class notation PMS and application for special class survey are made during the second to the fourth PMS annual audits, the survey unit is to examine all PMS items according to the equipment maintenance plan of PMS. After confirming that all due PMS survey items have been completed, items other than those indicated by "H" among PMS items completed within 15 months prior to the expiry date of the special survey period are to be overhauled to the satisfaction of the Surveyor, and the special survey may be restored. For ships of first PMS period, where application for the withdrawal of class notation PMS is made during the second to the fourth PMS annual audits, conversion

---

① Before PMS annual audit is extended, the surveyor is to re-check the outstanding recommendation or condition of class, PMS items are to be confirmed as far as practicable and the rest of the PMS items are also to be confirmed to ensure that the ship's safety is not affected.

may be made directly to special class survey. When special survey is due, implementation is to be in accordance with requirements for special survey.

3.6.2 Where the survey unit finds that the ship has not dealt with the survey of PMS seriously, it is to report this to the Headquarters. The Headquarters will remind the owner or ship management company in writing as appropriate, or require the owner or ship management company to take corrective actions within a specified period and failure to do so will result in cancellation of the class notation PMS. On that occasion, the survey is to comply with the requirements of 3.6.1 above.

Annex:

Items for Survey of PMS

PMS No.	CWBT code	Item	Details
1	MD-100-000-000	Diesel engine	
1.1	MD-101-000-000	Diesel engine	F① 1. General inspection
1.1.1	MD②-101-000-000 GD③-101-000-000	Cylinder cover	H④ 1. Inspecting each connected flange around cylinder cover and valve hole for defects, e.g. crack, ablation, unevenness. 2. Inspecting cooling water jacket space for scale and corrosion. 3. 0.7 MPa hydraulic test of cooling water jacket space after repair or where necessary
1.1.2	MD-102-010-000 GD-102-010-000	Piston	H Trunk piston: 1. Inspecting piston head, suspension lug, piston ring groove, piston pin hole, piston skirt, etc. for crack and ablation, and repair or renewal to be made where necessary. 2. Measuring and recording. H Crosshead type engine piston: 1. Inspecting piston head, suspension lug, piston ring groove and wear ring for crack, ablation, excessive wear, loosening, etc. 2. Inspecting water jacket space for scale and cleaning where necessary, hydraulic test. 3. Measuring and recording
1.1.3	MD-102-018-000 GD-102-018-000	Connecting rod	H 1. Inspecting the connecting rod for crack. 2. Inspecting bolts for crack, deformation, loosening, thread damage, and detection or renewal to be made where necessary
1.1.4	MD-102-011-000 MD-102-014-000	Piton rod Stuffing box	H 1. Cleaning, inspecting, measuring and recording. 2. Aligning the center and air clearance where necessary. 3. Disassembling, cleaning and inspecting the stuffing box, and renewing stuffing where necessary
1.1.5	MD-103-009-000 GD-103-009-000	Cylinder liner	H 1. Inspecting the cylinder liner for crack, scotch and excessive wear, etc. 2. Drawing out the liner for clean and inspection, and renewing the packing ring periodically in accordance with specifications. 3. Measuring and recording
1.1.6	MD.GD-101-002-000 MD.GD-101-003-000 MD.GD-101-005-000 MD.GD-101-006-000 MD.GD-101-007-000	Intake valve Exhaust valve Safety valve Indicator valve Starting valve	H 1. Inspecting casing, core and spring of each valve for crack, whether the working face between valve and valve seat is in normal order, and detection of valve rod to be made where necessary. 2. Checking the safety valve with opening pressure not exceeding 1.4 times the maximum combustion pressure
1.1.7	MD-102-015-000 MD-102-016-000	Crosshead pin & bearing Guide plate & sliding block	H 1. Inspecting the crosshead pin for crack and scotch, and detection to be made where necessary. 2. Inspecting crosshead pin, bearing and white metal of guide plate for crack, overheat, scotch, shelling, whether the connection is in order, and inspecting the connecting bolt. 3. Measuring the crosshead pin and recording. 4. Measuring the clearances of bearing, sliding block and guide plate and recording. 5. Correcting and adjusting where necessary

① F is the item of annual confirmatory survey.

② MD is the main diesel engine (main engine).

③ GD is the prime motor of diesel generating set (auxiliary engine).

④ H is the item overhauled at least once within each period of survey of PMS and the test of some systems.

PMS No.	CWBT code	Item	Details
1.1.8	MD-102-018-000	Bearing of connecting rod	H 1. Inspecting the bearing for crack, shelling, overheat, scotch, breakaway and other contact, wear conditions. 2. Measuring crank pin and recording. 3. Measuring clearance of bearing and recording
1.1.9	MD-106-000-000 GD-105-000-000	Transmission mechanism of intake valve Transmission mechanism of exhaust valve	H 1. Inspecting and measuring clearance of roller. 2. Inspecting the push rod and push rod seat
1.1.10	MD-103-055-000 GD-103-057-000	Frame & bedplate	H 1. Visual inspection for crack, deformation, damage, corrosion, etc. 2. Inspecting connection of frame, bedplate and cylinder block. 3. Hammering check of bolts and rivets for damage, fracture and tightening
1.1.11	MD-103-056-000 GD-103-056-000	Crankcase & safety device	H 1. Visual inspection. 2. The spring of explosion-proof door has no fracture and the valve is in order
1.1.12	MD-103-059-000 GD-103-055-000	Foundation bolts & packing blocks	H 1. Visual inspection. 2. Inspecting foundation bolts for loosening or fracture. 3. Inspecting the tightening of packing blocks and bolts
1.1.13	MD-104-020-000 GD-104-020-000	Main bearing & shaft journal	H 1. Inspecting the bearing for crack, shelling, overheat, scotch and contact, wear conditions. 2. Inspecting the shaft journal for scotch, pitting corrosion, and detection to be made where necessary. 3. Gauging the wear-down of crankshaft by bridge gauge, and where necessary, measuring and recording eccentric deviation. 4. Measuring thickness of bearing pillow, bearing clearance and recording. 5. Measuring the shaft journal and recording when the crankshaft is lift
1.1.14	MD-104-069-000 GD-104-168-000	Transmission mechanism of crankshaft	H 1. Tooth gear: inspecting the gear for crack, erosion, collapse, excessive wear, gear engagement and lubrication, measuring side clearance of the gear and recording. 2. Chain gear: inspecting links and rollers for crack, erosion, and wear, whether rollers are in order, and detection to be made and pre-tightening of chain adjusted where necessary
1.1.15	MD-105-000-000 GD-105-000-000	Camshaft Camshaft bearing	H 1. Inspecting the procedure for tightening cam on the shaft. 2. Inspecting the surface of cam for crack, pitting corrosion, scotch and excessive wear. 3. The bearing may not be dismantled where it has been in good operation with normal appearance and has not been repaired. 4. Overhauling, and measuring and recording the size and eccentric deviation of shaft journal and the clearance of bearing
1.1.16	MD-106-314-100	Scavenging fan	H 1. Inspecting the coupling and impeller. 2. Inspecting the automatic control device, and effectiveness test
1.1.17	MD-106-314-200	Emergency air blower	H 1. Inspecting the coupling and impeller. 2. Inspecting the automatic & manual control devices, and effectiveness test
1.1.18	MD-106-079-000	Scavenging pump	H 1. Piston-type scavenging pump: Inspecting piston, piston rod, cylinder liner, intake valve, exhaust valve for crack, scotch and excessive wear. Measuring the clearances of piston, piston ring, cylinder liner and bearing and recording. 2. Revolving scavenging pump: Inspecting pump case, impeller or gear, shaft, bearing and transmission gear components for crack, deformation, excessive wear, etc.
1.1.19	MD-107-029-000 GD-106-029-000	High-pressure oil pump	H 1. Overhauling the pump case and spring for defects, e.g. crack, deformation. 2. Inspecting the plunger, inlet valve and outlet valve for defects, e.g. crack, wear, scotch, pit corrosion, burr. 3. Check periodically
1.1.20	MD-109-051-000	Exhaust-gas	H 1. Inspecting the casing for crack, the cooling water jacket

PMS No.	CWBT code	Item	Details
	GD-109-051-000	turbocharger	space for scale and the corrosion, and thickness measurement to be made where necessary. Hydraulic test with 1.5 times working pressure (not less than 0.4 MPa) for cooling water jacket space of the casing. 2. Lifting out and inspecting the rotor, blades, guide blade and diffuser for defects, e.g. crack, bending, deformation, collapse, corrosion, and dynamic balance test to be made and a report submitted where necessary. 3. Inspecting the bearing for defects and renewing it in accordance with the specifications
1.1.21	MD-109-052-000 GD-109-052-000	Air cooler	H 1. To inspect whether the pipe and tube plate have deformation, damage, scale, corrosion, etc. 2. To wash the air and water jacket space. 3. To renew corrosion-proof zinc block. 4. Hydraulic test with 1.5 times working pressure is made at the side of air cooler
1.1.22		Spare parts and stores	H 1. The number of main spare parts is not less than the requirements of CCS Rules
1.1.23	MD-103-058-000 GD-103-058-000	Through bolt	H 1. To check the pre-tightening of through bolt in accordance with the specifications
1.1.24	MD-104-021-000 GD-104-021-000	Vibration damper or antivibrator	H 1. Flexible base: Inspecting the vibration isolating rubber and spring for damage. 2. Back balance antivibrator: to inspect the tightening of back balance and bolt. 3. Hydraulic spring-type antivibrator: Opening the covers at both sides of antivibrator, inspecting whether the spring unit, locating pin and oil hole are in order and unblocked, inspecting oil quality
1.1.25	MD-106-000-000	Scavenging air receiver & safety device	H 1. Opening scavenging receiver and cleaning manifold and the internal of receiver. 2. Inspecting internal valves and fittings, and repairing or renewing components where necessary. 3. Inspecting the passage of nozzles of emergency fire-extinguishing appliances. 4. Inspecting the reliability of explosion-proof door of scavenging receiver and valves
1.1.26	MD-01-10-025-000	Reversing arrangement	H 1. Inspecting components, e.g. reversing cam, reversing valve, reversing servo mechanism. 2. Overhauling relevant components, valves, etc. periodically in accordance with the specifications. 3. Effectiveness test
1.1.27	MD-109-061-000	Carriage turning gear (jacking engine)	H 1. Inspecting wear of worm wheel and worm. 2. Inspecting the reliability of carriage turning gear and interlocked valve. 3. Inspecting the coupling of motor and carriage turning gear. 4. Effectiveness test
1.1.28	MD-110-000-000 GD-108-152-000	Engine-driven air compressor	H Where engine-driven pump is a reciprocating pump: 1. Inspecting the reliability of engine-driven transmission mechanism. 2. Inspecting piston, piston rod, cylinder liner, air inlet valve, exhaust air (water, oil) valve and spring for crack, scotch and excessive wear. 3. Lifting out the piston and connecting rod, measuring the clearance of bearing and recording. 4. Effectiveness test and checking the safety valve H Where engine-driven pump is a rotating-type pump: 1. Inspecting the reliability of engine-driven transmission mechanism. 2. Inspecting the casing, impeller or gear or worm, bearing, shaft, shaft gland and components for crack, deformation, excessive wear, and renewal to be made where necessary. 3. Effectiveness test H Engine-driven air compressor: 1. Inspecting the items as shown in 5.1
1.1.29	MD-110-000-000	Engine-driven bilge pump	
1.1.30	MD-110-000-000 GD-106-141-000	Engine-driven diesel oil booster pump	
1.1.31	MD-110-000-000 GD-106-141-000	Engine-driven fuel oil booster pump	
1.1.32	MD-110-000-000 GD-106-141-000	Engine-driven diesel oil delivery pump	
1.1.33	MD-110-000-000 GD-106-141-000	Engine-driven fuel oil delivery pump	
1.1.34	MD-110-000-000 GD-107-142-000	Engine-driven freshwater pump	
1.1.35	MD-110-000-000 GD-107-142-000	Engine-driven cooling freshwater pump	
1.1.36	MD-110-000-000 GD-106-142-000	Engine-driven cooling pump of fuel injector	
1.1.37	MD-110-000-000	Engine-driven lub.	

PMS No.	CWBT code	Item	Details
		oil pump	
1.1.38	MD-110-000-000	Engine-driven reduction gear lub. oil pump	
1.1.39	MD-110-000-000	Engine-driven seawater circulating pump	
1.1.40	MD-110-000-000	Engine-driven seawater cooling pump	
1.1.41	MD-110-000-000	Engine-driven freshwater cooler	H 1. Cleaning seawater jacket space, renewing corrosion-proof zinc block and inspecting end cover gasket. 2. Washing freshwater jacket space. 3. Hydraulic test
1.1.42	MD-110-000-000	Engine-driven lub. oil cooler	H 1.Cleaning seawater jacket space, renewing corrosion-proof zinc block and inspecting end cover gasket. 2. Washing freshwater jacket space. 3. Hydraulic test
1.2	MD-110-000-200 GD-108-148-000	Partial pipeline of starting air system	H 1. Visual inspection for corrosion, damage or leakage trace, and hydraulic test or thickness measurement to be made where necessary. 2. Disassembling some valves and pipeline lengths of starting air system for internal inspection. 3. Checking the safety valve of starting air manifold (if any) with the pressure not exceeding 1.1 times working pressure. 4. Inspecting the tightness
1.3	MD-104-019-000 GD-104-019-000	Crankshaft	H 1. Inspecting the shaft journal of crankshaft for scotch, pitting corrosion, mechanical damage and wear, inspecting the fillet and oil hole for crack. 2. Inspecting crankshaft cylinder liner or press fit or loosening or offset. 3. Inspecting the reliable tightening of flange connection for sectional crankshaft and of back balance for assembled crankshaft. 4. Measuring the shaft journal of crankshaft and recording. 5. Measuring the crankshaft deflection and recording
2	MT-000-000-000	Turbine	
2.1	MT-000-000-000	Steam turbine	F 1. General inspection
2.1.1	MT-101-000-000	Cylinder block & cylinder cover	H 1. Dismantling the cylinder block and bedplate and inspecting for crack or other defects. 2. Inspecting for the tight connection of cylinder block and bedplate and for fracture of bolts. 3. Inspecting the joint surface of cylinder for mechanical damage and leakage trace. 4. Inspecting the bolts connecting upper and lower cylinder blocks for damage or crack. 5. Measuring the axial clearance of heat-expansion-prevention separator of cylinder and recording. 6. Inspecting the separator for corrosion, loosening and crack. 7. Inspecting the steam seal for wear, deformation or leakage
2.1.2	MT-103-310-000 MT-103-310-200 MT-103-310-300	Rotor, blades	H 1. Inspecting the rotor for deformation, loosening and crack. 2. Inspecting, measuring the working shaft journal and recording. 3. Inspecting the blade for defects, e.g. crack or wear, and detection to be made as the circumstance dictates. 4. Inspecting the blades for loosening and for securing of final blade, locking block, bracing, skirt and blades. 5. Inspecting the installation of rotor, measuring axial/radial clearances between rotor and separator and recording
2.1.3	MT-103-171-000 MT-103-171-200 MT-103-171-300	Elastic coupling	H 1. Inspecting for the connection and for defects of bolts. 2. Alignment. 3. Inspecting the elastic elements for crack and damage
2.1.4	MT-107-000-000	Condenser and steam bleeder	H 1. Inspecting the tube plate, pipe head and end cover for leakage and corrosion. 2. Inspecting the effectiveness during operation
2.1.5	MT-102-000-000	Main bearing, thrust pad and oil seal	H 1. Inspecting the white metal and thrust face of bearing. 2. Inspecting, measuring axial/radial clearances and recording.

PMS No.	CWBT code	Item	Details
			3. Gauging the wear-own of shaft journal by bridge gauge and recording. 4. Inspecting wear, deformation or leakage
2.1.6		Steam reheater	H 1. Inspecting the tube plate, pipe head and end cover for leakage and corrosion. 2. Inspecting the effectiveness during operation
2.1.7	TS-105-153-000	Steam superheater	
2.1.8		Heat reducer	
2.1.9	MT-108-073-300	Axial displacement protection	H 1. Inspecting for defects. 2. Effectiveness test and recording
2.1.10	MT-108-073-000	Overspeed protection	H 1. The same as 2.1.9
2.1.11	MT-108-070-200 MT-108-070-300	Ahead and astern steering gear and main control valve	H 1. Inspecting for connection and defects. 2. Effectiveness test and recording
2.1.12	MT-107-148-000	Main steam pipe between boiler and steam turbine	H 1. Inspecting the internal corrosion of some pipe lengths. 2. Thickness measurement for those suspect pipes and recording, or hydraulic test with 2 times working pressure
2.2	MG-100-000-000	Gas turbine	F 1. General inspection
2.2.1	MG-101-000-000	Rotor, impeller & blades	H 1. Refer to 2.1.2 as appropriate
2.2.2	MG-102-000-000	Casing of air compressor	H 1. Refer to 2.1.1 as appropriate
2.2.3	MG-103-000-000	Combustion chamber	H 1. Inspecting for defects, e.g. crack, corrosion and sooting
2.2.4	MG-104-000-000	Burner	H 1. Inspecting for defects, e.g. crack, corrosion. 2. Inspecting nozzle and fuel injector
2.2.5	MG-105-000-000	Intercooler	H 1. Refer to 2.1.4 as appropriate
2.2.6	MG-106-000-000	Heat exchanger	H 1. Refer to 2.1.6 as appropriate
2.2.7	MG-107-000-000	Starting and reversing devices	H 1. Refer to 2.1.11 as appropriate
3	PM-100-000-000	Shafting	
3.1	PM-101-000-000	Intermediate shaft and bearing	F 1. General visual inspection of shafting and bearing seat for crack and tightening, etc. H 1. Opening the upper cover and inspecting the wear of shaft journal. 2. Measuring and recording eccentric deviation of shaft journal. 3. Inspecting for the tightening of bolts for coupling flange. 4. Inspecting the passage of cooling water pipe. 5. The lower half of bearing not to be dismantled for inspection where the shafting alignment found good
3.2	PM-105-000-000	Thrust shaft and bearing	F 1. Inspecting the bearing shell and oil seal for crack, etc. 2. Inspecting the white metal of thrust pad for wear and loosening. 3. Inspecting the operation of lub. oil system. 4. Inspecting the operation of cooling water. H 1. Measuring and recording the clearance of thrust bearing
4	PM-000-000-000	Propelling system	
4.1	PM-104-000-000	Reduction/increasing gear	F 1. General visual inspection of gear box for leakage, crack and tightening. H 1. Inspecting gear shaft for wear and shaft journal for scotch, measuring and recording eccentric deviation of shaft journal. 2. Inspecting engagement of each gear and pinion for crack of root. 3. Inspecting wear of tooth face and measuring and recording clearance. 4. Inspecting lub. oil system
4.2	PM-103-000-000	Clutch	F 1. Inspecting external condition for leakage and the tightening of hold-down bolts, etc. H 1. Inspecting the items in accordance with the specifications. 2. Effectiveness test
5		Essential auxiliary machinery	
5.1	AS-102-000-000 AS-103-000-000 AS-203-000-000	Main air compressor Auxiliary air compressor Accessory safety device	F 1. General visual inspection for leakage and operation. H 1. Dismantling the cylinder head and inspecting valve hole and water hole. 2. Inspecting cooling water jacket space for scale and corrosion.

PMS No.	CWBT code	Item	Details
			3. Inspecting, measuring the wear of crankshaft journal and bearing and recording. 4. Measuring and recording each grade of cylinder liners. 5. Lub. oil condition, and effectiveness test of safety valve. 6. Opening the end cover of intercooler and inspecting cooling pipeline and sealing condition
5.2	SE-508-000-000	Emergency air compressor and air bottle	F 1. Inspecting the external corrosion. H 1. Effectiveness test of emergency air compressor. 2. Airtightness test of outlet valve and drain valve of emergency small air bottle. 3. Check of safety valve
5.3		Essential pumps and motors	All kinds of pumps are disassembled in accordance with the specifications
5.3.1	BW-102-142-000 BW-102-301-000	Seawater pump & motor for main engine	F 1. General visual inspection of the pump group and flange connection, and the tightening of seat. H 1. Inspecting shaft gland for wear and leakage. 2. Inspecting the impeller for corrosion and dynamical balance. 3. Measuring and recording the clearance between impeller and pump case. 4. Inspecting the wear of blade and tooth face, measuring and recording the clearance. 5. Inspecting the shaft gland for wear. 6. Inspecting the bearing for wear. 7. Effectiveness test after assembly. Key inspection in accordance with different types of pumps: Centrifugal pump: H 1. Inspecting suction pipeline for corrosion and self-priming capability. 2. Inspecting of impeller and blades for cavity corrosion. Gear pump: H 1. Measuring and recording the clearance between gear plane and end cover of pump case. Reciprocating pump: H 1. Inspecting the wear and the opening of piston ring. 2. Measuring and recording the size of pump cylinder. Screw pump: H 1. Watching the noise and stability during operation. 2. Inspecting by-pass safety valve for reliability. Sled (vane) pump: H 1. Measuring and recording the clearance of vane in chute. 2. Measuring and recording the clearance of vane end surface. Inspection of driving motors of various pumps: H 1. Measuring and recording insulance of motors. 2. Replacing the ball bearing or roller bearing and recording as the circumstance dictates and according to overhaul period. 3. Effectiveness test after assembly.
5.3.2	BW-104-142-000 BW-104-301-000	Seawater pump and motor for berthing	
5.3.3	FW-203-000-000	Fresh water pump & motor for main engine	
5.3.4	FW-207-000-000	Fresh water pump & motor for berthing	
5.3.5	TS-605-000-000	Feed pump & motor for boiler	
5.3.6	TS-306-000-000	Circulating water pump & motor for boiler	
5.3.7	TS-404-000-000	Circulating water pump & motor for exhaust boiler	
5.3.8	OS-502-000-000	Fuel pump & motor for boiler	
5.3.9	OS-302-000-000	Fuel pump & motor for main engine	
5.3.10	OS-303-302-000	Fuel pressure pump & motor for main engine	
5.3.11	LO-302-000-000	Lub. oil pump & motor for main engine	
5.3.12	LO-304-000-000	Oil pump & motor for main engine camshaft	
5.3.13	SE-101-000-000	fire pump & motor	
5.3.14	SE-05-01-000-000	Emergency fire pump & driving device	
5.3.15	BW-202-000-000	Ballast pump & motor	
5.3.16	KP-102-142-000 KP-102-301-000	Bilge pump & motor	
5.3.17	BW-203-000-000	Equalizing pump & motor	
5.3.18	BW-204-000-000	General service pump & motor	
5.3.19	FW-402-000-000	Seawater pump and motor for fresh water generator	
5.3.20	FW-405-000-000	Condensate pump and motor for fresh water generator	
5.3.21	OS-102-141-000 OS-102-301-000	Fuel transfer pump and motor	
5.3.22	OS-104-141-000	Diesel oil transfer pump and motor	
5.3.23	KP-104-141-000	Residual fuel pump	

PMS No.	CWBT code	Item	Details
	KP-104-301-000	& motor	
5.3.24	FW-302-000-000	Daily service fresh water pump & motor	
5.3.25	FW-303-000-000	Heat water circulating pump & motor	For various ejector pumps: H 1. Inspecting nozzle holes for wear. 2. Inspecting diffuser cone for erosion and corrosion. 3. Effectiveness test. For the 36 types of pumps and motors mentioned in the left column, general visual inspection is to be carried out every year
5.3.26	BW-402-000-000	Sanitary pump & motor	
5.3.27	FW-502-000-000	Drinking water pump & motor	
5.3.28	FW-205-142-000 FW-205-301-000	Cooling pump & motor of fuel injector for main engine	
5.3.29	FW-204-142-100 FW-204-301-100	Cooling pump & motor of piston for main engine	
5.3.30	FW-302-142-000 FW-302-301-000	Fresh water transfer pump and motor	
5.3.31	FW-403-000-000	Vacuum pump set of fresh water generator	
5.3.32	FW-404-000-000	Salt water pump & motor for fresh water generator	
5.3.33		Vacuum air pump	
5.3.34		Feed water jet pump	
5.3.35	BS-202-146-000	Bilge water jet pump	
5.3.36		All other engine-driven pumps	
5.3.37	DO-202-619-000 DO-202-313-000	Fuel oil separator & motor	H 1. Disassembling oil separator and inspecting each component. 2. Inspecting the vertical spindle for bending and wear. 3. Inspecting bearing for wear and measuring clearance. 4. Inspecting worm wheel and worm for engagement and wear of teeth. 5. Measuring insulance of motor and replacing ball bearing or roller bearing as the circumstance dictates and recording. 6. Effectiveness test after assembly
5.3.38	OS-204-151-000 OS-204-301-000	Diesel oil separator & motor	
5.3.39	LO-202-000-000	Lub. oil separator & motor	
6		Air bottles and various pressure vessels and accessories	
6.1	AS-104-155-000 AS-104-156-000 AS-105-156-000 AS-104-078-000 AS-105-078-000	Main & auxiliary air bottle, working air bottles and accessories such as safety valves	F 1. General visual inspection. H 1. Opening big and small manholes for internal cleaning. 2. Inspecting air bottle for internal corrosion. 3. Inspecting various valves for airtightness. 4. Checking safety valve. 5. Hydraulic test with 1.3 times working pressure for suspect air bottles
6.2	FW-300-000-000 BW-401-147-000 FW-500-000-000	Fresh water pressure tank, sanitary tank (seawater pressure tank) and potable fresh water tank	F 1. General visual inspection. H 1. Opening manholes for internal cleaning. 2. Inspecting internal corrosion, and hydraulic test to be made where necessary. 3. Effectiveness test of automatic control equipment
7	PM-400-000-000	Main & auxiliary steering gear and accessory equipment and control system	F 1. General visual inspection and effectiveness test. H 1. Inspecting each component of the main steering gear for flexibility and reliability of effective actions. 2. Inspecting auxiliary steering gear for flexible and reliable actions. 3. Inspecting whether various conversions of main steering gear are correct and flexible, and whether conversion between main and auxiliary steering gears is quick. 4. Inspecting each equipment of steering control system for flexible and reliable actions. 5. Inspecting feedback device, rudder indicator, etc. for accurate indication. 6. Inspecting whether communication between bridge and steering gear room is in order.

PMS No.	CWBT code	Item	Details
			7. Inspecting whether various alarms of control system are in order. 8. Measuring the insulance of motor, replacing ball bearing or roller bearing as the circumstance dictates and recording. 9. Inspecting the operation of each component of steering gear
8	DO-201-000-000	Windlass	
8.1	DO-201-313-000 DO-201-628-000 DO-201-304-000 DO-201-070-000 DO-201-608-000	Prime motor, driving and control units, operating and braking devices of windlass	F 1. Visual inspection and effectiveness test for windlass. H 1. Inspecting gear, chain sprocket, bearing, brake ribbon (shoe), etc. 2. Inspecting hydraulic cylinder, rotor, blade, bearing, sealing device, etc. 3. Inspecting the tightening of windlass base. 4. Steam windlass: inspecting cylinder, piston, piston ring, crankshaft, bearing, etc. and recording. 5. Inspecting valves, safety valve, etc. on each pipeline. 6. Measuring the insulance of motor and inspect ball bearing or roller bearing
9	KP-101-000-000	Bilge pipe, strainer, bilge well suction, sludge pipe	F 1. Effectiveness test. 2. Visual inspection of bilge well. H 1. Effectiveness test. 2. Inspecting suction screen and mud box for cleanness. 3. Action test of operating valve of emergency bilge suction in engine room
10	BW-201-000-000 BW-205-313-000	Ballast pipe, valve and ballast operating system	F 1. Effectiveness test. H 1. Effectiveness test. 2. Operating test of remote control valve
11	OS-301-150-000 OS-401-150-000 LO-301-150-000 LO-401-150-000 and so on	Pressure strainers, heaters, coolers and various strainers of fuel oil, lub. oil, cooling water, boiler water	H 1. Disassembling, cleaning and inspecting screen, sealing, pipe, etc. 2. Tubular heater or cooler: Opening the cover for internal washing, and external chemical washing of cooler. Inspecting watertight riveting of tube plate of and internal erosion. 3. Plate-type heater or cooler: Opening and scouring clamp plate, and inspecting for corrosion and sealing strips. 4. Visual inspection and effectiveness test after assembly
12	MD-100-000-000	Main engine trial	F 1. Operating test in working condition, including ahead steering, astern steering and reversion tests, and recording main operation parameters of main engine. H 1. Operating test in working condition, including ahead steering, astern steering and reversion tests, and recording operation parameters and thermal parameters of main engine; re-starting test after failure of starting; audible and visual alarm to be given to block the starting function after 3 failures of starting or wrong direction, if fitted
13		Miscellaneous	
13.1	HS-600-000-000	Fuel oil tank separated from hull	H 1. Inspecting internal structure. 2. Inspecting heating pipe. 3. Hydraulic test after overhaul
13.2	SE-102-000-000 SE-103-000-000 SE-104-000-000 SE-200-000-000	Fixed fire - extinguishing system (foam, CO_2, halide and dry powder)	F 1. Inspecting piping, control system, marks and operational instructions. 2. Inspecting ventilation, illumination, communication, instrument, etc. in rooms/stations. 3. Visual inspection of fire-extinguishing agent containers, valves, etc. 4. Measurement of stored quantity of fire-extinguishing agents and passage test of pipeline to be made once two years. 5. Action test of quick-closing valve of oil tank
13.3	HS-400-000-000	Escape route in engine room and boiler room	F 1. Inspecting escape route for unobstructed passage, especially exits not to be locked. 2. Inspecting whether self-closing devices of exit of engine and boiler rooms are effective
13.4	TS-200-172-000	Steam boiler, hot oil heater, pressure vessel, including their safety devices	F 1. Visual inspection. 2. Checking safety valves

PMS No.	CWBT code	Item	Details
14		Additional requirements for oil tankers	
14.1	CG-700-000-000	Cargo oil pump, bilge pump, stripping pump, segregated ballast pump in pump room	F 1. General inspection of cargo oil pump, bilge pump, stripping pump and segregated ballast pump. 2. Inspecting the bases of cargo oil pump, bilge pump, stripping pump and segregated ballast pump, as well as the reliability of gaskets and binding bolts, corrosion of bedplate and condition of locating pins
14.1.1	CG-702-141-000 CG-703-141-000 CG-704-141-000	Cargo oil pump	H 1. Disassembling cargo oil pump and prime motor, inspecting each component for obvious corrosion, deformation, wear, measuring clearance of each component and recording. 2. Inspecting shaft gland for leakage. 3. Aligning the shafting and recording. 4. Functional test of automatic control system and alarm system of prime motor and recording of parameters. 5. Action test of emergency and remote shutdown
14.1.2	CG-702-141-000 CG-703-141-000 CG-704-141-000	Stripping pump	H 1. Disassembling stripping pump and prime motor, inspecting operation of each component, measuring clearance and recording. 2. Inspecting shaft gland for leakage. 3. Action test of emergency and remote shutdown
14.1.3	BW-202-000-000	Segregated ballast pump	H 1. Disassembling segregated ballast pump, inspecting operation of each component, measuring clearance and recording
14.1.4	KP-102-000-000	Bilge pump	H 1. Disassembling bilge pump, inspecting operation of each component, measuring clearance and recording. Action test of emergency and remote shutdown
14.1.5	CG-705-014-000	Sealing device for pump drive assembly	H 1. Disassembling, inspecting and testing sealing device for pump drive assembly penetrating bulkhead
14.1.6	CG-701-000-000	Piping and fittings	H 1. Disassembling, inspecting, hydraulically testing piping and fittings of cargo oil and ballast pumps and recording
14.2	HS-302-000-000	Venting system of cargo oil tank	F 1. General inspection of venting system (including breathing valve) in cargo oil tank and slop tank. H 1. Disassembling and inspecting partial venting pipe in cargo oil tank. 2. Disassembling and inspecting the breathing valve in cargo oil tank, checking pressure and inspecting flame screen. 3. Disassembling and inspecting the quick venting valve in cargo oil tank fitted with IGS, checking pressure and inspecting flame screen
14.3	CG-708-506-000	Crude oil washing machine Washing heater	F 1. Visual inspection of crude oil washing system. 2. Visual inspection for washing heater
14.3.1	CG-708-506-000	Crude oil washing machine	H 1. Disassembling and inspecting crude oil washing machine and action test
14.3.2	CG-708-153-000	Washing heater	H 1. Disassembling washing heater, inspecting tube plate for corrosion, inspecting zinc plate, pipe and hydraulic test. 2. Disassembling, inspecting and testing the safety valve of washing heater, testing automatic temperature control system and automatic level control system. 3. Inspecting the valve or other mechanisms separating the heater from crude oil washing piping
14.4	CG-701-153-000	Cargo oil heating system	H 1. Inspecting cargo oil heating system and accessories (safety valve, reducing valve, automatic pressure regulator valve, regulator, etc. of pipeline). 2. Internal inspection, thickness measurement, hydraulic test of partial cargo oil heating pipe and recording. 3. Inspecting the fixing of heating pipes in cargo oil tank
14.5	CG-706-560-000	Ventilation system of cargo oil pump tank	F 1. General inspection for ventilation system of cargo oil pump tank. H 1. Disassembling and inspecting the ventilator in cargo oil pump tank. 2. Disassembling, inspecting and testing the sealing device of shaft drive assembly for ventilator in cargo oil pump tank that penetrates bulkhead. 3. Emergency shutdown of ventilator and effectiveness test of

PMS No.	CWBT code	Item	Details
			emergency vent. 4. Visual inspection of ventilator and inspecting the fixing of ventilator. 5. Inspecting the interlock of ventilator and illumination of pump room
14.6	CG-708-000-000	Relevant instruments of cargo oil & ballast control stations	F 1. General inspection of cargo oil and ballast control stations and relevant equipment. H 1. Checking relevant instruments of cargo oil and ballast control stations by contrast, e.g.: Steam inlet pressure gauge of steam turbine, tachometer of cargo oil pump, cargo outlet pressure gauge, cargo outlet thermometer, seawater outlet thermometer of washing heater, outlet pressure gauge of ballast pump, hydro-oil outlet pressure gauge of hydraulic pump station, and voltmeter, ammeter and control air pressure gauge of control station. 2. Inspecting the remote control valve and valve position indicator of cargo oil system for hydro-oil leakage and correct indication. 3. Test of high level alarm for pump room bilge. 4. Effectiveness test of alarming for combustible gas concentration
14.7	SE-701-000-000	Inert gas system	
14.7.1	SE-701-000-000	Inert gas system	Inspection of inert gas system (IGS) F 1. General inspection of pipeline and components, serious corrosion, water and oil leakage to be dealt with if found. 2. Action test of remote control, automatic control, soot blower, etc., as far as possible. 3. Alarm test by simulation for key alarming points of IGS. 4. Checking oxygen content meter
14.7.1.1	SE-702-315-000	Monitoring device of inert gas system	H 1. Checking the accuracy of oxygen content meter by Standard N2. 2. Inspecting the operation of audible and visual alarm, main control board and area control board. 3. Checking the parameters of primary alarming points and inspecting safety device for: a. excessive oxygen content in IGS manifold; b. excessively low gas pressure in IGS manifold; c. excessively low feed pressure of deck water seal; d. excessively high gas temperature in IGS manifold; e. excessively low feed pressure of scrubber; f. accuracy of portable oxygen content analyzer; g. interlocking with outlet pressure parameters of cargo oil pump
14.7.1.2	SE-702-307-000	Automatic control for inert gas system	H 1. Inspecting the action and delay time of automatic control regulating valve under different alarm levels and recording. 2. Inspecting the quality performance parameters (set and measured values of outlet pressure of inert gas), reaction sensitivity and accuracy of automatic control for the system
14.7.1.3	SE-701-709-000 SE-701-710-000 SE-701-711-000	Inert gas generator, scrubber, fan, deck water seal	H 1. Disassembling and inspecting inert gas generator, and effectiveness test to be made. 2. Disassembling scrubber and inspecting nozzle, screen, case, protective coating, discharging pipe. 3. Disassembling fan and inspecting impeller, shaft, case, and shaft seal, and test conversion with stand-by fan. 4. Disassembling deck water seal and inspecting internal coating, case, damper, passage of discharging pipe and operation of overboard discharging valve. 5. Disassembling pressure vacuum breaker and inspecting internal corrosion
14.7.1.4	SE-701-142-000	Cooling pump	H 1. Disassembling and inspecting the cooling pump of scrubber, measuring and recording clearance, and test conversion with stand-by pump. 2. Disassembling and inspecting deck water seal, measuring and recording clearance, and test conversion with stand-by pump
15	ES-000-000-000	Electrical	

PMS No.	CWBT code	Item	Details
		installations	
15.1	SE-000-000-000	Emergency equipment	
15.1.1	SE-305-305-000 SE-304-000-000	General alarm system Alarm system for releasing fire-extinguishing agent	F 1. Effectiveness test for inspecting the operation of each switch, button, alarm bell. H 1. Effectiveness test for inspecting the operation of each switch, button, alarm bell. Recording details of test, repair, renewal, etc.
15.1.2	SE-301-000-000	Fire detection & alarm system	F 1. Effectiveness test of fire detection & alarm system in accommodation space & engine room, and of smoke detection system & combustible gas monitoring system (if any) in cargo hold. H 1. Simulation test of fire detection & alarm system; the number of sampled fire detectors to be not less than 5% of the total, including those in boiler space, oil separator space and centralized control room. Recording the test of each space and details of repair, component renewal, etc.
15.1.3	SE-101-166-000	Automatic fire-extinguishing sprinkler system (if fitted)	F 1. Effectiveness test of control system. H 1. Effectiveness test of the system and recording details of repair, component renewal, etc.
15.1.4	SE-507-000-000	Emergency cut-off device for fan and oil pump	F 1. Effectiveness test as practicable as possible. H 1. Effectiveness test of each emergency cut-off device and recording details of test, repair, etc.
15.2	SE-502-000-000	Emergency electric network	
15.2.1	SE-502-000-000	Emergency generating set, emergency storage batteries	F 1. Emergency generating set: Power supply test by manual & automatic (if any) starting and automatic switching on, and recording time of automatic starting & automatic switching on for power supply. Manual starting to be tested three times if a secondary starting source is provided. 2. Emergency storage batteries: discharge test for automatic operation after simulated cutoff of main power source. H 1. Operation test of overhauled or repaired generating set under working load, recording details of overhaul and test. 2. Charging and discharging test of emergency storage batteries in rated condition and recording
15.2.2	SE-504-000-000	Emergency switchboard & emergency battery charging and discharging panel	F 1. Inspecting the working condition under operation. H 1. Measuring the insulance of each branch. 2. Effectiveness test of power distribution and supply, and recording indicated values of each instrument and working conditions. 3. Testing the interlock of main switchboard and shore power switch (if any)
15.2.3	SE-502-325-000	Emergency lighting, temporary emergency lighting, additional emergency lighting (if any)	F 1. Measuring the insulance of each branch. 2. Effectiveness test: Each light is in order with a distinct mark of emergency light
15.3	ES-300-000-000	Main electric network	
15.3.1	ES-101-000-000	Main generator (main engine – driven generating set)	H 1. Operation test of generator under working load and inspection of working condition. 2. Measuring and recording the clearance of rotor and stator of each generator or dismantling, inspecting the bearing and measuring the wear-down. 3. Single and parallel operation test of overhauled or repaired generators under working load, inspecting speed governing of prime motors and load distribution function of generators, and recording the details
15.3.2	ES-300-000-000	Main switchboard and accessories	H 1. Measuring the insulance of each branch. 2. Inspecting the working condition under operation and recording the indicated values of each instrument and working conditions. 3. Testing the interlock of shore power switch and main switch of each generator. 4. Primary instruments to be sent for calibration in accordance

PMS No.	CWBT code	Item	Details
			with the metering requirements
15.3.3	ES-303-000-000 SE-503-000-000	Protective systems of main and emergency power stations	H 1. Checking the overload and delay protection, under-voltage protection, reverse power protection (or reverse current protection), automatic unloading protection, etc. of each motor, recording protective setting and delay time in detail
15.3.4	GD-109-073-000	Safety and protective devices of auxiliary diesel engines	H 1. To test the protective functions such as inlet pressure of lub. oil for diesel engine is overdue low, outlet temperature of cooling fresh water is overdue high, etc. and to record each protective action value in detail
15.4	SE-500-000-000	Distributors, cables & others	
15.4.1	ES-508-000-000	Insulance of power system on board	F 1. Testing and recording the insulance of installations, such as generators, motors. H Measuring and recording the insulance of the following equipment under hot condition: 1. Each generator, motor, main lighting transformer and emergency lighting transformer (if any). 2. Main switchboard, emergency switchboard, emergency battery charging and discharging panel, power distributor. 3. Each power supply branch switch and cable for the items in subparagraph 2 above. 4. Various electrical heaters
15.4.2	ES-504-000-000 to ES-507-000-000	Insulance of lighting system on board	F 1. Testing and recording insulance of each lighting system. H Measuring and recording insulance of the following equipment in hot condition: 1. Each lighting distributor, power supply branch switch and cable. 2. Each navigation light, signal light and explosion-proof light
15.4.3	ES-50X-335-000	Cables	F 1. Inspecting cables for damage. H 1. Renewed and added cables to be in compliance with existing rules and detailed data of cable specifications, current-carrying capacity, etc. to be provided
15.4.4	ES-50X-302-000	Distributor & accessories	F 1. Inspecting whether each distributor is in order. H 1. Inspecting each branch switch, internal wiring, safety earthing, etc. and recording damage and repair
15.4.5	NC-802-374-200 NC-801-374-100	Navigation light, signal light	F 1. Effectiveness test of alarming for navigation light and duplicate supply failures and recording
15.4.6		Motors of essential equipment (see pump units for machinery installations)	F 1. Inspecting each motor in normal working condition. 2. Operational test of steering gear. H 1. Operational test of overhauled or repaired motors in working condition and recording details
15.4.7	NC-300-000-000	Internal communications (telegraph, sound-powered telephone)	F 1. Testing all communications between bridge and engine or centralized control room (including telegraph and sound-powered telephone). 2. Testing communications between bridge and steering gear room
15.4.8	PM-402-301-000 PM-403-301-000 PM-402-302-000 PM-403-302-000 PM-402-304-000 PM-403-304-000 PM-405-000-000 PM-406-331-000	Steering gear (electric) Main & auxiliary motors Main & auxiliary motor controllers Main & auxiliary motor automatic controlling devices Maneuvering part Rudder indicator	F 1. Steering test of main & auxiliary steering gears and recording each parameter (steering time, maximum rudder angle, etc.). 2. Checking rudder indicator by actual rudder angle. 3. Effectiveness test of emergency steering. 4. Effectiveness test of power supply from duplicate sources
15.4.9	RA-502-000-000 RA-404-000-400 TS-104-314-200 TS-204-314-200 TS-304-314-200 RA-406-000-600 RA-405-000-500	Ventilator set Ventilator in cargo hold Ventilator in engine room (including ventilators for auxiliary engine room and oil separator room) Forced ventilation for	F 1. Effectiveness test of each ventilator set. 2. Effectiveness test of emergency shutdown of ventilator sets. H 1. For ventilators having operated for a long time, operational test to be made after dismantling, replacing or repairing the bearing of motor, and maintenance and operational parameters to be recorded

PMS No.	CWBT code	Item	Details
		boiler Ventilator in pump room Ventilator in CO_2 room	
15.5	UA-000-000-000	Survey items to be added for ships having the class notation AUTO-0, MCC or BRC	
15.5.1	UA-100-000-000	Remote control system for main engine	F 1. Control position conversion test for remote control system of main engine. H 1. Testing the functions of emergency stopping button and override button (if any) for main engine on the control console of bridge, such buttons being independent from automatic system. 2. Testing the functions of emergency stopping button and override button (if any) for main engine on the centralized control console of engine room. 3. Testing conversion of control position for main engine between bridge, centralized control room in engine room and control console at engine, and inspecting visual and audible alarm and telegraph function. 4. Testing whether the revolution speed and direction of main engine are kept at the original condition when the power source of remote control system for main engine is interrupted
15.5.2	UA-200-000-000	Automatic control system of power plant	F 1. Effectiveness test of automatic control system of power plant. H 1. Inspecting the standby generating set for starting and being switched on automatically to supply power within the required time in a simulated condition of failure and stopping of the generating set in operation. 2. Inspecting primary pumps serving main and auxiliary engines for starting automatically in sequence after restoring power supply. 3. For two or more generators operating parallel, simulating failure and stopping of one generator, inspecting the actions of automatic unloading device and the standby generator for starting, being switched on and distributing load automatically within the required time, and recording details of such tests
15.5.3	UA-300-000-000	Automatic control system of boiler	F 1. Effectiveness test of automatic control system of boiler. H 1. Testing protective function for automatically stopping the operation of boiler in case of limited low water level, flame failure, excessive steam pressure, etc., inspecting visual and audible alarm and recording test process and data. 2. Testing automatic control procedure of boiler, especially conditions prior to scavenging. 3. Testing function of emergency stopping buttons for boilers in centralized control room
15.5.4	UA-501-000-000	Safety and protective devices of main engine	F 1. Simulating automatic stopping and reduction conditions of main engine and inspecting protective functions of safety system. H 1. Cutting off main power source of safety system, inspecting the system for being capable of automatically converting power source to independent standby storage batteries and giving visual and audible alarm. 2. Simulation test of automatic reduction and stopping functions of main engine in case of excessively low lub. oil inlet pressure, excessively high temperature of cooling water, excessive concentration of oil fog in crankcase, etc., checking the setting of each sensor and recording the details
15.5.5	UA-500-000-000	Alarm system of engine room	F 1. Effectiveness test of alarm system for normal operation of each visual and audible alarm unit. When main alarms are given, e.g. alarms for main engine, generating set, boiler, primary auxiliary machinery, high level of bilge well in engine room and fire in engine room, the failure logging device (if any) is to be capable of printing and recording correctly. H 1. Cutting off main power source of alarm system, inspecting

PMS No.	CWBT code	Item	Details
			the system for being capable of automatically converting power source to independent standby storage batteries and giving visual and audible alarm. 2. Testing at least the following alarm items (simulation test may be made): a. excessively low starting air pressure and failure of third automatic starting of main engine; b. low lub. oil inlet pressure of both main engine and auxiliary engine; c. low water level of boiler; d. power failure, loss of A.C. phase, etc of steering gear; e. high level of bilge well and long operation (or excessively frequent starting) of bilge pump in engine room. 3. Inspecting alarm system for extended alarming function (if any) and automatically starting engineers' alarm in case of no response within the set time, and inspecting engineers' alarm signal for being clearly audible in engineers' accommodation
15.5.6	UA-703-000-000	Condition monitoring system (if any)	F 1. Effectiveness test of condition monitoring equipment. H 1. Baseline data and measurement data of condition monitoring equipment kept on board. 2. Checking measured data of condition monitoring equipment with baseline data to ensure reliability of equipment when overhauling the equipment. 3. Overhaul and maintenance of monitored machinery and electrical installations may be carried out in accordance with the specifications of condition monitoring equipment provided that the condition monitoring techniques are proper and reliable
15.5.7	LO-302-304-000 OS-302-304-000 OS-303-304-000 FW-202-304-100 FW-203-304-000 BW-102-304-000 FW-204-304-000 LO-303-304-000 FW-205-304-000 TS-605-304-000 LO-502-304-000	Automatic switching of main pump sets Lub.oil pump of main engine Fuel pump of main engine Fresh water cooling pump Seawater cooling pump Cooling pump of piston (if provided independently) Cooling pump of fuel injector (if provided independently) Feedwater pump of boiler Fuel pump of boiler, etc.	F 1. Effectiveness test of automatic switching of main pump sets, recording automatic switch setting, adjustment and maintenance of each pump

Appendix 17 S19 EVALUATION OF SCANTLINGS OF THE TRANSVERSE WATERTIGHT CORRUGATED BULKHEAD BETWEEN CARGO HOLDS NOS. 1 AND 2, WITH CARGO HOLD NO. 1 FLOODED, FOR EXISTING BULK CARRIERS

S19.1 Application and definitions

These requirements apply to all bulk carriers of 150 m in length and above, in the foremost hold, intending to carry solid bulk cargoes having a density of 1.78 t/m^3, or above, with single deck, topside tanks and hopper tanks, fitted with vertically corrugated transverse watertight bulkheads between cargo holds Nos.1 and 2 where:

(i) the foremost hold is bounded by the side shell only for ships which were contracted for construction prior to 1 July 1998, and have not been constructed in compliance with IACS Unified Requirement S18;

(ii) the foremost hold is double side skin construction of less than 760 mm breadth measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999 and have not been constructed in compliance with IACS Unified Requirement S18 (Rev.2, Sept. 2000).

The net scantlings of the transverse bulkhead between cargo holds Nos.1 and 2 are to be calculated using the loads given in S19.2, the bending moment and shear force given in S19.3 and the strength criteria given in S19.4.

Where necessary, steel renewal and/or reinforcements are required as per S19.6.

In these requirements, homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for the two foremost cargo holds, does not exceed 1:20, to be corrected for different cargo densities.

S19.2 Load model

S19.2.1 General

The loads to be considered as acting on the bulkhead are those given by the combination of the cargo loads with those induced by the flooding of cargo hold No.1.

The most severe combinations of cargo induced loads and flooding loads are to be used for the check of the scantlings of the bulkhead, depending on the loading conditions included in the loading manual:

– homogeneous loading conditions;

– non-homogeneous loading conditions.

Non-homogeneous part loading conditions associated with multiport loading and unloading operations for homogeneous loading conditions need not be considered according to these requirements.

S19.2.2 Bulkhead corrugation flooding head

The flooding head h_f (see Figure 1) is the distance, in m, measured vertically with the ship in the upright position, from the calculation point to a level located at a distance d_f, in m, from the baseline equal to:

a) in general: D;

b) for ships less than 50,000 tonnes deadweight with Type B freeboard: 0.95 D. D being the distance, in m, from the baseline to the freeboard deck at side amidship (see Figure 1);

c) for ships to be operated at an assigned load line draught T_r less than the permissible load line draught T, the flooding head defined in a) and b) above may be reduced by $T - T_r$.

S19.2.3 Pressure in the flooded hold

S19.2.3.1 Bulk cargo loaded hold

Two cases are to be considered, depending on the values of d_1 and d_f, d_1 (see Figure 1) being a distance from the baseline given, in m, by:

$$d_1 = \frac{M_c}{\rho_c \cdot l_c \cdot B} + \frac{V_{LS}}{l_c \cdot B} + \left(h_{HT} - h_{DB}\right) \cdot \frac{b_{HT}}{B} + h_{DB}$$

Notes:

1 Changes introduced in Revision 2 to UR S19, i.e. the introduction of the first sentence of S19.6 as well as the Annex are to be applied not later than 1 July 1998.

2 Annex 2 contains, for guidance only, a flow chart entitled “Guidance to Assess Capability of Carriage of High Density Cargoes on Existing Bulk Carriers according to the Strength of Transverse Bulkhead between Cargo Holds Nos.1 and 2”.

3 Changes introduced in Rev.4 are to be uniformly implemented from 1 July 2001.

where: M_c – mass of cargo, in tonnes, in hold No.1;
ρ_c – bulk cargo density, in t/m^3;
l_c – length of hold No.1, in m;
B – ship's breadth amidship, in m;
V_{LS} – volume, in m^3, of the bottom stool above the inner bottom;
h_{HT} – height of the hopper tanks amidship, in m, from the baseline;
h_{DB} – height of the double bottom, in m;
b_{HT} – breadth of the hopper tanks amidship, in m.

a) $d_f \geq d_1$

At each point of the bulkhead located at a distance between d_1 and d_f from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by:

$$P_{c,f} = \rho \cdot g \cdot h_f$$

where: ρ – seawater density, in t/m^3;
g – 9.81 m/s^2, gravity acceleration;
h_f – flooding head as defined in S19.2.2.

At each point of the bulkhead located at a distance lower than d_1 from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by:

$$P_{c,f} = \rho \cdot g \cdot h_f + [\rho_c - \rho \cdot (1 - perm)] \cdot g \cdot h_1 \cdot \tan^2\gamma$$

where: ρ, g, h_f – as given above;
ρ_c – bulk cargo density, in t/m^3;
$perm$ – permeability of cargo, to be taken as 0.3 for ore (corresponding bulk cargo density for iron ore may generally be taken as 3.0 t/m^3);
h_1 – vertical distance, in m, from the calculation point to a level located at a distance d1, as defined above, from the base line (see Figure 1);
γ – 45° – (φ/2)
φ – angle of repose of the cargo, in degrees, and may generally be taken as 35° for iron ore.

The force $F_{c,f}$, in kN, acting on a corrugation is given by:

$$F_{c,f} = s_1 \cdot \left[\rho \cdot g \cdot \frac{(d_f - d_1)^2}{2} + \frac{\rho \cdot g \cdot (d_f - d_1) + (p_{c,f})_{le}}{2} \cdot (d_1 - h_{DB} - h_{LS}) \right]$$

where: s_1 – spacing of corrugations, in m (see Figure 2a);
ρ, g, d_1, h_{DB} – as given above;
d_f – as given in S19.2.2;
$(p_{c,f})_{le}$ – pressure, in kN/m^2, at the lower end of the corrugation;
h_{LS} – height of the lower stool, in m, from the inner bottom.

b) $d_f < d_1$

At each point of the bulkhead located at a distance between d_f and d_1 from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by:

$$p_{c,f} = \rho_c \cdot g \cdot h_1 \cdot \tan^2\gamma$$

where: ρ_c, g, h_1, γ – as given in a) above.

At each point of the bulkhead located at a distance lower than d_f from the baseline, the pressure $P_{c,f}$, in kN/m^2, is given by:

$$P_{c,f} = \rho \cdot g \cdot h_f + [\rho_c \cdot h_1 - \rho \cdot (1 - perm) \cdot h_f] \cdot g \cdot \tan^2\gamma$$

where: ρ, g, h_f, ρ_c, h_1, $perm$, γ = as given in a) above.

The force $F_{c,f}$, in kN, acting on a corrugation is given by:

$$F_{c,f} = s_1 \cdot \left[\rho_c \cdot g \cdot \frac{(d_1 - d_f)^2}{2} \cdot \tan^2\gamma + \frac{\rho_c \cdot g \cdot (d_1 - d_f) \cdot \tan^2\gamma + (p_{c,f})_{le}}{2} \cdot (d_f - h_{DB} - h_{LS}) \right]$$

where: s_1, ρ_c, g, γ, $(p_{c,f})_{le}$, h_{LS} – as given in a) above;
d_1, h_{DB} – as given in S19.2.3.1;
d_f – as given in S19.2.2.

S19.2.3.2 Empty hold

At each point of the bulkhead, the hydrostatic pressure p_f induced by the flooding head h_f is to be considered.

The force F_f, in kN, acting on a corrugation is given by:

$$F_f = s_1 \cdot \rho \cdot g \cdot \frac{(d_f - h_{DB} - h_{LS})^2}{2}$$

where: s_1, ρ, g, h_{LS} – as given in S19.2.3.1 a);
h_{DB} – as given in S19.2.3.1;
d_f – as given in S19.2.2.

S19.2.4 Pressure in the non-flooded bulk cargo loaded hold

At each point of the bulkhead, the pressure P_c, in kN/m^2, is given by:

$$p_c = \rho_c \cdot g \cdot h_1 \cdot \tan^2 \gamma$$

where: ρ_c, g, h_1, γ – as given in S19.2.3.1 a).

The force F_c, in kN, acting on a corrugation is given by:

$$F_c = \rho_c \cdot g \cdot s_1 \cdot \frac{(d_1 - h_{DB} - h_{LS})^2}{2} \cdot \tan^2 \gamma$$

where: ρ_c, g, s_1, h_{LS}, γ – as given in S19.2.3.1 a);
d_1, h_{DB} – as given in S19.2.3.1.

S19.2.5 Resultant pressure

S19.2.5.1 Homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p, in kN/m^2, to be considered for the scantlings of the bulkhead is given by:

$$p = p_{c,f} - 0.8 \cdot p_c$$

The resultant force F, in kN, acting on a corrugation is given by:

$$F = F_{c,f} - 0.8 \cdot F_c$$

S19.2.5.2 Non homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p, in kN/m^2, to be considered for the scantlings of the bulkhead is given by:

$$p = p_{c,f}$$

The resultant force F, in kN, acting on a corrugation is given by:

$$F = F_{c,f}$$

In case hold No.1, in non homogeneous loading conditions, is not allowed to be loaded, the resultant pressure p, in kN/m^2, to be considered for the scantlings of the bulkhead is given by:

$$p = p_f$$

and the resultant force F, in kN, acting on a corrugation is given by:

$$F = F_f$$

S19.3 Bending moment and shear force in the bulkhead corrugations

The bending moment M and the shear force Q in the bulkhead corrugations are obtained using the formulae given in S19.3.1 and S19.3.2. The M and Q values are to be used for the checks in S19.4.

S19.3.1 Bending moment

The design bending moment M, in kN·m, for the bulkhead corrugations is given by:

$$M = \frac{F \cdot l}{8}$$

where: F – resultant force, in kN, as given in S19.2.5;
l – span of the corrugation, in m, to be taken according to Figures 2a and 2b.

S19.3.2 Shear force

The shear force Q, in kN, at the lower end of the bulkhead corrugations is given by:

$$Q = 0.8F$$

where: F – as given in S19.2.5.

S19.4 Strength criteria

S19.4.1 General

The following criteria are applicable to transverse bulkheads with vertical corrugations (see Figure 2a).

Requirements for local net plate thickness are given in S19.4.7.

In addition, criteria given in S19.4.2 and S19.4.5 are to be complied with.

Where the corrugation angle φ shown in Figure 2a is less than 50°, an horizontal row of staggered shedder plates is to be fitted at approximately mid depth of the corrugations (see Figure 2a) to help preserve dimensional stability of the bulkhead under flooding loads. The shedder plates are to be welded to the corrugations by double continuous welding, but they are not to be welded to the side shell.

The thicknesses of the lower part of corrugations considered in the application of S19.4.2 and S19.4.3 are to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than 0.15 l.

The thicknesses of the middle part of corrugations considered in the application of S19.4.2 and S19.4.4 are to be maintained to a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than 0.3 l.

S19.4.2 Bending capacity and shear stress τ

The bending capacity is to comply with the following relationship:

$$10^3 \cdot \frac{M}{0.5 \cdot Z_{le} \cdot \sigma_{a,le} + Z_m \cdot \sigma_{a,m}} \leq 1.0$$

where: M – bending moment, in kN·m, as given in S19.3.1;

Z_{le} – section modulus of one half pitch corrugation, in cm^3, at the lower end of corrugations, to be calculated according to S19.4.3;

Z_m – section modulus of one half pitch corrugation, in cm^3, at the mid-span of corrugations, to be calculated according to S19.4.4;

$\sigma_{a,\,le}$ – allowable stress, in N/mm^2, as given in S19.4.5, for the lower end of corrugations;

$\sigma_{a,\,m}$ – allowable stress, in N/mm^2, as given in S19.4.5, for the mid-span of corrugations.

In no case Z_m is to be taken greater than the lesser of 1.15 Z_{le} and 1.15 Z'_{le} for calculation of the bending capacity, Z'_{le} being defined below.

In case effective shedder plates are fitted which:

– are not knuckled;

– are welded to the corrugations and the top of the lower stool by one side penetration welds or equivalent;

– are fitted with a minimum slope of 45° and their lower edge is in line with the stool side plating;

or effective gusset plates are fitted which:

– are fitted in line with the stool side plating;

– have material properties at least equal to those provided for the flanges.

The section modulus Z_{le}, in cm^3, is to be taken not larger than the value Z'_{le}, in cm^3, given by:

$$Z'_{le} = Z_g + 10^3 \cdot \frac{Q - h_g - 0.5 h_g^2 \cdot s_1 \cdot p_g}{\sigma_a}$$

where: Z_g – section modulus of one half pitch corrugation, in cm^3, according to S19.4.4, in way of the upper end of shedder or gusset plates, as applicable;

Q – shear force, in kN, as given in S19.3.2;

h_g – height, in m, of shedder or gusset plates, as applicable (see Figures 3a, 3b, 4a and 4b);

s_1 – as given in S19.2.3.1 a);

P_g – resultant pressure, in kN/m^2, as defined in S19.2.5, calculated in way of the middle of the shedder or gusset plates, as applicable;

σ_a – allowable stress, in N/mm^2, as given in S19.4.5.

Stresses τ are obtained by dividing the shear force Q by the shear area. The shear area is to be reduced in order to account for possible non-perpendicularity between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by sin φ, φ being the angle between the web and the flange.

When calculating the section moduli and the shear area, the net plate thicknesses are to be used.

The section moduli of corrugations are to be calculated on the basis of the requirements given in S19.4.3 and S19.4.4.

S19.4.3 Section modulus at the lower end of corrugations

The section modulus is to be calculated with the compression flange having an effective flange width, b_{ef}, not larger than as given in S19.4.6.1.

If the corrugation webs are not supported by local brackets below the stool top (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

a) Provided that effective shedder plates, as defined in S19.4.2, are fitted (see Figures 3a and 3b), when calculating the section modulus of corrugations at the lower end (cross-section ① in Figures 3a and 3b), the

area of flange plates, in cm^2, may be increased by:

$$2.5 \cdot a \cdot \sqrt{t_f \cdot t_{sh}} \cdot \sqrt{\frac{\sigma_{Fsh}}{\sigma_{Ffl}}}$$

(not to be taken greater than 2.5 $a \cdot t_f$)

where: a – width, in m, of the corrugation flange (see Figure 2a);
t_{sh} – net shedder plate thickness, in mm;
t_f – net flange thickness, in mm;
σ_{Fsh} – minimum upper yield stress, in N/mm^2, of the material used for the shedder plates;
σ_{Ffl} – minimum upper yield stress, in N/mm^2, of the material used for the corrugation flanges.

b) Provided that effective gusset plates, as defined in S19.4.2, are fitted (see Figures 4a and 4b), when calculating the section modulus of corrugations at the lower end (cross-section ① in Figures 4a and 4b), the area of flange plates, in cm^2, may be increased by $7h_g t_{gu}$) where: h_g = height of gusset plate in m, see Figures 4a and 4b, not to be taken greater than:

$$\frac{10}{7} \cdot s_{gu}$$

where: s_{gu} – width of the gusset plates, in m;
t_{gu} – net gusset plate thickness, in mm, not to be taken greater than t_f;
t_f – net flange thickness, in mm, based on the as-built condition.

c) If the corrugation webs are welded to a sloping stool top plate, which is at an angle not less than 45º with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. In case effective gusset plates are fitted, when calculating the section modulus of corrugations the area of flange plates may be increased as specified in b) above. No credit can be given to shedder plates only.

For angles less than 45º, the effectiveness of the web may be obtained by linear interpolation between 30% for 0º and 100% for 45º.

S19.4.4 Section modulus of corrugations at cross sections other than the lower end

The section modulus is to be calculated with the corrugation webs considered effective and the compression flange having an effective flange width, b_{ef}, not larger than as given in S19.4.6.1.

S19.4.5 Allowable stress check

The normal and shear stresses σ and τ are not to exceed the allowable values σ_a and τ_a, in N/mm^2, given by:

$$\sigma_a = \sigma_F$$
$$\tau_a = 0.5\,\sigma_F$$

where: b_F – minimum upper yield stress, in N/mm^2, of the material.

S19.4.6 Effective compression flange width and shear buckling check

S19.4.6.1 Effective width of the compression flange of corrugations

The effective width b_{ef}, in m, of the corrugation flange is given by:

$$b_{ef} = C_e \cdot a$$

where:

$$C_e = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \quad \text{for} \quad \beta > 1.25;$$

$$C_e = 1.0 \quad \text{for} \quad \beta \le 1.25;$$

$$\beta = 10^3 \cdot \frac{a}{t_f} \cdot \sqrt{\frac{\sigma_F}{E}};$$

t_f – net flange thickness, in mm;
a – width, in m, of the corrugation flange (see Figure 2a);
σ_F – minimum upper yield stress, in N/mm^2, of the material;
E – modulus of elasticity, in N/mm^2, to be assumed equal to 2.06×10^5 for steel.

S19.4.6.2 Shear

The buckling check is to be performed for the web plates at the corrugation ends.

The shear stress τ is not to exceed the critical value τ_c, in N/mm^2, obtained by the following:

$$\tau_C = \tau_E \qquad \text{when} \quad \tau_E \le \frac{\tau_F}{2}$$

$$\tau_C = \tau_F\left(1-\frac{\tau_F}{4\tau_E}\right) \qquad \text{when} \quad \tau_E \rangle \frac{\tau_F}{2}$$

$$\tau_F = \frac{\sigma_F}{\sqrt{3}}$$

where: τ_F – minimum upper yield stress, in N/mm^2, of the material;

$$\tau_E = 0.9k_t E\left(\frac{t}{1000c}\right)^2 \quad \text{N/mm}^2$$

where: k_t = 6.34

E – modulus of elasticity of material as given in S19.4.6.1;

t – net thickness, in mm, of corrugation web;

c – width, in m, of corrugation web (See Figure 2a).

S19.4.7 Local net plate thickness

The bulkhead local net plate thickness t, in mm, is given by:

$$t = 14.9 \cdot s_w \cdot \sqrt{\frac{p}{\sigma_F}}$$

where: s_w – plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is the greater (see Figure 2a);

p – resultant pressure, in kN/m^2, as defined in S19.2.5, at the bottom of each strake of plating; in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, or at the inner bottom, if no lower stool is fitted or at the top of shedders, if shedder or gusset/shedder plates are fitted;

σ_F – minimum upper yield stress, in N/mm^2, of the material.

For built-up corrugation bulkheads, when the thicknesses of the flange and web are different, the net thickness of the narrower plating is to be not less than t_n, in mm, given by:

$$t_n = 14.9 \cdot s_n \cdot \sqrt{\frac{p}{\sigma_F}}$$

where: s_n – width, in m, of the narrower plating.

The net thickness of the wider plating, in mm, is not to be taken less than the maximum of the following values:

$$t_w = 14.9 \cdot s_w \cdot \sqrt{\frac{p}{\sigma_F}}$$

$$t_w = \sqrt{\frac{440 \cdot s_w^2 \cdot p}{\sigma_F} - t_{np}^2}$$

where: $t_{np} \leq$ actual net thickness of the narrower plating and not to be greater than:

$$14.9 \cdot s_w \cdot \sqrt{\frac{p}{\sigma_F}}$$

S19.5 Local details

As applicable, the design of local details is to comply with the Society's requirements for the purpose of transferring the corrugated bulkhead forces and moments to the boundary structures, in particular to the double bottom and cross-deck structures.

In particular, the thickness and stiffening of gusset and shedder plates, installed for strengthening purposes, is to comply with the Society's requirements, on the basis of the load model in S19.2.

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society's requirements.

S19.6 Corrosion addition and steel renewal

Renewal/reinforcement shall be done in accordance with the following requirements and the guidelines contained in the Annex.

a) Steel renewal is required where the gauged thickness is less than t_{net} + 0.5 mm, t_{net} being the thickness used for the calculation of bending capacity and shear stresses as given in S19.4.2. Or the local net plate

thickness as given in S19.4.7. Alternatively, reinforcing doubling strips may be used providing the net thickness is not dictated by shear strength requirements for web plates (see S19.4.5 and S19.4.6.2) or by local pressure requirements for web and flange plates (see S19.4.7).

Where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.

b) Where steel renewal or reinforcement is required, a minimum thickness of t_{net} + 2.5 mm is to be replenished for the renewed or reinforced parts.

c) When:

$$0.8 \cdot (\sigma_{Ffl} \cdot t_{fl}) \geq \sigma_{Fs} \cdot t_{st}$$

where:

σ_{Ffl} – minimum upper yield stress, in N/mm^2, of the material used for the corrugation flanges;

σ_{Fs} – minimum upper yield stress, in N/mm^2, of the material used for the lower stool side plating or floors (if no stool is fitted);

t_{fl} – flange thickness, in mm, which is found to be acceptable on the basis of the criteria specified in a) above or, when steel renewal is required, the replenished thickness according to the criteria specified in b) above. The above flange thickness dictated by local pressure requirements (see S19.4.7) need not be considered for this purpose;

t_{st} – as-built thickness, in mm, of the lower stool side plating or floors (if no stool is fitted),

gussets with shedder plates, extending from the lower end of corrugations up to 0.1l, or reinforcing doubling strips (on bulkhead corrugations and stool side plating) are to be fitted.

If gusset plates are fitted, the material of such gusset plates is to be the same as that of the corrugation flanges. The gusset plates are to be connected to the lower stool shelf plate or inner bottom (if no lower stool is fitted) by deep penetration welds (see Figure 5).

d) Where steel renewal is required, the bulkhead connections to the lower stool shelf plate or inner bottom (if no stool is fitted) are to be at least made by deep penetration welds (see Figure 5).

e) Where gusset plates are to be fitted or renewed, their connections with the corrugations and the lower stool shelf plate or inner bottom (if no stool is fitted) are to be at least made by deep penetration welds (see Figure 5).

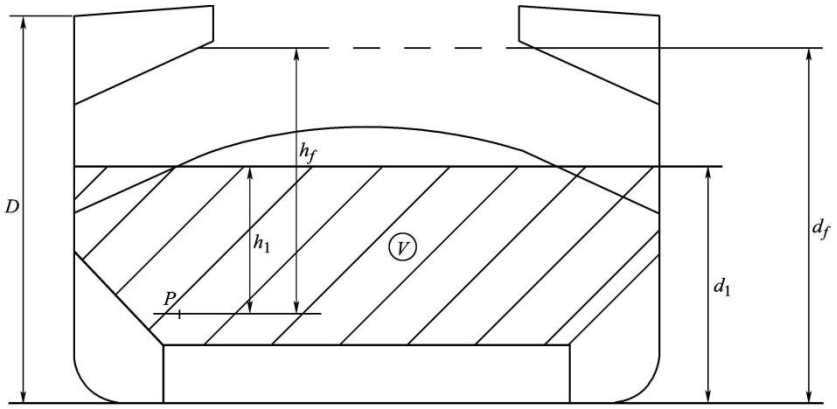


Figure 1

V – Volume of cargo; *P* – Calculation point

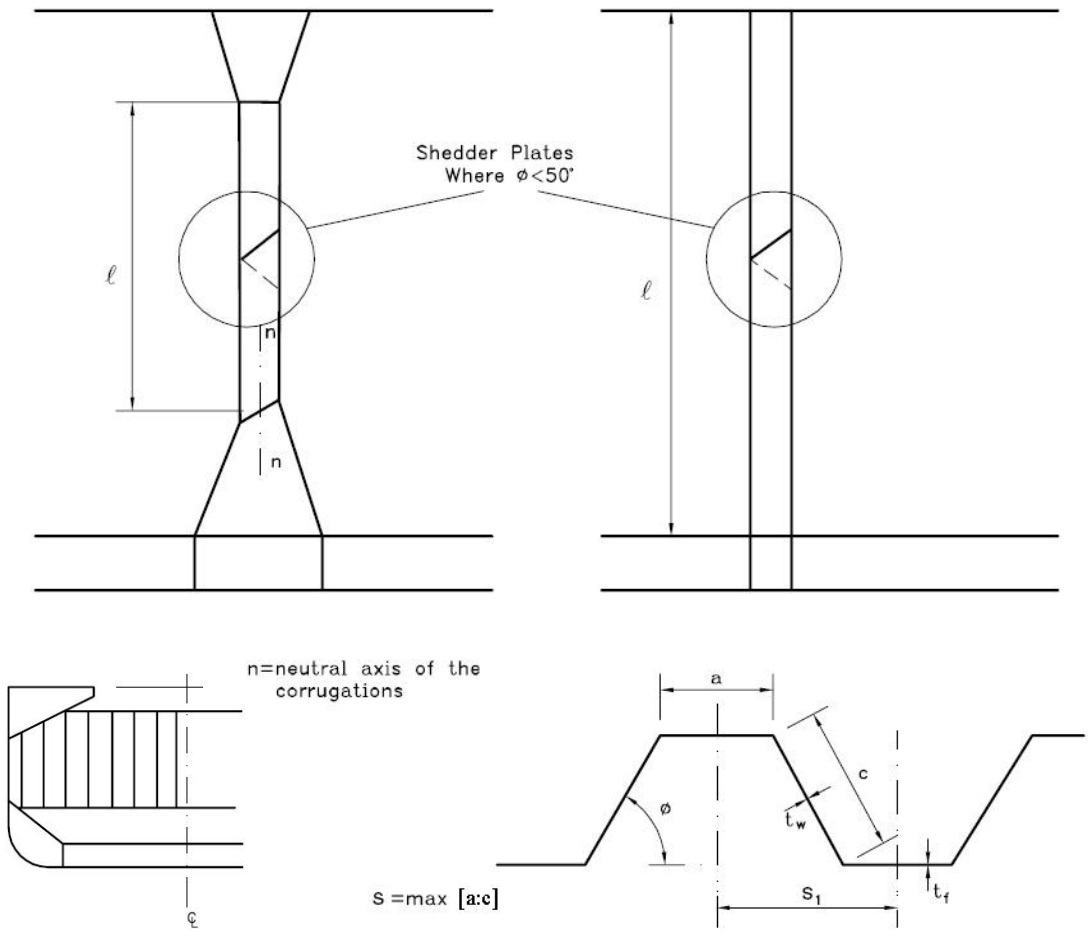
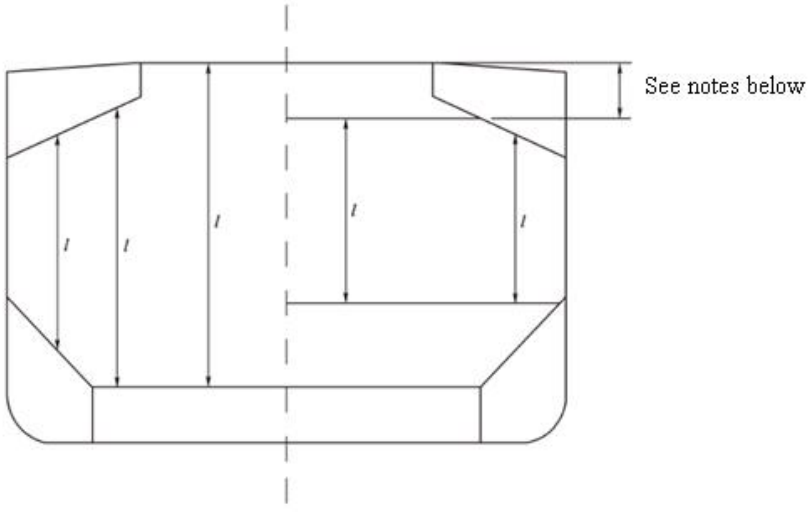


Figure 2a



Notes: For the definition of *l*, the internal end of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:

– 3 times the depth of corrugations, in general;

– 2 times the depth of corrugations, for rectangular stool.

Figure 2b

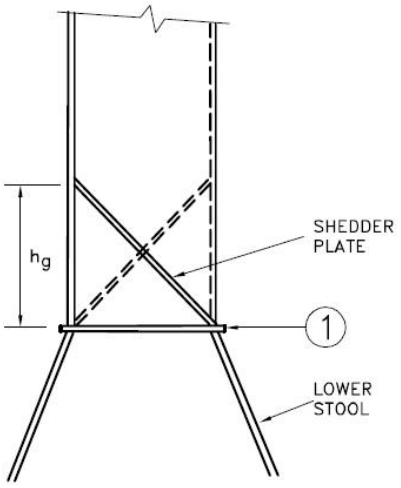


Figure 3a Symmetric shedder plates

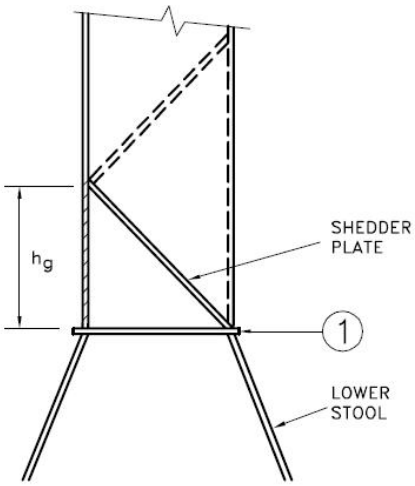


Figure 3b Asymmetric shedder plates

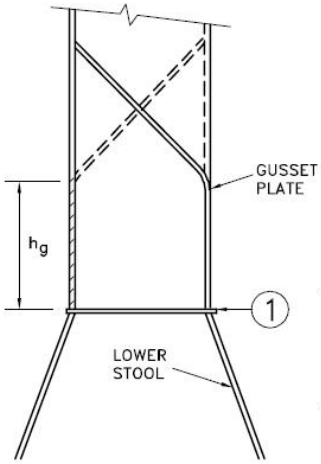


Figure 4a Symmetric gusset/shedder plates

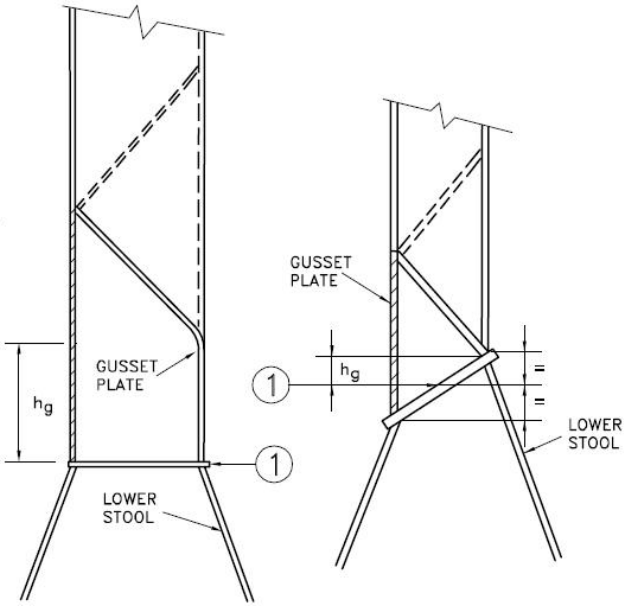
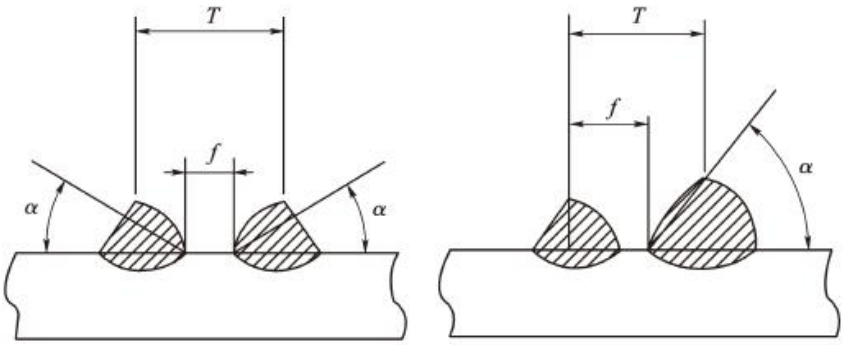


Figure 4b Asymmetric gusset/shedder plates



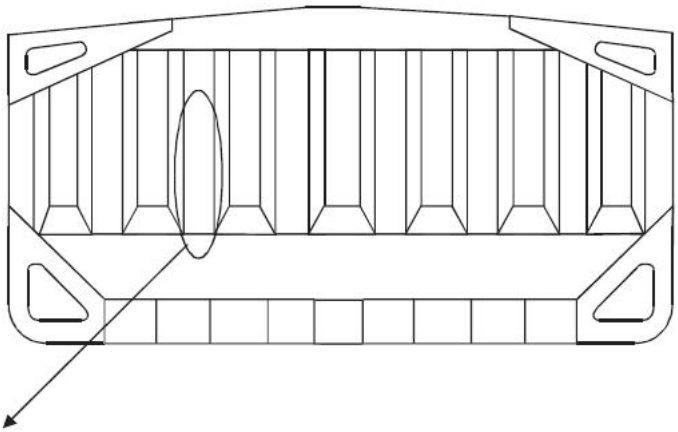
Root face (f): 3 mm to T/3 mm
Groove angle (α): 40° to 60°

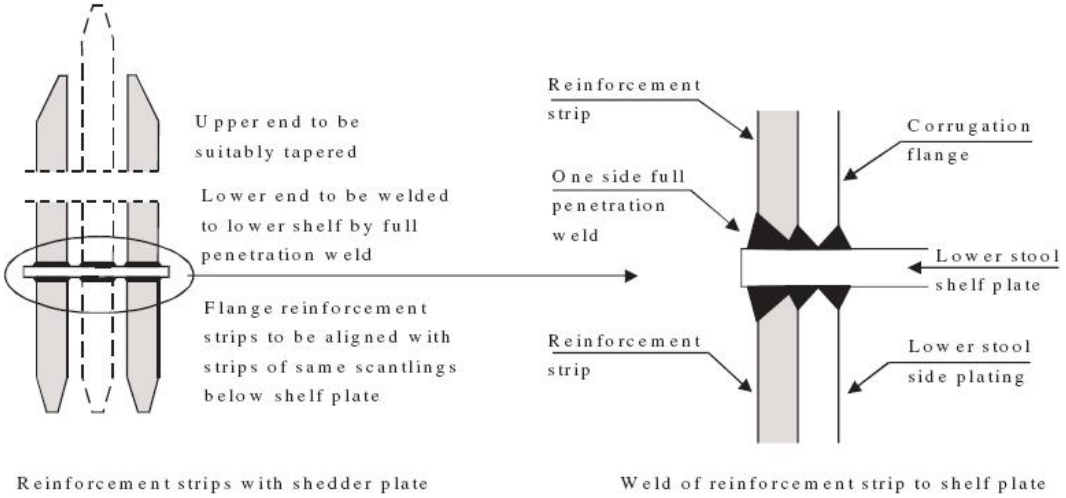
Figure 5

Annex 1
Guidance on Renewal/Reinforcement of Vertically Corrugated Transverse Watertight Bulkhead between Cargo Holds Nos.1 and 2

1. The need for renewal or reinforcement of the vertically corrugated transverse watertight bulkhead between cargo holds Nos.1 and 2 will be determined by the classification society on a case by case basis using the criteria given in S19 in association with the most recent gaugings and findings from survey.
2. In addition to class requirements, the S19 assessment of the transverse corrugated bulkhead will take into account the following:
   a. Scantlings of individual vertical corrugations will be assessed for reinforcement/renewal based on thickness measurements obtained in accordance with Annex III to UR Z10.2 at their lower end, at mid-depth and in way of plate thickness changes in the lower 70%. These considerations will take into account the provision of gusset and shedder plates and the benefits they offer, provided that they comply with S19.4.2 and S19.6.
   b. Taking into account the scantlings and arrangements for each case, permissible levels of diminution will be determined and appropriate measures taken in accordance with S19.6.
3. Where renewal is required, the extent of renewal is to be shown clearly in plans. The vertical distance of each renewal zone is to be determined by considering S19 and in general is to be not less than 15% of the vertical distance between the upper and lower end of the corrugation – measured at the ship's centreline.
4. Where the reinforcement is accepted by adding strips, the length of the reinforcing strips is to be sufficient to allow it to extend over the whole depth of the diminished plating. In general, the width and thickness of strips should be sufficient to comply with the S19 requirements. The material of the strips is to be the same as that of the corrugation plating. The strips are to be attached to the existing bulkhead plating by continuous fillet welds. The strips are to be suitably tapered or connected at ends in accordance with Class Society practice.
5. Where reinforcing strips are connected to the inner bottom or lower stool shelf plates, one side full penetration welding is to be used. When reinforcing strips are fitted to the corrugation flange and are connected to the lower stool shelf plate, they are normally to be aligned with strips of the same scantlings welded to the stool side plating and having a minimum length equal to the breadth of the corrugation flange.
6. Figure 1 gives a general arrangement of structural reinforcement.

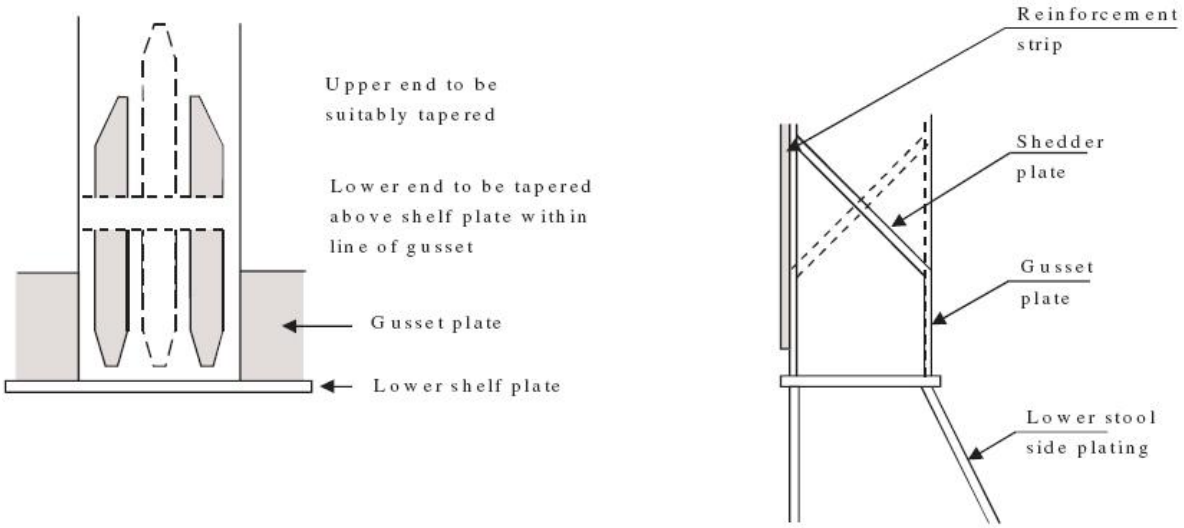
Notes to Figure 1 on reinforcement:
1. Square or trapezoidal corrugations are to be reinforced with plate strips fitted to each corrugation flange sufficient to meet the requirements of S19.
2. The number of strips fitted to each corrugation flange is to be sufficient to meet the requirements of S19.
3. The shedder plate may be fitted in one piece or prefabricated with a welded knuckle (gusset plate).
4. Gusset plates, where fitted, are to be welded to the shelf plate in line with the flange of the corrugation, to reduce the stress concentrations at the corrugation corners. Ensure good alignment between gusset plate, corrugation flange and lower stool sloping plate. Use deep penetration welding at all connections. Ensure start and stop of welding is as far away as practically possible from corners of corrugation.
5. Shedder plates are to be attached by one side full penetration welds onto backing bars.
6. Shedder and gusset plates are to have a thickness equal to or greater than the original bulkhead thickness. Gusset plate is to have a minimum height (on the vertical part) equal to half of the width of the corrugation flange. Shedders and gussets are to be same material as flange material.





Reinforcement strips with shedder plate

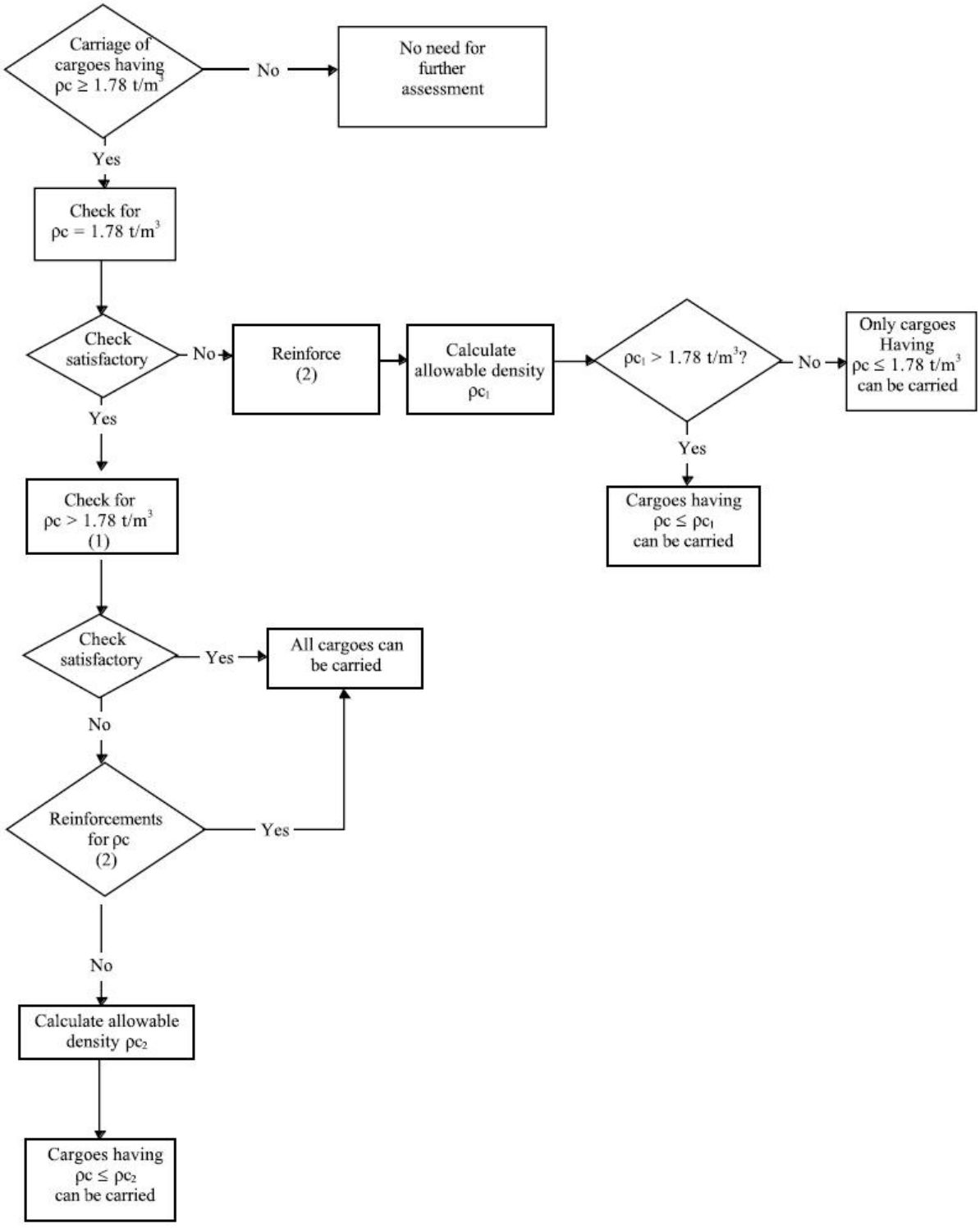
Weld of reinforcement strip to shelf plate



Reinforcement strips with shedder and gusset plates

Figure 1

Annex 2
Guidance to Assess Capability of Carriage of High Density Cargoes on Existing Bulk Carriers according to the Strength of Transverse Bulkhead between Cargo Holds Nos.1 and 2



Note:

(1) ρ_c typical of cargoes to be carried; in any case a value of 3 t/m^3, corresponding to ore cargo, is to be considered.

(2) In deciding the reinforcement needed, consideration will be given to the effects of restricting the cargo distribution (homogeneous loading condition or reduction in the ship deadweight).

Appendix 18 S22 EVALUATION OF ALLOWABLE HOLD LOADING OF CARGO HOLD NO.1 WITH CARGO HOLD NO.1 FLOODED, FOR EXISTING BULK CARRIERS

S22.1 Application and definitions

These requirements apply to all bulk carriers of 150 m in length and above, in the foremost hold, intending to carry solid bulk cargoes having a density of 1.78 t/m^3, or above, with single deck, topside tanks and hopper tanks, where:

(i) the foremost hold is bounded by the side shell only for ships which were contracted for construction prior to 1 July 1998, and have not been constructed in compliance with IACS Unified Requirement S20;

(ii) the foremost hold is double side skin construction less than 760 mm breadth measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999 and have not been constructed in compliance with IACS Unified Requirement S20 (Rev.2, Sept. 2000).

Early completion of a special survey coming due after 1 July 1998 to postpone compliance is not allowed.

The loading in cargo hold No.1 is not to exceed the allowable hold loading in the flooded condition, calculated as per S22.4, using the loads given in S22.2 and the shear capacity of the double bottom given in S22.3.

In no case, the allowable hold loading in flooding condition is to be taken greater than the design hold loading in intact condition.

S22.2 Load model

S22.2.1 General

The loads to be considered as acting on the double bottom of hold No.1 are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of hold No.1.

The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual:

– homogeneous loading conditions;

– non-homogeneous loading conditions;

– packed cargo conditions (such as steel mill products).

For each loading condition, the maximum bulk cargo density to be carried is to be considered in calculating the allowable hold limit.

S22.2.2 Inner bottom flooding head

The flooding head h_f (see Figure 1) is the distance, in m, measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance d_f, in m, from the baseline equal to:

– D in general;

– 0.95 D for ships less than 50,000 tonnes deadweight with Type B freeboard.

D being the distance, in m, from the baseline to the freeboard deck at side amidship (see Figure 1).

S22.3 Shear capacity of the double bottom of hold No.1

The shear capacity C of the double bottom of hold No.1 is defined as the sum of the shear strength at each end of:

– all floors adjacent to both hoppers, less one half of the strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted (see Figure 2);

– all double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted.

The strength of girders or floors which run out and are not directly attached to the boundary stool or hopper girder is to be evaluated for the one end only.

Note that the floors and girders to be considered are those inside the hold boundaries formed by the hoppers and stools (or transverse bulkheads if no stool is fitted). The hopper side girders and the floors directly below the connection of the bulkhead stools (or transverse bulkheads if no stool is fitted) to the inner bottom are not to be included.

When the geometry and/or the structural arrangement of the double bottom are such to make the above assumptions inadequate, to the Society's discretion, the shear capacity C of the double bottom is to be calculated according to the Society's criteria.

In calculating the shear strength, the net thicknesses of floors and girders are to be used. The net thickness t_{net}, in mm, is given by:

$$t_{net} = t - t_c$$

where: t – as-built thickness, in mm, of floors and girders;

t_c – corrosion diminution, equal to 2 mm, in general; a lower value of t_c may be adopted, provided that measures are taken, to the Society's satisfaction, to justify the assumption made.

S22.3.1 Floor shear strength

The floor shear strength in way of the floor panel adjacent to hoppers S_{f1}, in kN, and the floor shear strength in way of the openings in the "outermost" bay (i.e. that bay which is closest to hopper) S_{f2}, in kN, are given by the following expressions:

$$S_{f1} = 10^{-3} \cdot A_f \cdot \frac{\tau_a}{\eta_1}$$

$$S_{f2} = 10^{-3} \cdot A_{f,h} \cdot \frac{\tau_a}{\eta_2}$$

where: A_f – sectional area, in mm^2, of the floor panel adjacent to hoppers;

$A_{f,h}$ – net sectional area, in mm^2, of the floor panels in way of the openings in the "outermost" bay (i.e. that bay which is closest to hopper);

τ_a – allowable shear stress, in N/mm^2, to be taken equal to: $\sigma_F / \sqrt{3}$;

σ_F – minimum upper yield stress, in N/mm^2, of the material;

η_1 = 1.10;

η_2 = 1.20.

η_2 may be reduced, at the Society's discretion, down to 1.10 where appropriate reinforcements are fitted to the Society's satisfaction.

S22.3.2 Girder shear strength

The girder shear strength in way of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted) S_{g1}, in kN, and the girder shear strength in way of the largest opening in the "outermost" bay (i.e. that bay which is closest to stool, or transverse bulkhead, if no stool is fitted) S_{g2}, in kN, are given by the following expressions:

$$S_{g1} = 10^{-3} \cdot A_g \cdot \frac{\tau_a}{\eta_1}$$

$$S_{g2} = 10^{-3} \cdot A_{g,h} \cdot \frac{\tau_a}{\eta_2}$$

where: A_g – minimum sectional area, in mm^2, of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted);

$A_{g,h}$ – net sectional area, in mm^2, of the girder panel in way of the largest opening in the "outermost" bay (i.e. that bay which is closest to stool, or transverse bulkhead, if no stool is fitted);

η_1 = 1.10;

η_2 = 1.15.

η_2 may be reduced, at the Society's discretion, down to 1.10 where appropriate reinforcements are fitted to the Society's satisfaction

S22.4 Allowable hold loading

The allowable hold loading W, in t, is given by:

$$W = \rho_c \cdot V \cdot \frac{1}{F}$$

where: F = 1.05 in general

F = 1.00 for steel mill products

ρ_c – cargo density, in t/m^3; for bulk cargoes see S22.2.1; for steel products, ρ_c is to be taken as the density of steel;

V – volume, in m^3, occupied by cargo at a level h_1

$$h_1 = \frac{X}{\rho_c \cdot g}$$

X – for bulk cargoes, the lesser of X_1 and X_2 given by:

$$X = \frac{Z + \rho \cdot g \cdot \left(E \cdot - h_f\right)}{1 + \frac{\rho}{\rho_c}\left(perm - 1\right)}$$

$$X = Z + \rho \cdot g \cdot \left(E - h_f \cdot perm\right)$$

X – for steel products, X may be taken as X_1, using perm = 0;
ρ – sea water density, in t/m^3;
g – 9.81 m/s^2, gravity acceleration;
E – $d_f - 0.1 \cdot D$;
d_f, D – as given in S22.2.2;
h_f – flooding head, in m, as defined in S22.2.2;
$perm$ – permeability of cargo, to be taken as 0.3 for ore (corresponding bulk cargo density for iron ore may generally be taken as 3.0 t/m^3);
Z – the lesser of Z_1 and Z_2 given by:

$$Z_1 = \frac{C_h}{A_{DB,h}}$$

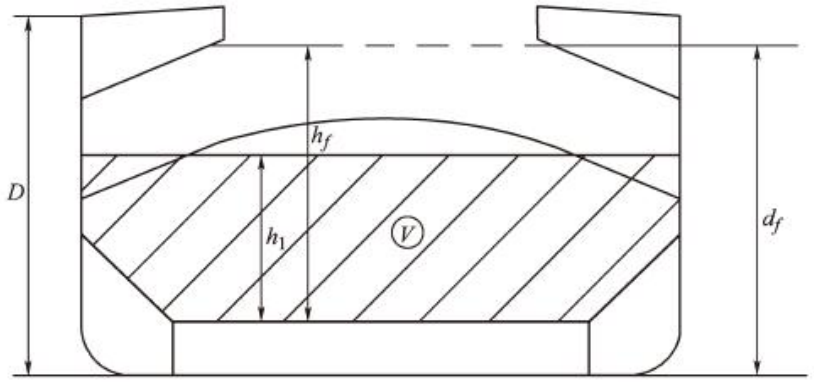
$$Z_2 = \frac{C_e}{A_{DB,e}}$$

C_h – shear capacity of the double bottom, in kN, as defined in S22.3, considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} (see S22.3.1) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see S22.3.2);
C_e – shear capacity of the double bottom, in kN, as defined in S22.3, considering, for each floor, the shear strength S_{f1} (see S22.3.1) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see S22.3.2);

$$A_{DB,h} = \sum_{i=1}^{n} S_i \cdot B_{DB,i}$$

$$A_{DB,h} = \sum_{i=1}^{n} S_i \cdot (B_{DB} - s)$$

n – number of floors between stools (or transverse bulkheads, if no stool is fitted);
S_i – space of ith-floor, in m;
$B_{DB,\,i} = B_{DB} - s$ – for floors whose shear strength is given by S_{f1} (see S22.3.1);
$B_{DB,\,i} = B_{DB,\,h}$ – for floors whose shear strength is given by S_{f2} (see S22.3.1);
B_{DB} – breadth of double bottom, in m, between hoppers (see Figure 3);
$B_{DB,\,h}$ – distance, in m, between the two considered openings (see Figure 3);
s – spacing, in m, of double bottom longitudinals adjacent to hoppers.



V = Volume of cargo

Figure 1

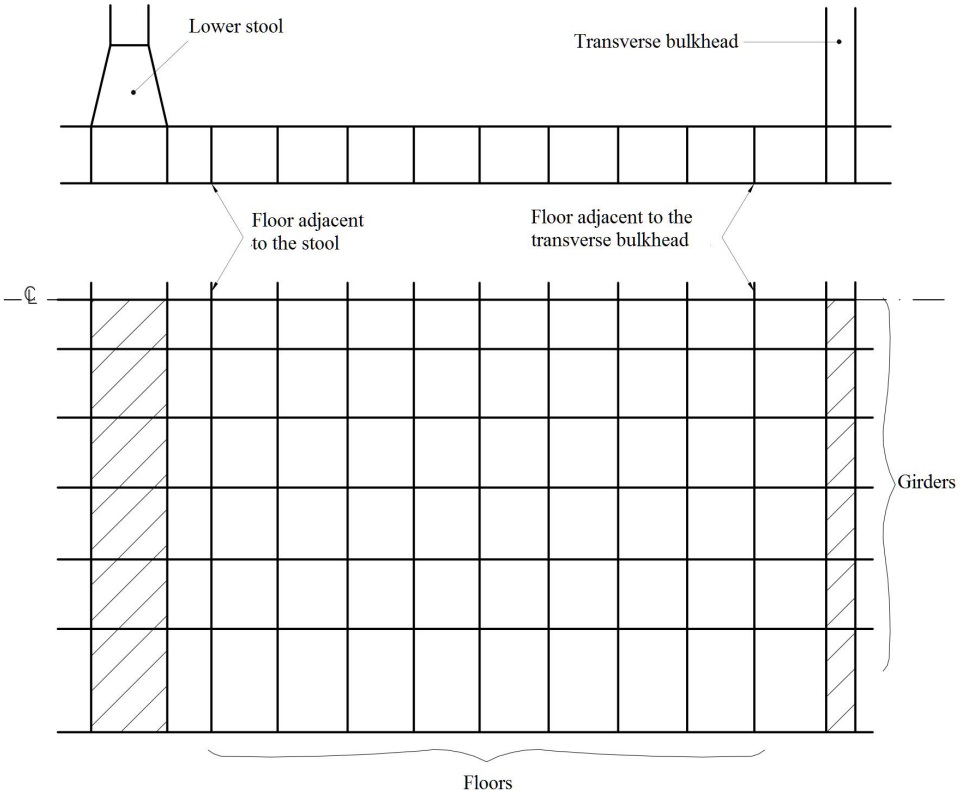


Figure 2

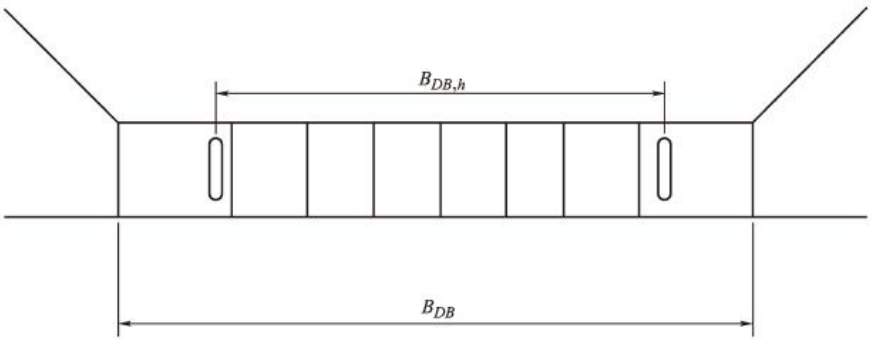


Figure 3

Appendix 19 S23 IMPLEMENTATION OF IACS UNIFIED REQUIREMENTS S19 AND S22 FOR EXISTING SINGLE SIDE SKIN BULK CARRIERS

S23.1 Application and implementation timetable①

a. Unified Requirements S19 and S22 are to be applied in conjunction with the damage stability requirements set forth in S23.2. Compliance is required:

i. for ships which were 20 years of age or more on 1 July 1998, by the due date of the first intermediate, or the due date of the first special survey to be held after 1 July 1998, whichever comes first;

ii. for ships which were 15 years of age or more but less than 20 years of age on 1 July 1998, by the due date of the first special survey to be held after 1 July 1998, but not later than 1 July 2002;

iii. for ships which were 10 years of age or more but less than 15 years of age on 1 July 1998, by the due date of the first intermediate, or the due date of the first special survey to be held after the date on which the ship reaches 15 years of age, but not later than the date on which the ship reaches 17 years of age;

iv. for ships which were 5 years of age or more but less than 10 years of age on 1 July 1998, by the due date, after 1 July 2003, of the first intermediate or the first special survey after the date on which the ship reaches 10 years of age, whichever occurs first;

v. for ships which were less than 5 years of age on 1 July 1998, by the date on which the ship reaches 10 years of age.

b. Completion prior to 1 July 2003 of an intermediate or special survey with a due date after 1 July 2003 cannot be used to postpone compliance. However, completion prior to 1 July 2003 of an intermediate survey the window for which straddles 1 July 2003 can be accepted.

S23.2 Damage Stability

a. Bulk carriers which are subject to compliance with Unified Requirements S19 and S22 shall, when loaded to the summer load line, be able to withstand flooding of the foremost cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in SOLAS regulation XII/4.3 to 4.7.

b. A ship having been built with an insufficient number of transverse watertight bulkheads to satisfy this requirement may be exempted from the application of Unified Requirements S19, S22 and this requirement provided the ship fulfills the requirement in SOLAS regulation XII/9.

Annex

1. Surveys to be held

The term “survey to be held” is interpreted to mean that the survey is “being held” until it is “completed”.

2. Due dates and completion allowance

2.1 intermediate survey:

2.1.1 Intermediate survey carried out either at the second or third annual survey: 3 months after the due date (i.e. 2nd or 3rd anniversary) can be used to carry out and complete the survey.

2.1.2 Intermediate survey carried out between the second and third annual survey: 3 months after the due date of the 3rd annual survey can be used to carry out and complete the survey.

2.2 Special survey: 3 months extension after the due date may be allowed subject to the terms/conditions of PR4;

2.3 Ships controlled by “1 July 2002”: same as for special survey;

2.4 Ships controlled by “age 15 years” or “age 17 years”: same as for special survey.

3. Intermediate survey interpretations/applications

3.1 If the 2nd anniversary is prior to or on 1 July 1998 and the intermediate survey is completed prior to or on 1 July 1998, the ship need not comply until the next special survey.

3.2 If the 2nd anniversary is prior to or on 1 July 1998 and the intermediate survey is completed within

① See Annex for details.

the window of the 2nd annual survey but after 1 July 1998, the ship need not comply until the next special survey.
3.3 If the 2nd anniversary is prior to or on 1 July 1998 and the intermediate survey is completed outside the window of the 2nd annual survey and after 1 July 1998, it is taken that the intermediate survey is held after 1 July 1998 and between the second and third annual surveys. Therefore, the ship shall comply no later than 3 months after the 3rd anniversary.
3.4 If the 2nd anniversary is after 1 July 1998 and the intermediate survey is completed within the window of the 2nd annual survey but prior to or on 1 July 1998, the ship need not comply until the next special survey.
3.5 If the 3rd anniversary is prior to or on 1 July 1998 and the intermediate survey is completed prior to or on 1 July 1998, the ship need not comply until the next special survey.
3.6 If the 3rd anniversary is prior to or on 1 July 1998 and the intermediate survey is completed within the window of the 3rd annual survey but after 1 July 1998, the ship need not comply until the next special survey.
3.7 If the 3rd anniversary is after 1 July 1998 and the intermediate survey is completed within the window prior to or on 1 July 1998, the ship need not comply until the next special survey.

4. Special survey interpretations/applications
4.1 If the due date of a special survey is after 1 July 1998 and the special survey is completed within the 3 month window prior to the due date and prior to or on 1 July 1998, the ship need not comply until the next relevant survey (i.e. special survey for ships under 20 years of age on 1 July 1998, intermediate survey for ships 20 years of age or more on 1 July 1998).

5. Early completion of an intermediate survey (coming due after 1 July 1998 to postpone compliance is not allowed):
5.1 Early completion of an intermediate survey means completion of the survey prior to the opening of the window (i.e. completion more than 3 months prior to the 2nd anniversary since the last special survey).
5.2 The intermediate survey may be completed early and credited from the completion date but in such a case the ship will still be required to comply not later than 3 months after the 3rd anniversary.

6. Early completion of a special survey (coming due after 1 July 1998 to postpone compliance is not allowed):
6.1 Early completion of a special survey means completion of the survey more than 3 months prior to the due date of the special survey.
6.2 The special survey may be completed early and credited from the completion date, but in such a case the ship will still be required to comply by the due date of the special survey.

Appendix 20 S31 RENEWAL CRITERIA FOR SIDE SHELL FRAMES AND BRACKETS IN SINGLE SIDE SKIN BULK CARRIERS AND SINGLE SIDE SKIN OBO CARRIERS NOT BUILT IN ACCORDANCE WITH UR S12 REV.1 OR SUBSEQUENT REVISIONS

Notes:
1. This UR is to be applied to bulk carriers and OBO carriers of single side skin construction, as defined above, in conjunction with UR Z10.2 (Rev.15, 2003 and Corr.1, 2004). Z10.2.1.1.5 refers.
2. The changes introduced in Rev.3 are to be applied not later than on assessments for compliance commenced on or after 1 July 2006.
3. The changes introduced in Rev.4 are to be applied not later than on assessments for compliance commenced on or after 1 July 2008.

S31.1 Application and definitions

These requirements apply to the side shell frames and brackets of cargo holds bounded by the single side shell of bulk carriers constructed with single deck, topside tanks and hopper tanks in cargo spaces intended primarily to carry dry cargo in bulk, which were not built in accordance with UR S12 Rev.1 or subsequent revisions.

In addition, these requirements also apply to the side shell frames and brackets of cargo holds bounded by the single side shell of oil/bulk/ore (OBO) carriers, as defined in UR Z11 but of single side skin construction.

In the case a ship as defined above does not satisfy above definition in one or more holds, the requirements in UR S31 do not apply to these individual holds.

For the purpose of this UR, “ships” means both “bulk carriers” and “OBO carriers” as defined above, unless otherwise specified.

Bulk carriers subject to these requirements are to be assessed for compliance with the requirements of this UR and steel renewal, reinforcement or coating, where required in accordance with this UR, is to be carried out in accordance with the following schedule and at subsequent intermediate and special surveys.

i. For bulk carriers which will be 15 years of age or more on 1 January 2004 by the due date of the first intermediate or special survey after that date.
ii. For bulk carriers which will be 10 years of age or more on 1 January 2004 by the due date of the first special survey after that date.
iii. For bulk carriers which will be less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.

Completion prior to 1 January 2004 of an intermediate or special survey with a due date after 1 January 2004 cannot be used to postpone compliance. However, completion prior to 1 January 2004 of an intermediate survey the window for which straddles 1 January 2004 can be accepted.

OBO carriers subject to these requirements are to be assessed for compliance with the requirements of this UR and steel renewal, reinforcement or coating, where required in accordance with this UR, is to be carried out in accordance with the following schedule and at subsequent intermediate and special surveys.

i. For OBO carriers which will be 15 years of age or more on 1 July 2005 by the due date of the first intermediate or special survey after that date.
ii. For OBO carriers which will be 10 years of age or more on 1 July 2005 by the due date of the first special survey after that date.
iii. For OBO carriers which will be less than 10 years of age on 1 July 2005 by the date on which the ship reaches 10 years of age.

Completion prior to 1 July 2005 of an intermediate or special survey with a due date after 1 July 2005 cannot be used to postpone compliance. However, completion prior to 1 July 2005 of an intermediate survey the window for which straddles 1 July 2005 can be accepted.

These requirements define steel renewal criteria or other measures to be taken for the webs and flanges of side shell frames and brackets as per S31.2.

Reinforcing measures of side frames are also defined as per S31.2.3.

Finite element or other numerical analysis or direct calculation procedures cannot be used as an alternative to compliance with the requirements of this UR, except in cases of unusual side structure arrangements or framing to which the requirements of this UR cannot be directly applied. In such cases, the analysis criteria and the strength check criteria are to be in accordance with each Society’s Rules.

S31.1.1 Ice strengthened ships

S31.1.1.1 Where ships are reinforced to comply with an ice class notation, the intermediate frames are not to be included when considering compliance with S31.

S31.1.1.2 The renewal thicknesses for the additional structure required to meet the ice strengthening notation are to be based on the class society's requirements.

S31.1.1.3 If the ice class notation is requested to be withdrawn, the additional ice strengthening structure, with the exception of tripping brackets (see S31.2.1.2.1.b and S31.2.3), is not to be considered to contribute to compliance with S31.

S31.2 Renewal or other measures

S31.2.1 Criteria for renewal or other measures

S31.2.1.1 Symbols used in S31.2.1

t_M – thickness as measured, in mm;

t_{REN} – thickness at which renewal is required. See S31.2.1.2;

$t_{REN,\ d/t}$ – thickness criteria based on d/t ratio. See S31.2.1.2.1;

$t_{REN,\ S}$ – thickness criteria based on strength. See S31.2.1.2.2;

t_{COAT} = 0.75 t_{SI2};

t_{SI2} – thickness in mm as required by UR S12 (Rev.3) in S12.3 for frame webs and in S12.4 for upper and lower bracket webs;

t_{AB} – thickness as-built, in mm;

t_C – see Table 1 below.

t_C values, in mm **Table 1**

Ship's length L, in m	Holds other than No.1		Hold No.1	
	Span and upper brackets	Lower brackets	Span and upper brackets	Lower brackets
≤100	2.0	2.5	2.0	3.0
150	2.0	3.0	3.0	3.5
≥200	2.0	3.0	3.0	4.0
Note: For intermediate ship lengths, t_C is obtained by linear interpolation between the above values.				

S31.2.1.2 Criteria for webs (Shear and other checks)

The webs of side shell frames and brackets are to be renewed when the measured thickness (t_M) is equal to or less than the thickness (t_{REN}) as defined below:

t_{REN} is the greatest of:

(a) $t_{COAT} - t_C$;

(b) 0.75 t_{AB};

(c) $t_{REN,\ d/t}$ (applicable to Zone A and B only);

(d) $t_{REN,\ S}$ (where required by S31.2.1.2.2).

S31.2.1.2.1 Thickness criteria based on d/t ratio

Subject to b) and c) below, $t_{REN,\ d/t}$ is given by the following equation:

$$t_{REN,}d/t = (\text{web depth in mm})/R$$

where: R = for frames:

$65k^{0.5}$ – for symmetrically flanged frames;

$55k^{0.5}$ – for asymmetrically flanged frames;

for lower brackets (see a) below):

$87k^{0.5}$ – for symmetrically flanged frames;

$73k^{0.5}$ – for asymmetrically flanged frames;

k = 1.0 – for ordinary hull structural steel and according to UR S4 for higher tensile steel.

In no instance is $t_{REN,\ d/t}$ for lower integral brackets to be taken as less than $t_{REN,\ d/t}$ for the frames they support.

a) Lower brackets

Lower brackets are to be flanged or face plate is to be fitted, refer to S31.2.1.3.

In calculating the web depth of the lower brackets, the following will apply:

- The web depth of lower bracket may be measured from the intersection of the sloped bulkhead of the hopper tank and the side shell plate, perpendicularly to the face plate of the lower bracket (see Figure 3).
- Where stiffeners are fitted on the lower bracket plate, the web depth may be taken as the distance between the side shell and the stiffener, between the stiffeners or between the outermost stiffener and the face plate of the brackets, whichever is the greatest.

b) Tripping bracket alternative

When t_M is less than $t_{REN,d/t}$ at section b of the side frames, tripping brackets in accordance with S31.2.3 may be fitted as an alternative to the requirements for the web depth to thickness ratio of side frames, in which case $t_{REN,d/t}$ may be disregarded in the determination of t_{REN} in accordance with S31.2.1.2. The value of t_{REN} is to be based on zone B according to UR Z10.2, Annex V, see Figure 1.

c) Immediately abaft collision bulkhead

For the side frames, including the lower bracket, located immediately abaft the collision bulkheads, whose scantlings are increased in order that their moment of inertia is such to avoid undesirable flexibility of the side shell, when their web as built thickness t_{AB} is greater than 1.65 $t_{REN,\,S}$, the thickness $t_{REN,\,d/t}$ may be taken as the value $t'_{REN,\,d/t}$ obtained from the following equation:

$$t'_{REN,d/t} = \sqrt[3]{t^2_{REN,d/t}\, t_{REN,S}}$$

where $t_{REN,\,S}$ is obtained from S31.3.3

S31.2.1.2.2 Thickness criteria based on shear strength check

Where t_M in the lower part of side frames, as defined in Figure 1, is equal to or less than t_{COAT}, $t_{REN,\,S}$ is to be determined in accordance with S31.3.3.

S31.2.1.2.3 Thickness of renewed webs of frames and lower brackets

Where steel renewal is required, the renewed webs are to be of a thickness not less than t_{AB}, 1.2 t_{COAT} or 1.2 t_{REN}, whichever is the greatest.

S31.2.1.2.4 Criteria for other measures

When $t_{REN} < t_M \leq t_{COAT}$, measures are to be taken, consisting of all the following:

a) sand blasting, or equivalent, and coating (see S31.2.2);

b) fitting tripping brackets (see S31.2.3), when the above condition occurs for any of the side frame zones A, B, C and D, shown in Figure 1. Tripping brackets not connected to flanges are to have soft toe, and the distance between the bracket toe and the frame flange is not to be greater than about 50 mm, see Figure 4;

c) maintaining the coating in "as-new" condition (i.e. without breakdown or rusting) at special and intermediate surveys.

The above measures may be waived if the structural members show no thickness diminution with respect to the as-built thicknesses and coating is in "as-new" condition (i.e. without breakdown or rusting).

When the measured frame webs thickness t_M is such that $t_{REN} < t_M \leq t_{COAT}$ and the coating is in GOOD condition, sand blasting and coating as required in a) above may be waived even if not found in "as-new" condition, as defined above, provided that tripping brackets are fitted and the coating damaged in way of the tripping bracket welding is repaired.

S31.2.1.3 Criteria for frames and brackets (Bending check)

When lower end brackets were not fitted with flanges at the design stage, flanges are to be fitted so as to meet the bending strength requirements in S31.3.4. The full width of the bracket flange is to extend up beyond the point at which the frame flange reaches full width. Adequate back-up structure in the hopper is to be ensured, and the bracket is to be aligned with the back-up structure.

Where the length or depth of the lower bracket does not meet the requirements in S12 (Rev.3), a bending strength check in accordance with S31.3.4 is to be carried out and renewals or reinforcements of frames and/or brackets effected as required therein.

The bending check need not to be carried out in the case the bracket geometry is modified so as to comply with S12 (Rev.3) requirements.

S31.2.2 Thickness measurements, steel renewal, sand blasting and coating

For the purpose of steel renewal, sand blasting and coating, four zones A, B, C and D are defined, as shown in Figure 1. When renewal is to be carried out, surface preparation and coating are required for the renewed structures as given in UR Z9 for cargo holds of newbuildings.

Representative thickness measurements are to be taken for each zone and are to be assessed against the criteria in S31.2.1.

When zone B is made up of different plate thicknesses, the lesser thickness is to be used for the application of the requirements in S31.

In case of integral brackets, when the criteria in S31.2.1 are not satisfied for zone A or B, steel renewal, sand blasting and coating, as applicable, are to be done for both zones A and B.

In case of separate brackets, when the criteria in S31.2.1 are not satisfied for zone A or B, steel renewal, sand blasting and coating is to be done for each one of these zones, as applicable.

When steel renewal is required for zone C according to S31.2.1, it is to be done for both zones B and C.

When sand blasting and coating is required for zone C according to S31.2.1, it is to be done for zones B, C and D.

When steel renewal is required for zone D according to S31.2.1, it needs only to be done for this zone.

When sand blasting and coating is required for zone D according to S31.2.1, it is to be done for both zones C and D.
Special consideration may be given by the Society to zones previously renewed or re-coated, if found in "as-new" condition (i.e., without breakdown or rusting).
When adopted, on the basis of the renewal thickness criteria in S31.2.1, in general coating is to be applied in compliance with the requirements of UR Z9, as applicable.
Where, according to the requirements in S31.2.1, a limited number of side frames and brackets are shown to require coating over part of their length, the following criteria apply.
a) The part to be coated includes:
- the web and the face plate of the side frames and brackets;
- the hold surface of side shell, hopper tank and topside tank plating, as applicable, over a width not less than 100 mm from the web of the side frame.

b) Epoxy coating or equivalent is to be applied.
In all cases, all the surfaces to be coated are to be sand blasted prior to coating application.
When flanges of frames or brackets are to be renewed according to S31, the outstanding breadth to thickness ratio is to comply with the requirements in UR S12.5.

S31.2.3 Reinforcing measures

Reinforcing measures are constituted by tripping brackets, located at the lower part and at midspan of side frames (see Figure 4). Tripping brackets may be located at every two frames, but lower and midspan brackets are to be fitted in line between alternate pairs of frames.
The thickness of the tripping brackets is to be not less than the as-built thickness of the side frame webs to which they are connected.
Double continuous welding is to be adopted for the connections of tripping brackets to the side shell frames and shell plating.
Where side frames and side shell are made of Higher Strength Steel (HSS), Normal Strength Steel (NSS), tripping brackets may be accepted, provided the electrodes used for welding are those required for the particular HSS grade, and the thickness of the tripping brackets is equal to the frame web thickness, regardless of the frame web material.

S31.2.4 Weld throat thickness

In case of steel renewal the welded connections are to comply with UR S12.7 of UR S12 (Rev.3).

S31.2.5 Pitting and grooving

If pitting intensity is higher than 15% in area (see Figure 5), thickness measurement is to be taken to check pitting corrosion.
The minimum acceptable remaining thickness in pits or grooves is equal to:
- 75% of the as-built thickness, for pitting or grooving in the frame and brackets webs and flanges;
- 70% of the as-built thickness, for pitting or grooving in the side shell, hopper tank and topside tank plating attached to the side frame, over a width up to 30 mm from each side of it.

S31.2.6 Renewal of all frames in one or more cargo holds

When all frames in one or more holds are required to be renewed according to UR S31, the compliance with the requirements in URS 12 (Rev. 1) may be accepted in lieu of the compliance with the requirements in UR S31, provided that:
- it is applied at least to all the frames of the hold(s);
- the coating requirements for side frames of "new ships" are complied with;
- the section modulus of side frames is calculated according to the Classification Society Rules.

S31.2.7 Renewal of damaged frames

In case of renewal of a damaged frame already complying with S31, the following requirements apply:
- The conditions accepted in compliance with S31 are to be restored as a minimum.
- For localised damages, the extension of the renewal is to be carried out according to the standard practice of each Classification Society.

S31.3 Strength check criteria

In general, loads are to be calculated and strength checks are to be carried out for the aft, middle and forward frames of each hold. The scantlings required for frames in intermediate positions are to be obtained by linear interpolation between the results obtained for the above frames.
When scantlings of side frames vary within a hold, the required scantlings are also to be calculated for the mid frame of each group of frames having the same scantlings. The scantlings required for frames in intermediate positions are to be obtained by linear interpolation between the results obtained for the calculated frames.

S31.3.1 Load model

The following loading conditions are to be considered:
– homogeneous heavy cargo (density greater than 1.78 t/m^3);
– homogeneous light cargo (density less than 1.78 t/m^3);
– nonhomogeneous heavy cargo, if allowed;
– multi-port loading/unloading conditions need not be considered.

S31.3.1.1 Forces

The forces $P_{fr,\,a}$ and $P_{fr,\,b}$, in kN, to be considered for the strength checks at sections a) and b) of side frames (specified in Figure 2; in the case of separate lower brackets, section b) is at the top of the lower bracket), are given by:

$$P_{fr,a} = P_S + \max\,(P_1, P_2)$$

$$P_{fr,b} = P_{fr,a}\,\frac{h - 2h_B}{h}$$

where: P_s – still water force, in kN:

= $sh\left(\frac{P_{S,U} + P_{S,L}}{2}\right)$ when the upper end of the side frame span h (see Figure 1) is below the load water line;

= $sh'\left(\frac{P_{S,L}}{2}\right)$ when the upper end of the side frame span h (see Figure 1) is at or above the load water line;

P_1 – wave force, in kN, in head sea:

= $sh\left(\frac{P_{1,U} + P_{1,L}}{2}\right)$;

P_2 – wave force, in kN, in beam sea:

= $sh\left(\frac{P_{2,U} + P_{2,L}}{2}\right)$;

h, h_B – side frame span and lower bracket length, in m, defined in Figures 1 and 2, respectively;

h’ – distance, in m, between the lower end of side frame span (see Figure 1) and the load water line;

s – frame spacing, in m;

$p_{S,\,U}$, $p_{S,\,L}$ – still water pressure, in kN/m^2, at the upper and lower end of the side frame span h (see Figure 1), respectively;

$p_{1,\,U}$, $p_{1,\,L}$ – wave pressure, in kN/m^2, as defined in S31.3.1.2.1) below for the upper and lower end of the side frame span h, respectively;

$p_{2,\,U}$, $p_{2,\,L}$ – wave pressure, in kN/m^2, as defined in S31.3.1.2.2) below for the upper and lower end of the side frame span h, respectively.

S31.3.1.2 Wave pressure

1) Wave pressure p_1

The wave pressure p_1, in kN/m^2, at and below the waterline is given by:

$$p_1 = 1.50\left[p_{11} + 135\,\frac{B}{2(B+75)} - 1.2(T - z)\right]$$

$$p_{11} = 3\,k_s\,C + k_f$$

The wave pressure p_1, in kN/m^2, above the water line is given by:

$$p_1 = p_{1wl} - 7.50\,(z - T)$$

2) Wave pressure p_2

The wave pressure p_2, in kN/m^2, at and below the waterline is given by

$$p_2 = 13.0\left[0.5B\,\frac{50C_f}{2(B+75)} + C_B\,\frac{0.5B + k_f}{14}\left(0.7 + 2\,\frac{z}{T}\right)\right]$$

The wave pressure p_2, in kN/m^2, above the water line is given by:

$$p_2 = p_{2wl} - 5.0\,(z - T)$$

where: p_{1wl} – p_1 wave sea pressure at the waterline;

p_{2wl} – p_2 wave sea pressure at the waterline;

L – Rule length, in m, as defined in UR S2;

B – greatest moulded breadth, in m;

C_B – block coefficient, as defined in UR S2, but not to be taken less than 0.6;

T – maximum design draught, in m;

C – coefficient:

= $10.75 - \left(\frac{300 - L}{100}\right)^{1.5}$ for $90 \le L \le 300$ m;

= 10.75 for 300 m < L;

C_f = $\left(1.25 - 0.025\frac{2k_r}{\sqrt{GM}}\right)k$ for $350 \text{ m} \le L \le 500$ m;

k = 1.2, for ships without bilge keel;

= 1.0, for ships with bilge keel;

k_r – roll radius of gyration, if the actual value of k_r is not available:

= 0.39 B, for ships with even distribution of mass in transverse section (e.g. alternate heavy cargo loading or homogeneous light cargo loading);

= 0.25 B, for ships with uneven distribution of mass in transverse section (e.g. homogeneous heavy cargo distribution);

GM – 0.12 B if the actual value of GM is not available;

z – vertical distance, in m, from the baseline to the load point;

k_s = $C_B + \frac{0.83}{\sqrt{C_B}}$ at aft end of L;

= C_B, between 0.2 L and 0.6 L from aft end of L;

= $C_B + \frac{1.33}{C_B}$ at forward end of L.

Between the above specified points, k_s is to be interpolated linearly;

k_f = $0.8C$.

S31.3.2 Allowable stresses

The allowable normal and shear stresses σ_a and τ_a, in N/mm^2, in the side shell frames and brackets are given by:

$$\sigma_a = 0.90\ \sigma_F$$
$$\tau_a = 0.40\ \sigma_F$$

where: σ_F is the minimum upper yield stress, in N/mm^2, of the material.

S31.3.3 Shear strength check

Where t_M in the lower part of side frames, as defined in Figure 1, is equal to or less than t_{COAT}, shear strength check is to be carried out in accordance with the following.

The thickness $t_{REN,\,S}$, in mm, is the greater of the thicknesses $t_{REN,\,S\,a}$ and $t_{REN,\,S\,b}$ obtained from the shear strength check at sections a) and b) (see Figure 2 and S31.3.1) given by the following, but need not be taken in excess of $0.75t_{S12}$.

at section a): $$t_{REN,Sa} = \frac{1000k_s P_{fr,a}}{d_a \sin\phi \tau_a}$$

at section b): $$t_{REN,Sb} = \frac{1000k_s P_{fr,b}}{d_b \sin\phi \tau_a}$$

where: k_s – shear force distribution factor, to be taken equal to 0.6;

$P_{fr,\,a}$, $P_{fr,\,b}$ – pressure forces defined in S31.3.1.1;

d_a, d_b – bracket and frame web depth, in mm, at sections a) and b), respectively (see Figure 2); in case of separate (non integral) brackets, d_b is to be taken as the minimum web depth deducing possible scallops;

φ – angle between frame web and shell plate;

τ_a – allowable shear stress, in N/mm^2, defined in S31.3.2.

S31.3.4 Bending strength check

Where the lower bracket length or depth does not meet the requirements in UR S12 (Rev. 3), the actual section modulus, in cm^3, of the brackets and side frames at sections a) and b) is to be not less than:

at section a): $$Z_a = \frac{1000P_{fr,a}h}{m_a\sigma_a}$$

at section b): $$Z_b = \frac{1000P_{fr,a}h}{m_b\sigma_a}$$

where: $P_{fr,\,a}$ – pressures force defined in S31.3.1.1;

h – side frame span, in m, defined in Figure 1;

σ_a – allowable normal stress, in N/mm^2, defined in S31.3.2;
m_a, m_b – bending moment coefficients as defined in Table 2.

Bending Moment Coefficients m_a and m_b **Table 2**

	m_a	m_b		
		$h_B \leq 0.08\ h$	$h_B = 0.1\ h$	$h_B \geq 0.125\ h$
Empty holds of ships approved to operate in non-homogeneous loading conditions	10	17	19	22
Other cases	12	20	22	26

Notes:
1. Non-homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, exceeds 1.20 corrected for different cargo densities.
2. For intermediate values of the bracket length h_B, the coefficient m_b is obtained by linear interpolation between the table values.

The actual section modulus of the brackets and side frames is to be calculated about an axis parallel to the attached plate, based on the measured thicknesses. For precalculations, alternative thickness values may be used, provided they are not less than:
– t_{REN}, for the web thickness;
– the minimum thicknesses allowed by the Society renewal criteria for flange and attached plating.
The attached plate breadth is equal to the frame spacing, measured along the shell at midspan of h.
If the actual section moduli at sections a) and b) are less than the values Z_a and Z_b, the frames and brackets are to be renewed or reinforced in order to obtain actual section moduli not less than 1.2 Z_a and 1.2 Z_b, respectively.
In such a case, renewal or reinforcements of the flange are to be extended over the lower part of side frames, as defined in Figure 1.

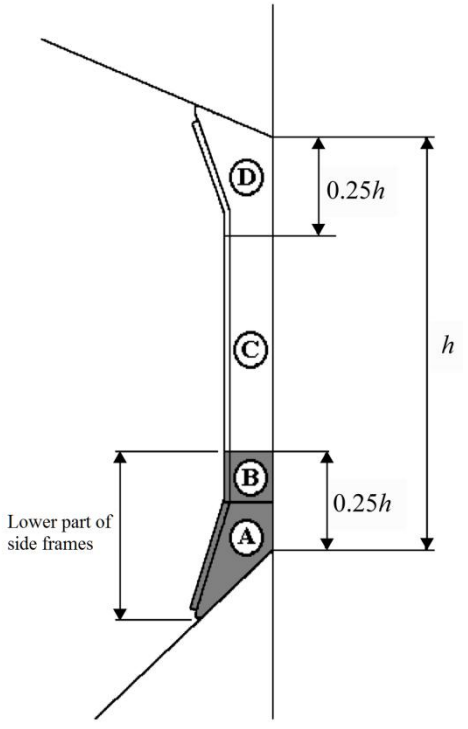


Figure 1 Lower Part and Zones of Side Frames

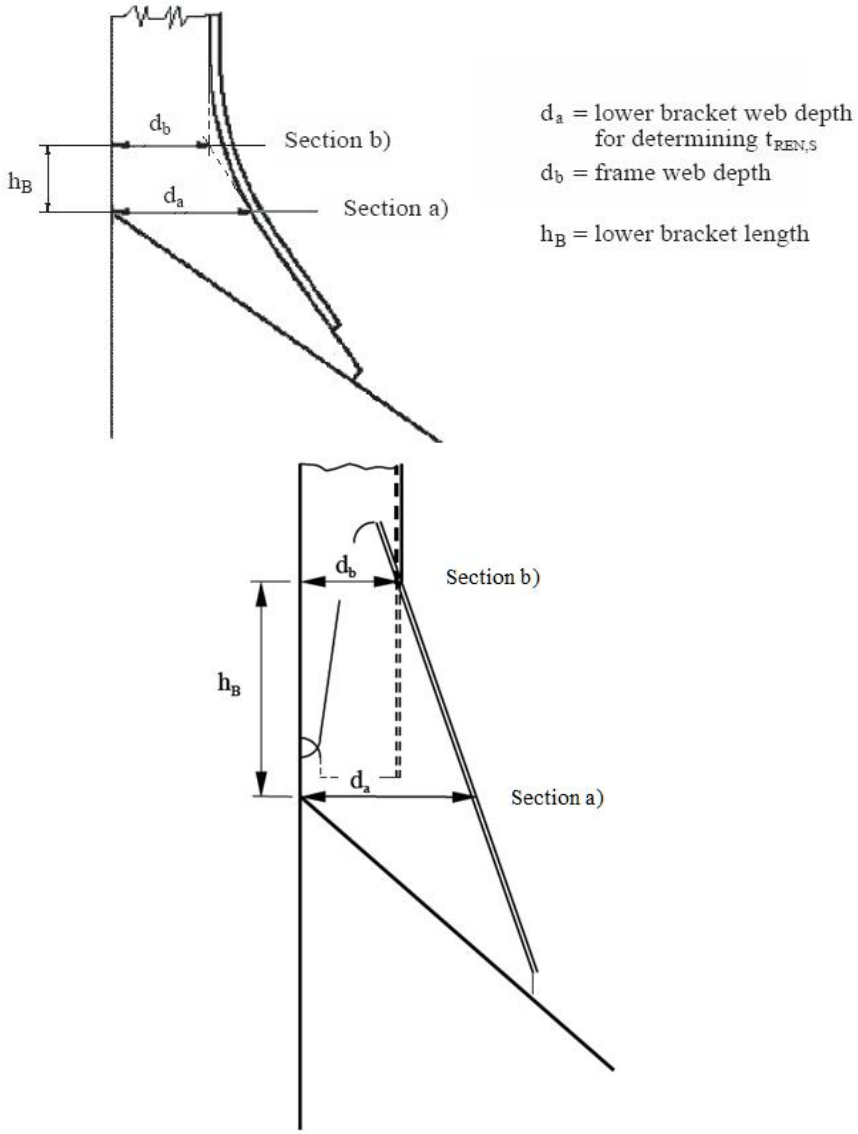


Figure 2 Sections a) and b)

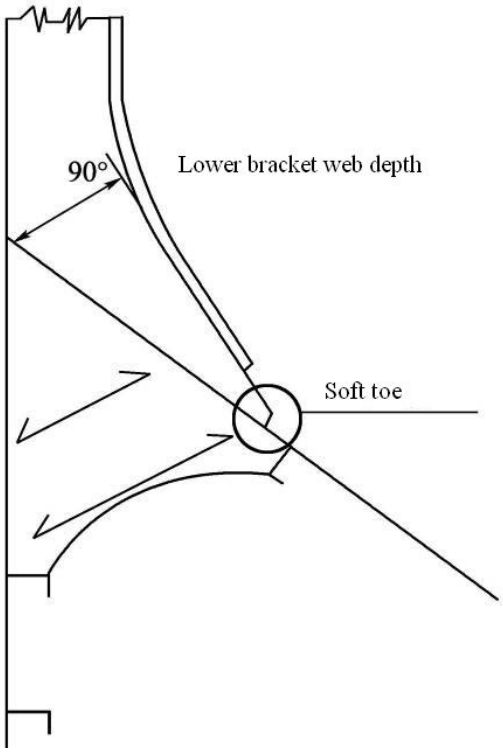


Figure 3 Definition of the Lower Bracket Web Depth for Determining $t_{REN,\ d/t}$

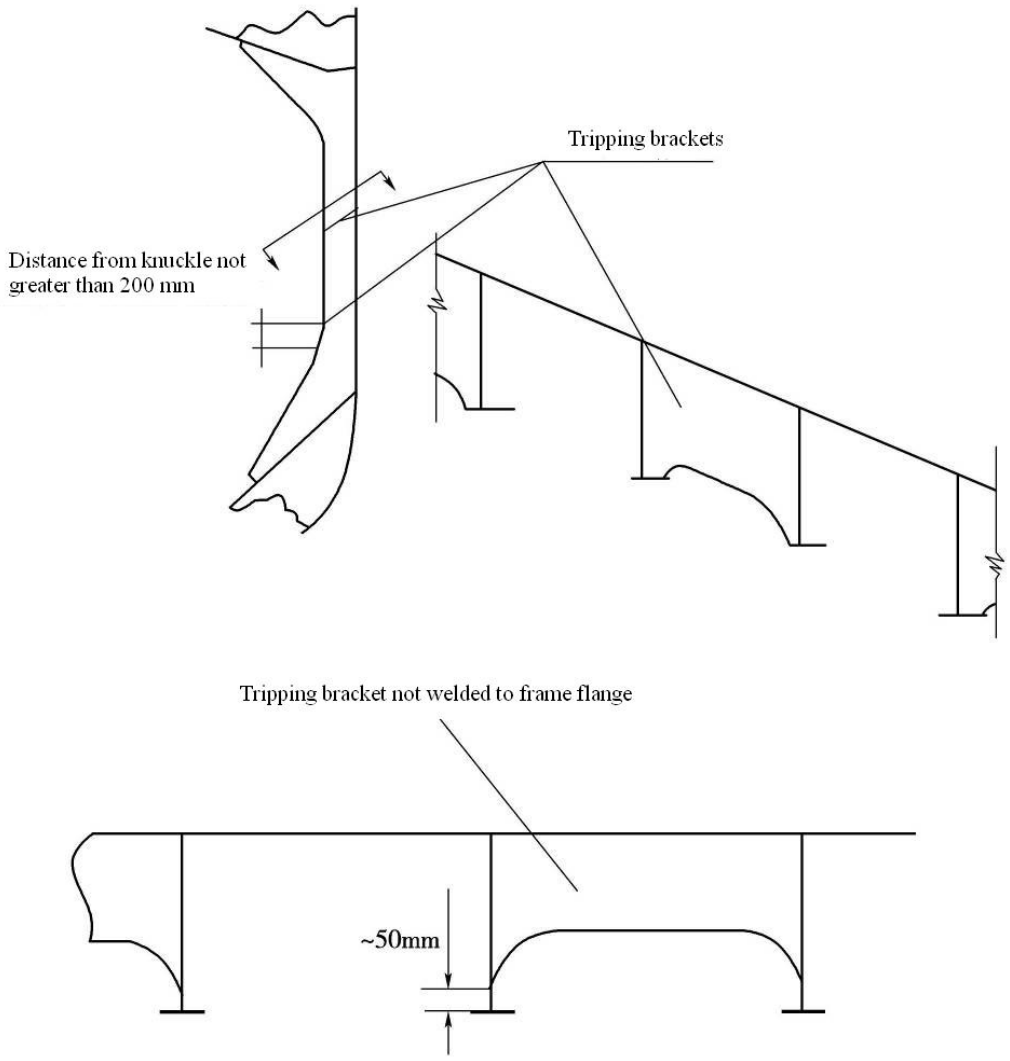


Figure 4 Tripping Brackets

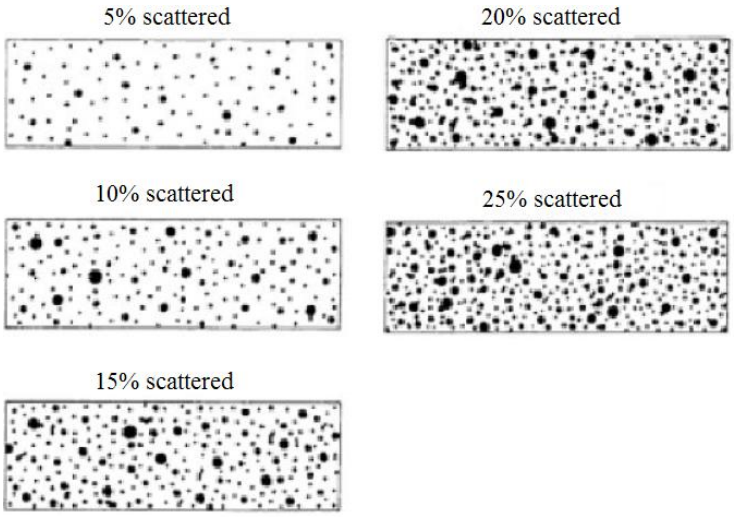


Figure 5 Pitting Intensity Diagrams (from 5% to 25% Intensity)

Appendix 21 GUIDELINES FOR PILOT SCHEMES OF EXTENDED INTERVAL BETWEEN SURVEYS IN DRY-DOCK − EXTENDED DRY-DOCKING (EDD) SCHEME

1 General requirements

1.1 Introduction

1.1.1 The intervals between inspections of the outside of the ship's bottom are specified in SOLAS, IACS Regulations and CCS Rules and require a minimum of two inspections to be carried out during the 5-year validity period of the Safety Construction Certificate/Special Survey period. SOLAS regulation I/10(v) only requires a minimum of two inspections of the outside of the ship's bottom and does not specify a ship must be dry-docked out of the water.

1.1.2 IMO resolution A.1053(27), as amended, "Survey guidelines for the harmonized system of survey and certification", requires that inspections of the outside of the ship's bottom should normally be carried out with the ship in a dry-dock. However, it also provides that Administrations may give consideration to alternate inspections being carried out with the ship afloat.

1.1.3 This Guidelines recommends the acceptance procedure for pilot schemes which extend the interval between surveys in dry-dock. Ships eligible for the Extended Dry-Docking (EDD) scheme are to meet the provisions and conditions described in this Guidelines.

1.1.4 Qualifying ships may be permitted to carry out two consecutive in-water surveys, subject to the conditions described in this Guidelines. A minimum of two inspections of the outside of the ship's bottom is to be carried out during the statutory renewal period/special survey period of five years and the intervals between any two inspections are not to exceed 36 months.

1.1.5 Pilot schemes which extend the interval between out of water dry-docking surveys are normally tripartite projects between the Owner, flag Administration and CCS. Acceptance into such a Pilot scheme is subject to the formal written agreement with the ship's flag Administration including any additional specific flag Administration requirements.

1.2 Application

1.2.1 Owners/Managers requesting a ship be considered for the EDD scheme, are to apply to CCS in writing confirming and describing compliance with the requirements and conditions specified in this Guidelines.

1.2.2 Upon the Owner's request, the extended interval for each ship will be considered on a case by case basis by CCS. CCS may assist in forwarding the Owner's application to the flag Administration.

1.2.3 The following ships and ship types are not eligible for the extended dry-docking scheme described in this Guidelines:

− passenger ships;
− ships subject to the Enhanced Survey Program (ESP);
− ships subject to requirements of section 5 of Chapter 5 of this PART;
− ships fitted with propulsion thrusters;
− ships where the propeller connection to the shaft is by means of a keyed taper;
− high speed craft (HSC).

1.2.4 The dry-docking scheme will operate, based upon the ship's age when entering the scheme. For ships already in service, the extended dry-docking scheme may be implemented at any time until a ship reaches 10 years of age. (Namely that once a ship reaches 10 years of age, inspections of the outside of the ship's bottom must be carried out in dry-dock during the 10-year special survey period.)

1.2.5 No extensions are to be granted for the dry-docking required at the end of each extended dry docking period.

1.3 Information to be submitted by the owner

1.3.1 Prior to acceptance into an EDD scheme, the owner is to submit the following information:

(1) provisions for carrying out maintenance required on electric/electronic sensors e.g. Echo-sounder, Doppler-Log, Speedlog (propeller speedlog or backpressure speedlog), seawater temperature gauges, electronic draught reading, etc.;

(2) provisions for maintaining the draft marks fore, aft and midships as well as load line marks (painted and welded figures) and all other required hull markings;

(3) maintenance required of thrusters and stabilisers, if fitted, and provision for carrying out surveys or maintenance or as required by the surveyor;

(4) service experience to-date with hull coating system covered by manufacturer's guarantee that the underwater coatings used are designed to last for the extended period since the coating is to remain effective for the extended dry docking period;
(5) impressed cathodic protection system or provisions for renewal of external hull sacrificial anodes in the afloat condition.

1.4 Preparatory reviews by CCS

1.4.1 CCS is to carry out the following reviews prior to accepting a ship into an EDD scheme:
(1) satisfactory review of the items submitted by the owner as required in 1.3 above;
(2) review of ship's history with particular attention to any previous findings affecting the underwater body.

1.5 Arrangements

1.5.1 Prior to acceptance into an EDD scheme, ships enrolled an extended dry-docking interval scheme are to comply with the following provisions:
(1) The ship is to comply with the In-Water Survey provisions in accordance with the corresponding requirements of CCS.
(2) Protective coating in double bottom/double side ballast tanks, void spaces and all other spaces adjacent to the shell is to be maintained in GOOD condition.
(3) The shafting arrangement is to fulfil the applicable CCS requirements for tailshaft condition monitoring survey arrangement. Namely that the ship is to be assigned with SCM class notation.
(4) Hull maintenance scheme to be implemented in accordance with ISM requirements.

2 Survey requirements

2.1 In-water survey requirements

2.1.1 The In-Water Survey is to be carried out in accordance with the requirements of 5.2.3, section 2 and section 11, Chapter 5 of this PART.
2.1.2 An in-water survey plan is to be submitted to CCS for review in advance of the survey and should include the following:
(1) scheduled time and location for survey;
(2) name of approved diving company;
(3) means for cleaning of the hull below waterline;
(4) means of access for examination of sea chests, sea valves and box coolers;
(5) provisions for determining the condition of anchoring equipment, ranging of anchor chain cables and examination of the chain lockers when due for survey and/or as required by the surveyor;
(6) provisions for surveying and maintaining sea connections including thickness measurements of sea chests;
(7) results of inspections by the Owner's personnel of double bottom/double side ballast tanks (during the last 3 years) and other spaces adjacent to the shell with reference to structural deterioration in general, leakages in tank boundaries and piping and condition of the protective coating;
(8) conditions for internal examination of double bottom/double side ballast tanks (e.g. information regarding tank cleaning, gas freeing, ventilation, lighting, etc.).
2.1.3 Prior to commencement of the in-water survey, a survey planning meeting is to be held between the attending surveyor(s), the owner's representative in attendance, the diving company and the master of the ship or an appropriate representative appointed by the owner for the purpose of ascertaining that all the arrangements envisaged in the survey plan are in place, so as to ensure the safe and efficient conduct of the survey work to be carried out.
2.1.4 A comprehensive report of findings, gaugings, clearances and any work undertaken, including recordings of representative CCTV images, must be submitted by the ship owner to all involved parties.

2.2 Special survey/statutory renewal requirements

2.2.1 It should be noted that the periodicity of the ship's special survey and statutory renewal surveys will not change, therefore provision must be made for carrying out all such surveys and any repairs afloat, where not dry-docking.

2.3 Survey findings

2.3.1 If the In-Water Survey reveals damage, deterioration or other conditions that requires early attention, the surveyor may require that the ship be dry-docked in order that a detailed survey can be undertaken and necessary repairs carried out.
2.3.2 If temporary repairs carried out to any underwater parts are considered acceptable these must be

made permanent within a due date decided by the surveyor.

2.3.3 The owner is to request CCS to perform a survey in dry-dock in any event or circumstance in the operation of the ship which could have led to underwater damages or deterioration in the crew's knowledge or opinion.

2.3.4 If the coating condition in double bottom/double side ballast tanks, void spaces and dry spaces is found in less than GOOD condition, the owner is to restore the coating to GOOD.

3 Termination of scheme

3.1 Termination of EDD scheme

3.1.1 The dry-docking survey required for the special survey at 15 years of age is to be carried out in a dry-dock. All ships in an EDD scheme are to be dis-enrolled once the ship reaches 15 years of age.

3.1.2 The Extended Dry-docking Scheme will be terminated in cases of change of the ship's owner, management or flag Administration.

3.1.3 CCS may dis-enroll a ship from an EDD scheme at any time should it be found that the conditions for maintaining this extended dry-dock scheme are not fulfilled anymore.

3.1.4 Once the conditions for the scheme are no longer present, the ship will return to the normal docking interval and any due dock survey is to be carried out by the due date.

Appendix 22 CONDITION MONITORING AND CONDITION BASED MAINTENANCE①

1 General

1.1 Application

1.1.1 These requirements apply to the approved Condition Monitoring and Condition Based Maintenance schemes where the condition monitoring results are used to influence the scope and/or frequency of Class survey.

1.1.2 This scheme may be applied to components and systems covered by Continuous Machinery Survey (CMS), and other components and systems as requested by the owner. The extent of Condition Based Maintenance and associated monitoring equipment to be included in the maintenance scheme is decided by the Owner.

1.1.3 These requirements can be applied only to vessels operating on approved PMS survey scheme.

1.1.4 The scheme may be applied to any individual items and systems. Any items not covered by the scheme shall be surveyed and credited in accordance with the requirements of Section 9 of this Chapter and / or Appendix 16 of this Chapter.

1.2 Definitions

1.2.1 The following standard terms are defined in ISO 13372:2012:

(1) Condition monitoring: acquisition and processing of information and data that indicate the state of a machine over time. The machine state deteriorates if faults or failures occur.

(2) Diagnostic: examination of symptoms and syndromes to determine the nature of faults or failures.

(3) Condition Based Maintenance: maintenance performed as governed by condition monitoring programmes.

1.3 Condition Monitoring (CM)

1.3.1 Where an approved condition monitoring system is fitted, credit for survey may be based on acceptable condition monitoring results. The condition monitoring results are to be reviewed during the annual audit.

1.3.2 Limiting parameters are to be based on the Original Equipment Manufacturers guidelines (OEM), or a recognised international standard.

1.3.3 The condition monitoring system is to provide an equivalent or greater degree of confidence in the condition of the machinery to traditional survey techniques.

1.3.4 The condition monitoring system shall be approved in accordance with CCS procedures.

1.3.5 A condition monitoring system may be used to provide a greater understanding of equipment condition, and a condition based maintenance scheme may be used to obtain maintenance efficiency. CCS approval is required where owners wish to change the survey cycle based on CM/CBM.

1.3.6 Software systems can use complex algorithms, machine learning and knowledge of global equipment populations/defect data in order to identify acceptability for continued service or the requirement for maintenance. These systems may be independent of the OEM recommended maintenance and condition monitoring suggested limits. Approval of this type of software is to be based on OEM recommendations, industry standards and CCS experience.

1.3.7 CCS retains the right to test or open-up the machinery, irrespective of the CM results, if deemed necessary.

---

① This revision is to be uniformly implemented on and after 1 January 2020.

1.4 Condition Based Maintenance (CBM)

1.4.1 Where an owner wishes to base their equipment maintenance on a CBM approach, this is to meet the requirements of the ISM Code.

1.4.2 Where an agreed planned maintenance and CBM scheme is in operation, the CMS and other survey intervals may be extended based on OEM maintenance recommendations and acceptable condition monitoring results.

1.4.3 Limiting parameters (alarms and warnings) are to be based on the OEM guidelines, or a recognised international standard.

1.4.4 The CBM scheme is to provide an equivalent or greater degree of confidence in the condition of the machinery to traditional maintenance techniques.

1.4.5 The scheme shall be approved in accordance with each CCS procedures.

1.4.6 Software systems can use complex algorithms, machine learning and knowledge of global equipment populations/defect data in order to identify acceptability for continued service or the requirement for maintenance. These systems may be independent of the OEM recommended maintenance and condition monitoring suggested limits. Approval of this type of software is to be based on OEM recommendations, industry standards and CCS experience.

2 Procedures and Conditions for approval of CM and CBM

2.1 Onboard Responsibility

2.1.1 The chief engineer shall be the responsible person on board in charge of the CM and CBM.

2.1.2 Documentation on the overhaul of items covered by CM and CBM schemes shall be reported by the chief engineer.

2.1.3 Access to computerized systems for updating of the maintenance documentation and maintenance program shall only be permitted by the chief engineer or other authorized person.

2.1.4 All personnel involved in CM and CBM shall be appropriately qualified.

Note: CM does not replace routine surveillance or the chief engineer's responsibility for taking decisions in accordance with his judgement.

2.2 Equipment and System Requirements

2.2.1 CM equipment and systems shall be approved in accordance with a procedure of CCS.

2.2.2 The CM/CBM scheme and its extent, are to be approved by CCS.

2.2.3 The CBM scheme is to be capable of producing a condition report, and maintenance recommendations.

2.2.4 A system is to be provided to identify where limiting parameters (alarms and warnings) are modified during the operation of the scheme.

2.2.5 Where CM and CBM schemes use remote monitoring and diagnosis (i.e. data is transferred from the vessel and analysed remotely), the system is to meet the applicable standards for Cyber Safety and Security. The system shall be capable of continued onboard operation in the event of loss of the communication function.

2.2.6 CBM schemes are to identify defects and unexpected failures that were not prevented by the CM system.

2.2.7 Systems shall include a method of backing up data at regular intervals.

2.3 Documentation and Information

2.3.1 The following documentation shall be made available for the approval of the scheme:

(1) Procedure for changes to software system and CM parameters;

(2) Listing of equipment to be included in the scheme;

(3) Listing of acceptable condition monitoring parameters;
(4) Description of CBM scheme;
(5) Listing, specifications and maintenance procedures for condition monitoring equipment;
(6) Baseline data for equipment with condition monitoring;
(7) Qualification of personnel and company responsible for analysing CM results.

2.3.2 In addition to the above documentation the following information shall be available on board:
(1) All clauses in 2.3.1 in an up-to-date fashion;
(2) Maintenance instructions (manufacturer's and shipyard's);
(3) Condition monitoring data including all data since last opening of the machine and the original base line data;
(4) Reference documentation (trend investigation procedures etc.);
(5) Records of maintenance including repairs and renewals carried out;
(6) Records of changes to software systems and parameters;
(7) Sensors calibration records / certification / status.

2.4 Approval validity

2.4.1 An Annual Audit shall be carried out to maintain the validity of the CM/CBM scheme.

2.4.2 The survey arrangement for machinery under CM/CBM can be cancelled by CCS if the scheme is not being satisfactorily carried out either from the maintenance records or the general condition of the machinery.

2.4.3 The case of sale or change of management of the ship or transfer of class shall cause the approval to be reconsidered.

2.4.4 The ship owner may, at any time, cancel the survey arrangement for machinery under the scheme by informing CCS in writing and for this case the items which have been inspected under the scheme since the last annual Audit can be credited for class at the discretion of the attending surveyor.

3 Surveys

3.1 Installation Survey

3.1.1 Condition monitoring equipment is to be installed and surveyed in accordance with CCS rules, and a set of base line readings is to be taken.

3.2 Implementation Survey

3.2.1 The Implementation Survey shall be carried out by CCS surveyor no earlier than 6 months after installation survey and no later than the first Class annual survey.

3.2.2 During the Implementation survey the following shall be verified by a surveyor:
(1) the CM/CBM scheme is implemented according to the approval documentation, including a comparison with baseline data;
(2) the scheme is producing the documentation required for the Annual Audit and the requirements of surveys and testing for the maintenance of class are complied with;
(3) the onboard personnel are familiar with operating the scheme;
(4) records of any limiting parameters (alarms and warnings) that have been modified during the operation of the scheme;
(5) records of any failures of monitored equipment are to be reviewed to ensure that the condition monitoring scheme is effective / sufficient.

3.2.3 When this survey is carried out and the implementation is found in order, a report describing the scheme shall be submitted to CCS and the scheme may be put into service.

3.3 Annual Audit

3.3.1 An annual audit of the CM and CBM scheme shall be carried out by a CCS surveyor concurrently

with the Class annual survey.

3.3.2 The purpose of this audit shall be to verify that the scheme is being correctly operated and that the machinery has been functioning satisfactorily since the previous audit. This is to include any limiting parameters (alarms and warnings) that have been modified since the last audit. A general examination of the items concerned shall be carried out.

3.3.3 The performance, condition monitoring and maintenance records shall be examined to verify that the machinery has functioned satisfactorily since the previous survey, or action has been taken in response to machinery operating parameters exceeding acceptable tolerances.

3.3.4 Written details of break-down or malfunction shall be made available.

3.3.5 At the discretion of the surveyor, function tests, confirmatory surveys and random check readings, where Condition Monitoring / Condition Based Maintenance equipment is in use, shall be carried out as far as practicable and reasonable.

3.3.6 The familiarity of the chief engineer and other personnel involved with the CM system shall be verified.

3.3.7 Calibration status of sensors and equipment shall be verified.

3.3.8 Verification that the suitability of the CM/CBM scheme has been reviewed following defects and failures shall be carried out.

3.4 Damage and repairs

3.4.1 Damage to components or items of machinery is to be reported to CCS. The repairs of such damaged components or items of machinery are to be carried out to the satisfaction of the Surveyor.

3.4.2 Details of repairs and maintenance carried out shall be examined. Any machinery part, which has been replaced by a spare one, due to damage, is to be retained on board where possible until examined by CCS Surveyor.

3.4.3 Defect and failure data is to be reviewed in order to ensure the system output is appropriate. Where necessary, following review of the failure data, there is to be a method of amending the CM and CBM scheme.

Appendix 23 REQUIREMENTS FOR NDT SERVICE SUPPLIERS

1 General

1.1 Scope

1.1.1 Firms providing Non-Destructive Testing (NDT) and Advanced Non-Destructive Testing (ANDT[①]) Services on the new construction of ships and offshore structures subject to classification, need to fulfil the requirements set out in this Appendix. In this Appendix, such firms will be referred to as the NDT Service Supplier.

1.1.2 This Appendix applies to:

(1) Independent NDT companies;

(2) Internal departments of fabricators, e.g., shipyards, hull block/section fabricators performing NDT.

The NDT service specified in this Appendix covers the service application to the following hull structure and associated items at the fabrication stage during new construction:

(1) The welding of components that are integrated into the ship or offshore structure;

(2) The fabrication of independent fuel or cargo tanks (including those intended for low flashpoint fuels, e.g. type A, B and C independent tanks as described in IMO IGC and IGF Codes);

(3) Items listed within the definition of hull structure, as defined in 2.1, Appendix 1, Chapter 4 of this PART;

(4) Rudders of welded construction.

1.1.3 NDT Service Suppliers in the context of this Appendix are not included as part of the scope of Appendix 8, Chapter 5 of this PART.CCS shall verify the NDT Service Supplier in order to determine compliance with the requirements of this Appendix.

1.2 Objective

The objective of this Appendix is to ensure that the NDT Service Supplier is using appropriate procedures, has qualified and certified personnel and has implemented written procedures for training, experience, education, examination, certification, performance, application, control, verification and reporting of NDT. In addition, the NDT Service Supplier shall furnish appropriate equipment and facilities commensurate with providing a professional service.

1.3 Terms and definitions

The following terms and definitions apply for this document.

NDT	Non-destructive testing - the development and application of technical methods to examine materials or components in ways that do not impair their future usefulness and Serviceability, in order to measure geometrical characteristics and to detect, locate, measure and evaluate flaws. NDT is also known as non-destructive examination (NDE), non-destructive inspection (NDI) and non-destructive evaluation (NDE). Comprising, but not limited to the following methods and techniques MT, PT, RT, VT, UT, and ET
ANDT	The above definition of NDT applies, however ANDT includes advanced methods such as RT-D, PAUT, TOFD and AUT
NDT Service Supplier	Independent NDT company or NDT department/section that forms a part of a company providing NDT services on the new construction of ships and offshore structures, as applicable to the bodies performing NDT on the items as listed in paragraph 1.1.2 of this Appendix.
Society	The Classification Society
MT	Magnetic Particle Testing
PT	Penetrant Testing
RT	Radiographic Testing
RT-D	Digital Radiography (Several techniques within the method RT, e.g. Computed Radiography or Direct Radiography).
UT	Ultrasonic Testing
PAUT	Phased Array Ultrasonic Testing (Technique within the method UT).
TOFD	Time of Flight Diffraction (Technique within the method UT).
AUT	Automated Ultrasonic Testing. A technique by which an object is tested by ultrasound using probes operating under mechanical control and where ultrasonic data is collected automatically
ET	Electromagnetic Testing (i.e. Eddy Current Testing and/or Alternating Current Field

① For the remainder of this Appendix, wherever there is a reference to NDT, it also includes ANDT.

Measurements [ACFM])

VT Visual Testing

Industrial sector Section of industry or technology where specialised NDT practices are used, requiring specific product-related knowledge, skill, equipment and/or training.

Product sector A category of component that may be defined by type of manufacturing, fabrication, and/or shape, which may have unique, and/or general manufacturing/fabrication defect characteristics. Product sector examples include (but not limited to): castings, wrought products (forgings), rolled products, extruded products, and welds. NDT personnel may hold certification in a method which is related to a product sector.

1.4 References

The following referenced documents are to be used for the application of this document as appropriate. For undated references, the latest edition of the referenced document (including any amendments) applies.

(1) ISO 9712:2021; Non-destructive testing - Qualification and certification of NDT personnel;

(2) ISO/IEC 17020:2012; Conformity assessment – Requirements for the operation of various types of bodies performing inspection;

(3) ISO/IEC 17024:2012; Conformity assessment – General requirements for bodies operating certification of persons;

(4) ISO 9001:2015; Quality Management Systems – Requirements.

(5) SNT-TC-1A: 2020; Personnel Qualification and Certification in Nondestructive Testing;

(6) ANSI/ASNT CP-189:2020; ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel.

Other national adoptions of the standards listed above are accepted as compliant and hence are accepted for use together with this document.

2 Requirements for the NDT Service Supplier

The NDT Service Supplier shall document, as required in 2.2 to 2.9, that it has the competence and control needed to perform the specified NDT services.

2.1 Requirements for documents

The following documents shall be available for CCS upon request:

(1) an outline of the NDT Service Supplier's organisation and management structure, including any subsidiaries;

(2) information on the structure of the NDT Service Supplier’s Quality Management System;

(3) quality manual and documented procedures covering the requirements given in item 2.2;

(4) for companies with in-house certification of personnel scheme; a written practice developed in accordance with a recognised standard or recommended practice (i.e. ASNT’s SNT-TC-1A, 2020 ANSI/ASNT CP-189, 2020 or similar);

(5) operational work procedures for each NDT method including selection of the NDT technique;

(6) training- and follow-up programmes for NDT operators including practical training on various ship and offshore products;

(7) written statement issued by the employer, based upon the scope of certification, authorising the operator to carry out specified tasks;

(8) procedure for supervisor’s authorisation of NDT operators;

(9) experience of the NDT Service Supplier in the specific service area;

(10) for companies which obtain certification from an accredited certification body; a list of documented training and experience for NDT operators within the relevant NDT service area, including qualifications and third party certification per ISO 9712:2021 based certification schemes;

(11) description of equipment(s) used for the NDT services performed by the NDT Service Supplier;

(12) a guide for NDT operators to use equipment mentioned above;

(13) record formats for recording results of the NDT services referred to in item 2.9;

(14) information on other activities which may present a Conflict of interest, if applicable;

(15) record of customer claims and corrective actions, where applicable;

(16) any legal proceedings against the company in the past/currently in the courts of law, where applicable.

2.2 Quality management system

2.2.1 The NDT Service Supplier shall have a documented quality management system, covering at least:

(1) work procedures for all tasks and operations, including the various NDT methods and NDT techniques for which the NDT Service Supplier is involved;

(2) preparation, issuance, maintenance and control of documents;

(3) maintenance and calibration of the equipment;

(4) training programs for the NDT operators and the supervisors;

(5) maintenance of records for NDT operators’ and the supervisors’ training, qualification and certification;

(6) certification of NDT operators including re-validation and recertification;
(7) procedure for test of operators' visual acuity;
(8) supervision and verification of operation to ensure compliance with the NDT procedures;
(9) quality management of subsidiaries;
(10) job preparation;
(11) order reference system where each engagement is traceable to when, who and where the test was carried out;
(12) recording and reporting of information, including retention time of records;
(13) code of conduct for the NDT Service Supplier's activities; especially the NDT activities;
(14) periodic review of work process procedures;
(15) corrective and preventive action;
(16) feedback and continuous improvement;
(17) internal audits;
(18) the provision of accessibility to required codes, standards and procedures to assist NDT operators.

2.2.2 A documented quality system complying with the most current version of ISO/IEC 17020:2012 and including the above would be considered acceptable. The NDT Service Supplier should satisfy the requirements of Type A or Type B or Type C inspection body, as described in ISO/IEC 17020:2012. In all cases, production staff shall not be allowed to inspect their own work in the case of Type C inspection body.

2.3 Qualification and certification of NDT personnel

2.3.1 The NDT Service Supplier is responsible for the qualification and preferably 3rd party certification of its supervisors and operators to a recognised certification scheme based on ISO 9712:2021.

2.3.2 Personnel qualification to an employer based qualification scheme as e.g. SNT-TC-1A, 2020 or ANSI/ASNT CP-189, 2020 may be accepted if the NDT Service Supplier's written practice is reviewed and found acceptable by the Society. The NDT Service Supplier's written practice shall as a minimum, except for the impartiality requirements of a certification body and/or authorised body, generally comply with the requirements of ISO 9712:2021.

For NDT operators holding certificates issued via an employer based scheme, the employer's certification shall be deemed revoked when employment is terminated by either party.

2.3.3 The supervisors' and operators' certificates and competence shall comprise all industrial and product sectors and techniques being applied by the NDT Service Supplier.

2.3.4 Level 3 personnel shall be certified by one of the following means:
(1) obtain certification from an accredited certification body.
(2) obtain certification from an employer based scheme via the examination method, as detailed in the written practice. It is not permissible to directly appoint a level 3 without examination if the intended certification route is from an employer based scheme.

2.4 Supervisor

The NDT Service Supplier shall have a supervisor or supervisors, responsible for the following:
(1) validate NDT instructions and procedures established and reviewed by level 3 personnel;
(2) review of NDT reporting;
(3) supervise all tasks and NDT operations at all levels;
(4) inspection of NDT equipment, tools and calibration;
(5) re-evaluate the qualification of the operators annually on behalf of the NDT Service Supplier.

Normally, the NDT Service Supplier shall employ (on a full-time basis) a level 3 supervisor, certified to level 3 in the applicable method(s) as per the requirements of this Appendix.

It is recognised that an NDT Service Supplier may not directly employ a Level 3 in all the stated methods practiced. In such cases, it is permissible to employ an external Level 3 who is certified by an accredited certification body in those methods not held by the full-time Level 3(s) of the NDT Service Supplier.

Alternatively, and by agreement with CCS, the NDT Service Supplier may appoint an internal (full-time employed) supervisor of NDT activities, who does not hold level 3 certification. In this case, the supervisor shall be certified to a minimum of level 2. For NDT Service Suppliers operating this alternative approach, the NDT Service Supplier shall comply with all other requirements of this Appendix and shall employ (either part time or on a contract basis) Level 3 NDT Services (to carry out functions such as procedure development, procedure approval, consultancy, review etc.) from outside the NDT Service Supplier organisation. The appointed external level 3 shall be certified by an accredited certification body in all the applicable methods appropriate to the scope of the NDT operations.

2.5 Operators

2.5.1 The operator carrying out the NDT and interpreting indications, shall as a minimum, be qualified and certified to Level 2 in the NDT method(s) concerned and as described in item 2.3. However, operators

only undertaking the gathering of data using any NDT method and not performing data interpretation or data analysis may be qualified and certified as appropriate, at level 1.

2.5.2 The operator shall have adequate knowledge of materials, weld, structures or components, NDT equipment and limitations that are sufficient to apply the relevant NDT method for each application appropriately.

2.6 Equipment

2.6.1 The NDT Service Supplier shall maintain records of the NDT equipment used and detail information related to maintenance, calibration and verification activities. If the NDT Service Supplier hires equipment, such equipment shall have updated calibration records, and the operators shall be familiar with the specific equipment type prior to using it. Under any circumstance, the NDT Service Supplier shall possess sufficient equipment to carry out the services being a part of the NDT scope required by CCS.

2.6.2 Where the equipment is of unique nature, the NDT operators shall be trained by competent personnel in the operation and use of the equipment before carrying out NDT using this equipment.

2.7 Work instructions and procedures

The NDT Service Supplier shall produce written procedures for the NDT being applied. These procedures are to be written, verified or approved by the NDT Service Supplier's Level 3(either internal, or external, as described in section 2.4). Procedures shall define all relevant information relating to the inspection including defect evaluation against acceptance criteria in accordance with the Society Rules. All NDT procedures and instructions shall be properly documented in such a way that the performed testing can be easily retraced and/or repeated at a later stage. All NDT procedures are to be acceptable to CCS.

2.8 Sub-contractors

2.8.1 The NDT Service Supplier shall give information of agreements and arrangements if any part(s) of the services provided are subcontracted, included level 3 NDT Services (as described in section 2.4). The NDT Service Supplier, in the following-up of subcontracts shall give emphasis to the quality management system of the subcontractor.

2.8.2 Subcontractors shall meet the same requirements placed on NDT Service Suppliers for any NDT performed.

2.9 Reporting

2.9.1 All NDT shall be properly documented in such a way that the performed testing and examination can be easily retraced and/or repeated at a later stage. The reports shall identify the defects present in the tested area, and a conclusive statement as to whether the material, weld, component or structure satisfies the acceptance criteria or not.

2.9.2 The report shall include a reference to the applicable standard, NDT procedure and acceptance criteria applied in the applicable NDT method/technique. In general, the acceptance criteria shall comply with the Society Rules. Reports shall be signed by the personnel with the appropriate level of certification, and the appropriate signatory status as defined in the Quality Management System.

Appendix 24 REMOTE CLASSIFICATION SURVEYS

1 General

The survey of ships may utilize different methods and concepts. This Appendix contains principles and minimum requirements for carrying out remote surveys.

Remote survey will only be appropriate provided the level of assurance is not compromised, and the survey is carried out with the same effectiveness as and is equivalent to, a survey carried out with attendance on board by a Surveyor.

1.1 Application

These requirements apply to all vessels, self-propelled or not. These requirements are not mandatory for offshore units.

1.2 Definitions

1.2.1 Remote Survey

A "Remote Survey" is a process of verifying that a ship and its equipment are in compliance with the rules of the Classification Society where the verification is undertaken, or partially undertaken, without attendance on board by a surveyor.

1.2.2 Information and Communication Technology (ICT)

Information and Communication Technology (ICT) are the technologies used in the scope of remote surveys for gathering, storing, retrieving, processing, analysing, and transmitting information which includes both software and hardware

Notes:

1 'Attendance on board by a surveyor' means physical attendance on board the ship by a surveyor.

2 Remote classification activities not requiring a survey, such as some administrative tasks, are not to be considered as remote surveys.

3 An administrative task is a task where a survey decision is not being made, for example reissue of a certificate or record following a correction, or an update to the ship's records held by CCS or a document review.

2 Requirements for equivalency

The requirements for equivalency of a remote survey to a survey attended on board by a Surveyor include eligibility of the remote survey, qualification of Surveyors, planning of the remote survey, performance of the remote survey, assessment of the remote survey and reporting.

Equivalency is obtained when, with the use of available ICT, a surveyor can perform a survey remotely being able to:

- obtain the supporting and technical evidence required according to the applicable rules,
- verify applicable survey items and relevant tests,

and the results of the remote survey provide the same level of assurance obtained with attendance on board by a Surveyor.

2.1 Eligibility of the remote survey

2.1.1 Eligibility of the remote survey is to be decided based on type and scope of the requested survey, in accordance with 3.1 and, if applicable, flag State Administration acceptance and possible instructions, when the classification survey is also related to a statutory item, and CCS is carrying out the statutory survey on behalf of the flag State Administration.

2.1.2 A remote survey is deemed eligible when it provides the same level of assurance, according to the requirements for equivalency, as if it was conducted with attendance on board by a Surveyor.

2.1.3 Remote surveys are generally to be carried out with internet connection allowing a live streaming visual examination, although, at the discretion of the Surveyor, a combination of remote survey methods (see 2.4) may be used. For simple/limited verifications, other types of ICT may be accepted by the Surveyor.

2.2 Qualification and monitoring of Surveyors

2.2.1 Qualification

2.2.1.1 Surveyors engaged in remote surveys are to be qualified as per standard procedures for the type of ship and type of survey, i.e., in accordance with IMO RO Code (MSC.349(92)), IACS Procedural Requirement PR 7, and CCS training and qualification scheme.

2.2.1.2 Additional training is to be carried out, covering the ICT used for the remote survey, in relation to the applicable remote survey scope and methods, in order to fully qualify the Surveyor engaged in remote surveys.
2.2.1.3 The additional training required for qualification for remote surveys shall be in accordance with CCS procedures and shall provide:
(1) knowledge of the operation of CCS remote survey software, if applicable;
(2) knowledge of the technical and procedural aspects related to remote surveys;
(3) knowledge of the connectivity aspects related to remote survey.
2.2.2 Monitoring
2.2.2.1 The monitoring of a Surveyor qualified for remote surveys is to be carried out in accordance with IACS Procedural Requirement PR 6.
2.2.3 Surveyor's Record
2.2.3.1 Records of Surveyor's training and qualification for remote surveys shall be maintained and updated as per CCS standard procedures.
Notes:
1 CCS personnel engaged in remote classification activities not requiring a survey (refer to 1.2.1) are to be trained and qualified according to CCS standard procedures.
2 On board personnel/Crew:
- Training and qualification of on board personnel/Crew are regulated by the STCW Convention and is a prerogative of the flag State Administration.
- The ship's flag State Administration may require that the Safety Management System of the ship is updated by the Company to include provisions for specific training of the crew engaged in remote surveys.

2.3 Planning of the remote survey
2.3.1 Planning of the remote survey is required to ensure that the remote survey is carried out in accordance with the applicable requirements. The content of the planning shall be based on the scope of the remote survey
2.3.2 To ensure that the Surveyor can properly plan the remote survey and communicate with personnel/crew, so that the survey is carried out according to the applicable rules, adequate means are to be available enabling the Surveyor and allowing CCS to:
- properly interact with personnel/crew involved in the remote survey, before and during the survey process;
- agree on ICT means to be used;
- verify that personnel/crew involved in the remote survey are suitably skilled to use the electronic devices and/or software used by the Society to perform the remote survey;
- acquire as deemed necessary information on identity and ranking of personnel/crew involved in the remote survey;
- provide the survey item/scope to the personnel/crew involved in facilitating the remote surveys, including the tests that will be performed;
- communicate, during the remote survey, additional actions depending on the evidence to be collected.
2.3.3 One or more of the following means is to be provided for planning the remote survey:
- live-streaming video and audio connection;
- exchange of data / electronic documents;
- other means acceptable to CCS.
2.3.4 The owner is to provide the necessary facilities for the safe execution of the survey.

2.4 Performance of the remote survey
2.4.1 To ensure that the Surveyor can properly perform the remote survey according to the applicable rules, the available evidence must allow the attending surveyor to:
- examine and assess a survey item and/or a group of items and/or supporting documents;
- verify and assess applicable tests and/or services.
2.4.2 The evidence provided to the Surveyor is subject to the technical evaluation and final acceptance by the Surveyor with respect to the completeness and accuracy, necessary to perform the requested survey according to the applicable requirements.
2.4.3 One or more of the following evidence is to be provided for performing the remote survey:
- live-streaming video and audio;
- recorded videos provided by the Owner's representative;
- photos provided by the Owner's representative;
- other data and/or supporting documents acceptable to CCS.

2.5 Assessment of the remote survey

2.5.1 The Surveyor shall evaluate all evidence received and accept them before crediting the remote survey.

2.5.2 The means used for the remote survey must allow the Surveyor to collect the necessary evidence that will be examined according to the Surveyor's professional judgement in order to satisfactorily complete and credit the relevant survey items.

2.5.3 In case the Surveyor, according to their professional judgement, deems that the remote survey does not provide the same level of assurance as a survey with attendance on board by a Surveyor, the Surveyor may decide not to credit the relevant survey items.

3 Scope and procedures

A remote survey will be only appropriate provided it reaches the same level of assurance as, and is equivalent to, a survey attended on board by a Surveyor.

3.1 Scope - Eligible survey items

3.1.1 A remote survey may be proposed as an alternative to a survey attended on board by a Surveyor for the surveys listed in Table 1.

3.1.2 When the classification survey is also related to a statutory item, and CCS is carrying out the statutory survey on behalf of the flag State Administration, then the flag State Administration acceptance is required, and possible additional requirements are to be complied with.

3.1.3 The Surveyor may require to confirm the results of the remote survey, by a survey attended on board by a Surveyor, to credit the relevant survey items, in case the remote survey is not carried out to the Surveyor's satisfaction or it is required by CCS.

Table 1: Eligible remote survey items

No.	Surveys and related items eligible to remote survey	Live streaming required (See Notes)
1	Postponement, issuance, deletion of Condition of Class	X (1)
2	Postponement of Class surveys	X (1)
3	Items of Continuous Survey for Machinery (UR Z18) or Planned Maintenance Scheme (UR Z20, PMS)	X (1)
4	Occasional survey for change of ship's name	X (1)
5	Occasional survey for loss of anchor	X (1)
6	Occasional survey for minor machinery or equipment damage	X (1)
7	Occasional survey for minor hull damage	X (1)
8	Occasional survey for minor deficiencies/defects not subject to a Condition of Class	X (1)
9	In-water bottom survey	X
10	Specified items of a class periodical survey (excluding additional specific items of initial or renewal surveys), including completion of remaining items of a part held class periodical survey	X (1)(2)
11	Non-propelled / un-manned barges/pontoon – annual surveys when no survey of hull compartments is due	X
12	Minor retrofit / installation/upgrade of equipment	X (1)
13	Documentary or data based initial / periodical / renewal / occasional verifications and surveys	

Notes:

1 "(1)" means that live streaming may not be required for minor survey scope or that a combination remote survey method, as listed in 2.4, may be used at the sole discretion of CCS.

2 (2)" means that pure documentary verifications are eligible in accordance with item 13.

3 Live streaming may be required for surveys not marked X in the Table, depending on the survey scope at the sole discretion of CCS.

4 "Minor" in the items 6, 7, 8 and 12 means that the item can be surveyed remotely according to requirements for equivalency given in 2

3.2 Procedures

3.2.1 Eligibility: Refer to 2.1.

3.2.2 Digital information quality, completeness, and accuracy

3.2.2.1 Final appraisal of the quality of digital information is at the discretion of the Surveyor, who is to be satisfied with the content and the quality of digital information collected, and the survey carried out, allowing the Surveyor to confirm its completion.

3.2.2.2 The Owner is responsible for the completeness and accuracy of digital information provided. The

digital information submitted by the Owner to the Surveyor is to reflect the real situation of the surveyed item. The date and time, when a photo or video was taken are to be made available to the Surveyor or identifiable from its metadata.
3.2.2.3 CCS is to collect and store digital information as evidence of the survey. It is not necessary to store all of digital information received; the exact digital information stored shall support the survey decision and is to be decided by the Surveyor crediting the survey.
3.2.2.4 The remote survey is carried out under the supervision and upon instructions of the Surveyor, who is in charge of crediting the remote surveys. A surveyor attendance on board may be required to complete the survey, upon the Surveyor's request and at their discretion.
3.2.3 Requirements for a remote survey when live streaming is not used
3.2.3.1 When live streaming is not used, communication and digital information collection are to be performed through an ICT channels (such as emails, data streams and clouds), which is to be accepted by CCS prior to the survey.
3.2.3.2 The Owner’s representative is to confirm the identity of the ship at the commencement of the survey.
3.2.4 Requirements for a remote survey when live streaming is used
3.2.4.1 The Owner’s is to ensure that:
- the Owner’s representative is attending onboard and has access to the areas intended to be surveyed;
- the Owner’s representative has at his disposal a 2-ways visual and audible communication means complying with the requirements in 4;
- ICT solution is available on the communication means and meets the requirement described in 4.
In the case these requirements cannot be fulfilled, the remote survey may be rejected. The Surveyor is to verify the identity of the ship at the commencement of the survey by live streaming.

3.3 Hardware and ICT solution
Refer to 4.1.

3.4 Requirements for Connectivity
3.4.1 The Owner’s representative is to ensure that internet connectivity tests are carried out before the survey and that proper connectivity is available and maintained during the survey.
3.4.2 When remote survey by live streaming is being undertaken, a connection that enables live streaming between the Surveyor and the Owner’s representative attending on board is required. The quality of the live streaming connection (audio and video) is to ensure proper communication and to allow the Surveyor to carry out the survey remotely, to the Surveyor's satisfaction. In the case where a live streaming connection with the Surveyor is not possible or is not continuous at the place of the survey (e.g., Engine Room), partly online sequences (where the Owner is able to capture pictures and videos offline of those items not covered by live streaming) may be accepted by the Surveyor.

4 Information and Communication Technology (ICT)
This section outlines the minimum requirements for the use of ICT that can capture images, record video and/or live stream video or other data from a ship as considered acceptable to CCS.

4.1 Hardware
4.1.1 The Owner is responsible for ensuring that all hardware installations on board used for the remote survey shall comply with the applicable requirements relevant for use and location on board, including hazardous areas. The ICT shall typically consist of:
- A host computer device, to receive the streaming of images/data/video. This is usually a laptop or desktop computer compatible with the software application used for the remote survey;
- On board standalone device which may include digital cameras capable of capturing videos/photos/data;
- On board smart device compatible with the applicable software/technology;
- Communication accessories like headphones and microphone for the noisy environment as applicable and as deemed necessary.

Notes: The smart device may be a smartphone, tablet, computer, wearable device, smart glass, digital camera, or any other device which can be connected to the network and capable of transmitting the necessary data/images to shore.

4.1.2 The communication equipment used for the live streaming shall have the following minimum functionality:
- both ends shall simultaneously see the same image/videos in near real-time (i.e., live streaming);
- two-way direct voice communication;

- possibility to take screenshots.

4.1.3 When using a portable device on board for live streaming, the movement of the handheld device may affect the stability of the video and the image, leading to lower quality outputs. When necessary, a suitable anti-shake device shall be used to provide proper stability.

Notes:

1 The host computer screen is to be able to present an image quality that is sufficient to enable a survey decision to be made.

2 Portable equipment on board shall be equipped with a power capacity suitable for the intended scope and time of the survey.

4.2 Internet Connectivity (coverage and speed)

4.2.1 For internet connectivity requirements on board, refer to 3.4.

4.2.2 The on board smart devices shall have the capability of transmitting the images/video/data over a Cellular, Wi-Fi or Satellite Connection to the remote Surveyor.

4.2.3 When live streaming communication is applied, the internet connection shall have sufficient and stable bandwidth capacity to ensure quality (such as resolution and frame rate) of the direct colour image/video and voice communication to the remote survey location to the satisfaction of the Surveyor.

4.3 Software and data security:

4.3.1 The software used for the remote survey is to be acceptable to CCS. The overall function and ability of the software used to ensure the security of data shall be evaluated prior to use as per the below requirements.

4.3.1.1 The Surveyor shall normally control the live video call, providing instructions to the on-site personnel/crew and supervising survey activities for capturing relevant information. The on board device shall have the capability of transmitting the data over a Cellular, Wi-Fi, or Satellite Connection to the Surveyor.

4.3.1.2 The software used to perform the remote survey may also be provided with technologies that support the Surveyor in the process of making a decision, such as:

- Artificial Intelligence (AI) for the recognition and the classification of defects,
- Internet of things (IoT) for collecting parameters and evaluating acceptability/working condition of machinery and equipment,
- Data driven verification or other means considered acceptable by CCS.

4.3.1.3 The above software and technologies are to be evaluated and accepted by CCS in each case.

4.3.2 When considering the use of software/applications and other technologies, data protection shall be considered in accordance with applicable requirements of CCS before the remote survey is commenced. The software/application used to perform the remote survey is to be compatible with the technical requirements detailed in this paragraph; in addition, the software used is to comply with CCS applicable requirements for:

- cybersecurity;
- data protection and confidentiality for the transmitted data.

4.3.3 When not provided by CCS itself, the audio/video software or application used to perform the remote survey is to be accepted by CCS.

4.3.4 During the survey preparation, it is the Owner’s responsibility to ensure that their data security policies are implemented as per the Company's Safety Management System.

Notes: The Company’s SMS may take into account IMO resolution MSC.428(98), MSC-FAL.1/Circ.3 and IACS Rec.166.

5 Recording of evidence and reporting of survey

5.1 Recording of Evidence

5.1.1 Required evidence (refer to 2.4)

In principle, live streaming video and audio shall be applied to remote surveys as a primary means (refer to Table 1 in 3.1). Additionally, and/or alternatively, one or more of the following evidence may be submitted or verified as requested by the Surveyor during remote survey so that the Surveyor is able to verify conditions of survey items:

- Recorded video and audio;
- Photos;
- Master's/chief engineer's statement;
- Ship's logbook;
- Owner’s confirmation.

5.1.1.1 Live streaming video and audio: Live streaming video and audio using ICT shall be in accordance with the requirements in 4.

5.1.1.2 Recorded videos/photos

For the recorded videos/photos, the following information is to be available:

- confirmation that they were actually taken on the ship by the Owner’s representative;
- date and time when they were taken;
- identity of the personnel/crew responsible for taking evidence.

5.1.1.3 Master's/chief engineer's statement

Recorded videos/photos provided by the Owner’s representative may be supplemented with a statement signed by the master and/or the chief engineer confirming the condition of the items shown in the evidence. The final evaluation of the remote survey by the Surveyor is to be based on all of the provided evidence, and it does not delegate the responsibility to the master/chief engineer’s statement only.

5.1.1.4 Ship's logbook

The Master shall make entries into ship's logbook on the following occasions and submit copies of the relevant pages when requested by the Surveyor:

- when a remote survey is carried out by the Surveyor;
- when videos/photos are taken and submitted to the Surveyor with the master's/chief engineer's statement and additional documents as applicable.

5.1.1.5 Owner’s confirmation

The Owner’s representative or the master is to confirm the correctness and completeness of the provided information and evidence (if any) relevant to the condition of the items requested to be surveyed. This confirmation may be included in the survey application.

5.1.2 Retaining/filing evidence

5.1.2.1 The evidence submitted by the Owner’s representative or master shall be retained/filed in accordance with CCS procedures which shall include:

- type of evidence to be retained/filed;
- duration/location to be retained/filed.

5.1.2.2 It is not required for CCS to record and save live streaming video and audio as evidence unless the Surveyor considers it necessary.

5.1.3 Other supporting documents

5.1.3.1 The Surveyor may request the Owner’s representative or master to submit supplementary documents such as ship's maintenance reports and record for the operation of machinery, and equipment and service reports issued by manufacturers, service suppliers or service providers.

5.1.3.2 While the Surveyor shall verify that the documents are duly prepared and issued to the ship, they may not be required to be retained/filed by CCS as evidence.

5.2 Reporting of remote survey

5.2.1 The report of a remote survey shall be issued in accordance with CCS procedure. The survey report shall also include the following additional information:

- indication that the survey was carried out remotely;
- description of the means used during the remote survey;
- indication of the provided evidence;
- confirmation of the flag State Administration’s authorization, when applicable.

CHAPTER 6 SURVEYS RELATED TO CLASS NOTATIONS

Section 1 GENERAL PROVISIONS

6.1.1 General requirements

6.1.1.1 The purpose of this Chapter is to give details on the scope of surveys related to class notations assigned to ships for special duties, special equipment, machinery and environmental protection. The scope of these surveys covers specific requirements to be complied with for the maintenance of the relevant additional class notations.

6.1.1.2 These specific requirements are additional to those laid down for surveys of all ships in Chapter 5 of this PART. These surveys may be carried out concurrently with the surveys of the same type, i.e. the annual, intermediate or special survey.

6.1.2 Class notations subject to additional surveys

6.1.2.1 The specific requirements detailed in this Chapter are linked to the class notation(s) assigned to the ship. Where a ship has more than one class notation, the specific requirements linked to each class notation are applicable.

6.1.2.2 The owner is to promptly notify CCS of any change, damage or failure of the equipment and systems having a class notation that affects the maintenance of the notation, and apply for an occasional survey.

Section 2 SURVEYS RELATED TO CLASS NOTATIONS FOR SPECIAL DUTIES

6.2.1 General requirements

6.2.1.1 The general requirements for surveys during and after construction as specified respectively in Chapters 4, 5 of this PART and in addition, the relevant survey requirements specified in this Section are to be complied with.

6.2.2 Fire-fighting ships

6.2.2.1 General requirements

(1) This paragraph applies to fire-fighting ships having one of the following class notations:

① Fire-fighting ships of Grade 1: Fire Fighting Ship 1;

② Fire-fighting ships of Grade 2: Fire Fighting Ship 2;

③ Fire-fighting ships of Grade 3: Fire Fighting Ship 3.

6.2.2.2 Initial classification

(1) A ship applying for one of the class notations for fire-fighting ships is to submit, above all, the plans and documents required by 1.1.3 of Chapter 1, PART EIGHT of the Rules.

(2) During survey of a fire-fighting ship under construction, hull, stability, propulsion machinery, equipment, fire protection and fire-fighting systems, electrical installations are to be inspected, and all installed devices and equipment are to be tested in working condition for confirming compliance with Chapter 1, PART EIGHT of the Rules.

6.2.2.3 Annual surveys

(1) Fire protection of ship:

① overall examination of the arrangement of structural fire protection;

② pipelines and nozzles of water spray systems are to be tested with compressed air for unimpeded passage, and pipelines and operating valves externally examined.

(2) Water monitor system:

① external examination of pipelines, valves, fire pumps, etc. of the system;

② examination of the system for normal working;

③ examination of seating arrangements and manual control of monitors.

(3) Fixed foam monitor system:

① The foam concentrate tank is to be examined externally and no serious corrosion or rotting-out is allowed; the level of the tank is to be checked, and stored foam concentrate is also to be examined.

Control valves are to be tested operationally, all foam generators and distribution pipelines are to be tested for unimpeded water flow and no blockage of any pipeline, nozzle or foam generator is allowed.

② The foam containers of mobile fire-fighting equipment provided on fire-fighting ships of Grades 2, 3 are to be examined externally, and pipelines, nozzles and foam generators are to be tested for unimpeded passage.

6.2.2.4 Intermediate surveys

The requirements for intermediate surveys are the same as those for annual surveys.

6.2.2.5 Special surveys

(1) The special survey is to be carried out in accordance with 6.2.2.3 above and in addition, to cover the following:

① an appropriate nozzle of the water spray system is to be selected for effectiveness test;

② an effectiveness test of the water monitor system is to be performed, and the minimum range of monitors is to be as required by Table 1.1.1.3 of Chapter 1, PART EIGHT of the Rules;

③ random check of foam concentrate of the fixed foam monitor system and the mobile fire-fighting equipment.

6.2.3 Oil recovery ships

6.2.3.1 General requirements

(1) This paragraph applies to oil recovery ships having one of the following class notations:

① Oil Recovery Ship with Cargo Tank;

② Oil Recovery Ship without Cargo Tank;

③ Oil Recovery Ship not suitable for products with a flash point of 60℃ and less.

(2) The following documents are to be available on board:

① operating manual;

② overhaul records for gas detection and alarm system.

6.2.3.2 Initial classification

(1) Submission of plans and documents

① For any newbuilding, the classification survey of which is intended, the plans and documents specified in Chapter 3 of PART EIGHT are to be submitted to CCS for approval.

② For any oil recovery ship constructed not under the supervision of CCS, the classification survey of which is intended, the plans and documents listed in Chapter 3 of PART EIGHT are to be submitted in addition to those required by Section 14 of Chapter 5 of this PART.

(2) Survey

① Upon completion of construction of the ship, operation test and simulated operation of the oil recovery equipment are to be carried out.

② Operation test of the oil recovery equipment is to be carried out during the initial classification of existing ships.

6.2.3.3 Annual surveys

(1) Checking the recovered oil transfer system, and checking ballast systems and bilge systems etc. in hazardous areas; confirming that they are in effective condition.

(2) Checking the venting system of recovered oil tanks and other ventilation systems in the hazardous area; confirming that they are in effective condition.

(3) Confirming that air lock (if fitted) is in effective condition.

(4) Confirming that the gas detection and alarm system and the portable gas detection equipment are in effective condition.

(5) Confirming that no potential sources of ignition are present in or near the recovered oil transfer pump room and that access ladders are in good condition.

(6) Examination of bulkheads of the recovered oil transfer pump room for signs of leakage or fractures, and in particular, the sealing arrangements of all penetrations in these bulkheads.

(7) Confirming that installed pressure gauges on recovered oil transfer piping and level indicator systems of recovered oil tanks are operational.

(8) Examination, so far as practicable, of pumps in the recovered oil transfer pump room for excessive gland seal leakage; verification of proper operation of electrical and mechanical remote operating and shutdown devices.

(9) Examination of the fixed fire-fighting system for the recovered oil transfer pump room, and confirming, as far as practicable and when appropriate, the operation of the remote means for closing the various

openings.
(10) Overall survey of recovered oil tanks. Where the tank is adjacent to the engine room, the bulkhead is to be subjected to a close-up survey to confirm that there are no signs of leakage or fractures.
6.2.3.4 Intermediate surveys
(1) The items specified for annual surveys.
(2) Effectiveness test as required by the Surveyor if deemed necessary.
(3) Where a tank adjacent to the engine room is intended for the storage of recovered oil, the tank is subject to pressure test.
(4) For weather decks, an examination as far as applicable of recovered oil transfer, bunker, ballast, steam and vent piping systems is to be carried out. If upon examination there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, thickness measured or both.
6.2.3.5 Special surveys
(1) The special survey is to cover the items specified for intermediate surveys.
(2) The recovered oil transfer system, and ballast systems and bilge systems etc. in hazardous areas are to be operationally tested to working pressure, confirming that their tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in oil recovery tanks and recovered oil transfer piping in ballast tanks and void spaces.

6.2.4 Pusher tug-barge combinations

6.2.4.1 General requirements
(1) This paragraph applies to pusher tug-barge combinations having one of the following class notations:
① Rigidly connected pusher tug-barge combination:
Pusher tug: Rigid Connection PB Combination – Pusher;
Barge: Rigid Connection PB Combination – Barge.
② Pusher tug-barge combination connected in articulated manner:
Pusher tug: Articulated Connection PB Combination – Pusher;
Barge: Articulated Connection PB Combination – Barge.
(2) The surveys of the pusher tug and barge in a combination, carried out respectively as for a single ship, are to comply with the requirements in this Chapter for the same ship type.
6.2.4.2 Initial classification
(1) For any pusher tug-barge combination, the initial classification survey of which is intended, the plans and documents specified in Chapter 7 of PART EIGHT are to be submitted to CCS for approval.
(2) 6.2.4.1(2) is to be complied with and in addition, the connector including associated equipment and control system are to be examined and tested after they are installed.
6.2.4.3 Annual surveys
(1) The connector including associated equipment and control system are to be examined to confirm that they are in an effective condition;
(2) The hull structural condition in the periphery of the connector is to be confirmed.
6.2.4.4 Intermediate surveys
The requirements for intermediate surveys are the same as those for annual surveys.
6.2.4.5 Special surveys
The special survey is to include the requirements of 6.2.4.3 and in addition, the following:
(1) The connector including associated equipment and control system are to be examined and tested to confirm that they are in an effective condition.
(2) Confirming corrosion, deformation and damage of the hull structural condition in the periphery of the connector.

6.2.5 Petroleum asphalt carriers

6.2.5.1 General requirements
(1) This paragraph applies to petroleum asphalt carriers having one of the following class notations:
① Petroleum asphalt carriers fitted with independent tanks:
Asphalt Carrier (Independent tank, Max. cargo temperature ≤ ××× ℃)[①], F. P.>60℃;
② Petroleum asphalt carriers fitted with integral tanks:
Asphalt Carrier (Integral tank, Max. cargo temperature ≤ ××× ℃)[①], F. P.>60℃, ESP.
(2) Any petroleum asphalt carrier intended to be classed is to be surveyed in accordance with the relevant requirements of Chapters 4, 5 of this PART and this Chapter.

---

① ×××℃ in the notation represents highest design temperature for cargo.

(3) When the survey is carried out according to the relevant requirements of the Rules, the inside surface of cargo tanks (including independent tanks and integral tanks) dedicated in carrying petroleum asphalt need not be inspected.

6.2.5.2 Initial classification of newbuildings

(1) For any newbuilding, plans and documents are to be submitted for approval and/or examination in accordance with Chapter 10 of PART EIGHT of the Rules.

(2) The hull under construction is to be surveyed and tested in accordance with Chapter 4 of this Part. For the welding and tightness test of independent tanks, the requirements for deep tanks may be referred to. Tightness test method may be determined depending on the design mode of the independent tank, and tightness test of the independent tank is to be completed prior to laying the heat-insulating material.

(3) In construction of an asphalt carrier fitted with independent tanks, if the main deck is large opened, measures to prevent hull deformation are to be taken by the shipyard.

(4) The arrangement of supporting means of the independent cargo tank is to be inspected.

(5) The arrangement of longitudinal and transverse limiting devices of the independent tank is to be inspected.

(6) The installation of anti-flotation arrangements of the independent tank is to be inspected.

(7) The laying of heat-insulating material on the independent tank and thermal oil pipeline is to be inspected.

(8) The installation positions of monitoring alarms and sensors related to liquid cargo are to be inspected for compliance with the requirements of approved drawings. The connecting cables of sensors in cargo tanks are not to contact with liquid cargo.

(9) Effectiveness test may be carried out for monitoring alarms related to liquid cargo by means of simulation.

(10) Effectiveness test is to be carried out to bilge well high-level alarm in hold space.

(11) Survey and test are to be carried out for installation of thermal oil boiler (or thermal oil heater) and automated part therein.

6.2.5.3 Initial classification of existing ships

(1) Converted asphalt carriers are to be subject to an initial classification survey according to the requirements of 6.2.5.2 of this Chapter, in addition to the survey as required by Section 15, Chapter 5 of this PART.

(2) Existing asphalt carriers constructed not under the supervision of CCS are to be surveyed according to the relevant requirements of Section 14, Chapter 5 of this PART and in addition:

① evaluated according to plans and documents submitted as required by 6.2.5.2(1) of this Chapter;

② surveyed according to the relevant requirements of 6.2.5.4 of this Chapter depending on the age of ships.

(3) For integral tank asphalt carriers converted from other ships and carrying asphalt with temperature over 180℃, thermal stress analysis data of hull structural members are to be submitted for check.

6.2.5.4 Annual surveys

(1) For asphalt carriers fitted with independent tanks, in addition to the applicable items as specified in 5.4.2 and 5.6.3 of Chapter 5 of this PART, the following items are to be inspected:

① checking the records of monitoring alarm related to liquid cargo;

② checking the monitoring records of bilge well high-level alarm in hold space.

(2) For asphalt carriers fitted with integral tanks, in addition to the applicable items as specified for oil tankers in Chapter 5 of this PART, the item of 6.2.5.4(1)① is to be included.

6.2.5.5 Intermediate surveys

(1) For asphalt carriers fitted with independent tanks, in addition to the applicable items as specified in 6.2.5.4(1) of this Chapter, the following items are to be inspected:

① a number of monitoring points, as small as practicable, is to be selected for various monitoring alarms related to liquid cargo and tested by means of simulation for effectiveness;

② bilge well high-level alarm in hold space is to be tested for effectiveness.

(2) For asphalt carriers fitted with integral tanks, in addition to the applicable items as specified for oil tankers in Section 6, Chapter 5 of this PART, the items of 6.2.5.4(1)① and 6.2.5.5(1)① above are to be included.

6.2.5.6 Special surveys

(1) For asphalt carriers fitted with independent tanks, in addition to the applicable items as specified in 6.2.5.5(1) of this Chapter, the following items are to be inspected:

① examining the locating devices of the independent tank and adjacent components;

② confirming that heat-insulating material of the independent tank is in good condition;

③ confirming that anti-flotation arrangements of the independent tank are in good condition.

(2) For asphalt carriers fitted with integral tanks, in addition to the applicable items as specified for oil tankers in Section 6, Chapter 5 of this PART, the items of 6.2.5.4(1)① and 6.2.5.5(1)① above are to be included.

6.2.6 DP notation

6.2.6.1 General requirements

(1) This paragraph applies to ships which have been assigned one of the following class notations related to dynamic positioning systems:

① DP – 1;

② DP – 2;

③ DP – 3.

6.2.6.2 Initial classification

(1) For a ship intended for the notation DP, the plans and documents required by 11.1.4 of Chapter 11, PART EIGHT of the Rules are to be submitted for approval.

(2) The survey of the ship during construction is to include examinations and tests of the following items:

① The control system of DP system and relevant reference system are to be subjected to type approval in accordance with Chapter 3 of this PART to demonstrate that they are in compliance with the requirements of Chapter 11, PART EIGHT of the Rules, suitable for the environmental conditions at sea and issued a Marine Products Certificate, including the following systems:

a. dynamic positioning control system (including computer system);
b. an independent joystick system with automatic heading control;
c. positioning reference system.

② Checking Marine Products Certificates of relevant equipment.

③ Confirming that the equipment and arrangement of DP system is in compliance with the approved plans and Chapter 11, PART EIGHT of the Rules.

④ All sensors, peripheral equipment and reference systems are to be tested before the test of the whole DP system. Alarm system and logical conversion are to be calibrated by simulating the failure of sensors.

⑤ The following tests are to be carried out to thrusters:

a. function test to control and alarm systems of each thruster;
b. test of signal exchanges between each thruster and DP system computer;
c. test of different control methods of the thruster.

⑥ Test is to be carried out to the capacity of the UPS batteries.

⑦ Test is to be carried out to all functions of the independent joystick system.

⑧ The following tests are to be carried out to the whole set of DP system:

a. test to system functions in all operational modes;
b. test to conversion method, back-up system and alarm system;
c. positioning is to be performed on all possible combinations of position reference systems (PRSs), and on each PRS as a single system. Selecting and de-selecting of PRSs are also to be tested;
d. test to manual override function under normal operation and failure conditions;
e. continuous site test for at least 6 to 8 hours to the whole set of automatic system and any failure occurred is to be recorded and analyzed;
f. the whole DP system is to be tested for at least 2 hours under specified environmental conditions. Weather conditions are to be such as to make the average thruster load level reach 50% or higher. Where the environmental conditions can not satisfy such requirement, the test may be carried out as a special test later on an appropriate occasion.

⑨ For steering gears included under DP-control, a test is to be carried out to verify that maximum design temperature of actuator and all other steering gear components is not exceeded when the rudder is continuously put over from border to border within the limits set by the DP-control system, until temperature is stabilized.

⑩ For class notations DP-2 and DP-3, FMEA test is to be carried out in accordance with approved FMEA test procedures. The FMEA test is to be based on the simulation of failures and is to be performed under as realistic conditions as practicable.

6.2.6.3 Annual surveys

(1) The apparatus such as generator and thruster system related to DP system are to be surveyed in accordance with the requirements of the main class.

(2) It is to be confirmed that the DP system has been normally maintained in good working order.

6.2.6.4 Special surveys

(1) The following tests are to be carried out to thrusters:

① function test to control and alarm systems of each thruster;

② test of signal exchanges between each thruster and DP system computer;

③ test of different control methods of the thruster.

(2) Test is to be carried out to all functions of the independent joystick system:

① tests to conversion method, back-up system and alarm system with all operation modes and in various simulated failure conditions;

② test to manual override function under normal operation and failure conditions;

③ continuous site test for at least 6 to 8 hours to the whole set of automatic system and any failure occurred is to be recorded and analyzed;

④ the whole DP system is to be tested for at least 2 hours under specified environmental conditions. Weather conditions are to be such as to make the average thruster load level reach 50% or higher. Where the environmental conditions can not satisfy such requirement, the test may be carried out as a special test later on an appropriate occasion.

(3) The following tests are to be carried out to the whole set of DP system:

① test to system functions in all operational modes;

② test to conversion method, back-up system and alarm system;

③ positioning is to be performed on all possible combinations of position reference systems (PRSs), and on each PRS as a single system. Selecting and de-selecting of PRSs are also to be tested;

④ test to manual override function under normal operation and failure conditions;

⑤ continuous site test for at least 6 to 8 hours to the whole set of automatic system and any failure occurred is to be recorded and analyzed.

6.2.6.5 Survey to alteration of DP system

(1) Where a major alteration is made to the hardware or software of the DP system (i.e. adding a position reference system, installing more or different thruster(s) or adding a different control method, changes in power system, structural changes etc.), the owner or the entrusted shipyard is to advise CCS in a timely manner. CCS will consider the need for a re-survey or test.

Section 3 SURVEYS RELATED TO CLASS NOTATIONS FOR SPECIAL EQUIPMENT AND SYSTEM

6.3.1 Helicopter Facilities notation

6.3.1.1 Application

(1) This paragraph applies to ships which have been assigned the following class notation:

① Helicopter Facilities.

6.3.1.2 Initial classification

(1) For a ship intended for the notation Helicopter Facilities, the plans and documents required by 5.1.3 of PART SIX of the Rules are to be submitted for approval, and the operation manual with information on models and parameters of helicopters to be used (including maximum takeoff weight, diameter of rotor, size of wheel print and tracking width) is to be submitted for information.

(2) During survey of the ship under construction, compliance of the arrangement of helicopter deck, the securing arrangements of helicopter and the fire safety system with the rules and approved plans are to be confirmed.

6.3.1.3 Annual surveys

(1) Helicopter deck and its supporting structure, securing arrangements, safety net, visual aids, etc. are to be generally examined to confirm that they are in good working condition.

(2) Means of access for inspections, including means of escape, are to be in good condition, free from obstructions and clearly marked.

(3) Confirming so far as practicable that no substantial change has been made to the fireproof structure and arrangement of the helicopter deck; fire-fighting appliances are to be examined externally to confirm that they are in good working condition and so located as required.

(4) Drainage, refueling and oil storage facilities (including earthing, emergency shutdown devices and oil leakage response means) are to be examined generally to confirm that they are in good working condition.

(5) Mechanical ventilation systems of the enclosed hangar facilities and any enclosed space in which

refueling equipment is located are to be examined to confirm that they are in good working condition.

6.3.1.4 Intermediate surveys

(1) The scope of the intermediate survey is the same as that of the annual survey.

6.3.1.5 Special surveys

(1) In addition to the above requirements for the annual survey, the special survey is to include the following:

① examination of the helicopter deck to confirm the continuing effectiveness of structural integrity;

② effectiveness test of fire-fighting appliances;

③ examination and test of electrical installations and associated ventilation systems within refueling area;

④ examination and test of earthing, emergency shutdown devices of refueling and oil storage facilities.

6.3.2 Equipped with Container Securing Arrangements notation

6.3.2.1 Application

(1) This paragraph applies to ships which have been assigned the following class notation:

① Equipped with Container Securing Arrangements.

6.3.2.2 Initial classification

(1) For a ship intended for the notation Equipped with Container Securing Arrangement, the plans and documents required by 1.3 of Appendix 1 of Chapter 7, PART TWO of the Rules are to be submitted for approval.

(2) During survey of the ship under construction, an overall survey of the materials, workmanship and arrangement of securing devices is to be carried out to confirm their compliance with Appendix 1 of Chapter 7, PART TWO of the Rules and the approved plans.

6.3.2.3 Annual surveys

(1) Confirmation of the effectiveness of the securing manual, paying attention to the maintenance and renewal records for the portable securing arrangements specified in the manual and if necessary, checking such arrangements randomly.

(2) Container corner fittings welded to hull structure or hatch covers are to be examined for cracks and deformation.

(3) Cell guides and associated components are to be examined for cracks, deformation or corrosion.

6.3.2.4 Intermediate surveys

The requirements for intermediate surveys are the same as those for annual surveys.

6.3.2.5 Special surveys

(1) In addition to the above requirements for the annual survey, the special survey is to include the following:

① The container securing arrangements are to be surveyed as follows:

a. the cell guide structure is to be thoroughly examined and particular attention is to be given to the connections between vertical cell guides and the cross ties. The cell guides and their entry devices are to be verified for efficient condition;

b. portable frameworks or other forms of structural restraint are to be thoroughly examined;

c. Fittings attached to the hull structure are to be carefully examined and no leakage is allowed around fittings in way of tanks.

② Where any renewal is required, the new item is to be of approved type and manufacture. Where test certificates are not available, the item is to be tested in accordance with Appendix 1, Chapter 7 of PART TWO of the Rules.

6.3.3 CLC notation

6.3.3.1 General requirements

(1) This paragraph applies to ships which have been assigned one of the following class notations related to container securing:

① CLC: lashing calculation programme;

② CLC(V): securing of containers for specified voyage;

③ CLC(V,W): securing of containers for specified weather.

6.3.3.2 Initial classification

(1) In respect to the initial classification for assigning the notations CLC, CLC(V) and CLC (V,W), the programme approval, the plan approval and the actual installation survey are to be carried out in accordance with the relevant requirements of Appendix 1 of Chapter 7, PART TWO of the Rules.

6.3.3.3 Annual surveys

(1) The owner is to declare to the attending Surveyor that no major change unapproved by CCS has been made.
(2) The annual survey is to include:
① examination of ambient conditions and location of system installation;
② system function test of a selected approved condition;
③ inquiry into any change of main parameters of the ship, and the effect of any change on calculation results;
④ inquiry whether an operating manual together with a test report approved by CCS are kept on board.

6.3.3.4 Special surveys

(1) In addition to the above requirements for the annual survey, the special survey is to include the following:
① programme privacy test;
② programme stability test.
(2) The special survey is to be carried out in the presence of the CCS Surveyor.

6.3.4 Loading Computer notation

6.3.4.1 General requirements

(1) This paragraph applies to ships which have been assigned one of the following class notations related to loading computers:
Loading Computer, and special notations: S, I, G, D
where:
S: the loading computer may be used in calculation and check of hull strength in all loading conditions;
I: the loading computer may be used in calculation and check of intact stability;
G: the loading computer may be used in calculation and check of stability of grain carried in bulk;
D: the loading computer may be used in calculation and check of damage stability.

6.3.4.2 Initial classification

(1) In respect to the initial classification for assigning the notation Loading Computer, the software approval, the plan approval and survey related to hardware and the actual installation survey are to be carried out in accordance with the relevant requirements of Appendix 1 of Chapter 2, PART TWO of the Rules.

6.3.4.3 Annual surveys

(1) The owner is to declare to the attending Surveyor that no major change unapproved by CCS has been made.
(2) The annual survey is to include:
① examination of ambient conditions and location of system installation;
② system function test of a selected approved condition;
③ inquiry into any change of main parameters of the ship, and the effect of any change of hull structure, lightweight and its distribution on calculation results;
④ inquiry whether an operating manual together with a loading calculation and test report approved by CCS are kept on board.

6.3.4.4 Special surveys

(1) In addition to the above requirements for the annual survey, the special survey is to include the following:
① software privacy test;
② system stability test;
③ self-checking function test of hardware and peripheral equipment.
(2) The special survey is to be carried out in the presence of the CCS Surveyor.

6.3.5 HMS & HMS (×) notations

6.3.5.1 General requirements

(1) This paragraph applies to ships which have been assigned one of the following class notations for hull monitoring systems:
HMS and HMS (×)

6.3.5.2 Initial classification

(1) For a ship intended for the notation HMS or HMS (×), the plans and documents required by 21.1.3 of Chapter 21, PART EIGHT of the Rules are to be submitted for approval.

(2) Initial classification surveys are to include the survey and testing of following items:

① examination of the Type Approval Certificate of the hull monitoring system;

② confirmation that the arrangement of each sensor is in conformity with the approved plans;

③ confirmation that the instruction manual and the log for maintenance and calibration have been kept on board;

④ in the sea trials:

a. confirmation that the initial readings of the sensors comply with the still water loading condition specified in 21.2.2.14, Chapter 21, PART EIGHT of the Rules;

b. carrying out performance tests of system functions;

⑤ confirmation that the software version of the hull monitoring system is the same as that on the approval certificate.

6.3.5.3 Annual surveys

(1) Examination of the log for maintenance and calibration of the hull monitoring system.

(2) Verification of the proper operation of the hull monitoring system.

(3) External examination of each sensor and its protective measures so far as practicable.

6.3.5.4 Intermediate surveys

(1) The scope of the intermediate survey is the same as that of the annual survey.

6.3.5.5 Special surveys

(1) In addition to the requirements of annual surveys mentioned above, the watertightness of sensors installed externally is to be inspected.

6.3.6 BDE-1/BDE-2/BDE-3 notation

6.3.6.1 General requirements

(1) This paragraph applies to ships having the class notation BDE-1/BDE-2/BDE-3.

6.3.6.2 Initial classification

(1) For a ship intended for the notation BDE-1/BDE-2/BDE-3, the plans and documents required by 4.1.4 of Chapter 4, PART EIGHT of the Rules are to be submitted for approval.

(2) During survey of the ship under construction, compliance of the arrangement and visibility of navigation bridge and wheelhouse, required systems and equipment with the rules and approved plans is to be confirmed.

6.3.6.3 Annual surveys

(1) Confirming that the field of vision in the wheelhouse complies with the design requirements and has not been altered.

(2) Examining systems and equipment for normal operation.

6.3.6.4 Intermediate surveys

(1) The scope of the intermediate survey is the same as that of the annual survey.

6.3.6.5 Special surveys

(1) The scope of the special survey is the same as that of the annual survey.

Section 4 SURVEYS RELATED TO CLASS NOTATIONS FOR AUTOMATIC CONTROL

6.4.1 General requirements

6.4.1.1 The requirements of this Section apply to ships assigned the following class notations:

(1) AUT−0 — indicating that the ship's propulsion plant can be remotely controlled from the bridge control station with the machinery spaces (including engine room centralized control station or room) periodically unattended;

(2) MCC — indicating that the machinery and electrical installations are capable of being operated with continuous supervision by watch-keepers from a centralized control station or room in the engine room;

(3) BRC — indicating that the ship's propulsion plant can be remotely controlled from the bridge control station with the engine room attended by watch-keepers.

6.4.2 Initial classification

6.4.2.1 The following surveys are to be carried out with regard to the class notation AUT−0:

(1) functional tests of safety systems, overriding function and alarm indicators;
(2) functional tests of control systems of main engines, auxiliary engines, boilers, power stations and other equipment;
(3) functional tests of changeover between each control station;
(4) relay alarm function and communication function of the navigation bridge and the engineers' accommodation;
(5) functional tests of fixed fire-extinguishing, fire detection and alarm systems;
(6) functional examination of bilge level alarm;
(7) the setting of alarm points and the preset parameters of safety systems is recorded and maintained onboard for information.

6.4.2.2 The following surveys are to be carried out with regard to the class notation MCC:
(1) functional tests of safety systems, overriding function and alarm indicators;
(2) functional tests of control systems of main engines, auxiliary engines and boilers;
(3) functional tests of fixed fire-extinguishing, fire detection and alarm systems;
(4) functional examination of bilge level alarm;
(5) the setting of alarm points and the preset parameters of safety systems is recorded and maintained onboard for information.

6.4.2.3 The following surveys are to be carried out with regard to the class notation BRC:
(1) functional tests of safety systems, overriding function and alarm indicators;
(2) functional tests of control systems of main engines;
(3) the setting of alarm points and the preset parameters of safety systems is recorded and maintained onboard for information.

6.4.2.4 Where computer based systems are used in the automation system, onboard tests are to be carried out in conjunction with surveys of automation systems in accordance with the requirements of Section 6, Chapter 2, PART SEVEN of the Rules.

6.4.3 Annual survey

6.4.3.1 Examining the engine logbook since the last survey, including the record of normal use of main engines, auxiliary engines, boilers, power stations and other essential equipment and the record of automatic speed reduction and stop as well as overriding, any identified abnormality or functional failure, and the record of corrective actions taken.

6.4.3.2 Carrying out functional tests required in 6.4.2 of this Section.

6.4.3.3 Where computer based systems are used in the automation system, functional tests of computer based systems are to be carried out in conjunction with surveys of automation systems. Examining the record of change of software and hardware.

6.4.4 Intermediate survey

6.4.4.1 Same as annual survey.

6.4.5 Special survey

6.4.5.1 Same as annual survey.

Section 5 SURVEYS RELATED TO CLASS NOTATIONS FOR GREEN ECO-SHIPS

(This Section is deleted)

Section 6 SURVEYS RELATED TO CLASS NOTATIONS FOR REFRIGERATED CARGO INSTALLATIONS

6.6.1 General requirements

6.6.1.1 This Section applies to ships which have been assigned one or more of the following class notations related to refrigerated cargo installations:

(1) Cargo refrigeration: CRS (×× hold – ××℃, ××℃ Max. sea Water);
Cargo fruit preservation: CF (added to refrigerating plant suitable for carrying fruit cargo);

6.6.2 Initial classification

6.6.2.1 Plans and documents

(1) Plans, information and technical documents of refrigerated cargo installations are to be submitted to CCS for approval in accordance with relevant requirements as specified in 1.1.5 of Chapter 1, PART FIVE of the Rules. Additional plans, information and technical documents may be required, if considered necessary.

(2) Any subsequent modifications or alterations to the approved plans, information or technical documents are to be resubmitted to CCS for approval.

(3) Where refrigerated cargo installations are fitted with remote or automatic controls, the information and specifications of such controls are to be submitted to CCS for approval.

6.6.2.2 Survey during construction

(1) The complete installations together with their installing and arrangement are to be examined and tested.

(2) The materials used for the construction are to be tested in accordance with the relevant requirements of the Rules for Materials and Welding. Materials for which no requirement is made in the Rules may be tested in accordance with the technical specifications recognized by CCS.

(3) The principal materials and essential components such as compressors, condensers and oil separators, etc., intended for the refrigerated cargo installations are subject to products approval surveys by CCS.

(4) On completion of the construction, and after having been subjected to a refrigeration test and a thermal resistance test of the cargo chambers, the refrigerated cargo installation is to be subjected to a thermal balance test to determine the capability of the installation to perform its maximum duty. For ships of the same type with similar refrigerated cargo installations, subsequent thermal balance test may be waived, provided that the results of the refrigeration test and the thermal resistance test of refrigerated holds/chambers are satisfactory.

(5) Where the proposed construction of the refrigerated cargo installations is novel in design or involves the use of unusual material, additional tests may be required by CCS.

6.6.3 Annual surveys

6.6.3.1 General requirements

(1) For the annual survey of classed refrigerated cargo installations, opening up for examination of the machinery or dismantling of the insulation arrangements is not normally required. If any defects or indications of deficiency in the installation affecting the class or the temperature notation assigned are found, the Surveyor may require opening up the suspected items for examination to assure the installation to be in an efficient working condition.

(2) An examination of the logbook or other records of the refrigerated cargo installation is to be made, and any breakdown or malfunction of the installation during the last 12 months is to be noted in the survey report.

(3) Examination of the machinery is to be made under working conditions.

6.6.3.2 Examination of refrigerated holds/chambers

(1) A surface inspection of the insulated holds/chambers is to be carried out for the condition of insulation linings and fastenings on the sides, bulkheads and deckheads.

(2) The coverings on deck, tank top and tunnel top insulation are to be examined.

(3) Any indication of dampness or deterioration of the insulation is to be investigated.

(4) The condition of air ducting, cooler casings, hatch covers and plugs, access plugs, access doors and fastenings, bilge and manhole plugs, and air refreshing pipes with their closing appliances, is to be examined.

(5) Scuppers for chambers and cooler trays are to be examined.

(6) Examination of refrigeration equipment and thermometers

① Air cooler coils, cooling grids, brine cooler coils and grids, the shells of shell-and-tube type and double-pipe type condensers and evaporators, oil separators, receivers, driers, filters and other pressure vessels, piping and arrangements are to be examined.
② Any evidence of corrosion of water end covers of shell-and-tube type and double-pipe type condensers is to be examined.
③ All pressure vessels, including fittings and safety devices, are to be externally examined.
④ If there is evidence of dampness of the insulation covering pressure vessels, their connections and/or piping, the cause is to be ascertained.
⑤ Thermometers and apparatus used for measuring the temperature in refrigerated holds/chambers, and of the air inlet and outlet ducting, are to be examined. A random test for thermometers is to be made to verify their accuracy.

(7) Electrical equipment
① A general examination is to be made for electrical motors driving refrigerant compressors, pumps and fans, together with their control gear and cables. A random test for insulation resistance relative to earth is to be made on the cables, switchgear, motors, etc. The installation may be divided for the purpose of this test, and the Surveyor may at his discretion accept the results of testing carried out by competent personnel.
② A random test is to be made to demonstrate that the automatic controls, safety devices and alarms are in good working order.

(8) Refrigeration tests: Refrigeration tests and thermal insulation tests for holds/chambers are to be made to the refrigerated cargo installations.

6.6.4 Special surveys

6.6.4.1 At the special survey, in addition to all items required for annual surveys, the following items are to be surveyed.

6.6.4.2 First special survey after construction:

(1) Examination of compressors and pumps
① Each reciprocating compressor is to be opened out. Cylinder bores, pistons, piston rods, connecting rods, crankshafts, valves and seats, glands, relief devices, suction filters and lubricating arrangements are to be examined. Crankcase glands and the lower halves of main bearings need not be exposed provided that the Surveyor is satisfied as to the alignment and wear.
② Screw-type compressors are to be opened out and examined.
③ Refrigerant condenser cooling water pumps, including standby pump(s) which may be used in other services, are to be opened out and examined.
④ Brine and refrigerant circulating pumps are to be opened out and examined. Special consideration will be given to survey requirements for refrigerant circulating pumps of the hermetically sealed type.

(2) Examination of pressure vessels and heat exchangers
① The water end covers of shell-and-tube type and double-pipe type condensers are to be removed for examination of the tubes, tube plates and covers.
② The shells and connections of shell-and-tube type and double-pipe type condensers and evaporators, separators, receivers, driers, filters and other pressure vessels, and the coil terminals of coil-in-casing type condensers and evaporators, are to be examined in so far as practicable.
③ In the case of pressure vessels covered by insulation, any evidence of dampness or deterioration of the insulation which could lead to external corrosion of the vessels or their connections is to be investigated.
④ When in doubt, sufficient insulation is to be stripped from insulated pressure vessels to permit the condition of the vessels to be ascertained. Care is to be taken that in replacement of the insulation, the vapour sealing of the outer covering is made good.

(3) Examination of piping and fittings
① Confirming that the insulation of pipes carrying the refrigerant both outside and inside the insulated chambers is in good order, and examining the pipes, including their connections, under working conditions for confirming that they are in normal order. Care is to be taken that in replacement of the insulation, the vapour sealing of the outer covering is made good.
② Confirming that all pressure relief valves and safety discs throughout the refrigerating plant are in good order. However, no attempt is to be made to test refrigerant pressure relief valves on board.
③ Sea connections to refrigerant condensers are to be opened out and examined at the hull or

machinery special survey.

(4) Examination of electrical equipment

① The electrical motors driving refrigerant compressors, pumps and fans, together with their control gear and cables, are to have their insulation resistance relative to earth tested. For the purpose of this test, the installation may be subdivided to any desired extent.

② All automatic controls and alarms are to be tested.

(5) Examination of refrigerated holds/chambers

① Examining insulation and air trunking of hold/chamber overhead and vertical surfaces and confirming that they are in normal condition. Care is to be taken that in repairing, the insulation or the ducts are sealed against air blowing into the insulation, or against moisture ingress.

② Confirming that the tank top insulation and protection are in normal condition. Care is to be taken that in repair or in replacement, the insulation or the protection is sealed against air blowing into the insulation, or against moisture ingress.

③ Due consideration is to be given to the type of insulation used in the holds/chambers when determining repair or replacement of the insulation. Where organic foam insulation has been used, including foamed in-situ type or other insulation slabs, the Surveyor may require an examination of the insulation by drilling holes.

④ Under normal circumstances, the condition of hold/chamber insulation, grounds, etc. may be inspected when examining the ship's steelwork at the special survey.

⑤ Arrangements made for defrosting air coolers and for draining condensate from trays below coolers are to be examined to confirm that they are in a good working condition.

⑥ Any air refreshing arrangements are to be examined.

6.6.4.3 Second and subsequent special surveys

(1) In addition to the items specified for the first special survey, the following additional items are to be examined:

① Gas condensers of the shell-and-tube type, and gas evaporators (brine coolers) of the shell-and-tube type in which refrigerant is in the shell, are to have the water or brine end covers removed and the shell pneumatically tested with the refrigerant or air, or a mixture of inert gas and refrigerant, to the pressures as required in Table 2.1.4.1 of Chapter 2, PART FIVE of the Rules, depending on the different refrigerants used.

② Gas evaporators (brine coolers) of the shell-and-tube type in which the refrigerant is in coil, are to have the refrigerant end covers removed and the shell hydraulically tested to 1.5 times the designed pressure, but not less than 0.34 MPa.

③ Heat exchangers used for cooling refrigerant liquid would normally require to be specially examined internally only if leakage is suspected between high and low pressure sides. This type of heat exchangers is to be examined and tested at the discretion of the Surveyor according to the design of such equipment.

6.6.4.4 At the request of the owner and upon approval by CCS, a system of continuous surveys may be undertaken whereby the special survey requirements are carried out in regular rotation.

Section 7 SURVEYS RELATED TO CLASS NOTATIONS FOR EOM

6.7.1 EOM system function and composition

EOM (Online Comprehensive Monitoring of Ship Energy Efficiency) system is a computerized system for ship's energy efficiency real-time on-line monitoring, which is capable of automatic acquisition of energy consumption and operating condition of ship's energy-consuming equipment such as main engine, generator engine, boiler, etc., as well as operating parameters of navigational equipment such as shaft power meter (for electric propulsion ships, shaft power can be calculated through generator power), GPS, anemorumbometer, speed log, electronic clinometer (if such equipment has signal access to EOM software system) and echo-sounder (if such equipment has signal access to EOM software system), and capable of data synchronization with the shore-based system at regular time, for the purpose of realizing on-line monitoring of operating condition of ship's energy-consuming equipment and consumption of energy as well as realizing the function of ship equipment monitoring, energy management and energy efficiency management by means of analysis of collected data.

6.7.2 Examination of plans

6.7.2.1 The following plans and documents are to be submitted to the plan approval center for approval:
(1) electrical system of EOM system (including system power supply, system input and output signal circuit and list of parameters);
(2) electrical system and arrangement of shaft power meter;
(3) fuel oil supply piping of main engine, generator engine and boiler;
(4) calculation method for shaft power for electric propulsion ships.
6.7.2.2 After the above plans are approved by the plan approval center, any non-principled revision may be reviewed and approved by the site Surveyor.
6.7.2.3 Mooring test and sea trial program of EOM system are to be reviewed and approved by the site Surveyor.

6.7.3 Product certification requirements and on-site check

6.7.3.1 Certification requirements for related hardware equipment are given in Appendix 1A, Chapter 3 of this PART.
6.7.3.2 For flowmeters and shaft power meters which are installed on ships applying for EOM notation and delivered before 31 December 2015, the existing type test report or other equivalent documents may be accepted by CCS.

6.7.4 Requirements for on-site survey

6.7.4.1 Equipment installation and system testing of EOM system are to be carried out in accordance with approved plans and equipment installation techniques approved by CCS (where applicable), and functional tests are to be carried out during mooring test and sea trial. Upon inspection and confirmation of peripheral hardware of EOM system and signal access to such system, the site Surveyor is to confirm relevant functions of modules related to ship equipment monitoring, energy management and energy efficiency management in EOM software system in accordance with approved test program.
6.7.4.2 Installation and survey of relevant signal acquisition equipment
For the following equipment within the statutory and class scope, in addition to complying with statutory and class inspection requirements for such equipment, they are also to be inspected in accordance with the following requirements:
(1) Shaft power meter:
  a) Installation survey is to be carried out in accordance with approved plans and manufacturer's instructions.
  b) Taking into account the effect of ship deformation and local vibration on the performance of shaft power meter, the stator mounting base of shaft power meter is to be welded firmly, generally on ship's strength members and it is not permitted to be welded on the shell plating.
  c) Witnessing calibration process and result of shaft power meter.
(2) Flowmeter:
  a) Checking the verification report of flowmeter.
  b) Installation survey is to be carried out in accordance with approved plans and manufacturer's instructions. Flowmeter is also to be installed by satisfying the requirements of Appendix 1.
(3) Electronic clinometer (if such equipment has signal access to EOM software system):
  a) Installation survey is to be carried out in accordance with approved plans and manufacturer's instructions.
  b) The electronic clinometer is to be calibrated during the performance test, confirming the output results of 0° and other angles of inclination.
(4) Anemorumbometer:
  a) Installation survey is to be carried out in accordance with approved plans and manufacturer's instructions.
  b) Survey of the performance test.
(5) Echo-sounder (if such equipment has signal access to EOM software system):
  a) Installation survey is to be carried out in accordance with approved plans and manufacturer's instructions.
  b) Survey of the performance test.
(6) Global Position System (GPS):
  a) Installation survey is to be carried out in accordance with approved plans and manufacturer's instructions.
  b) Survey of the performance test.
(7) Speed log:

a) Installation survey is to be carried out in accordance with approved plans and manufacturer's instructions.
b) Survey of the performance test.

(8) Engine room monitoring and alarm system:
a) Installation survey is to be carried out in accordance with approved plans.
b) Survey of the performance test.
c) Checking that the range of signal output to EOM system satisfies the minimum requirements for ship condition monitoring parameters in Appendix 2.

(9) Tank liquid level measuring system:
a) Installation survey is to be carried out in accordance with approved plans and manufacturer's instructions.
b) Survey of the performance test.

(10) Ship's draft measuring system (if such equipment has signal access to EOM software system):
a) Installation survey is to be carried out in accordance with approved plans and manufacturer's instructions.
b) Survey of the performance test.

6.7.4.3 Checking signal input and output of signal acquisition equipment:

(1) Checking the integrity of range of parameter input into EOM system (see Appendix 2).

(2) Checking the consistency between the parameter data of receiving end of EOM software system and that of sending end of signal acquisition equipment.

6.7.4.4 Verification of function of EOM software

To verify the following functions of the modules such as equipment monitoring, energy management and energy efficiency management in EOM software system:

(1) Equipment monitoring: to verify the real-time acquisition of the following parameter data within acquisition cycle by software system:
a) power, pressure, temperature of energy-consuming equipment such as main engine, generator engine and boiler (see the parameters required to be selected in Appendix 2);
b) flow of the fuel oil flowmeter of energy-consuming equipment such as main engine, generator engine and boiler;
c) shaft revolution, torque, power of shaft power meter of the main engine;
d) wind direction, wind forcer of anemorumbometer;
e) position, course, speed of the Global Position System (GPS);
f) water-tracing speed of the speed log;
g) angle of heel of electrical clinometer (if such equipment has signal access to EOM software system);
h) depth value of echo-sounder (if such equipment has signal access to EOM software system);
i) ship's draft of ship's draft measuring system (if such equipment has signal access to EOM software system).

(2) Energy management: to verify the indication of the following energy consumption indexes by the software system:
a) fuel consumption per hour;
b) daily fuel consumption.

(3) Energy efficiency management: to verify the calculation of the following main energy efficiency indexes by software system; energy efficiency indexes may be adjusted according to ship types and operation characteristics:
a) EEOI;
b) fuel consumption per mile;
c) fuel consumption per transport work;
d) CO_2 emissions per mile;
e) CO_2 emissions per transport work unit.

(4) The verification of software function above may be carried out by examining function of software system or outputting the report.

(5) Ship-shore communication: to verify the data transmission smoothly between ship side and shore side of EOM software system.

Appendix 1 REQUIREMENTS FOR INSTALLATION OF FLOWMETER

1 Requirements for installation position of flowmeters of fuel oil system of main/generator engines

1.1 The installation position of flowmeter is to satisfy the requirements for onboard arrangement.

1.2 Inlet flowmeter: where the signal of existing oil supply unit is available, the flow signal supplied by such unit may be used. Where the signal of existing oil supply unit is unavailable, an additional flowmeter may be fitted near the flowmeter of existing oil supply unit, generally positioned after fuel oil supply pump and before fuel oil circulation pump in order to avoid calculation of fuel oil circulation.

1.3 Outlet flowmeter: in the conventional arrangement of fuel oil system, after passing through a three-way valve, one way of return flow of main engine is returned to the air separator and such amount of oil is not included in repetitive calculation; another way is returned to the service tank. It is recommended to fit the flowmeter of return flow on the pipe returning to the service tank.

2 Requirements for installation position of a set of flowmeters of fuel oil system shared by main engines and generator engines

2.1 Reference may be made to plan 1 for installation position of flowmeter. In order to calculate the oil consumption of generator engine, separate flowmeters are to be fitted on the inlet and outlet main pipes of fuel oil system of generator engine. Although some fuel oil participates in the circulation, the calculated circulation data is not large due to low oil consumption of generator engine.

3 Requirements for installation position and number of flowmeters of fuel oil system of boiler

3.1 Reference may be made to installation plan of flowmeter of main engine. In case of no return flow or return flow is only returned to the air separator, the installation of return flow flowmeter is not necessary.

4 Requirements for installation of flowmeters

4.1 The flowmeter is to be provided with a by-pass device so that normal supply of fuel oil can be ensured in case of failure of the flowmeter.

4.2 With regard to the pressure requirement of the flowmeter, the operating pressure in way of instrument is at least to be greater than medium flash pressure + 3 times pressure loss of instrument itself, where the operating pressure means the operating pressure in way of instrument instead of the operating pressure supplied by the upstream source (see Figure 2).

$P_{\text{out}} = \text{outlet pressure}$
$P_{\text{dp}} = \text{pressure loss in way of instrument}$
$P_{\text{vp}} = \text{medium flash pressure}$

$$P_{\text{out}} \geq \left(3 \times P_{\text{dp}}\right) + P_{\text{vp}}$$

Figure 2 Pressure of Flowmeter

The flowmeter in general generates pressure loss of approximately 0.2 bar, not including pressure loss caused by other parts of the pipeline, e.g. bend, necking etc. Where the circulating medium has a low viscosity, the pressure loss can be calculated accurately. But where the HFO used has a high viscosity, the pressure loss within pipeline and instrument cannot be controlled satisfactorily, which will give rise to flow fluctuation or even no circulation during practical application. For the use of HFO medium, the operating pressure is to be supplied by pump in order to ensure that the pipeline is unblocked and the flow is steady.

4.3 The flowmeter is to be installed to avoid siphon and air pocket. During installation, the vertical down or inclined down direction is to be avoided, because a flowmeter installed in such a way may give rise to siphon. Additionally, where the outlet of a flowmeter installed horizontally is provided with a long pipeline in the vertical down direction, air pocket may occur (see Figure 3 for specific installation examples).

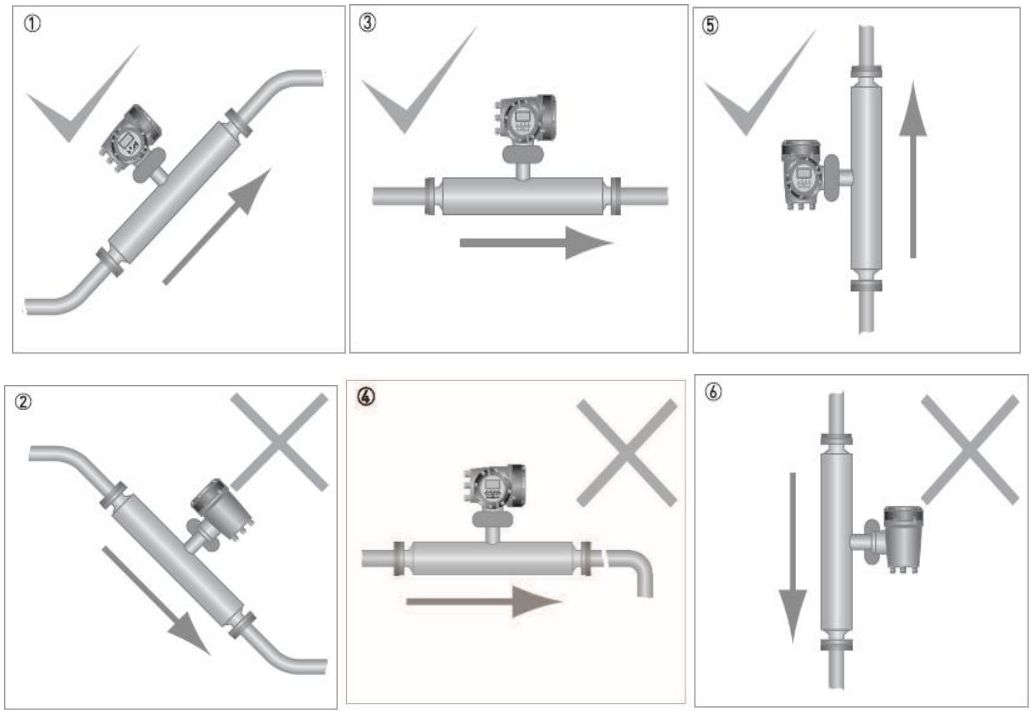


Figure 3 Installation of Flowmeters

4.4 In addition to the above requirements for installation of flowmeters, the requirements of the manufacturer may be accepted.

Appendix 2 SUMMARY OF PARAMETERS OF ENERGY EFFICIENCY EQUIPMENT

1 Alarm systems

The normal monitoring parameters of the operating conditions of ship's energy-consuming equipment such as main engine, generator engine and boiler may be selected from the summary of parameters below; the parameters with "*" are those required to be selected for EOM software system and others are optional monitoring parameters; a slight difference is permitted based on different design of ships. "#X" is the multi-equipment number and the corresponding parameters may be increased taking into account the number of equipment.

No.	English name of switch-in parameters	Unit	Remark
Parameters of main engine			
1	M/E JACKET C F W INLET PRESS.*	MPa	
2	M/E C W IN AIR COOLER PRESS.	MPa	
3	M/E EXHAUST VALVE SPRING AIR INLET PRESS.	MPa	
4	M/E CONTROL AIR INLET PRESS.	MPa	
5	M/E JACKET C F W IN TEMP.*	℃	
6	M/E #X CYL C F W OUTLET TEMP.*	℃	
7	M/E C F W IN AIR COOLER TEMP.	℃	
8	L T F W PRESS.	MPa	
9	L T F W TEMP.	℃	
10	COOLING S W TEMP.	℃	
11	COOLING S W PRESS.	MPa	
12	M/E MAIN & THRUST BRG L O INLET PRESS.*	MPa	The monitoring points may be in common use or be substituted for each other based on design
13	M/E MAIN BRG L O INLET PRESS.*	MPa	
14	M/E THRUST BRG L O INLET PRESS.*	MPa	
15	M/E L O &P C O INLET PRESS.*	MPa	
16	M/E P C O INLET PRESS.	MPa	
17	M/E T/C L O INLET PRESS.	MPa	
18	M/E #X T/C L O INLET PRESS.	MPa	
19	M/E T/C L O OUTLET TEMP.	℃	
20	M/E #X T/C L O OUTLET TEMP.	℃	
21	M/E MAIN BRG L O IN TEMP.*	℃	The monitoring points may be in common use or be substituted for each other based on design
22	M/E THRUST BEARING PAD TEMP.*	℃	
23	M/E L O & P C O IN TEMP.*	℃	
24	M/E P C O IN TEMP.*	℃	
25	M/E #X PISTON COOL O OUTLET TEMP.*	℃	
26	M/E F O INLET PRESS.*	MPa	
27	M/E F O IN TEMP.*	℃	
28	FO VISCOSITY	cSt	
29	M/E T/C REVOLUTION	rpm	
30	M/E #X T/C REVOLUTION	rpm	
31	SHAFT REVOLTION COUNT	10R	
32	SHAFT REVOLUTION*	rpm	
33	FO IN SERVICE		
34	MDO IN SERVICE		
35	M/E SCAV AIR PRESS.*	MPa	
36	M/E #X SCAV AIR BOX TEMP.*	℃	
37	M/E SCAV AIR TEMP. BEFORE AIR COOLER	℃	
38	M/E SCAV AIR TEMP. AFTER AIR COOLER	℃	
39	M/E SCAV AIR RECEIVER TEMP.*	℃	
40	M/E #X CYL EXH GAS OUTLET TEMP.*	℃	

No.	English name of switch-in parameters	Unit	Remark
41	M/E T/C IN EXH GAS TEMP.*	℃	
42	M/E #X T/C IN EXH GAS TEMP.*	℃	
43	M/E T/C OUT EXH GAS TEMP.*	℃	
44	M/E #X T/C OUT EXH GAS TEMP.*	℃	
Parameters of shafting			
45	INTERMED SHAFT BRG TEMP.	℃	
46	S/T FORE BRG TEMP.	℃	
47	S/T AFT BRG TEMP.	℃	
48	S/T AFT BRG(P) TEMP.	℃	
49	S/T AFT BRG(S) TEMP.	℃	
Parameters of boiler			
50	COMP BLR STEAM PRESS.*	MPa	
51	COMP BLR F O TEMP.	℃	
52	BOILER F O PRESS.	MPa	
53	COMP FO IN SERVICE		
54	COMP MDO IN SERVICE		
Parameters of generator engine			
55	G/E F O IN TEMP.*	℃	An oil supply unit may be shared with main engine and substituted with main engine temperature based on design
56	#X G/E CONTROL AIR INLET PRESS.	MPa	
57	#X G/E CHARGE AIR PRESS.	MPa	
58	#X G/E L O INLET PRESS.*	MPa	
59	#X G/E F O INLET PRESS.*	MPa	
60	#X G/E H/T F W INLET PRESS.*	MPa	
61	#X G/E H/T F W IN TEMP.	℃	
62	#X G/E L O IN TEMP.*	℃	
63	#X G/E H/T F W OUTLET TEMP.*	℃	
64	#X G/E #X CYL EXH GAS OUTLET TEMP.*	℃	To be determined based on the number of cylinders, the form of grouping may be selected or substituted by temperature of exhaust manifold
65	#X G/E #1,2,3 EXH G T/C IN TEMP.*	℃	
66	#X G/E #4,5,6 EXH G T/C IN TEMP.*	℃	
67	#X G/E EXH G T/C IN TEMP.*	℃	
68	#X G/E L/T F W A/C INLET PRESS.	MPa	
69	#X G/E L/T F W A/C IN TEMP.	℃	
70	#X G/E EXH G T/C OUTLET TEMP.	℃	
71	#X G/E CHARGE AIR IN TEMP.	℃	
72	#X G/E BEARING TEMP.*	℃	May be substituted for each other based on design
73	#X G/E FORE BEARING TEMP.*	℃	
74	#X G/E AFT BEARING TEMP.*	℃	
75	#X G/E POWER*	kW	
76	G/E FO IN SERVICE		
77	G/E MDO IN SERVICE		
Parameters of fuel oil tank			
78	#X HFO SERV TK TEMP.	℃	
79	#X HFO SETT TK TEMP.	℃	
80	#X L S HFO SERV TK TEMP.	℃	
81	#X L S HFO SETT TK TEMP.	℃	
82	#X MDO /MGO SERV TK TEMP.	℃	
83	#X MDO /MGO SETT TK TEMP.	℃	
84	#X L S MDO /MGO SERV TK TEMP.	℃	

No.	English name of switch-in parameters	Unit	Remark
85	#X L S MDO /MGO SETT TK TEMP.	℃	
86	#X MDO/MGO TK （P/C/S）TEMP.	℃	
87	#X L S MDO /MGO TK（P/C/S）TEMP.	℃	
88	#X HFO TK（P/C/S）TEMP.	℃	
89	#X L S HFO（P/C/S） TK TEMP.	℃	
90	#X HFO SERV TK LEVEL	cm/m^3	
91	#X HFO SETT TK LEVEL	cm/m^3	
92	#X L S HFO SERV TK LEVEL	cm/m^3	
93	#X L S HFO SETT TK LEVEL	cm/m^3	
94	#X MDO /MGO SERV TK LEVEL	cm/m^3	
95	#X MDO /MGO SETT TK LEVEL	cm/m^3	
96	#X L S MDO /MGO SERV TK LEVEL	cm/m^3	
97	#X L S MDO /MGO SETT TK LEVEL	cm/m^3	
98	#X MDO/MGO TK （P/C/S）LEVEL	cm/m^3	
99	#X L S MDO /MGO TK（P/C/S）LEVEL	cm/m^3	
100	#X HFO TK（P/C/S）LEVEL	cm/m^3	
101	#X L S HFO（P/C/S） TK LEVEL	cm/m^3	
102	F O OVERFLOW TK LEVEL	cm/m^3	
Parameters of ship's draft			
103	SHIP'S DRAFT (FORE)	m	
104	SHIP'S DRAFT (PORT)	m	
105	SHIP'S DRAFT (STARBOARD)	m	
106	SHIP'S DRAFT (STERN)	m	
Fuel oil flowmeter			
107	M/E F O FLOW*	L	
108	M/E F.O.FLOW COUNTER	L/h	
109	M/E & D/G COMM FO FLOW*	L	
110	M/E F O RETURN FLOW*	L	If the main engines and generator engines share the inlet flow counter, the parameter may also indicate that the main engines and generator engines share the return oil
111	G/E F O FLOW*	L	
112	G/E F O RETURN FLOW*	L	
113	COMP BLR H F O FLOW*	L	
114	COMP BLR D F O FLOW	L	
115	COMP BLR FO RETURN FLOW*	L	

2 Anemorumbometer

No.	English name of switch-in parameters	Unit	Remark
1	WIND SPEED*	kts	
2	WIND DIRECTION*	°	
3	WIND SPEED UNIT		If any
4	T/R FLAG		
Remark			

3 Electronic clinometer

No.	English name of switch-in parameters	Unit	Remark
1	X*	°	
2	Y*	°	
Remark	The calibration for the installation of electronic clinometer is to be carried out to ensure that the electronic clinometer output the inclining conditions of the ship accurately		

4 Shaft power meter

No.	English name of switch-in parameters	Unit	Remark
1	SHAFT REVOLUTION*	rpm	
2	SHAFT TORQUE*	kNm	
3	SHAFT POWER*	kW	
4	SHAFT THRUST	kN	If any
Remark	The data may be accessible in the navigation bridge as an independent signal or together with the main signal of the engine room		

5 Global Position System

No.	English name of switch-in parameters	Unit	Remark
1	LATITUDE*		
2	N/S		
3	LONGITUDE*		
4	E/W		
5	SPEED OVER GROUND*		
6	COURSE OVER GROUND*		
7	UTC*		
Remark			

6 Speed log

No.	English name of switch-in parameters	Unit	Remark
1	LONGITUDINAL WATER-TRACING SPEED*	knots	
2	TRANSVERSE WATER-TRACING SPEED	knots	If any
3	LONGITUDINAL GROUND-TRACING SPEED	knots	If any
4	TRANSVERSE GROUND-TRACING SPEED	knots	If any
5	STERN TRANSVERSE WATER-TRACING SPEED	knots	If any
6	STERN TRANSVERSE GROUND-TRACING SPEED	knots	If any
7	TOTAL CUMULATIVE WATER DISTANCE	NM	
8	WATER DISTANCE SINCE RESET	NM	
9	TOTAL CUMULATIVE GROUND DISTANCE	NM	
10	GROUND DISTANCE SINCE RESET	NM	
Remark	The number of parameters is determined according to the number of cylinders of the ship's main engine, #X is the number of cylinder		

7 Echo-sounder

No.	English name of switch-in parameters	Unit	Remark
1	WATER DEPTH RELATIVE TO TRANSDUCER*	m	
2	OFFSET FROM TRANSDUCER	m	
3	MAXIMUM RANGE SCALE IN USE	m	
Remark			

Appendix 3 CHECKLIST OF SYSTEM FUNCTIONS OF EOM SOFTWARE

To verify the following functions of the modules such as data acquisition and monitoring, energy management and energy efficiency management in EOM software system:

1 Data acquisition and monitoring: to verify the real-time acquisition of the following parameter data within acquisition cycle by software system:

No.	Items to be surveyed	Result
1	Power, pressure, temperature of energy-consuming equipment such as main engine, generator engine and boiler	
2	Flow of the fuel oil flowmeter of energy-consuming equipment such as main engine, generator engine and boiler	
3	Shaft revolution, torque, power of shaft power meter of the main engine	
4	Wind direction, wind force of anemorumbometer	
5	Position, course, speed of Global Position System (GPS)	
6	Water-tracing speed of speed log	
7	Angle of heel of electronic clinometer (if such equipment has signal access to EOM software system)	
8	Depth value of echo-sounder (if such equipment has signal access to EOM software system)	
9	Ship's draft of ship's draft measuring system (if such equipment has signal access to EOM software system)	

2 Energy management: to verify the indication of the following energy consumption indexes by the software system:

No.	Items to be surveyed	Result
1	Fuel consumption per hour	
2	Daily fuel consumption	

3 Energy efficiency management: to verify the calculation of the following main energy efficiency indexes by software system:

No.	Items to be surveyed	Result
1	EEOI	
2	Fuel consumption per mile	
3	Fuel consumption per transport work	
4	CO_2 emissions per mile	
5	CO_2 emissions per transport work unit	

Place of survey: Attending surveyor:
Date of survey:

e

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2025

PART TWO HULL

CONTENTS

CHAPTER 1 GENERAL 2-1
Section 1 GENERAL PROVISIONS 2-1
Section 2 HULL STRUCTURAL MEMBERS 2-3
Section 3 MATERIALS 2-10
Section 4 WELD DESIGN FOR HULL STRUCTURES 2-17
Section 5 DIRECT STRENGTH CALCULATIONS 2-27
Section 6 CORROSION CONTROL FOR HULL STRUCTURES 2-43
Section 7 FORE DECK FITTINGS 2-44
Section 8 TANK SLOSHING 2-48
Section 9 INTACT STABILITY 2-49
Section 10 DAMAGE STABILITY 2-52
Section 11 LOAD LINE MARKS AND MARKING 2-53
Section 12 STRUCTURAL ARRANGEMENT 2-56
Section 13 MARKING OF OPERATING DRAFT OF WORKING SHIPS 2-63
CHAPTER 2 HULL STRUCTURES 2-68
Section 1 GENERAL PROVISIONS 2-68
Section 2 LONGITUDINAL STRENGTH 2-70
Section 3 SHELL PLATING 2-90
Section 4 DECKS 2-95
Section 5 SINGLE BOTTOMS 2-100
Section 6 DOUBLE BOTTOMS 2-105
Section 7 SIDE FRAMING 2-114
Section 8 DECK FRAMING 2-121
Section 9 CANTILEVERS 2-130
Section 10 PILLARS 2-134
Section 11 NON-WATERTIGHT PILLAR BULKHEADS 2-137
Section 12 WATERTIGHT BULKHEADS 2-137
Section 13 DEEP TANKS 2-143
Section 14 STEMS, STERN FRAMES, BULBOUS BOWS AND PROPELLER SHAFT BRACKETS 2-150
Section 15 STRENGTHENING AT ENDS OF SHIP 2-155
Section 16 ENGINE SEATINGS AND SHAFT TUNNELS 2-161
Section 17 SUPERSTRUCTURES AND DECKHOUSES 2-163
Section 18 HELICOPTER DECKS 2-172
Section 19 BULWARKS AND GUARDRAILS 2-175
Section 20 HATCHWAYS AND HATCH COVERS 2-176
Section 21 VEHICLE DECKS 2-212
Section 22 STRENGTHENED FOR HEAVY CARGOES 2-216
Section 23 STRENGTHENING FOR GRABS 2-217
Section 24 ANALYSIS OF TEMPERATURE FIELD AND THERMAL STRESS OF CARGO TANK STRUCTURE 2-218
Section 25 STRUCTURAL STRENGTHENING LOADED BY STEEL COILS ON A WOODEN SUPPORT 2-225
Appendix 1 LOADING INSTRUMENTS 2-233
Appendix 2 IACS UR L5 COMPUTER SOFTWARE FOR ONBOARD STABILITY CALCULATIONS 2-244
Appendix 3 GUIDELINES FOR UR S11.2.1.3 FOR BALLAST LOADING CONDITIONS OF CARGO VESSELS INVOLVING PARTIALLY FILLED BALLAST TANKS 2-254
Appendix 4 SLAMMING STRENGTH ASSESSMENT OF BOW BOTTOM STRUCTURES 2-273
Appendix 5 BUCKLING STRENGTH ASSESSMENT OF SHIP STRUCTURAL ELEMENTS 2-281
CHAPTER 3 EQUIPMENT AND OUTFITS 2-324
Section 1 RUDDERS 2-324
Section 2 ANCHORING AND MOORING EQUIPMENT 2-341
Section 3 CEILINGS AND CARGO BATTENS 2-352
Section 4 MASTS OR DERRICK POSTS 2-352

Section 5 EMERGENCY TOWING ARRANGEMENTS 2-353
Section 6 SHIPBOARD FITTINGS AND SUPPORTING HULL STRUCTURES ASSOCIATED WITH TOWING AND MOORING ON CONVENTIONAL VESSELS 2-356
Section 7 SUPPORT STRUCTURE FOR DECK EQUIPMENT 2-361
Section 8 ENERGY-SAVING APPENDAGES IN FRONT OF PROPELLERS 2-365
Appendix 1 GUIDELINES FOR CALCULATION OF BENDING MOMENT AND SHEAR FORCE DISTRIBUTION 2-367
Appendix 2 DIRECT MOORING ANALYSES 2-374
Appendix 3 DIRECT FORCE CALCULATION FOR ANCHORING EQUIPMENT 2-377
CHAPTER 4 STRENGTHENING FOR NAVIGATION IN ICE 2-380
Section 1 GENERAL PROVISIONS 2-380
Section 2 ICE STRENGTHENING FOR CLASSES B1*, B1, B2 AND B3 2-380
Section 3 ICE STRENGTHENING FOR CLASS B 2-391
CHAPTER 5 DOUBLE HULL OIL TANKERS 2-393
Section 1 GENERAL PROVISIONS 2-393
Section 2 SHELL PLATING 2-396
Section 3 DECKS 2-398
Section 4 DOUBLE BOTTOM STRUCTURE 2-398
Section 5 DOUBLE HULL CONSTRUCTION 2-401
Section 6 DECK FRAMING 2-403
Section 7 PLANE TRANSVERSE OILTIGHT BULKHEADS 2-404
Section 8 PLANE LONGITUDINAL OILTIGHT BULKHEADS 2-406
Section 9 CORRUGATED TRANSVERSE OILTIGHT BULKHEADS 2-408
Section 10 CORRUGATED LONGITUDINAL OILTIGHT BULKHEADS 2-409
Section 11 NON-OILTIGHT BULKHEADS AND WASH BULKHEADS 2-410
Section 12 SPECIAL REQUIREMENTS 2-411
Section 13 CARGO TANK HATCHWAYS 2-413
Appendix 1 DIRECT STRENGTH CALCULATION OF DOUBLE HULL OIL TANKERS 2-415
CHAPTER 6 SINGLE HULL OIL TANKERS 2-421
Section 1 GENERAL PROVISIONS 2-421
Section 2 SHELL PLATING AND DECKS 2-421
Section 3 LONGITUDINAL BOTTOM FRAMING 2-422
Section 4 TRANSVERSE BOTTOM FRAMING 2-425
Section 5 LONGITUDINAL SIDE FRAMING 2-426
Section 6 TRANSVERSE SIDE FRAMING 2-427
Section 7 TRANSVERSE DECK FRAMING 2-428
Section 8 TRUNK STRUCTURE 2-429
CHAPTER 7 CONTAINER SHIPS 2-431
Section 1 GENERAL PROVISIONS 2-431
Section 2 LONGITUDINAL STRENGTH 2-432
Section 3 DECK STRUCTURE 2-443
Section 4 SHELL PLATING 2-445
Section 5 SIDE FRAMING 2-445
Section 6 DOUBLE BOTTOM 2-446
Section 7 BULKHEADS 2-447
Section 8 BOW SIDE STRUCTURE STRENGTHENING 2-447
Section 9 ADDITIONAL REQUIREMENTS FOR CONTAINER SHIPS OF GREATER THAN 250 M IN LENGTH 2-449
Section 10 LONGITUDINAL STRENGTH OF COMBINED BENDING AND TORSIONAL MOMENTS FOR SHIPS WITH LARGE OPENINGS 2-456
Appendix 1 CONTAINER SECURING 2-458
Appendix 2 DIRECT STRENGTH CALCULATION OF CONTAINER SHIPS 2-478
Appendix 3 CALCULATION OF SHEAR FLOW 2-511
Appendix 4 BUCKLING CAPACITY 2-514
Appendix 5 HULL GIRDER ULTIMATE BENDING CAPACITY 2-527
CHAPTER 8 BULK CARRIERS 2-536
Section 1 GENERAL PROVISIONS 2-536
Section 2 BOTTOM STRUCTURES 2-537
Section 3 SIDE FRAMING 2-537

Section 4 WATERTIGHT BULKHEADS 2-540
Section 5 HOPPER TANKS 2-541
Section 6 TOPSIDE TANKS 2-543
Section 7 ADDITIONAL REQUIREMENTS FOR LOADING MANUALS AND LOADING INSTRUMENTS 2-545
Section 8 OVERALL LONGITUDINAL STRENGTH IN FLOODED CONDITION 2-548
Section 9 STRENGTH OF CORRUGATED TRANSVERSE WATERTIGHT BULKHEADS IN HOLD-FLOODED CONDITIONS 2-549
Section 10 ALLOWABLE HOLD LOADING CONSIDERING HOLD FLOODING 2-558
Section 11 HATCH COVERS OF CARGO HOLDS 2-561
Section 12 HARMONIZED NOTATIONS AND CORRESPONDING DESIGN LOADING CONDITIONS FOR BULK CARRIERS 2-561
Section 13 REQUIREMENTS FOR THE FITTING OF A FORECASTLE 2-567
Section 14 DOUBLE SIDE STRUCTURE 2-568
Section 15 ADDITIONAL REQUIREMENTS FOR STIFFENING STRUCTURAL MEMBERS 2-570
Appendix 1 DIRECT STRENGTH CALCULATION OF BULK CARRIERS 2-573
Appendix 2 HOLD MASS CURVES 2-579
CHAPTER 9 Roll on-roll off ships, PASSENGER SHIPS, RO-RO PASSENGER SHIPS AND FERRIES 2-585
Section 1 GENERAL PROVISIONS 2-585
Section 2 HULL STRUCTURE 2-585
Section 3 MOVABLE PLATFORMS AND SLOPING VEHICLE RAMPS 2-588
Section 4 BOW DOORS AND INNER DOORS 2-589
Section 5 SIDE SHELL AND STERN DOORS 2-596
Section 6 VEHICLE RAMPS 2-599
Section 7 DIRECT CALCULATIONS 2-600
Section 8 EXTERNAL GLASS BALUSTRADES 2-603
CHAPTER 10 TUGS 2-605
Section 1 GENERAL PROVISIONS 2-605
Section 2 HULL FRAMING 2-605
Section 3 MACHINERY CASINGS 2-605
Section 4 BULWARKS AND FENDERS 2-605
Section 5 TOWING ARRANGEMENTS AND SUPPORTING STRUCTURE 2-606
Section 6 TOWING WINCH EMERGENCY RELEASE SYSTEMS 2-606
CHAPTER 11 OFFSHORE SUPPLY SHIPS 2-610
Section 1 GENERAL PROVISIONS 2-610
Section 2 CARGO CONTAINMENT AND OTHER FITTINGS 2-610
Section 3 SHELL AND DECK PLATING 2-612
Section 4 HULL ENVELOPE FRAMING 2-612
Section 5 SUPERSTRUCTURES AND DECKHOUSES 2-613
CHAPTER 12 BARGES 2-614
Section 1 GENERAL PROVISIONS 2-614
Section 2 LONGITUDINAL STRENGTH 2-615
Section 3 SHELL AND DECK PLATING 2-616
Section 4 HULL ENVELOPE FRAMING 2-616
Section 5 STRENGTHENING AT ENDS OF SHIP 2-619
Appendix METHOD OF CHECKING TRANSVERSE STRENGTH OF PONTOON BARGES 2-622
CHAPTER 13 FLOATING CRANES 2-625
Section 1 GENERAL PROVISIONS 2-625
Section 2 LONGITUDINAL STRENGTH 2-625
Section 3 SHELL PLATING 2-625
Section 4 DECKS 2-626
Section 5 SINGLE BOTTOMS 2-626
Section 6 DOUBLE BOTTOMS 2-627
Section 7 SIDE FRAMING 2-628
Section 8 STRENGTH DECK FRAMING 2-628
Section 9 PILLARS AND TRUSSES 2-629
CHAPTER 14 DREDGERS 2-630

Section 1 GENERAL PROVISIONS 2-630
Section 2 LONGITUDINAL STRENGTH 2-631
Section 3 SHELL ENVELOPE PLATING 2-633
Section 4 DECKS AND DECK FRAMING 2-634
Section 5 BOTTOM FRAMING 2-635
Section 6 SIDE FRAMING 2-636
Section 7 BOTTOM STRENGTHENING FOR OPERATING AGROUND 2-637
Section 8 HOPPERS 2-637
Section 9 SPLIT HOPPER DREDGERS AND BARGES 2-642
Section 10 MISCELLANEOUS 2-648
CHAPTER 15 SEMI-SUBMERSIBLE VESSELS 2-650
Section 1 GENERAL PROVISIONS 2-650
Section 2 STRUCTURAL STRENGTH 2-650
CHAPTER 16 Ore Carriers 2-653
Section 1 GENERAL PROVISIONS 2-653
Section 2 LONGITUDINAL STRENGTH 2-654
Section 3 HULL FRAMING 2-655
Section 4 BULKHEADS 2-659
CHAPTER 17 LAUNCHING WORK BARGES 2-662
Section 1 GENERAL PROVISIONS 2-662
Section 2 LONGITUDINAL STRENGTH 2-663
Section 3 TRANSVERSE STRENGTH 2-664
Section 4 LOCAL STRENGTH 2-664
Section 5 DIRECT STRENGTH CALCULATION 2-668
Appendix 1 DIRECT STRENGTH CALCULATION OF LAUNCHING WORK BARGES 2-669
CHAPTER 18 TWIN-HULL CRAFT 2-671
Section 1 GENERAL PROVISIONS 2-671
Section 2 STRUCTURAL STRENGTH 2-671
Section 3 TOTAL LOAD 2-671
Appendix 1 DIRECT STRENGTH CALCULATION OF TWIN-HULL CRAFT 2-674
CHAPTER 19 SAND CARRIERS 2-678
Section 1 GENERAL PROVISIONS 2-678
CHAPTER 20 MEMBRANE TANK LIQUEFIED GAS CARRIERS 2-680
Section 1 GENERAL PROVISIONS 2-680
Section 2 HULL GIRDER LONGITUDINAL STRENGTH AND ULTIMATE STRENGTH 2-683
Section 3 SHELL PLATING 2-685
Section 4 DECKS 2-687
Section 5 DECKS STRUCTURES 2-688
Section 6 DOUBLE SKIN CONSTRUCTION 2-691
Section 7 DOUBLE BOTTOM STRUCTURE 2-693
Section 8 PLANE TRANSVERSE BULKHEAD STRUCTURES 2-695
Section 9 STRUCTURAL DETAILS 2-696
Appendix 1 DIRECT CALCULATION OF HULL STRUCTURES WITHIN THE CARGO TANK REGION 2-698
APPENDIX 2 STRUCTURAL STRENGTH ASSESSMENT OF HULL AND PUMP TOWER UNDER SLOSHING LOADS 2-715
APPENDIX 3 CALCULATION OF TEMPERATURE FIELD AND THERMAL STRESS 2-741
APPENDIX 4 DIRECT CALCULATION OF GLOBAL STRENGTH OF SHIPS 2-748

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 Application

1.1.1.1 This PART applies to sea-going steel ships of all welded construction.

1.1.1.2 In addition, the hull is to comply with the applicable requirements in PART ONE of the Rules.

1.1.1.3 CSR oil tankers and bulk carriers are to satisfy the requirements of PART NINE of the Rules.

1.1.2 Definitions

1.1.2.1 Length of ship L (in m), i.e. the Rule length, is the distance measured on the waterline at the scantling draught from the forward side of the stem to the aft side of the rudder post, or to the centre of the rudder stock if there is no rudder post. L is not to be less than 96%, and need not be greater than 97%, of the extreme length on the waterline at the scantling draught. In ships with unusual stern and bow arrangement, the length L is to be specially considered.

For pontoon hulls, L is the distance on the waterline at the scantling draught from the forward side of the fore end plate to the aft side of the aft end plate.

For ships without rudder stocks (such as ships provided with azimuth thrusters), L is 97% of the extreme length on the waterline at the scantling draught.

1.1.2.2 Breadth of ship B (in m), is the greatest moulded breadth measured amidships at the scantling draught.

1.1.2.3 Moulded depth D (in m), is the vertical distance measured at the middle of the length L from top of keel to top of the deck beam at side on the uppermost continuous deck. When a rounded gunwale is arranged, the moulded depth is to be measured to the point of intersection of the continued moulded lines of the deck and side shell plating.

1.1.2.4 Draught d (in m) , i.e. the scantling draught, is the vertical distance measured at the middle of the length L from top of keel to the waterline at the scantling draught. Scantling draught, at which the strength requirements for the scantlings of the ship are met and represents the full load condition. The scantling draught is to be not less than that corresponding to the assigned freeboard.

1.1.2.5 Block coefficient C_b is the moulded block coefficient corresponding to the waterline at the scanting draught, to be determined by the following formula:

$$C_b = \frac{\nabla}{LBd}$$

where: ∇ — moulded displacement, in m³, at scantling draught d;

L, B, d — see 1.1.2.1, 1.1.2.2 and 1.1.2.4 of this Section.

1.1.2.6 Uppermost continuous deck is the uppermost deck which extends from the stem to the stern.

1.1.2.7 Strength deck means:

(1) the uppermost continuous deck;

(2) the superstructure deck extending within 0.5 L amidships, and having a length not less than 0.15 L, and the uppermost continuous deck extending outside the region of such a superstructure.

1.1.2.8 Lower decks: The continuous deck next below the uppermost continuous deck is to be named as 2nd deck, and so on. They are generally called lower decks.

1.1.2.9 Bulkhead deck is the highest deck to which the transverse watertight bulkheads extend.

1.1.2.10 Freeboard deck is the deck from which the freeboard is measured in accordance with the International Convention on Load Lines, 1966.

1.1.2.11 Platform decks are the non-continuous decks below the strength deck, which are not considered to be effective decks for longitudinal strength.

1.1.2.12 Superstructure and deckhouse: Superstructure is an enclosed structure on the uppermost continuous deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 4% of the breadth B. Forecastle, bridge and poop are regarded as superstructures. All other enclosed structures are to be termed as deckhouses.

1.1.2.13 Long superstructure and short superstructure: A superstructure having a length greater than 0.15 L and not less than 6 times its height is to be termed as a long superstructure, otherwise it is to be regarded as a short superstructure.

1.1.2.14 Long deckhouse and short deckhouse: A deckhouse having a length greater than 0.15 L and not less than 6 times its height is to be termed as a long deckhouse, otherwise it is to be regarded as a short deckhouse.

1.1.2.15 Stowage rate γ (m^3/t) is the volume of the hold, in m^3, excluding the volume contained within the depth of the cargo hatchway, divided by the mass of cargo, in tons, stowed therein.

1.1.2.16 Forward and after perpendiculars: The forward perpendicular is to coincide with the foreside of the stem on the scantling draught waterline on which the length L is measured. The after perpendicular is the perpendicular to the scantling draught waterline at a distance L aft of the fore end.

1.1.2.17 Large openings: A deck opening is to be regarded as a large opening if any of the following conditions applies:

(1) $\frac{b}{B_1} \geq 0.7$;

(2) $\frac{l_H}{l_{BH}} \geq 0.89$;

(3) $\frac{b}{B_1} > 0.6$ and $\frac{l_H}{l_{BH}} > 0.7$.

where: b — breadth of the opening, in m. Where there are several hatches abreast, b is the sum of individual widths of these openings, i.e. $b = b_1 + b_2$, as shown in Figure 1.1.2.17;

B_1 — maximum breadth of deck, in m, including opening, measured at the mid-length of the opening;

l_H — length of the hatch, in m;

l_{BH} — distance between centrelines of the deck strips at each end of the opening, in m, as shown in Figure 1.1.2.17. Where there are no further hatches fore or aft of the one under consideration, then l_{BH} is to be measured to the bulkhead.

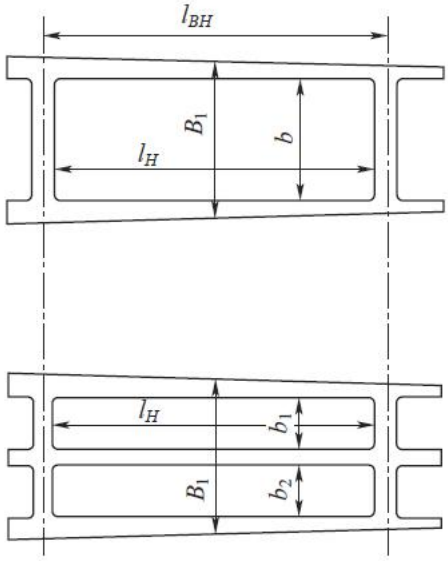


Figure 1.1.2.17

1.1.2.18 Primary members: The primary supporting members of hull are regarded as primary members, such as web frames, side stringers, transverses, deck girders, plate floors, bottom girders, bulkhead webs, etc.

1.1.2.19 Secondary members: The stiffeners of the plate are generally regarded as secondary members, i. e. frames, longitudinals, beams, bulkhead stiffeners and members of bracket floors, etc.

1.1.2.20 Load line length L_L (in m) is the ship's length as defined in Regulation 3 of Annex I to the International Convention on Load Lines, 1966.

1.1.2.21 Position 1 is as defined in Regulation 13 of Annex I to the International Convention on Load Lines, 1966.

1.1.2.22 Position 2 is as defined in Regulation 13 of Annex I to the International Convention on Load Lines, 1966.

1.1.2.23 Main frames are side frames between the collision bulkhead and the aft peak bulkhead, and below the lowest deck.

1.1.2.24 Frames in a 'tween deck space are frames between two decks.

1.1.2.25 Fore peak is a compartment situated forward of the collision bulkhead and below the bulkhead deck.

1.1.2.26 Aft peak is a compartment situated aft of the aft watertight bulkhead at the aft end of the ship

and below the bulkhead deck or the watertight platform deck.
1.1.2.27 V, the maximum service speed, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught at the maximum propeller RPM and corresponding engine MCR (Maximum Continuous Rating).

Section 2 HULL STRUCTURAL MEMBERS

1.2.1 General requirements

1.2.1.1 Except where otherwise stated, the Rule section modulus or moment of inertia in this PART is the minimum required value of the section in association with attached plating, and the attached plating is assumed as being normal to the web. When the attached plating is not normal to the web and the angle between them is less than 75°, the sectional characteristics (moment of inertia, section modulus and shear area) are to be calculated in respect to the axis parallel to the attached plating. When a structural member is of rolled section(s), its actual section modulus may be approximately determined by the following formula:

$$W = W' \sin\alpha \qquad \text{cm}^3$$

where:
W' — actual section modulus with the attached plating assumed as being normal to the web, in cm^3;
α — angel between web and attached plating, in degrees.

1.2.1.2 Except where otherwise stated in the Rules, holes are not to be cut at random in the structural members specified in this PART.
1.2.1.3 In formulae or tables where only midship and end scantlings are given, the reduction from the midship to the end scantlings is to be effected in as gradual a manner as practicable. At the break of structures, constructional arrangement is to be made to ensure a gradual transition.
1.2.1.4 Unless otherwise stated, any intermediate value between the values listed in the Tables may be obtained by linear interpolation.
1.2.1.5 As commercialized marine plates and rolled sections are not produced in sequential size series and for the purpose of providing an economic and reasonable structural requirement without compromising structural strength, the rounding tolerance for selecting steel plates according to the sizes of structural members as required in this PART is to be based on the following principles:
(1) Where the decimal part of the calculated plate thickness in this PART is 0.25 mm or less, it may be neglected; where it is greater than 0.25 mm but less than 0.75 mm, to be taken as 0.5 mm; where it is 0.75 mm or more, a round number of 1 mm is to be taken.
(2) For a structural member made of rolled section(s), its section modulus with the effective attached plate being taken into account, may be 3% less than the value required in this PART.
(3) When same sizes are taken during construction for a group of members of a same type made of rolled sections adjacent to each other in the same area, their respective section moduli with their effective attached plates being taken into account, are not to be less than the mean value of the values respectively required in this PART for individual members of the group. However, this mean value is not to be less than 95% of the greatest value required in this PART for an individual member of the group.
(4) The above principles (2) and (3) are not to be applied together.
1.2.1.6 Unless otherwise stated, all scantlings given in this PART are to be regarded as the minimum required. When designing structural members, those subject to excessive corrosion or wear and tear in service may be adequately increased in thickness.
1.2.1.7 Local members which may frequently bear the forces resulting from docking, pushing or towing, etc., are to be strengthened appropriately.

1.2.2 Attached plating of members

1.2.2.1 The effective sectional area A of attached plating of primary members is to be determined as follows, but is not to be less than the sectional area of the face plate:
(1) For a member attached to plane plating:

$$A = 10\, fbt_p \qquad \text{cm}^2$$

(2) For a member attached to corrugated plating and parallel to the corrugations:

$$A = 10\, at \qquad \text{cm}^2$$

(3) For a member attached to corrugated plating and at right angles to the corrugations:

$$A = 10\, b_f t_f \qquad \text{cm}^2$$

where: f — factor, equal to $0.3(l/b)^{2/3}$, but not to exceed 1;
b — the mean width, in m, of the load-bearing area of primary members;

l — the overall length, in m, of the primary member;
t_p — the mean thickness, in mm, of the attached plating;
b_f — the width, in m, of the face plate of primary members;
t_f — the thickness, in mm, of the face plate of primary members;
a — the width, in m, of corrugated plating flange;
t — the thickness, in mm, of corrugated plating.

1.2.2.2 For secondary members, the width of attached plating is taken as one spacing of the corresponding members.

1.2.3 The span point of members

1.2.3.1 Except where otherwise stated, the span used for the calculating of the members in this PART is the effective span between the span points.

1.2.3.2 For primary members, the span point is to be taken at a point b_e distant from the end of the member (See Figure 1.2.3.2):

$$b_e = b_b(1-\frac{d_w}{d_b})$$

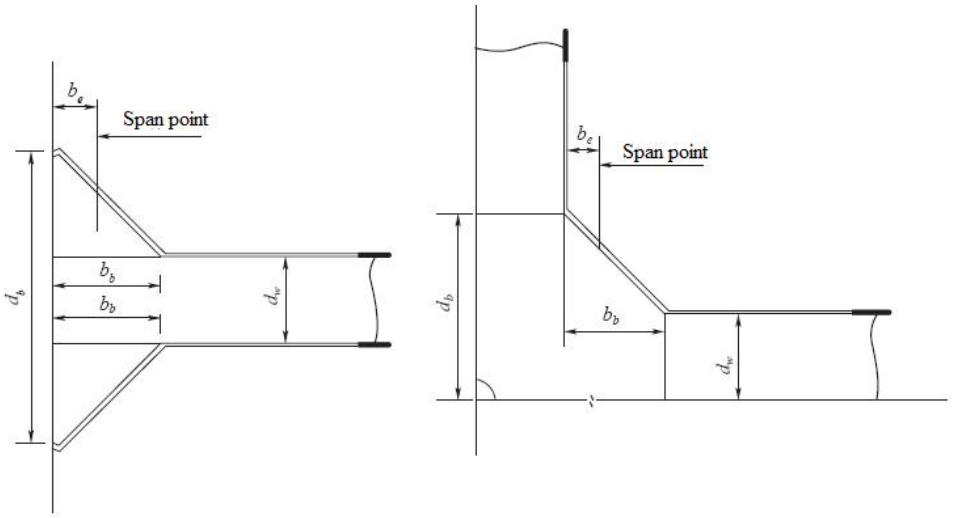


Figure 1.2.3.2

1.2.3.3 For span points of secondary members where end brackets are fitted, see Figure 1.2.3.3 (1). Where there is no end bracket, the span point is to be taken at the end of the member (as shown in Figure 1.2.3.3 (2)).

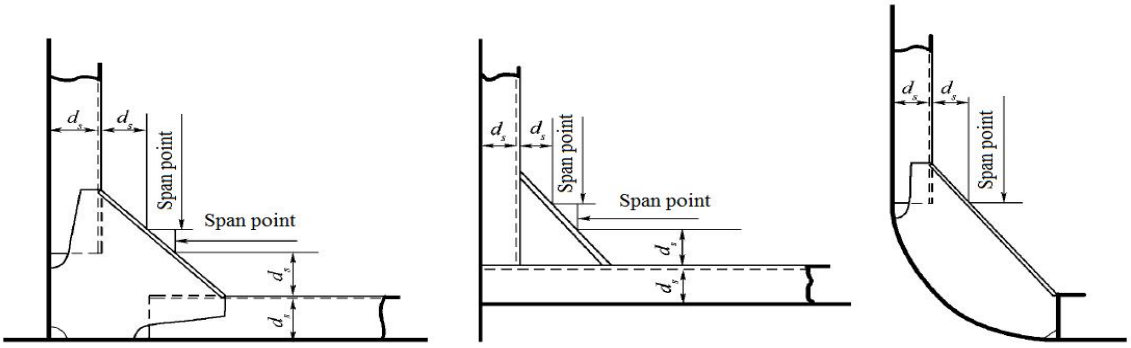


Figure 1.2.3.3(1)

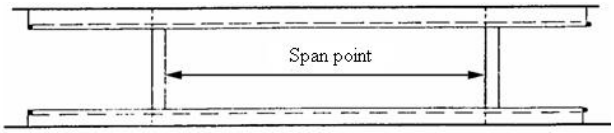


Figure 1.2.3.3(2)

1.2.3.4 Unless otherwise specified in this PART, the span of curved members is defined as the chord length between span points.

1.2.3.5 Where the ends of stiffening members are not substantially fixed against rotation and displacement, consideration will be given to the effective span to be used for the stiffener.

1.2.4 Geometrical characteristics of members

1.2.4.1 Section area A_z, moment of inertia I and section modulus W of rolled sections (including bulb flats, unequal angle bars, and unequal angle bars of unequal thickness) (see Figure 1.2.4.1) together with attached plating are to be calculated by the following formulae:

$$A_z = A_1 + A \qquad \text{cm}^4$$

$$I = I_{x1} + (y_1 - y)^2 A_1 + \frac{At^2}{12} \times 10^{-2} + (0.05\,t + y)^2 A \qquad \text{cm}^4$$

$$W = \frac{I}{0.1h - y} \qquad \text{cm}^3$$

where: h — height of the sections, in mm;

A_1 — sectional area of the sections, in cm^2;

I_{x1} — moment of self-inertia of the sections, in cm^4;

y_1 — neutral axis of the sections, in cm;

A — sectional area of the attached plate, in cm^2;

t — thickness of the attached plate in mm;

y — neutral axis with attached plate being considered, to be calculated by the following formula:

$$y = \frac{A_1 y_1 - 0.05At}{A_Z} \quad \text{cm}$$

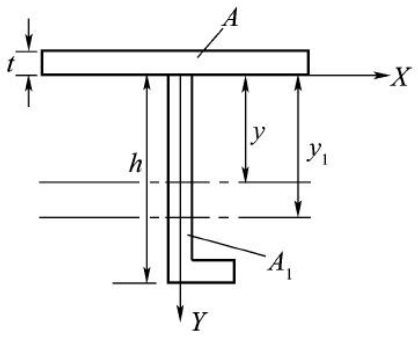


Figure 1.2.4.1

1.2.4.2 Where the thickness of both face plate and attached plate of T sections is not greater than 1/10 of web depth, section modulus W and moment of inertia I for T sections with attached plating (see Figure 1.2.4.2) may be calculated by the following formulae:

$$W = \frac{d_W}{10}\left[a + \frac{f_s}{6}\left(1 + \frac{2(A-a)}{2A + f_s}\right)\right] \quad \text{cm}^3$$

$$I = \frac{d_W^2}{100}\left[\frac{1}{3} f_s + \frac{Aa - 0.25 f_s^2}{A + a + f_s}\right] \qquad \text{cm}^4$$

where: a — sectional area of face plate, in cm^2;

A — sectional area of attached plating, in cm^2; where $A < a$, it is taken as $A = a$;

f_s — sectional area of web plate, in cm^2;

d_w — depth of web, in mm.

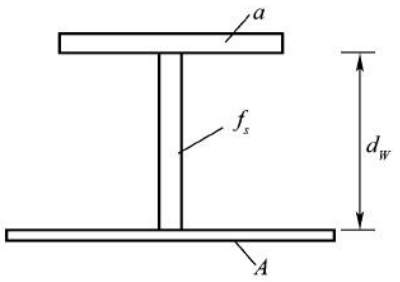


Figure 1.2.4.2

1.2.4.3 The section modulus W and moment of inertia I of a corrugation over a spacing s for corrugated bulkheads (see Figure 1.2.4.3) may be calculated by the following formulae:

$$W = d_w t\left(a + \frac{b}{3}\right) \quad \text{cm}^3$$

$$I = \frac{1}{20} d_w^2 t\left(a + \frac{b}{3}\right) \quad \text{cm}^4$$

where: a — width of corrugation flange, in m;
b — width of corrugation web, in m;
d_w — depth of corrugation, in mm;
t — thickness of corrugated bulkhead plating, in mm;
α — angle between web and flange of a corrugation.

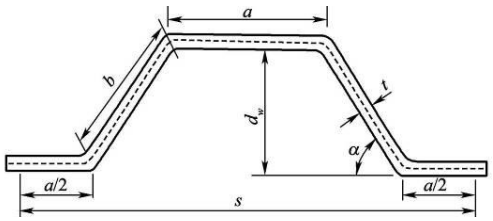


Figure 1.2.4.3

1.2.4.4 The section modulus W and moment of inertia I of double skin bulkheads (see Figure 1.2.4.4) may be calculated by the following formulae:

$$W = b\left(fst_p + \frac{bt_w}{6}\right) \times 10^3 \quad \text{cm}^3$$

$$I = 5\left(fst_p + \frac{bt_w}{6}\right) b^2 \times 10^4 \quad \text{cm}^4$$

where: b — spacing of double skins, in m;
s — average spacing of diaphragms, in m;
t_p — thickness of double skin bulkheads, in mm;
t_w — thickness of web, in mm;
f — factor, the same as specified in 1.2.2.1 of this Chapter.

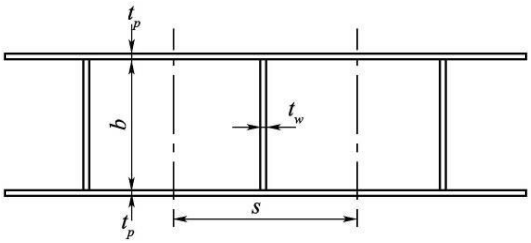


Figure 1.2.4.4

1.2.4.5 The minimum radius r of inertia of sectional area of members is to be calculated by the following formula:

$$r = \sqrt{\frac{I}{A}} \quad \text{cm}$$

where: I — minimum moment of inertia of sectional area of members, in cm^4;
A — sectional area of members, in cm^2.

1.2.5 Structural details

1.2.5.1 Primary members are to be so arranged as to ensure effective continuity of structure, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring framing. The connections of the ring framing are to be made of rounded corners having an adequate radius, and the radius of rounded corners is in general not to be less than the web depth of the adjacent members.

1.2.5.2 The web thickness t_w of primary members is not to be less than 0.01 S_w, in mm (where S_w = spacing of horizontal stiffeners on primary member web, or depth of unstiffened web, in mm); but not less than 7 mm in dry spaces and not less than 8 mm in tanks. For ships of less than 60 m in length, the web thickness may be reduced by 1 mm. For ships of less than 40 m in length, the web thickness may be reduced by 2 mm.

1.2.5.3 The sectional area A_f of face plate of primary members is not to exceed $d_w t_w/150$, in cm^2 (where d_w = depth of primary member web, in mm, t_w = thickness of primary member web, in mm).

1.2.5.4 Primary members are to be supported by tripping brackets. Where the primary members are of symmetrical section, the tripping brackets are to be fitted four secondary member spaces apart and if the width of the face plate of primary members is more than 400 mm, a back bracket is to be provided in way of the tripping bracket. Where the primary members are of asymmetrical section, tripping brackets are to be fitted on one side of the web at alternate secondary members. Tripping brackets are also to be fitted to the primary members in way of concentrated loads. If the ratio of depth to thickness of the web is greater than 55, tripping brackets or stiffeners are to be fitted close to the toes of end brackets.

The height of tripping brackets is to be extended to the face plate of primary members. The breadth is not to be less than 40% of the height. Where the unsupported breadth of the face plate or flange of primary members exceeds 15 t (t being thickness of face plate of primary members), the tripping brackets are to be welded to the face plate or flange of primary members. The thickness t_b (in mm) of tripping brackets is not to be less than 5 + 0.025 L, but need not be greater than that of web of primary members, where L being length of ship (which need not be greater than 300 m in calculation). Where the free edge length l_b (in m) is greater than 0.06 t_b, the tripping brackets are to have face plate or flange, and the sectional area A (in cm^2) of which is generally not to be less than 10 l_b.

1.2.5.5 All openings on structural members are to be kept clear of areas of stress concentration and where this is impracticable, corresponding compensation is to be made. All corners of openings are to be well rounded. Where structural members are directly connected with plates, hard points are to be avoided.

1.2.5.6 Within 0.4 L amidships, where the web height of strength deck girders is greater than 65 $t\sqrt{K}$ (t being web thickness, while K being material factor), horizontal stiffeners are to be provided parallel to face plate.

1.2.6 Secondary member end connections

1.2.6.1 Unless otherwise specified in this PART, the end connections of secondary members are to comply with the requirements of 1.2.6.

1.2.6.2 The ends of secondary members are generally to be bracketed, see Figure 1.2.6.2. Where secondary members pass through primary members, secondary members are to be connected to the webs of primary members by welding.

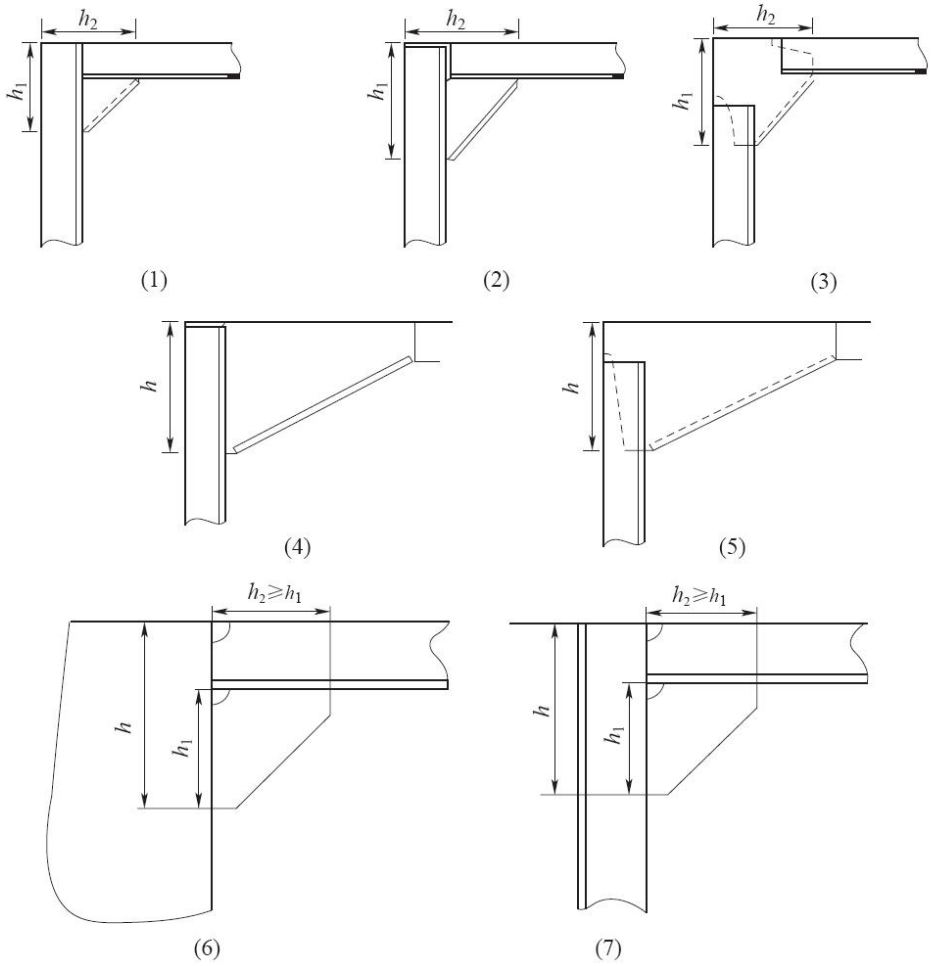


Figure 1.2.6.2

1.2.6.3 Where the secondary members contributing to longitudinal bending strength are cut in way of bulkheads or transverse primary members, connecting brackets are to be provided so as to ensure the longitudinal continuity. The brackets at both sides of the bulkheads or transverse primary members are to be in alignment.

1.2.6.4 The section modulus W of frames that is used for determining the scantlings of brackets is to be selected as follows:

(1) For the brackets connecting the secondary to the primary members, W is the section modulus of the secondary members.

(2) For the brackets at frame ends, W is the section modulus of the frames.

(3) For other brackets, W is the lesser of section moduli of two connecting members.

1.2.6.5 The thickness t of brackets is to be not less than that obtained from the following formulae:

$$t = (0.25\sqrt{W} + 2)\sqrt{\frac{R_{eH_s}}{R_{eH_b}}} + C \quad \text{mm, for brackets with face plate or flanged brackets}$$

$$t = (0.25\sqrt{W} + 3.5)\sqrt{\frac{R_{eH_s}}{R_{eH_b}}} + C \quad \text{mm, for brackets without face plate or unflanged brackets}$$

where: W — Rule section modulus of frames, in cm^3;

R_{eH_s} — yield stress of material of frames, in N/mm^2;

R_{eH_b} — yield stress of material of brackets, in N/mm^2;

C — coefficient, taken as 2.5 for brackets in tanks or 1.5 for other brackets.

The minimum thickness of brackets is generally to be 6.5 mm and need not be greater than 15 mm.

1.2.6.6 Where the Rule section modulus W of frames is not less than 500 cm^3 or the free edge is more than 50 times the thickness of brackets in length, the brackets are to be flanged or fitted with face plates. The breadth b of the flanges or face plates is not to be less than that obtained from the following formula:

$$b = 0.04W + 40 \text{ mm, and not less than 50 mm}$$

where: W — Rule section modulus of frames, in cm^3.

1.2.6.7 The arm length h of brackets is not to be less than 2.2 times the web depth of frames (where the ends of frames are welded, it may be reduced to not less than twice the web depth, see Figure 1.2.6.2 (1)), and is not to be less than that obtained from the following formula:

$$h = 75\sqrt{\frac{W}{t - C}} \text{ mm}$$

where: W — Rule section modulus of frames, in cm^3;
t — thickness of brackets, in mm;
C — coefficient, see 1.2.6.5 of this Section.

1.2.6.8 The two arms of the brackets are to be as far as possible equal in length. Where the two arms are not the same in length, they are to comply with the following:

$$h_1 + h_2 \geq 2h$$
$$h_1 \geq 0.8h$$
$$h_2 \geq 0.8h$$

where: h_1, h_2 — actual length of bracket arms, in mm, as shown in Figure 1.2.6.2;
h — arm length of brackets, in mm, see 1.2.6.7 of this Section.

1.2.6.9 Where the frame is lapped to the bracket, the length of overlap is not to be less than 1.25 times the web depth of the frame.

1.2.6.10 Where the frames are bracketed to primary members, such brackets are in general to be extended to the face plates of primary members.

1.2.7 Primary member end connections

1.2.7.1 Unless otherwise specified in this PART, the end connections of primary members are to be in compliance with the requirements of 1.2.7.

1.2.7.2 The ends of primary members are to be fitted with connecting brackets. Where two primary members are connected with a bracket, the scantlings of the bracket may be determined based upon the primary member having the lesser section modulus.

1.2.7.3 The arm length of the end bracket, which includes the web depth of the primary member, is not to be less than twice the web depth of the primary member, and the thickness of the bracket is not to be less than that of the web plate of the primary member. The brackets are to be flanged or fitted with face plates, the scantlings of which are generally to be the same as the face plates of primary members. The web plates of primary members are to be welded to connecting members. Where the side length of the non-stiffened triangle of the bracket is greater than $100t$ (t being the web thickness of the bracket), stiffeners parallel to the face plate of the bracket are to be fitted in accordance with 5.12.2.6 of Chapter 5 of this PART.

1.2.7.4 Where primary members, which are not in tanks, are connected by integral end brackets to bulkheads (i.e. the web plates of primary members gradually raised at ends), the arm length of brackets is not to be less than 1.5 times the web depth of primary members. The web plates of primary members are to be welded to bulkheads and the face plates are to be extended continuously to the bulkheads.

1.2.7.5 Where the deck girders or transverses are to be connected to bulkheads or vertical members of shell plating, the increase of scantlings of the vertical members may be required in order to ensure that connecting joints have adequate resistance to rotation.

1.2.7.6 In order to avoid the stress concentration at ends of primary strength members, the thickness of their web plates are to be adequately increased in way of toe ends of large brackets, and the face plates of brackets are to be beveled to ends. The height of toes is in general not to be greater than the thickness t_w of bracket toes, and is not to be less than 15 mm. For the recommended structural configuration of toe ends of large brackets, see Figure 1.2.7.6.

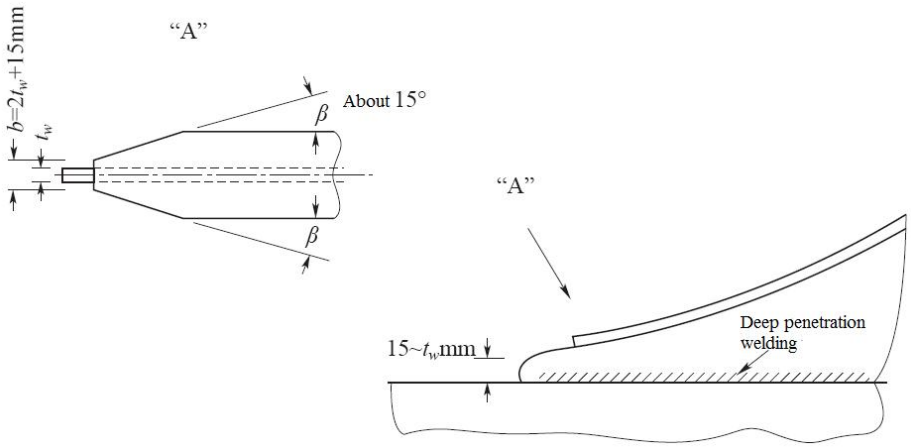


Figure 1.2.7.6

1.2.8 Standard spacing of framing members

1.2.8.1 The standard spacing s_b of frames, beams or longitudinals (bottom, side and deck) is to be calculated by the following formula:

$$s_b = 0.0016L + 0.5 \quad \text{m, but not greater than 0.7 m}$$

where: L — length of ship, in m.

1.2.8.2 In fore and aft peak tanks, the standard spacing s_b of frames or side longitudinals is to be that obtained from 1.2.8.1 or 0.6 m, whichever is the lesser.

1.2.8.3 Within $0.05L$ at ends, the standard spacing s_b of deck longitudinals or deck transverses of superstructures and deckhouses is to be that obtained from 1.2.8.1 or 0.6 m, whichever is the lesser.

Section 3 MATERIALS

1.3.1 General requirements

1.3.1.1 The chemical composition and mechanical properties of hull structural steels are to comply with the relevant requirements of Chapter 3 of PART ONE of CCS Rules for Materials and Welding.

1.3.1.2 Manufacture and testing of hull structural steels are to comply with the requirements of Chapter 1 and Chapter 2 of PART ONE of CCS Rules for Materials and Welding.

1.3.1.3 Steel castings or steel forgings used for the construction of stems, rudder posts, shaft brackets, rudder stocks and other hull structures are to comply with the relevant requirements of Chapter 5 and Chapter 6 of PART ONE of CCS Rules for Materials and Welding.

1.3.1.4 Except where otherwise stated, the elastic modulus of steel is to be taken as 2.06×10^5 N/mm^2.

1.3.1.5 Steels having a yield point not less than 265 N/mm^2 are regarded as higher tensile steels.

1.3.1.6 Where higher tensile steel is used for hull structures, its category, grade, location and extent are to be marked on the structural drawings so as to facilitate for maintenance.

1.3.1.7 The material factor K of hull structural steel is given in Table 1.3.1.7.

1.3.1.8 Unless specially provided, the yield strength of material (yield stress or yield point of material) is the specified minimum yield stress in the Rules for Materials and Welding, and the non-proportional extension strength is the minimum value of specified non-proportional extension stress.

Material Factor K **Table 1.3.1.7**

Yield strength R_{eH} (N/mm^2)	Material factor K	Yield strength R_{eH} (N/mm^2)	Material factor K
235	1.0	355	0.72
265	0.92	390	0.68 (0.66①)
315	0.78	460	0.62②

Notes:

① only apply to the strength deck and hatch coaming of containerships complying with the requirements of 7.1.1.4 of Section 1, Chapter 7 of this PART;

② only apply to the strength deck, hatch coaming plate and top plating with the range of thickness 50 mm < t ≤ 100 mm onboard container ships.

③ for materials with yield strength not listed in the table, the material factor may be specially considered.

1.3.2 Requirements for hull structural steel at normal temperature

1.3.2.1 In ships of 90 m or over in length, the hull structural steel is to comply with the requirements of 1.3.2.2 below. For strength members not covered by Tables 1.3.2.2(1) to 1.3.2.2(6) or in ships of less than 90 m in length, grade A/AH steel can generally be used for hull structure. The steel grade is to correspond to the as-built plate thickness and material class.

1.3.2.2 Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Table 1.3.2.2(1) to Table 1.3.2.2(7). General requirements are given in Table 1.3.2.2(1), while additional minimum requirements are given in the following Tables:

Table 1.3.2.2(2): for ships, excluding liquefied gas carriers covered in Table 1.3.2.2(3), with length exceeding 150 m and single strength deck;

Table 1.3.2.2(3): for membrane type liquefied gas carriers with length exceeding 150 m;

Table 1.3.2.2(4): for ships with length exceeding 250 m;

Table 1.3.2.2(5): for single side bulk carriers subjected to SOLAS regulation XII/6.4;

Table 1.3.2.2(6): for ships with ice strengthening.

1.3.2.3 For hull structural members of different material classes, the grades of steel are to be selected from Table 1.3.2.2(7) in accordance with the thickness of the structural members.

1.3.2.4 Where plate thickness is greater than that required in the Rules, the grade of steel is to be selected from Table 1.3.2.2(7) in accordance with the as-built thickness of plates.

Material Classes and Grades for Ships in General **Table 1.3.2.2(1)**

Category	Structural member	Material class/grade
Secondary	(1) Longitudinal bulkhead plating, other than that belonging to the Primary category (2) Deck plating exposed to weather, other than that belonging to the Primary or Special category (3) Side plating	Class I within 0.4*L* amidships Grade A/AH outside 0.4*L* amidships
Primary	(1) Bottom plating, including keel plate (2) Strength deck plating, excluding that belonging to the Special category (3) Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings (4) Uppermost strake in longitudinal bulkhead (5) Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	Class II within 0.4*L* amidships Grade A/AH outside 0.4*L* amidships
Special	(1) Sheer strake at strength deck① (2) Stringer plate in strength deck① (3) Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships①	Class III within 0.4*L* amidships Class II outside 0.4*L* amidships Class I outside 0.6*L* amidships
	(4) Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configurations	Class III within 0.4*L* amidships Class II outside 0.4*L* amidships Class I outside 0.6*L* amidships Min. Class III within cargo region
	(5) Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch opening configurations (5.1) Trunk deck and inner deck plating at corners of openings for liquid and gas domes in membrane type liquefied gas carriers	Class III within 0.6*L* amidships Class II within rest of cargo region
	(6) Bilge strake in ships with double bottom over the full breadth and length less than 150 m	Class II within 0.6*L* amidships Class I outside 0.6*L* amidships
	(7) Bilge strake in other ships①	Class III within 0.4*L* amidships Class II outside 0.4*L* amidships Class I outside 0.6*L* amidships
	(8) Longitudinal hatch coamings of length greater than 0.15*L* including coaming top plate and flange (9) End brackets and deck house transition of longitudinal cargo hatch coamings	Class III within 0.4*L* amidships Class II outside 0.4*L* amidships Class I outside 0.6*L* amidships Not to be less than Grade D/DH

Note: ① Single strakes required to be of Class III within 0.4*L* amidships are to have breadths not less than 800 + 5*L* mm (*L* being the ship's length), need not be greater than 1,800 mm, unless limited by the geometry of the ship's design.

Minimum Material Grades for Ships with Length Exceeding 150 m and Single Strength Deck

Table 1.3.2.2(2)

Structural member category	Material grade
Longitudinal plating of strength deck where contributing to the longitudinal strength Continuous longitudinal plating of strength members above strength deck	Grade B/AH within 0.4*L* amidships
Single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and the strength deck	Grade B/AH within cargo region

Note: This Table is applicable to ships other than the liquefied gas carriers covered in Table 1.3.2.2(3).

Minimum Material Grades for Membrane Type Liquefied Gas Carriers with Length Exceeding 150 m①

Table 1.3.2.2(3)

Structural member category		Material grade
Longitudinal plating of strength deck where contributing to the longitudinal strength		Grade B/AH within 0.4*L* amidships
Continuous longitudinal plating of strength members above the strength deck	Trunk deck plating	Class II within 0.4*L* amidships
	Inner deck plating Longitudinal strength member plating between the trunk deck and inner deck	Grade B/AH within 0.4*L* amidships

Note: ① Table 1.3.2.2(3) is applicable to membrane type liquefied gas carriers with deck arrangements as shown in Figure 1.3.2.2. Table 1.3.2.2(3) may apply to similar ship types with a 'double deck' arrangement above the strength deck.

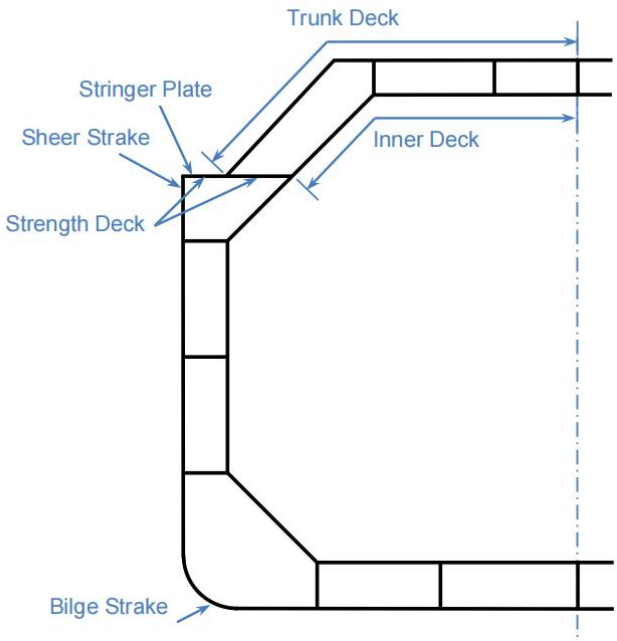


Figure 1.3.2.2 Typical Deck Arrangement for Membrane Tank Liquefied Gas Carriers

Minimum Material Grades for Ships with Length Exceeding 250 m **Table 1.3.2.2(4)**

Structural member category	Material grade
Shear strake at strength deck①	Grade E/EH within 0.4*L* amidships
Stringer plate in strength deck①	Grade E/EH within 0.4*L* amidships
Bilge strake①	Grade D/DH within 0.4*L* amidships

Note: ① Single strakes required to be of Grade D/DH or Grade E/EH as shown in the above table and within 0.4*L* amidships are to have breadths not less than 800 + 5*L* mm (*L* being the ship's length), need not be greater than 1800 (mm), unless limited by the geometry of the ship's design.

Minimum Material Grades for Single-Side Skin Bulk Carriers Subjected to SOLAS Reg. XII/6.4

Table 1.3.2.2(5)

Structural member category	Material grade
Lower bracket of ordinary side frame①②	Grade D/DH
Side shell strakes included totally or partially between the two points located to 0.125*l* above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate②	Grade D/DH

Notes: ① The term "lower bracket" means webs of lower brackets and webs of the lower part of side frames up to the point of 0.125*l* above the intersection of side shell and bilge hopper sloping plate or inner bottom plate.

② The span of the side frame, *l*, is defined as the distance between the supporting structures.

Minimum Material Grades for Ships with Ice Strengthening **Table 1.3.2.2(6)**

Structural member category	Material grade
Shell strakes in way of ice strengthening area for plates	Grade B/AH

Steel grade requirements for Material Classes **Table 1.3.2.2(7)**

Material class	I		II		III	
Thickness (mm)	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 15$	A	AH	A	AH	A	AH
$15 < t \leq 20$	A	AH	A	AH	B	AH
$20 < t \leq 25$	A	AH	B	AH	D	DH
$25 < t \leq 30$	A	AH	D	DH	D	DH
$30 < t \leq 35$	B	AH	D	DH	E	EH
$35 < t \leq 40$	B	AH	D	DH	E	EH
$40 < t \leq 50$	D	DH	E	EH	E	EH

1.3.2.5 Plating materials for stern frames supporting the rudder and propeller boss, rudders, rudder horns and shaft brackets are, in general, not to be of lower grades than those corresponding to class II. For rudder and rudder body plates subjected to stress concentrations, e.g. in way of lower support of semi-spade rudders (i.e. rudder horn recess) or at upper part of spade rudders, class III is to be applied.

1.3.2.6 For ships of less than 90 m in length, single strakes required to be of class III within 0.4*L* amidships are to have breadths not less than 800 + 5*L* mm (*L* being length of the ship, in m), but need not be greater than 1,800 mm.

1.3.2.7 The material class used for reinforcement and the quality of materials (i.e. whether mild or higher tensile steel) used for welded attachments, such as backing bars of bilge keels, is generally to be similar to that of the hull envelope plating in way.

Where attachments are made to rounded gunwale plates, special consideration will be given to the required grade of steel, taking account of the intended structural arrangements and attachment details.

1.3.2.8 The material class for deck plating, sheer strake and upper strake of longitudinal bulkhead within 0.4 *L* amidships is also to be applied at the poop front and at the ends of the bridge.

1.3.2.9 In the case of container ships, the material class for strength deck, sheer strake and torsion box structure within 0.4 *L* amidships is also to be applied in way of the entire cargo area.

1.3.2.10 On tankers having a poop, the quality of strength deck plating extending forward of the poop to any pump room openings is to be kept unchanged.

1.3.2.11 For hull structures having T connections or cruciform connections, with full penetration welding, and plate material of which is subject to high tensile stress through thickness, the use of Z-direction steel plates having through thickness properties is recommended.

1.3.3 Requirements for steel used for refrigerated space structures

1.3.3.1 Where the minimum design temperature t_D of the steel falls below 0 ℃ in refrigerated spaces, in addition to the requirements of 1.3.2 of this Section, the steel grade for the deck plating, webs of deck girders, longitudinal bulkhead strakes attached to deck and beams for supporting hatchway covers and their face plates is to comply with the requirements of Table 1.3.3.1.

Steel Grade of Structural Members in Refrigerated Spaces **Table 1.3.3.1**

Thickness (mm)	-10℃≤t_D<0℃		-25℃≤t_D<-10℃		-40℃≤t_D<-25℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 12.5$	B	AH	D	DH	E	EH
$12.5 < t \leq 25.5$	D	DH	E	EH	Specially considered①	Specially considered②
$t > 25.5$	E	EH	Specially considered①	Specially considered②	Specially considered①	Specially considered②

Notes: ① Austenitic stainless steel may generally be used.
② Grade FH may generally be used.

1.3.3.2 The minimum design temperature of the refrigerated space deck may be assessed by a temperature gradient calculation or may be determined in accordance with Table 1.3.3.2. Where one of the internal spaces concerned is not refrigerated, the temperature of the space is to be taken as 5℃.

Minimum Design Temperature of Refrigerated Space Deck **Table 1.3.3.2**

Item	Arrangement	Deck temperature
1	Deck not covered with insulation in the refrigerated space	Temperature of the refrigerated space
2	Deck covered with insulation in the refrigerated space and not insulated on the other side	Temperature of the space on the uninsulated side
3	Deck covered with insulation on both sides: (1) Temperature difference not greater than 11℃ (2) Temperature difference greater than 11℃ but not greater than 33℃	 Mean of the temperatures of the spaces above and below the deck Mean of the temperatures of the spaces above and below the deck less 3℃

1.3.4 Ships exposed to low air temperatures

1.3.4.1 For ships intended to operate in areas with low air temperatures (below -10℃), e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D. The design temperature t_D is to be taken as defined in 1.3.4.6.

1.3.4.2 Materials in the various strength members above the lowest ballast waterline (BWL) exposed to low air temperatures (including the plating covered by note ⑤ of Table 1.3.4.2) and materials of cargo tank boundary plating to which 1.3.4.7 is applicable are not to be lower than those as given in Table 1.3.4.2. For non-exposed hull structural steel above BWL (except for ⑤ as indicated in Table 1.3.4.2) and hull structural steel below BWL, the requirements in 1.3.2 of this Section apply.

1.3.4.3 Grades of steel for hull structural members of different material classes are to be selected according to Table 1.3.4.3 depending on plate thickness and design temperature. Where the design temperature t_D is below -55℃, the grades of steel are to be subject to special consideration by CCS.

1.3.4.4 Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less than $800 + 5L$ mm (L being length of the ship, in m), but need not be greater than 1,800 mm.

1.3.4.5 Plating materials for stern frames, rudders, rudder horns and shaft brackets are not to be of lower grades than those required in 1.3.2 of this Section.

Material Classes at Low Temperatures **Table 1.3.4.2**

Structural member category	Structural member	Material class	
		Within 0.4L amidships	Outside 0.4L amidships
Secondary	Deck plating exposed to weather in general, side plating above BWL, transverse bulkheads above BWL⑤ Cargo tank boundary plating exposed to cold cargo⑥	I	I
Primary	Strength deck plating① Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings Longitudinal bulkhead above BWL⑤ Top wing tank bulkhead above BWL⑤	II	I

Structural member category	Structural member	Material class	
		Within 0.4*L* amidships	Outside 0.4*L* amidships
Special	Sheer strake at strength deck, including rounded gunwale② Stringer plate in strength deck② Deck strake at longitudinal bulkhead③ Continuous longitudinal hatch coamings④	III	II

Notes: ① Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.

② Not to be less than grade E/EH within 0.4 *L* amidships in ships with length exceeding 250 m.

③ In ships with breadth exceeding 70 m at least three deck strakes to be class III.

④ Not to be less than grade D/DH.

⑤ Applicable to plating attached to hull envelope plating exposed to low air temperature. At least one strake is to be considered in the same way as exposed plating and the strake width is to be at least 600 mm.

⑥ For cargo tank boundary plating exposed to cold cargo for ships other than liquefied gas carriers, the requirements of 1.3.4.7 are to be satisfied.

Material Grade Requirements for Classes I, II and III at Low Temperatures Table 1.3.4.3

Class I										
Plate thickness, in mm	-11～-15℃		-16～-25℃		-26～-35℃		-36～-45℃		-46～-55℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	A	AH	A	AH	B	AH	D	DH	D	DH
$10 < t \leq 15$	A	AH	B	AH	D	DH	D	DH	D	DH
$15 < t \leq 20$	A	AH	B	AH	D	DH	D	DH	E	EH
$20 < t \leq 25$	B	AH	D	DH	D	DH	D	DH	E	EH
$25 < t \leq 30$	B	AH	D	DH	D	DH	E	EH	E	EH
$30 < t \leq 35$	D	DH	D	DH	D	DH	E	EH	E	EH
$35 < t \leq 45$	D	DH	D	DH	E	EH	E	EH	–	FH
$45 < t \leq 50$	D	DH	E	EH	E	EH	–	FH	–	FH
Class II										
Plate thickness, in mm	-11～-15℃		-16～-25℃		-26～-35℃		-36～-45℃		-46～-55℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	A	AH	B	AH	D	DH	D	DH	E	EH
$10 < t \leq 20$	B	AH	D	DH	D	DH	E	EH	E	EH
$20 < t \leq 30$	D	DH	D	DH	E	EH	E	EH	–	FH
$30 < t \leq 40$	D	DH	E	EH	E	EH	–	FH	–	FH
$40 < t \leq 45$	E	EH	E	EH	–	FH	–	FH	–	–
$45 < t \leq 50$	E	EH	E	EH	–	FH	–	FH	–	–
Class III										
Plate thickness, in mm	-11～-15℃		-16～-25℃		-26～-35℃		-36～-45℃		-46～-55℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	B	AH	D	DH	D	DH	E	EH	E	EH
$10 < t \leq 20$	D	DH	D	DH	E	EH	E	EH	–	FH
$20 < t \leq 25$	D	DH	E	EH	E	EH	E	FH	–	FH
$25 < t \leq 30$	D	DH	E	EH	E	EH	–	FH	–	FH
$30 < t \leq 35$	E	EH	E	EH	–	FH	–	FH	–	–
$35 < t \leq 40$	E	EH	E	EH	–	FH	–	FH	–	–
$40 < t \leq 50$	E	EH	–	FH	–	FH	–	–	–	–

Note: "–" in the Table = Not applicable.

1.3.4.6 The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

mean: statistical mean over observation period;

daily average: average during one day and night;

lowest: lowest during year.

For seasonally restricted service the lowest value within the period of operation applies.

Figure 1.3.4.6 illustrates the temperature definition.

For the purpose of issuing a Polar Ship Certificate in accordance with the Polar Code, the design temperature t_D is to be no more than 13℃ higher than the Polar Service Temperature (PST) of the ship.

In the Polar Regions, the statistical mean over observation period is to be determined for a period of at least 10 years.

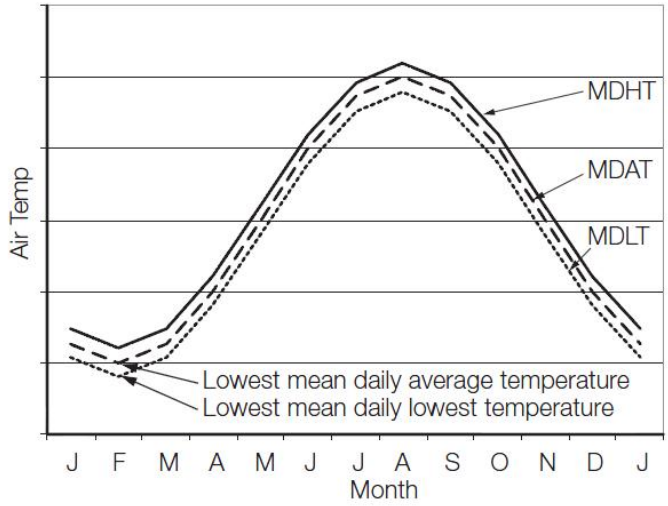


Figure 1.3.4.6 General Temperature Definitions

1.3.4.7 Cold cargo for ships other than liquefied gas carriers

For ships other than liquefied gas carriers, intended to be loaded with liquid cargo having a temperature below -10℃, e.g. loading from cold onshore storage tanks during winter conditions, the material grade of cargo tank boundary plating is defined in Table 1.3.4.3 based on the following:

(1) t_c design minimum cargo temperature in ℃;

(2) steel grade corresponding to Class I as given in Table 1.3.4.2.

The design minimum cargo temperature, t_c is to be specified in the loading manual.

1.3.5 Use of aluminium alloy

1.3.5.1 The use of aluminum alloy is permitted for superstructures, deckhouses, hatch covers, or other similar structures, based on equivalent strength, instead of hull structural steel as required in the Rules. The chemical composition and mechanical properties of aluminum alloys used are to comply with the relevant requirements of Chapter 8, PART ONE of CCS Rules for Materials and Welding.

1.3.5.2 Unless stated otherwise, the modulus of elasticity of aluminium alloy may be taken as 70,000 N/mm².

1.3.5.3 The scantlings of aluminium alloy structures may be obtained from the following formulae:

For plating thickness: $t_a = t_s \sqrt{K_a}$ mm

For section modulus: $W_a = W_s K_a$ cm³

where:

t_s — thickness of mild steel plating as required in the Rules, in mm;

W_s — section modulus of mild steel as required in the Rules, in cm³;

K_a — material factor for aluminium alloy, $K_a = \frac{235}{R'_{\text{lim}}}$;

R'_{lim} — the minimum yield stress $R'_{p0.2}$ of parent material which could be guaranteed under welding condition, in N/mm², to be taken not greater than 70% minimum tensile strength R'_m of parent material which could be guaranteed under welding condition:

$$R'_{p0.2} = \eta_1 R_{p0.2}$$

$$R'_m = \eta_2 R_m ;$$

$R_{p0.2}$ — the minimum yield stress of parent material which could be guaranteed under delivery condition, in N/mm²;

R_m — the minimum tensile strength of parent material which could be guaranteed under delivery condition, in N/mm². η_1 and η_2 are given in Table 1.3.5.3(1).

Aluminium Alloy used for Welded Structures **Table 1.3.5.3(1)**

Aluminium alloy	η_1	η_2
Not treated by hardening (5000 series under annealed condition O or annealing leveling condition H111)	1	1
Treated by hardening (5000 series other than O or H111)	$R'_{p0.2}/R_{p0.2}$	R'_m/R_m
Heat treated and hardened (6000 series) (1)	$R'_{p0.2}/R_{p0.2}$	0.6

Note: (1) If information is not provided, the factor η_1 is to be taken as metallographic efficiency coefficient β defined in Table 1.3.5.3(2);

$R'_{p0.2}$ — the minimum yield stress of material which could be guaranteed under welding condition, in N/mm^2;

R'_m — the minimum tensile strength of material which could be guaranteed under welding condition, in N/mm^2.

Alunimun Alloy — Metallographic Efficiency Coefficient β **Table 1.3.5.3(2)**

Aluminium alloy	Tempering condition	Total thickness (mm)	β
6005A (opening section)	T5 or T6	$t \le 6$	0.45
		$t > 6$	0.40
6005A (closed section)	T5 or T6	All	0.50
6061 (section)	T6	All	0.53
6082 (section)	T6	All	0.45

1.3.5.4 The welding procedures for aluminium alloy are to be subject to approval. The methods used for connecting aluminium alloy with steel members and the information for measures to be taken for corrosion control are to be submitted to CCS for examination.

1.3.6 Use of stainless steel

1.3.6.1 Stainless steel may be used for tanks onboard oil tankers and chemical tankers to equivalently substitute the hull structure steels required in the Rules.

1.3.6.2 Except where otherwise stated, the elastic modulus of stainless steel may be taken as 2.06×10^5 N/mm^2.

1.3.6.3 The material factor K is to be calculated by the following formula:

$$K=\frac{235}{R_{eHT}}$$

where: R_{eHT} — the minimum yield strength or non-proportional extension strength of stainless steel under the designed allowable maximum cargo temperature, in N/mm^2, to be calculated by the following formulae:

for no nitrogen austenitic stainless steel:

$$R_{eHT}=-40\ln(T)+127+R_{P0.2};$$

for nitrogen austenitic stainless steel:

$$R_{eHT}=-48\ln(T)+142+R_{P0.2};$$

for duplex stainless steel:

$$R_{eHT}=-65\ln(T)+200+R_{P0.2}.$$

T — the designed allowable maximum cargo temperature, in℃;

$R_{p0.2}$ — the minimum yield strength or non-proportional extension strength of stainless steel, in N/mm^2 at room temperature, in accordance with the relevant requirements of Section 8, Chapter 3, PART ONE of CCS Rules for Materials and Welding.

For duplex stainless steel, K is not to be less than 0.68.

Section 4 WELD DESIGN FOR HULL STRUCTURES

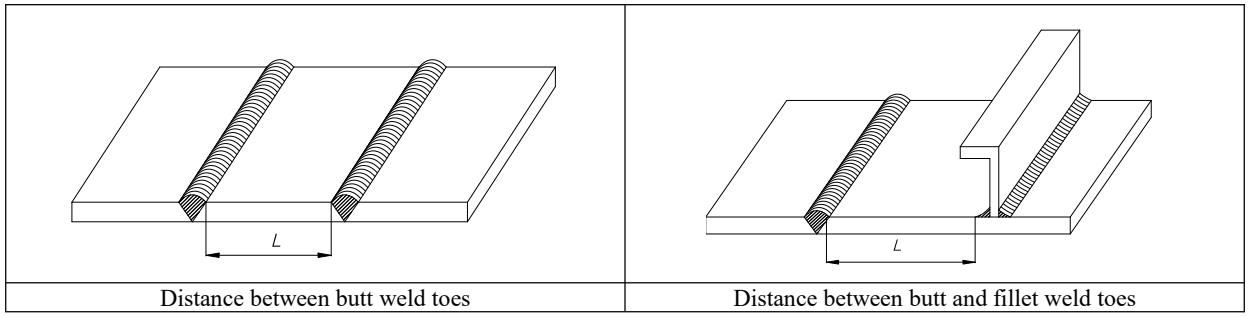
1.4.1 General requirements

1.4.1.1 This Section applies to the weld design for normal hull structures and components. Welding procedures for the construction of hull are to comply with the relevant requirements of CCS Rules for Materials and Welding.

1.4.1.2 The arrangement of welds in hull structures is to be such as to allow adequate access for completion of all welding operations. Welded joints are to be so arranged as to facilitate the use of flat (downhand) welding wherever possible.

1.4.1.3 Where welding is used for hull structures, care is to be taken to avoid the arrangement of welded joints in positions of stress concentration. Adequate transition is to be made in way of the abrupt changes of shape or section, and excessive concentration of welds over such positions is to be avoided.

1.4.1.4 Parallel welded seams in the main hull structures are to be spaced an adequate distance apart. The distance l_1 between two parallel butt welded seams is not to be less than 100 mm, and the butt welded seams are not to be intersected with an acute angle. Where a butt welded seam is in parallel with a fillet welded seam, the distance l_2 between them is not to be less than 10 mm. The distance between the above two welded seams is in general the distance between inner edges of two weld toes (as shown in Figure 1.4.1.4).



Distance between butt weld toes | Distance between butt and fillet weld toes

Figure 1.4.1.4 Distance between parallel welded seams

1.4.1.5 The shell plating, deck plating, inner bottom plating and bulkhead plating are all to be connected by butt welds.

1.4.1.6 Overlaps are generally not to be used to connect plates in hull structures, particularly for plates which may be subjected to high stress.

1.4.1.7 The use of permanent backing bars in highly stressed welds in hull structures is to be avoided as far as possible.

1.4.1.8 Double continuous fillet welding is to be adopted in the following locations:

(1) boundaries of weathertight decks and erections, including hatch coamings, companionways and coamings of other openings;

(2) boundaries of tanks and watertight compartments;

(3) connections in foundations and supporting structures;

(4) all structure in the aft peak and the aft peak bulkhead stiffeners;

(5) all welding inside tanks intended for chemicals or edible liquid cargoes;

(6) main frames and their upper and lower brackets in cargo holds of bulk carriers to side shell plating and sloped bulkhead plating of topside tanks and hopper side tanks;

(7) all lap welds in tanks;

(8) primary and secondary members to bottom shell in the 0.25 L forward;

(9) centreline girder to keel plate;

(10) boundaries of galleys, pantries, laundry rooms, bathrooms, toilets and storage battery rooms, etc.;

(11) primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections;

(12) other special connections or attachments, and in particular the attachment of minor fittings to higher tensile steel plating, will be specially considered.

1.4.1.9 Where higher tensile steel is used, double continuous fillet welds are normally to be adopted.

1.4.1.10 Details of the welded connections of main structural members of the hull, including type and size of welds, are to be clearly indicated on the plans submitted for approval. The extent to which automatic welding is used is to be indicated on the plans.

1.4.1.11 When arranging side joints of shell plating, the arrangement of longitudinal members such as deck plating, longitudinals and inner bottom margin plates are to be taken into account, avoiding coincidence of the side joints and fillet welds of longitudinal members or their intersection to an excessively small angle. The butt welds of end joint of the shell are to avoid the toes of internal longitudinal members and the fillet welding of transverse members as far as practicable.

1.4.2 Welding consumables

1.4.2.1 Welding consumables used for hull structures are to comply with the requirements of CCS Rules for Materials and Welding. The grade of welding consumables selected is to be suitable for the grade of hull structural steel, and is to comply with the requirements of Table 1.4.2.1. Welding consumables of H47 steels are to be selected by referring to CCS Guidelines for Application of Thick Higher Strength Steel Plates for Ships and welding consumables of other steels are to be selected by referring to CCS Guidelines for Inspection of Hull Welds.

Selection of Welding Consumables **Table 1.4.2.1**

Hull structural steel grade / Grade of welding consumables	A	B	D	E	AH27 AH32 AH36	DH27 DH32 DH36	EH27 EH32 EH36	FH27 FH32 FH36	AH40	DH40	EH40	FH40
1	×											
2	×	×	×									
3	×	×	×	×								
1Y	×				×②							
2Y	×	×	×		×	×						
3Y	×	×	×	×	×	×	×					
4Y	×	×	×	×	×	×	×	×				
2Y40	①	①	①		×	×			×	×		
3Y40	①	①	①	①	×	×	×		×	×	×	
4Y40	①	①	①	①	×	×	×	×	×	×	×	×
5Y40	①	①	①	①	×	×	×	×	×	×	×	×

Notes: "×" means applicable;

① When joining structural steels of normal strength, it is not recommended to use a much higher grade of welding consumable.

② When using Grade 1Y welding consumables, the material thicknesses should not exceed 25 mm.

1.4.2.2 For the joining of steels of different strength levels, the welding consumables in general may be of a type suitable for the lower strength level except at structural discontinuities or areas of stress concentration. For the joining of steels of the same strength level but of different toughness grades, the welding consumables in general may be of a type suitable for the lower toughness grade except for the structural members subjected to complicated forces or severe construction conditions.

1.4.2.3 Low hydrogen welding consumables are to be used for the welding of the following structural members and components:

(1) Circumferential butt welds in the joining of block sections and butt welds of girders;

(2) End and side joints of the shell of ships with ice strengthening;

(3) Masts, derricks, boat davits, bollards and other outfits subjected to heavy loads and all other highly stressed fittings;

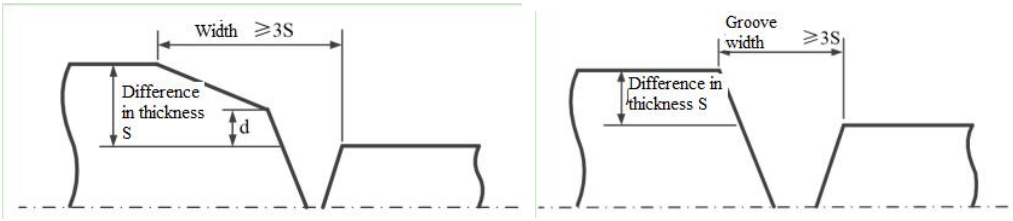
(4) Components for which high rigidity is required, such as stems, stern frames, propeller shaft brackets, and joints between them and the shell plating and the hull framing;

(5) Main engine seatings and the associated structural members.

1.4.2.4 It is recommended that low hydrogen welding consumables be used for the joining of higher strength structural steel or of steel with carbon equivalent over 0.41%.

1.4.3 Butt, lap and slot welds

1.4.3.1 Where plates of different thicknesses are to be butt welded and the difference in thickness of one side is less than or equal to 4 mm, the transition may be achieved within the width of the weld. Where the difference in thickness of one side is greater than 4 mm, the edge of the thicker plate is to be tapered so as to ensure a uniform transition with the weld. The width is not to be less than 3 times the difference in thickness of one side, and the difference in height of the two sides of the groove d is not to be greater than 4 mm, as shown in Figure 1.4.3.1(1). Where the groove width is not less than 3 times the difference in thickness of one side, taper may not be necessary and the transition may be achieved within the width of the weld, as shown in Figure 1.4.3.1(2).



(1) (2)

Figure 1.4.3.1 Butt welding of steel plates of different thickness

1.4.3.2 Overlaps are generally not to be used to connect plates which may be subjected to high tensile stress or compressive loading. Where plate overlaps are adopted, the breadth (*b*) of the overlap is not to exceed four times nor be less than three times the thickness of the thinner plate, see Figure 1.4.3.2. The joints are to be positioned as to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

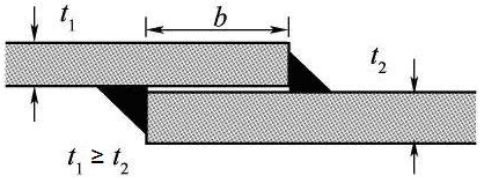


Figure 1.4.3.2

1.4.3.3 For the connection of plating to internal webs, where access for fillet welding is not practicable, the closing plating is to be attached by continuous full penetration welds or slot fillet welds to face plates fitted to the webs. Slots are to have a minimum length of 75 mm and a minimum width of twice the plating thickness, with well rounded ends, and spaced not more than 150 mm apart. Slots are normally not to be filled with welding.

1.4.4 Fillet welds

1.4.4.1 T-connections of hull structures are generally to be made by fillet welds on both sides of the abutting plate, including fillet welds, partial penetration fillet welds and full penetration fillet welds. The types and application of fillet welds are to be as shown in Table 1.4.4.1.

1.4.4.2 The size of fillet welds for hull structural connection is to be determined as follows:

(1) The throat thickness *h* of fillet welds is to be determined from the following formula:

$$h = w_\tau t_p \frac{d}{l} \quad \text{mm}$$

where: t_p — thickness of the thinner plate of the abutting plates, in mm, e.g. t_1 or t_2 in item 1 of Table 1.4.4.1 of this Section, whichever is the lesser;

d — distance between weld fillets, in mm, i.e. the distance between start positions of successive weld fillets for intermittent welding, as shown in items Figure 1.4.4.2 of this Section; where the fillet weld is continuous, d is to be equal to l;

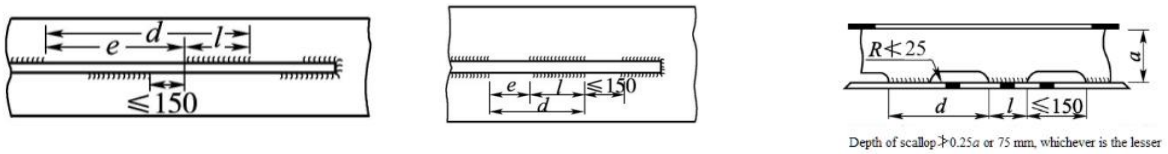
l — the length of weld fillet, in mm, clear of end craters, and is not to be less than 75 mm;

w_τ — weld factor. The weld factors used for hull structures are as specified in Table 1.4.4.2 of this Section. Where an approved automatic deep penetration procedure is used, W_τ may be 85% of the value given in the Table.

The fillet leg length *K* is not to be less than the value obtained from the following formula:

$$K = \sqrt{2}h \text{ mm}$$

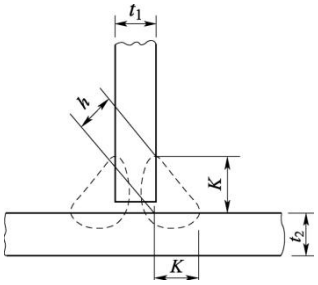
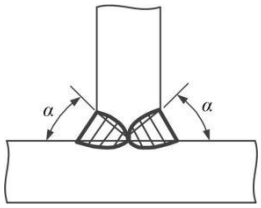
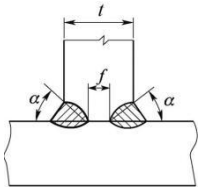
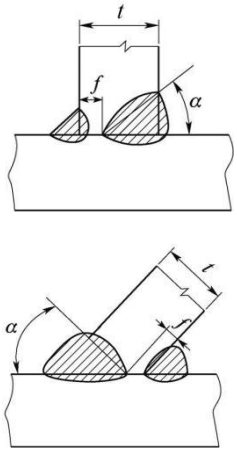
(2) In case of full penetration welding, there is no requirement for root face. For partial penetration welds the root face, *f*, is, to be taken between 3 mm and 1/3*t*. The groove angle made to ensure welding bead penetrating up to the root of the groove, α, is usually from 40° to 60°. The welding bead of the full/partial penetration welds is to cover root of the groove.



l – length of weld, e – spacing of welds, d – distance between weld fillets, welding to be carried round both ends of plating for intermittent fillet welds and ends of all lugs for scalloped construction.

Figure 1.4.4.2

Types of Fillet Welds **Table 1.4.4.1**

Item	Fillet weld	Type	Remark
1	Double continuous		Used for ordinary connection K – leg length h – throat thickness t_1, t_2 – thickness of plates
2	Double full penetration welding		Used in areas with high tensile stresses or areas considered critical α — groove angle
3	Double symmetrical groove partial penetration welding		Used in areas with relatively high tensile stresses or areas considered critical t —thickness of weldment f—root face α —groove angle
4	Double asymmetrical groove partial penetration welding		Used in areas with relatively high tensile stresses or areas considered critical t —thickness of weldment f—root face α —groove angle

Weld Factors **Table 1.4.4.2**

Item		Weld factor	Remark
1 General application (except as required below):			
(1) Watertight or oiltight plate boundaries		0.34	
(2) Non-tight plate boundaries		0.13	
(3) Longitudinals, frames, beams, and other secondary members to shell, deck or bulkhead plating		0.10	
		0.13	In tanks
		0.21	In way of end connections
(4) Panel stiffeners (i.e. small stiffeners)		0.10	
(5) Overlap welds		0.27	
(6) Longitudinals of the flat-bar type to plating		0.21	Double continuous
2 Bottom construction in way of holds or tanks			
(1) Tight centre girder	to keel	0.44	
	to inner bottom	0.44	
(2) Non-tight centre girder (or centre keelson)	to keel	0.27	
	to inner bottom (or face plate of centre keelson)	0.21	No scallops
(3) Tight boundaries of floors, girders		0.39	
(4) Non-tight boundaries of floors, girders (or side keelson) and brackets		0.16	
		0.21	In way of 0.2 × span at ends
		0.27	In way of brackets at lower end of main frame
(5) Inner bottom longitudinals or reverse frames to inner bottom		0.13	Under holds strengthened for heavy cargoes
(6) Floors supporting plane, corrugated, double plate bulkheads and bulkhead stools to inner bottom		0.44	Double continuous
3 Hull framing			
(1) Webs of web frames and stringers to shell		0.16	
(2) Webs of web frames and stringers to face plate		0.13	
(3) Tank side brackets to shell and inner bottom		0.34	
(4) Main frames of cargo holds in bulk carriers to shell plating		0.40	See 8.3.6 in this PART
(5) End brackets of main frames of cargo holds in bulk carriers		0.44	See 8.3.6 in this PART
4 Decks and supporting structure			
(1) Strength deck plating to shell		0.44	See 5.2.5 of PART THREE of CCS Rules for Materials and Welding Generally double continuous
(2) Other decks to shell and bulkheads (except where forming tank boundaries)		0.21	
(3) Webs of cantilevers to deck and to shell in way of root bracket		0.44	
(4) Webs of cantilevers to face plate		0.21	
(5) Pillars:	end connections	0.34	0.21 in a length of 0.15 span of hatch girders at ends
	end connections (tubular)	0.44	
(6) Girder web connections and brackets in way of pillar heads and heels		0.21	
(7) Web plates of hatch girders and deck web beams to deck, their face plates		0.16	
5 Bulkheads and tank construction			
(1) Watertight plane, corrugated, double plate bulkheads to bottom, inner bottom, bilge plating, hopper and topside tanks, decks and face plates of		0.44	

Item		Weld factor	Remark
bulkhead stools			
(2) Upper and lower bulkhead stool plates to their face plates		0.44	Full penetration in way of lower stool
(3) Bulkhead stool plates to inner bottom, deck and bilge		0.44	
(4) Bulkhead plating to side shell		0.34	
(5) Bulkhead plating to secondary members where acting as pillars		0.13	
(6) Non-watertight pillar bulkhead boundaries		0.13	
(7) Perforated flats and wash bulkhead boundaries		0.10	
6 Structure in cargo tanks of oil tankers			
(1) Bottom longitudinals to shell		0.21	For forward of 0.25L
(2) Connections between primary structural members		0.44	At bottom
		0.34	At deck
(3) Longitudinal oiltight bulkhead boundaries		0.44	Throat thickness $h \geq 0.34t$, t being bulkhead thickness, in mm
(4)	Transverse oiltight bulkhead to bottom	0.44	Throat thickness $h \geq 0.34t$, t being bulkhead thickness, in mm
	Transverse oiltight bulkhead to deck, sides and longitudinal bulkhead	0.34	
(5) Non-tight bulkhead boundaries		0.21	Generally
(6) Boundaries of non-watertight girders and floors in double bottom		0.34	Within 0.2L at ends of ship
		0.40	Under bulkhead stools
		0.44	
(7) Frames rings in hopper and topside tanks to shell, deck and sloping (top) plating		0.34	
(8) Boundaries of diaphragms or frame rings, side girders in double hull		0.34	Generally
		0.40	Within 0.2L at ends of ship
(9) Between primary structural members in double hull, double bottom, hopper tanks and topside tanks		0.34	
(10) Longitudinal girders or frame rings to face plates in hopper tanks, topside tanks and double hull		0.27	
(11) Web plates of primary structural members in cargo tanks to longitudinal and transverse bulkheads, inner bottom and deck		0.34	Generally
		0.44	Within 0.2L at ends of ship
(12) Web plates of primary structural members in cargo tanks to face plates		0.27	Generally
		0.34	Within 0.2L at ends of ship
7 Structure in hoppers of hopper dredgers			
(1) Bulkhead boundary connections		0.44	At bottom and bilge
		0.34	At deck and coamings
(2) Cross members to longitudinal bulkheads		0.44	
(3) Pillar end connections		0.34	
(4) Hopper door hinges of self-unloading ships		0.44	Partial penetration
8 Structure in machinery space			
(1) Non-tight centre girder (or centre keelson) to keel and inner bottom (or face plate of centre keelson)		0.27	
(2) Non-tight floors to centre girder (or centre keelson) in way of engine, thrust and boiler bearers		0.27	
(3) Non-tight floors and girders (or side keelsons) to shell and inner bottom		0.21	Partial penetration, girders to be tapered to both sides, root face ≤ 1/3 girder thickness
(4)	Main engine foundation girders to top plate	0.44	
	Main engine foundation girders to hull structure	0.44	

Item			Weld factor	Remark
	Floors to main engine foundation girders		0.27	
	Brackets to main engine foundation girders		0.21	
(5) Transverse and longitudinal framing to shell			0.13	
9 Construction in 0.25*L* forward				
(1) Floors and girders (or centre keelson, etc.) to shell and inner bottom			0.21	
(2) Bottom longitudinals to shell			0.13	
(3) Transverse and longitudinal side framing to shell			0.13	
(4) Tank side brackets to frame and inner bottom			0.34	
(5) Panting stringers to shell and frames			0.34	
(6) All internal structure in fore peak			0.13	Unless a greater weld factor is required
10 Aft peak construction: All internal structure including stiffeners on aft peak bulkhead			0.21	Unless a greater weld factor is required
11 Superstructure and deckhouses				
(1) Connection of external bulkheads to deck			0.34	1st and 2nd tier erections
			0.21	Elsewhere
(2) Internal bulkheads to deck			0.13	
12 Hatchways and closing arrangements				
(1) Hatch coamings to deck			0.34	0.44 at corners
(2) Hatch coaming stays (stiffeners, brackets)		To coaming	0.13	
		To deck	0.21	
(3) Hatch cover rest bar			0.16	
(4) Cleats and fittings			0.44	Increased welding may be required
(5) Primary and secondary stiffening of hatch covers			0.10	0.13 for tank covers and where covers strengthened for loads over
13 Steering control systems				
(1) Rudder	① Fabricated mainpiece and mainpiece to side plates and webs		0.44	
	② Slot welds inside plates		0.44	
	③ Remaining construction		0.21	
(2) Fixed and steering nozzles		Main structure	0.44	
		Elsewhere	0.21	
(3) Thruster units and stabilizers		Main structure	0.44	
		Elsewhere	0.21	
14 Miscellaneous fittings and equipment				
(1) Rings for manhole type covers to deck, inner bottom or bulkhead			0.34	
(2) Frames of shell and weathertight bulkhead doors			0.34	
(3) Stiffening of watertight doors			0.21	
(4) Ventilator, air pipe, etc., coamings		To deck	0.34	Positions 1 and 2 specified by Load Line assignment
		Elsewhere	0.21	
(5) Ventilator, etc., fittings			0.21	
(6) Scuppers and discharges, to deck			0.44	
(7) Masts, derrick posts, crane pedestals, etc., to deck			0.44	See 5.2.7 of PART THREE of CCS Rules for Materials and Welding
(8) Deck machinery seats to deck			0.21	Special equipment subject to design

Item	Weld factor	Remark
(9) Mooring equipment (bollards, etc.) seats to deck	0.21	Increased or full penetration welding may be required
(10) Bulwark stays to deck	0.21	
(11) Bulwark attachment and guard rails, stanchions, etc., to deck	0.34	
(12) Bilge keel backing bars to shell	0.34	
(13) Bilge keels to backing bars	0.21	

1.4.4.3 Where the thickness of the abutting member of the T connection (e.g. the web of a stiffener or longitudinal) is greater than 15 mm and exceeds the thickness of the table member (e.g. bulkhead plating, shell plating or deck plating), the welding is to be double continuous and the throat thickness h of the weld is to be neither less than the value given in Table 1.4.4.4(2) of this Section, nor less than the greater of the following:

$$h = 0.5Ct_v \quad \text{mm}$$

$$h = 0.21t_h \quad \text{mm}$$

where: t_v — thickness of the abutting member, in mm;

t_h — thickness of the table member, in mm;

C — coefficient, 0.21 for dry cargo holds, or 0.27 for liquid tanks.

1.4.4.4 Except as permitted by 1.4.4.2 and 1.4.4.3 of this Section, the throat thickness of all fillet welds is to comply with the following requirements:

(1) The limits of throat thickness are to be as shown in Table 1.4.4.4(1);

(2) The minimum value of throat thickness is also to comply with the requirements of Table 1.4.4.4(2).

Limits of Throat Thickness **Table 1.4.4.4(1)**

Item	Limits of throat thickness (mm)	
	Minimum	Maximum
Double continuous welding	0.21 t_p	0.44 t_p
Intermittent welding	0.27 t_p	0.44 t_p

Notes: ① For t_p, see 1.4.4.2(1) of this Section.

② When the actual plate thickness t_p' exceeds 25 mm, $t_p = 0.5(t_p' + 25)$.

Minimum Throat Thickness **Table 1.4.4.4(2)**

Plate thickness t_p		≤ 7.5	> 7.5
Minimum throat thickness (mm)	Manual or automatic welding	3	3.25
	Automatic deep penetration welding	3	3

Note: For t_p, see 1.4.4.2(1) of this Section.

1.4.4.5 Where intermittent fillet welds are used for the connection of hull members, double continuous fillet welding is to be carried out for a specified length of round-the-end weld in the following locations:

(1) The length of the round-the-end weld at the ends of brackets is not to be less than the depth of the connecting members, nor less than 75 mm.

(2) Where the ends of sections, particularly of short sections, are snipped off, the length of the round-the-end weld is to be not less than the height of such sections or the length of snipping.

(3) Where fillet welding is used in way of brackets, lugs and scallops and at the orthogonal connections with other members, the length of the round-the-end weld is not to be less than 75 mm for plate thickness > 12 mm, and not less than 50 mm for plate thickness ≤ 12 mm.

1.4.4.6 Where scallops are cut in the structural members for intermittent welding, both ends of the scallop are to be rounded and smooth. But no scallops are permitted in the following positions:

(1) in way of the ends of brackets where stress concentration occurs;

(2) in the main frames, longitudinals and stiffeners for a region of at least 230 mm on each side of the intersection with a primary supporting member.

1.4.4.7 Where a structural member passes through a watertight or an oiltight bulkhead, in addition to the fitting of a welded collar on the bulkhead, a small semicircular notch is to be cut on one side of the passing

member as shown in Figure 1.4.4.7(1). And double continuous fillet welding is to be carried out round the end of the semicircular notch to the bulkhead so as to ensure tightness of the bulkhead.

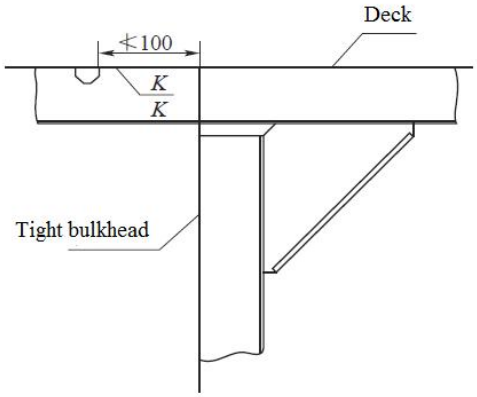


Figure 1.4.4.7(1)

For bulkheads adjacent to tanks, fillet welds in way of 150 mm fore and aft of oil/gastight or watertight bulkheads are to be properly beveled and full penetration is required in order to prevent the leakage of dangerous gases or liquids into adjacent compartments, see Figure 1.4.4.7(2). Other equivalent means may also be adopted.

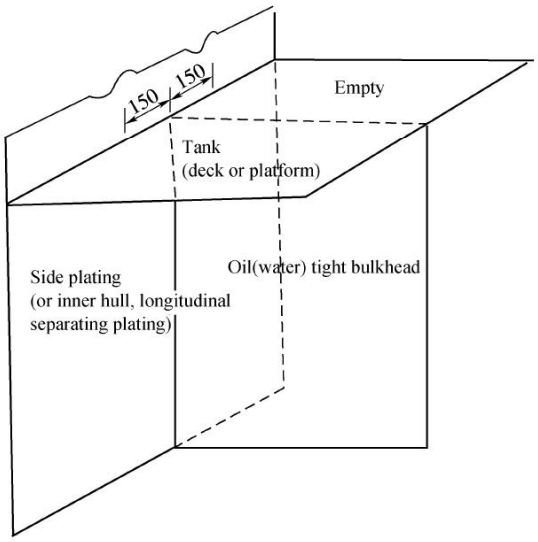


Figure 1.4.4.7(2)

1.4.4.8 The size of fillet welds in primary members is to comply with the following:
(1) Weld factors may be obtained from Table 1.4.4.8.

Weld Factors of Primary Members **Table 1.4.4.8**

Cross-sectional area of face plate of T-type members (cm^2)	Position①	In tanks		In dry spaces	
		To face plate	To plating	To face plate	To plating
		w_τ	w_τ	w_τ	w_τ
$A \le 30$	At ends	0.21	0.27	0.21	0.21
	Remainder	0.10	0.16	0.10	0.13
$30 < A \le 65$	At ends	0.21	0.34	0.21	0.21
	Remainder	0.13	0.27	0.13	0.16
$65 < A \le 95$	At ends	0.34	0.44③	0.21	0.27
	Remainder	0.27②	0.34	0.16	0.21
$95 < A \le 130$	At ends	0.34	0.44③	0.27	0.34
	Remainder	0.27②	0.34	0.21	0.27
A > 130	At ends	0.44	0.44③	0.34	0.44③
	Remainder	0.34	0.34	0.27	0.34

Notes: ① The weld factors "at ends" are to be applied for 0.2 × the length of the member from each end, but at least beyond the toes of the member end brackets. On vertical webs the increased welding may be omitted at the top, but is to extend at least 0.3 × length from the bottom. "Length of the member" means the overall length of the member (including the end brackets).

② In cargo oil tanks, the weld factor is to be 0.34. The final throat thickness of the weld fillet is not to be less than 0.34 t_p. For t_p, see 1.4.4.2(1) of this Section.

③ Where the web plate thickness is increased locally, the throat thickness is to be determined by 0.44 t_p or 0.34 t_c, whichever is the greater. For t_p, see 1.4.4.2(1) of this Section, and t_c is the increased thickness of plate.

④ In oil tankers over 120 m in length, the weld factors of the connection of bottom transverses to shell, and of side transverses to shell and vertical webs to longitudinal and transverse bulkheads, all in the lower half depth, are not to be less than 0.34.

(2) Where the webs of primary members are cut for the passage of secondary members and the width of the notch exceeds 15% of the stiffener spacing, the weld factor W_τ or the leg length K of fillet weld is to be multiplied by coefficient C obtained from the following formula:

$$C = \frac{0.85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

(3) In calculation of the throat thickness, the overall length of the weld at the ends of the member may be taken into account.

1.4.4.9 The area of welding of end connections of primary members is not to be less than the cross-sectional area of the member, and the weld factor is not to be less than 0.34 in tanks or 0.27 elsewhere.

1.4.4.10 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area A_w of weld is not to be less than the cross-sectional area of the strength member.

1.4.4.11 Where the secondary member passes through, and is supported by, the web of a primary member, the weld connection is to be in accordance with the following:

(1) The area A_w of weld is to be not less than 0.5 $\sqrt{W}$ and the weld factor not less than 0.34 in tanks or 0.27 in dry spaces, where W is the section modulus of the secondary member, in cm^3.

(2) In cargo oil tanks, the size of weld is to be increased by 20% above that obtained from (1) above.

1.4.4.12 The fillet welding of secondary member end connections is to be in accordance with Table 1.4.4.12 and where two values are given, the greater is to be taken.

Weld Factors of End Connections of Secondary Members **Table 1.4.4.12**

Connection	Weld area A_w (cm^2)	Weld factor w_τ
1. Stiffener welded direct to deck, shell, bulkhead plating etc.	0.25 A_s or 6.5	0.34
2. Stiffener to bracket or bracket lapped to stiffener (1) in dry space (2) in tank (3) main frame to tank side bracket in 0.15L forward		 0.27 0.34 0.34
3. Bracket welded to face of stiffener and bracket connection to shell, deck, bulkhead plating, etc.	–	0.34
4. Stiffener to plating for 0.1 × span at ends where not fixed by welding	–	0.34

Notes: A_s – cross-sectional area of the stiffener, in cm^2;

A_w – area of the weld (in cm^2), and is calculated as total length of weld (in cm) × throat thickness (in cm).

1.4.4.13 Single-sided continuous fillet welding may be acceptable for dry spaces in deckhouse. Where this is adopted, the fillet leg length K is to be 2 times the value calculated in 1.4.4.2, where d / l is to be taken as 1.

Section 5 DIRECT STRENGTH CALCULATIONS

1.5.1 General requirements

1.5.1.1 Where specifically required in this PART, or a novel structural configuration is adopted, or structural arrangements, ship's proportions and scantlings are not covered by the Rules, direct calculations are to be performed.

1.5.1.2 Except as otherwise specified, this Section in general applies to finite element (FE) analysis of cargo holds and the whole ship.

1.5.1.3 The loading conditions taken into account for direct strength calculations are to include most severe conditions for the design of ships.

1.5.1.4 The as-built thicknesses are to be applied for FE model scantlings, no additional thickness given by the shipowner is to be taken into consideration.
1.5.1.5 Except as otherwise specified, the structural scantlings required by this PART can not be reduced for the direct strength calculation.
1.5.1.6 Suitable general programs may be employed in direct calculations. Where a not generally used program is to be employed, supporting information is also to be submitted to substantiate the validity of the computer program.
1.5.1.7 The service coefficient f_r =1.
1.5.1.8 The following documentation is to be submitted:
(1) list of drawings used;
(2) description of FE calculation progeams used;
(3) detailed description of structrual FE model;
(4) description of physical properties and material properties of structrual model;
(5) detailed description of boundary conditions;
(6) detailed description of loading conditions;
(7) details of applied loads;
(8) figures of the overall and local deformations;
(9) results of yield strength evaluation;
(10) results of buckling strength evaluation;
(11) output showing whether the structure meet design criteria or not.
1.5.1.9 Definitions
(1) A right-handed coordinate system is to be used, see Figure 1.5.1.9, with:
① the X-axis measured in the longitudinal direction, positive forward;
② the Y-axis measured in the transverse direction, positive to port from the centerline;
③ the Z-axis measured in the vertical direction, positive upwards.

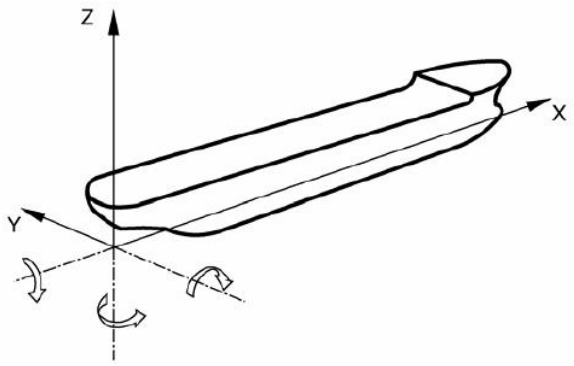


Figure 1.5.1.9 Coordinate system

(2) The von Mises stress σ_e is to be determined by the following formula:

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2}$$

where: σ_x — stress of element in direction x, in N/mm^2;
σ_y — stress of element in direction y, in N/mm^2;
τ_{xy} — shear stress of element in plane xy, in N/mm^2.
(3) The shear stress τ, in N/mm^2; for the primary structural members along the depth direction, the average shear stress of plate element may be calculated as follows:

$$\tau = \frac{\sum_{i=1}^{n}(\tau_i A_i)}{A_w} \quad \text{N/mm}^2$$

where: A_i — the effective shear area of element i, in mm^2;
τ_i — the shear stress of element i, in N/mm^2;
A_w — the total effective shear area of actual structure, in mm^2.

1.5.2 Motions and accelerations

1.5.2.1 Ship's absolute motions and accelerations

(1) The roll period T_R of the ship is to be calculated as follows:

$$T_R = 2\frac{k_r}{\sqrt{GM}} \qquad \text{s}$$

where: k_r — roll radius of gyration, in m, to be assumed as follows if no specific values available:

$k_r = 0.35B$ ballast condition for oil tankers;

$k_r = 0.25B$ ore carriers;

$k_r = 0.39B$ others;

where: B — breadth of ship, in m;

GM — initial metacentric height in the condition considered, to be assumed as follows if no specific values available:

$GM = 0.12B$ for tankers and bulk carriers;

$= 0.07B$ for others.

(2) The maximum roll angle φ_m is to be calculated as follows, but need not be greater than 0.523 rad:

$$\varphi_m = f_r k \frac{62.5 - 1.25T_R}{B + 75} \qquad \text{rad}$$

where: T_R — calculated as (1);

B — breadth of ship, in m;

f_r — service coefficient, see 1.5.1.7 of this Section;

k — coefficient, to be taken as follows:

$k = 1.2$ for ships without bilge keel;

$k = 1.0$ for ships with bilge keel;

$k = 0.8$ for ships with activated stabilizers.

(3) Pitch period T_P is to be calculated as follows:

$$T_P = 1.80\sqrt{\frac{L}{10}} \qquad \text{s}$$

where: L — length of ship, in m.

(4) The maximum pitch angle ψ_m is to be calculated as follows, but need not be greater than 0.14 rad:

$$\psi_m = 0.25\frac{a_0}{C_b} \qquad \text{rad}$$

where: C_b — block coefficient;

a_0 — acceleration factor, to be calculated as follows:

$$a_0 = f_\gamma \left(3\frac{C}{L} + C_V \frac{V}{\sqrt{L}} \right)$$

where: f_r — service coefficient, see 1.5.1.7 of this Section;

$C_V = \frac{\sqrt{L}}{50}$, not to be greater than 0.2;

V — maximum service speed, in kn;

C — coefficient, see 2.2.3.1 of Section 2, Chapter 2 of this PART;

L — length of ship, in m.

1.5.2.2 Ship's relative motions and accelerations

(1) Surging acceleration a_x is to be calculated as follows:

$$a_x = 2a_0\sqrt{C_b} \qquad \text{m/s}^2$$

where: C_b — block coefficient;

a_0 — see 1.5.2.1(4) of this Section.

(2) Sway acceleration a_y is to be calculated as follows:

$$a_y = 3a_0 \qquad \text{m/s}^2$$

where: a_0 — see 1.5.2.1(4) of this Section.

(3) Heave acceleration a_z is to be calculated as follows:

$$a_z = 7\frac{a_0}{\sqrt{C_b}} \qquad \text{m/s}^2$$

where: C_b — block coefficient;

a_0 — see 1.5.2.1(4) of this Section.

(4) Roll acceleration a_r is to be calculated as follows:

$$a_r = \varphi_m \left(\frac{6.28}{T_R} \right)^2 \qquad \text{rad/s}^2$$

where: T_R — roll period, in sec., to be calculated according to 1.5.2.1(1) of this Section;

φ_m — maximum roll angle, in rad, to be calculated according to 1.5.2.1(2) of this Section.

(5) Pitch acceleration a_p is to be calculated as follows:

$$a_p = \psi_m \left(\frac{6.28}{T_p} \right)^2 \qquad \text{rad/s}^2$$

where: T_P — pitch period, in sec., to be calculated according to 1.5.2.1(3) of this Section;

ψ_m — maximum pitch angle, in rad, to be calculated according to 1.5.2.1(4) of this Section.

(6) Transverse combined acceleration a_t is to be calculated as follows:

$$a_t = \sqrt{a_y^2 + \left[a_r \left(z - z_{rp} \right) + 10 \sin \varphi_m \right]^2} \qquad \text{m/s}^2$$

where: a_y — sway acceleration, see 1.5.2.2(2);

a_r — roll acceleration, see 1.5.2.2(4);

φ_m — maximum roll angle, see 1.5.2.1(2) of this Section;

z — vertical distance from the point considered to baseline;

z_{rp} — vertical distance from axis of gyration for roll and that for pitch to baseline, to be taken from the values obtained by the following two formulae, whichever is the lesser;

$$z_{rp1} = \frac{D}{4} + \frac{d_1}{2} \qquad \text{m}$$

$$z_{rp2} = \frac{D}{2} \qquad \text{m}$$

where:

D — moulded depth, in m;

d_1 — draught the condition considered, in m.

(7) Longitudinal combined acceleration a_l is to be obtained by the following formula:

$$a_l = \sqrt{a_x^2 + \left[a_p \left(z - z_{rp} \right) + 10 \sin \psi_m \right]^2} \qquad \text{m/s}^2$$

where: z_{rp}, z — see 1.5.2.2 (6);

a_x — surge acceleration, see 1.5.2.2 (1);

a_p — pitch acceleration, see 1.5.2.2 (5);

ψ_m — maximum roll angle, in rad, calculated according to 1.5.2.1 (4) of this Section.

(8) Vertical combined acceleration a_v is to be taken from the values obtained by the following two formulae, whichever is greater:

$$a_{v1} = \sqrt{a_z^2 + a_r^2 y^2} \qquad \text{m/s}^2$$

$$a_{v2} = \sqrt{a_z^2 + a_p^2 \left(x - 0.45L \right)^2} \qquad \text{m/s}^2$$

where: a_z — heave acceleration, see 1.5.2.2 (3);

a_r — roll acceleration, see 1.5.2.2(4);

a_p — pitch acceleration, see 1.5.2.2(5);

x — longitudinal distance from the point considered to AP, in m;

y — transverse distance from the point considered to longitudinal centerline, in m;

L — length of ship, in m.

1.5.3 External sea pressure

1.5.3.1 The external sea pressure consists of hydrostatic pressure and hydrodynamic wave pressure.

1.5.3.2 The hydrostatic pressure P_{hs} is to be calculated as follows:

$p_{hs} = \rho_w g \left(d_1 - z \right)$ kN/m^2 for the considered load point below the waterline;

$= 0$ kN/m^2 for the considered load point above the waterline.

where: ρ_w — density of sea water, taken as 1.025 t/m^3;

d_1 — draught in the considered condition, in m;

z — vertical distance measured from the considered point to the baseline, in m.

1.5.3.3 Hydrodynamic wave pressure

(1) The hydrodynamic wave pressure p_{WL} at the side waterline of the ship is to be calculated by the following formula:

$$p_{WL} = f_r\left(2B^{0.66} + 3CC_b + 0.4d_1\right) \quad \text{kN/m}^2$$

where: f_r — service coefficient, see 1.5.1.7 of this Section;

B — breadth of ship, in m;

C_b — block coefficient;

d_1 — draught under the loading condition for calculation, in m;

C — coefficient, see 2.2.3.1 of Section 2, Chapter 2 of this PART.

(2) The hydrodynamic wave pressure p_{BS} at the bilge of the ship is to be calculated by the following formula:

$$p_{BS} = p_{WL} - 1.2d_1 \quad \text{kN/m}^2$$

where: p_{WL}, d_1 — see 1.5.3.3(1).

(3) The hydrodynamic wave pressure p_{BC} at the bottom centerline is to be calculated by the following formula:

$$p_{BC} = 0.5\left(p_{WL} - 1.2d_1\right) \quad \text{kN/m}^2$$

where: p_{WL}, d_1 — see 1.5.3.3(1).

(4) The hydrodynamic wave pressure p_{hd} (see Figure 1.5.3.3) at any point below the waterline is to be calculated by the following formula:

$$p_{hd} = p_{WL} + \left(p_{BS} - p_{WL}\right)\left(1 - \frac{z}{d_1}\right) + \left(p_{BC} - p_{BS}\right)\left(1 - \frac{2y}{B}\right) \quad \text{kN/m}^2$$

where: p_{WL} — calculated according to 1.5.3.3 (1);

p_{BS} — calculated according to 1.5.3.3 (2);

p_{BC} — calculated according to 1.5.3.3 (3);

B — breadth of ship, in m;

d_1 — draught in the considered condition, in m;

y — transverse distance measured from the considered point to the centreline, in m;

z — vertical distance measured from the considered point to the baseline, in m.

(5) The hydrodynamic wave pressure p_{hd} (see Figure 1.5.3.3) at any point at side shell plating above the waterline is to be calculated by the following formulae:

$$p_{hd} = p_{WL} - 10\left(z - d_1\right) \quad \text{kN/m}^2 \quad \text{for } d_1 < z \le d_1 + \frac{p_{WL}}{10}$$

$$p_{hd} = 0 \quad \text{kN/m}^2 \quad \text{for } d_1 + \frac{p_{WL}}{10} < z$$

where: p_{WL} — calculated according to 1.5.3.3 (1);

d_1 — draught under the considered condition, in m;

z — vertical distance measured from the considered point to the baseline, in m.

(6) The green sea load p_{wdk} (see Figure 1.5.3.3) on weather deck is to be calculated by the following formula, but not less than zero:

$$p_{wdk} = p_{WL} - 10\left(z_{dk} - d_1\right) \quad \text{kN/m}^2$$

where: p_{WL} — calculated according to 1.5.3.3(1);

d_1 — draught under the considered condition, in m;

z_{dk} — vertical distance measured from the weather deck to the baseline, in m.

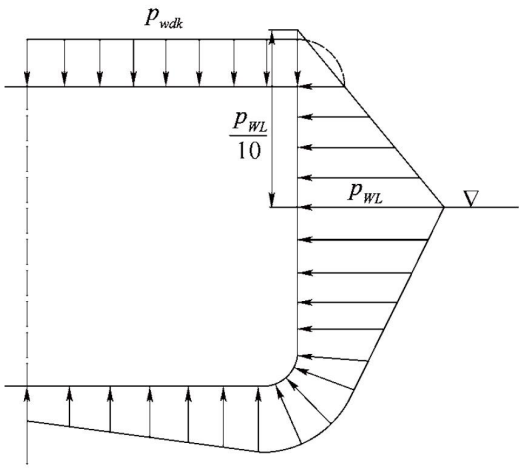


Figure 1.5.3.3 External Hydrodynamic Wave Pressure

1.5.4 Dry bulk cargo pressure

1.5.4.1 The pressure caused by dry bulk cargo is to be calculated according to 1.5.4.2 and 1.5.4.3.

1.5.4.2 The top surface of dry bulk cargo is to be determined according to the following requirements:

(1) For a prismatic cargo hold where the dry bulk cargo is loaded to the top of the hatch coaming, the top surface of cargo is to be determined equivalently according to the same cargo volume within the cargo hold. The equivalent cargo horizontal surface at h_C above the inner bottom, as shown in Figure 1.5.4.2(1), is to be calculated by the following formula:

$$h_C = h_{HPU} + h_0 \quad \text{m}$$

where:

h_{HPU} — vertical distance from inner bottom to the lower point of intersection of topside tank with side shell plating or inner hull plating, in m, see Figure 1.5.4.2(1);

h_0 — vertical distance from the lower point of intersection of topside tank with side shell plating or inner hull to equivalent cargo horizontal surface, $h_0 = \frac{S_A}{B_H}$, in m;

where:

$S_A = S_0 + \frac{V_{HC}}{l_H}$

S_0 —shadow area from the lower point of intersection of topside tank with side shell plating or inner hull plating to horizontal surface of upper deck, in m^2, see Figure 1.5.4.2(1);

V_{HC} — volume enclosed by hatch coaming from deck to coaming top, in m^3;

l_H — length of cargo hold, in m;

B_H — average breadth of cargo hold, in m.

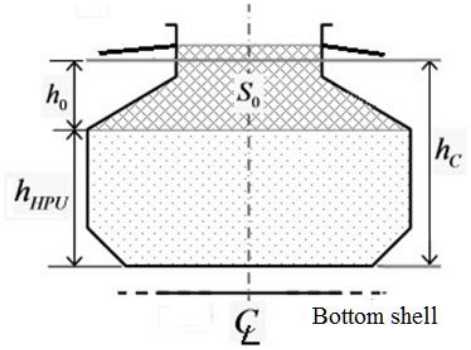


Figure 1.5.4.2(1) Definitions of h_c, h_0, h_{HPU} and S_0

(2) For a prismatic cargo hold where the dry bulk cargo is not loaded to upper deck, it is assumed that its top surface is parabolic across along the hull and the shape of each cross section along the length of the cargo hold is the same, as shown in Figure 1.5.4.2(2). Parameters of the top surface shape are to be determined according to cargo volume in the cargo hold (taken as M/ρ_C) and calculated as follows:

$h_C = h_y + h_2 + h_{HPL}$ in m, when $h_2 \geq 0$

$h_C = h_y + h_{22}$ in m, when $|y| \leq \frac{B_2}{2}$ and $h_2 < 0$

$h_C = 0$ in m, when $|y| > \frac{B_2}{2}$ and $h_2 < 0$

where:

h_2 — distance, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$h_2 = \frac{M}{\rho_C B_H l_H} - \frac{B_H + B_{IB}}{2B_H} h_{HPL} - \frac{B_H}{6} \tan\delta + \frac{V_{TS}}{B_H l_H}$$

h_y — distance, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$h_y = h_1 (1 - \frac{4y^2}{B_H^2}) \quad \text{if } h_2 \geq 0$$

$$h_y = h_1 (1 - \frac{4y^2}{B_2^2}) \quad \text{if } h_2 < 0$$

B_2 — cargo surface breadth if $h_2 < 0$, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$B_2 = \sqrt{\frac{\frac{6}{l_H}(\frac{M}{\rho_C} + V_{TS}) + \frac{3B_{IB}^2}{B_H - B_{IB}} h_{HPL}}{\tan\delta + \frac{3h_{HPL}}{B_H - B_{IB}}}}$$

h_{22} — distance if $h_2 < 0$, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$h_{22} = h_{HPL} (\frac{B_2 - B_{IB}}{B_H - B_{IB}})$$

h_{HPL} — vertical distance from inner bottom to the upper point of intersection of hopper side tank with side shell plating or inner hull, in m, see Figure 1.5.4.2(2). If there is no hopper side tank, h_{HPL} is taken as 0.

h_1 — distance, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$h_1 = \frac{B_H}{4} \tan\delta \quad \text{if } h_2 \geq 0$$

$$h_1 = \frac{B_2}{4} \tan\delta \quad \text{if } h_2 < 0$$

M — mass of dry bulk cargo in cargo hold, in t;

V_{TS} — total volume of lower stool of transverse bulkhead within cargo hold length l_H, in m^3. This does not include the portion of hopper side tank that passes through transverse bulkhead;

B_H, l_H — see (1) of this paragraph;

B_{IB} — average breadth of inner bottom, in m, see Figure 1.5.4.2 (2);

ρ_C — density of dry bulk cargo, in t/m^3;

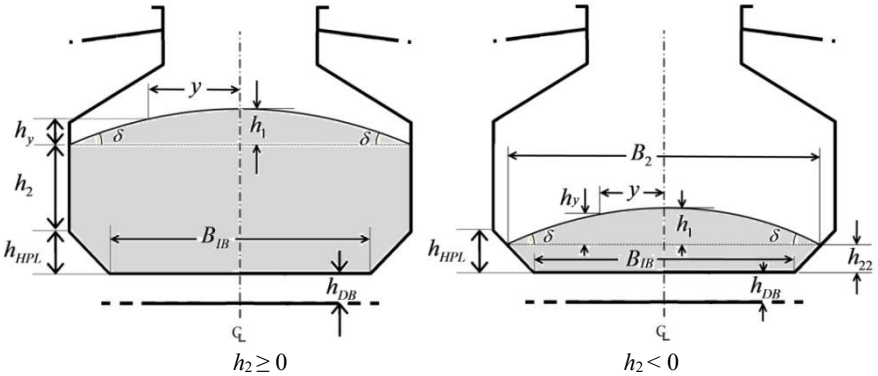
δ — angle of repose of cargo, determined as follows:

$\delta = 35°$ for ore and coal;

$\delta = 30°$ for salt, yellow sand, stone, grain, etc.;

$\delta = 25°$ for bulk cement;

y — transverse distance from considered point to the longitudinal centerline section, in m.



$h_2 \geq 0$ $h_2 < 0$

Figure 1.5.4.2(2) Definitions of h_y, h_1, h_2, h_{22} and h_{HPL}

(3) For a non-prismatic cargo hold, the top surface of dry bulk cargo may be taken at the horizontal surface of upper deck, and density taken as M/V_H, where V_H is cargo hold volume, not including its portion enclosed by hatch coaming.

1.5.4.3 The total pressure p_C caused by dry bulk cargo is to be calculated by the following formula and taken not less than zero:

$$p_C = \rho_C K_C (g + 0.5a_v)(h_C + h_{DB} - z) \quad \text{kN/m}^2$$

where:

ρ_C — density of dry bulk cargo, in t/m^3;

a_v — vertical acceleration in way of considered centroid of cargo hold, in m/s^2, see 1.5.2.2 (8) of this Section;

h_C — vertical distance from the inner bottom to the top surface of dry bulk cargo, in m, determined according to 1.5.4.2 of this Section;

h_{DB} — height of double bottom, in m;

z — vertical height of the considered point, measured from baseline, in m;

K_C — coefficient, to be calculated as follows:

$K_C = \cos^2\alpha + \tan^2(45^\circ - 0.5\delta)\sin^2\alpha$, for inner bottom, hopper side tank, transverse bulkhead and longitudinal bulkhead, lower stool, vertical upper stool, inner hull and side plate;

$K_C = 0$, for top side tank, upper deck and inclined upper stool;

α — included angle between considered plate and horizontal plane, in deg;

δ — angle of repose of cargo, in deg, see 1.5.4.2(2) of this Section.

1.5.5 Liquid pressure in tank

1.5.5.1 The lateral pressure p_l caused by liquid in tank is to be calculated by the following formula:

$$p_l = \rho g(h + 2.5f_r) \quad \text{kN/m}^2$$

where:

ρ — mass density of liquid, in t/m^3, to be taken not less than 1.025 t/m^3;

h — vertical distance from the considered point to top of tank, or half the vertical distance to the top of the overflow, whichever is the greater, in m;

f_r — service coefficient, see 1.5.1.7 of this Section.

1.5.6 Direct strength calculation for cargo holds

1.5.6.1 The design load is to be in compliance with the following requirements:

(1) In general, the global load and local loads are to be taken into account, including vertical bending moment, external sea pressure, cargo loading, liquid pressure in tank, etc.

(2) The wave bending moment M_w is to be calculated as in 2.2.3 of Section 2, Chapter 2 of this PART, and $f_r M_w$ is to be taken according to the service coefficient in 1.5.1.7 of this Section.

1.5.6.2 The extent of model is to be in compliance with the following requirements:

(1) Normally, the longitudinal extent is to cover the length of 1/2 hold + 1 hold + 1/2 hold within the cargo area amidships.

(2) In general, when both primary members and design loads are symmetrical to the longitudinal centerline section, only half breadth, starboard or port side is to be modeled. When the hold structure or load is not symmetrical to the longitudinal centerline section, a full-breadth model is to be required.

(3) The vertical extent is to be taken as all members within the main hull, including all the primary members on the main deck.

1.5.6.3 The element is to be selected in compliance with the following principles:

(1) In general, inner and external shell plates, deep webs of transverse rings, girders, floors, plane bulkhead web stiffeners, frames and other members as well as corrugated bulkheads and bulkhead stools are to be simulated by plate elements. In high stress areas and areas of significant stress gradient, such as lightening holes, manholes, connection of stool to bulkhead, positions adjacent to brackets or structural discontinuities, triangular elements are to be avoided as practicable as possible.

(2) Stiffeners of plates, which are subject to external sea pressure or cargo pressure, are simulated by beam elements, taking eccentric effects into consideration. The face plates and stiffeners of primary members (e.g. girders, floor stiffeners, frames and brackets may be simulated by rod elements.

1.5.6.4 The meshing of elements is to be in compliance with the following principles:

(1) Meshes are divided for each spacing of longitudinals or similar spacing in transverse and vertical direction of hull and for each spacing of frames or similar spacing in longitudinal direction of hull, and so are side meshes divided. Meshes are to be shaped square as far as practicable.

(2) Not less than three plate elements are to be arranged in vertical direction for bottom girders and floors. Not less than two plate elements are to be arranged in vertical direction for ring structures of hopper tanks and top wing tanks.
(3) In general, each flange plate or web plate of a corrugated bulkhead is to be taken at least as a plate element; for the plate elements at the lower end of the corrugated bulkhead in the vicinity of lower stool and for the elements adjacent to stool plate, the aspect ratio is to be close to 1.
(4) Normally, the aspect ratio of plate elements is not to exceed 3, and the aspect ratio of plate elements for corrugated bulkhead is not to exceed 2. Triangular plate elements are to be minimized in modeling as far as possible; the aspect ratio of plate elements is to be close to 1 as far as possible within the high stress area or area of high stress gradient and triangular plate elements are to be avoided.
1.5.6.5 Strength evaluation is to be carried out for all primary members in the cargo holds amidships (including bulkheads) within the longitudinal extent.
1.5.6.6 When the stress distribution or stiffness of members is affected by the openings on primary members, the following methods may be adopted:
(1) For openings, e.g. lightening holes, manholes, of web plates of primary structural members, simulation is to be carried out according to Table 1.5.6.6 of this Section.

Simulation of Openings of Web Plates of Primary Structural Members Table 1.5.6.6

$h_0/h < 0.35$ and $g_0 < 1.2$	Modeling not needed for openings
$0.35 \le h_0/h < 0.5$ and $g_0 < 1.2$	Equivalent plate thickness being $t_1 = \frac{h-h_0}{h} t_w$
$h_0/h < 0.5$ and $1.2 \le g_0 < 2$	Equivalent plate thickness being $t_2 = \frac{h-h_0}{hg_0} t_w$
$h_0/h \ge 0.5$ or $g_0 \ge 2$	Modeling based on geometry of openings or by means of removing the appropriate elements in way of openings

where: t_w — thickness of web plates;
l_0 — opening length perpendicular to height of web plates, see Figure 1.5.6.6(1); where the space d_0 of continuous openings is less than 0.25 h, $l0$ is to be taken as the length across the openings, see Figure 1.5.6.6(2);
h_0 — opening height parallel to height of web plates, see Figure 1.5.6.6(1);
h — height of web plates in way of openings, see Figure 1.5.6.6(1);

$$g_0 = 1 + \frac{l_0^2}{2.6(h-h_0)^2}.$$

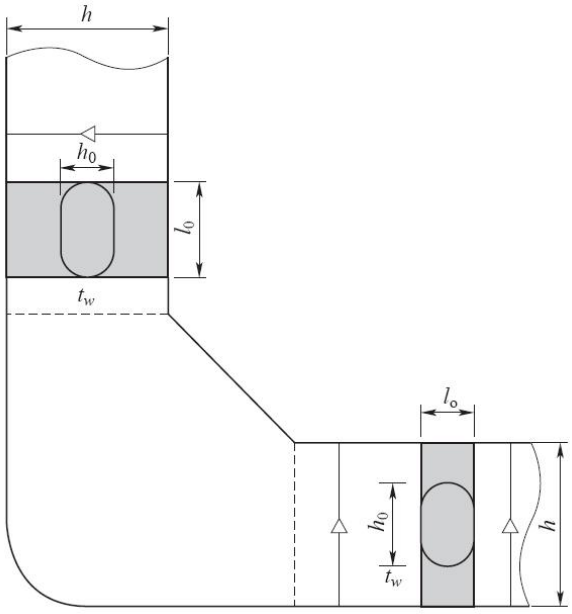


Figure 1.5.6.6(1) Openings of Web Plates

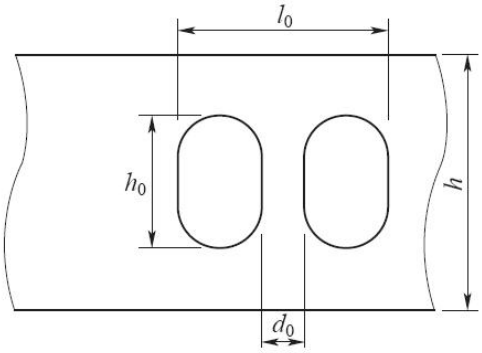


Figure 1.5.6.6(2) Length l_0 for Space of Continuous Openings $d_0 < 0.25\ h$

(2) For detailed stress analysis, the mesh size of the innermost two cycles of elements around the opening is not to be greater than 50 mm × 50 mm. The meshing is to be such that the transition from refined to coarse meshes is smooth. Stiffeners welded directly to the edges of the opening are to be simulated by plate elements; web stiffeners located more than 50 mm away from the edges of the opening can be simulated by rod or beam elements, as indicated in Figure 1.5.6.6(3). The allowable stress is to be as follows:

$$[\sigma_e] = 1.6 \times 235 / K \quad \text{N/mm}^2$$

where: K — material factor.

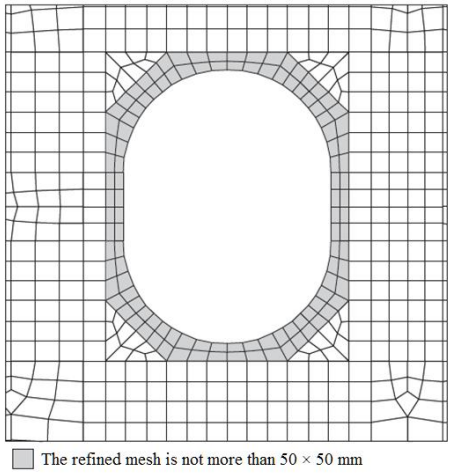


Figure 1.5.6.6(3) Refined Opening of Web Plate

1.5.7 Direct calculation of global strength of the ship

1.5.7.1 The flowchart of direct calculation of global strength of the ship is shown in Figure 1.5.7.1.

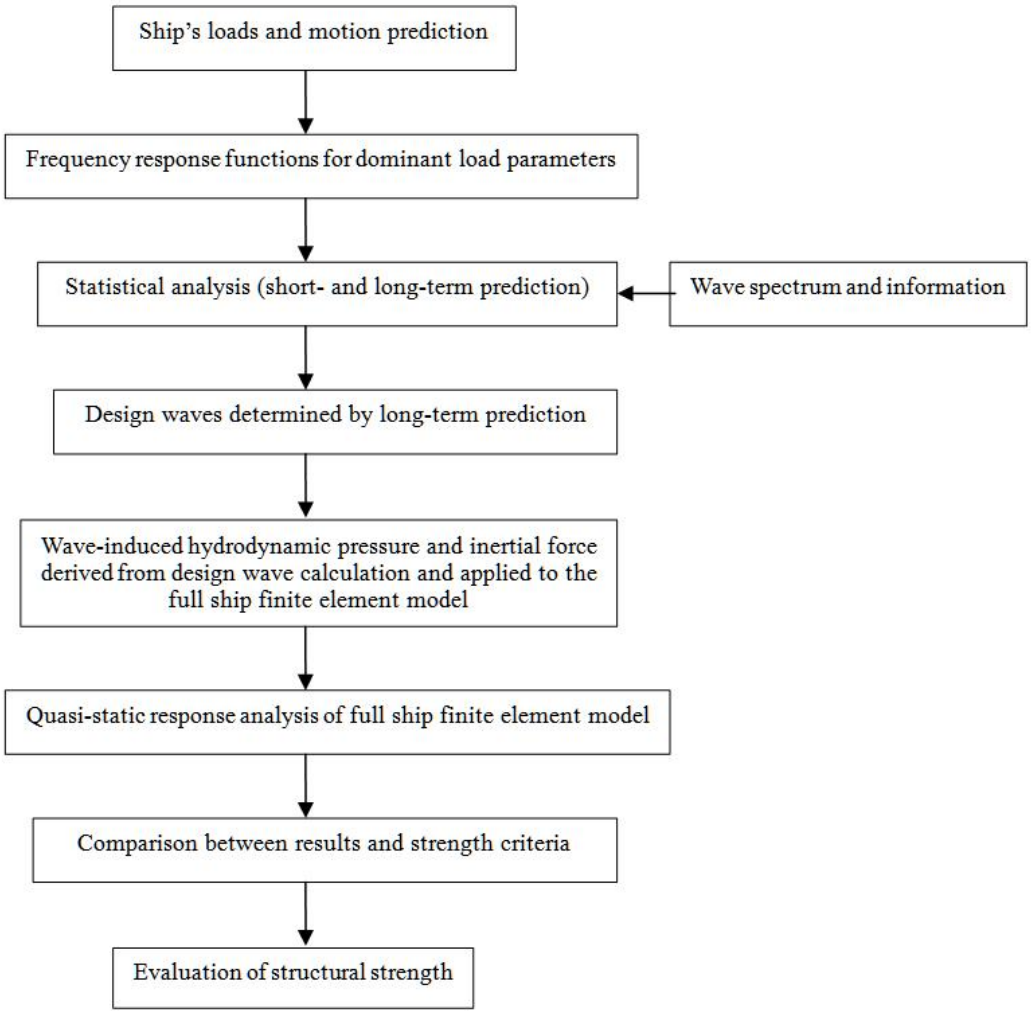


Figure 1.5.7.1 Flowchart of Direct Calculation of Global Strength of the Ship

1.5.7.2 The wave loads are to be determined by the equivalent design wave method, and in compliance with the following requirements:

(1) Ship motion and wave load are to be calculated based on the two-dimensional linear strip theory, the three-dimensional linear theory (considering non-linear corrections) or the non-linear wave theory.

(2) To calculate the ship motions and loads under design waves for each loading condition, the input data are considered as follows:

① the number of wave frequency (or wave length) is not to be less than 20, range of wave frequency taken as 0.2 to 3 according to the ratio of wave length to ship's length (λ / L), and the increments taken as 0.1;

② not less than 7 wave heading angles are to be taken, including 0º (head sea), 30º, 60º, 90º, 120º, 150º, 180º (following sea);

③ ship speed is taken as 0.

1.5.7.3 Statistical analysis is to be carried out according to the following requirements:

(1) *P-M* wave spectrum is used for calculation of ship's motion on irregular waves, wave load response and its short- and long-term prediction:

$$S(\omega, H_{1/3}, T_2, \theta) = \begin{cases} \dfrac{2}{\pi} 124 H_{1/3}^2 T_2^{-4} \omega^{-5} \exp\left(-\dfrac{496}{T_2^4 \omega^4}\right) \cos^2 \theta, & |\theta| \le \dfrac{\pi}{2} \\ 0, & \theta \text{ as other values} \end{cases}$$

where: ω — circular frequency of waves, in rad/s;

$H_{1/3}$ — significant wave height, in m;

T_2 — zero-crossing wave period, in sec.;

$\frac{2}{\pi}\cos^2\theta$ — energy spread function;

θ — included angle between complex wave and main sea direction, in rad.

(2) In the wave scatter diagram used in the calculations, the worst wave data of the ship navigating in service areas are used.

1.5.7.4 The design waves are to be calculated as follows:

(1) The design wave parameters are defined as shown in Figure 1.5.7.4(1):

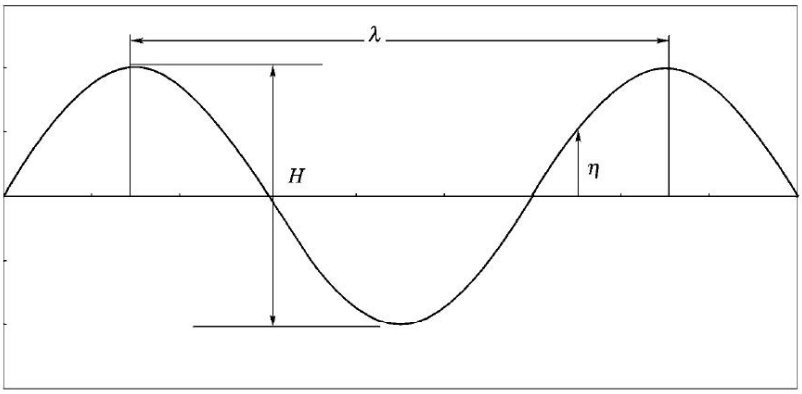


Figure 1.5.7.4(1) Design Wave Parameters

where:

λ — wave length, minimum distance between two adjacent wave crests, in m;

H — wave height, minimum distance from wave crest to wave trough, in m;

η — wave surface, as sine equation.

(2) The probability level of long-term prediction values is to be selected according to the dominant load parameters.

(3) To calculate the curve of frequency response functions of dominant load parameters under different heading angles of regular waves, as shown in Figure 1.5.7.4(2).

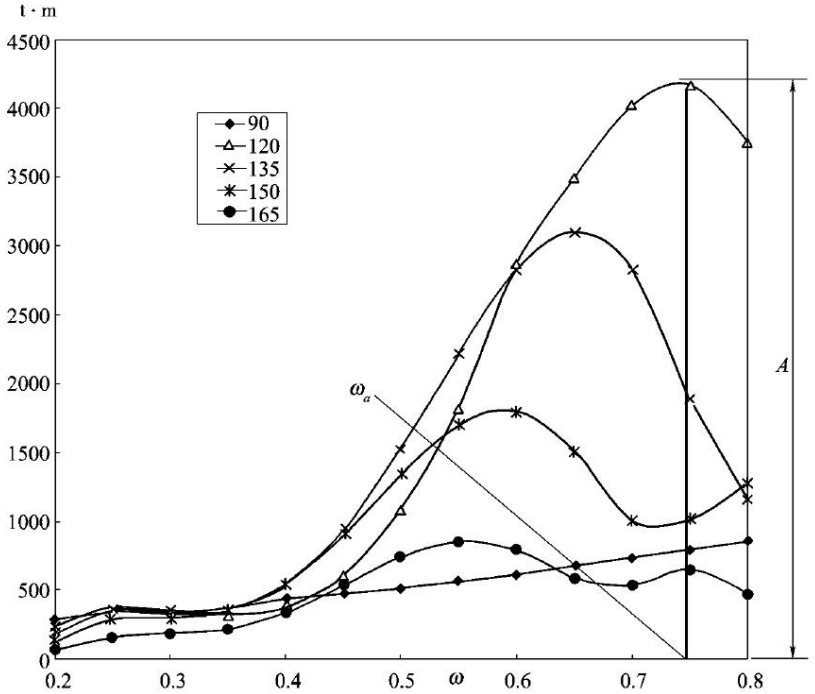


Figure 1.5.7.4(2) Frequency Response Functions

(4) The wave frequency ω_a where dominant load parameters are at the maximum amplitude are determined according to frequency response functions.

(5) Design wave length λ is to be calculated as follows:

$$\lambda = (2\pi g)/\omega_a^2 \quad \text{m}$$

where:

g — gravitational acceleration;

ω_a — wave frequency corresponding to dominant load parameters exceeding the maximum amplitude, to be determined by 1.5.7.4(4), in rad/s.

(6) Amplitude of design waves is to be calculated as follows:

$$a_w = \frac{L_j}{A_j}$$

where: a_w — amplitude of design waves;

A_j — maximum amplitude of dominant load parameters;

L_j — long-term extreme value of dominant load parameter at the probability level according to 1.5.7.4(2);

j — dominant load parameter number.

(7) The time t_j instant where the dominant load parameter reaches maximum is to be determined as follows:

$$t_j = (n\pi + \pi/2 - \varepsilon_j)/\omega_a$$

where: ω_a — wave frequency corresponding to dominant load parameters exceeding the maximum amplitude, to be determined by 1.5.7.4(4), in rad/s;

ε_j — phase angle corresponding to dominant load parameters exceeding the maximum amplitude, in rad;

j — as in 1.5.7.4(6);

n — 0 or 1.

(8) Wave pressure and other load components under design waves are to be calculated as follows:

$$P_i = A_i a_w \sin(\omega_a t_j + \varepsilon_i)$$

where: P_i — wave pressure or other load components at arbitrarily considered position of hull;

A_i — amplitude of frequency response function of wave pressure or other load component P_i;

ε_i — phase corresponding to wave pressure or other load component P_i;

t_j — time instant where dominant load parameter reaches maximum, determined according to 1.5.7.4(7).

1.5.7.5 Load components and applying

(1) The ship's light weight: the masses of steel materials, outfits and small equipment are to be simulated by regulating the material density of each component. Large equipment and ballast water are to be simulated by mass elements, which may be established on the corresponding structures, and also may be connected to the actual structures through the simulated structures.

(2) The weight of cargo in hold and on deck is to be simulated by appropriate mass elements.

(3) External hydrostatic pressure, which acts, according to draft under the considered condition, on external wet surface of hull.

(4) Wave pressure is to be calculated according to the equivalent design wave method, acting on external wet surface of hull.

(5) Inertial load is to be based on the initial acceleration obtained by the equivalent design wave method, acting on the whole model.

1.5.7.6 The mass model of whole ship is to be matched with ship's hydrostatic buoyancy. The error between the total weight and total buoyancy is not to be more than 0.0001Δ, where Δ is the moulded displacement, in t, at the corresponding draught; the error of longitudinal coordinate for centers of mass and buoyancy is not to be more than $0.0025L$, where L is the length of ship, in m; the error of horizontal coordinate is not to be more than $0.001B$, where B is the breadth of ship, in m.

1.5.8 Yield strength evaluation

1.5.8.1 The stress of members is not to exceed the relevant allowable stress criteria.

1.5.8.2 Membrane stress, i.e. median stress at center of bending plate element is to be taken for plate element.

1.5.8.3 For corrugated bulkheads, the stress in way of corrugation end may be obtained by extrapolation of average stresses of bulkhead plating.

1.5.8.4 For those elements of concentrated stress and poor shape, the stresses are not to be taken into consideration.

1.5.9 Buckling strength evaluation

1.5.9.1 The buckling safety factor λ of plate panel is not to be less than the related minimum one.

1.5.9.2 The buckling strength evaluation of plate panel is to be carried out for all primary members. During the evaluation, the appropriate standard thickness deduction is to be taken into consideration for the critical buckling compressive stresses.

1.5.9.3 The biaxial compressive stress and shear stress are to be taken into account for the buckling strength evaluation and membrane stress of plate panel is to be used for the buckling strength evaluation.

1.5.9.4 Critical buckling stress and plastic correction

(1) The elastic critical buckling stress σ_{xcr_e} of the plate panel, of which the shorter side is subjected to compression and bending, is defined as follows:

$$\sigma_{xcr_e} = k_x C_1 \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{s}\right)^2 \qquad \text{N/mm}^2$$

where: k_x — buckling coefficient for shorter side subjected to compression and bending, to be calculated according to Table 1.5.9.4(1);

C_1 — boundary constraint coefficient, see Table 1.5.9.4(2);

t — thickness of plate panel, in mm;

s — length of shorter side of plate panel, in mm, taken as spacing of stiffeners;

E — material's elastic modulus, in N/mm^2;

v — Poisson's ratio, $v = 0.3$ for steel;

x — axial direction of longer side of plate panel.

Buckling Coefficient of Plate Panel **Table 1.5.9.4(1)**

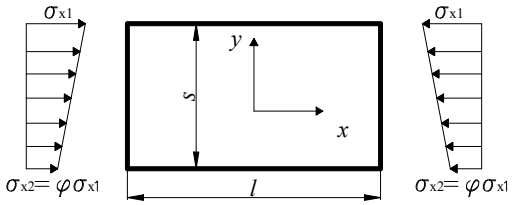
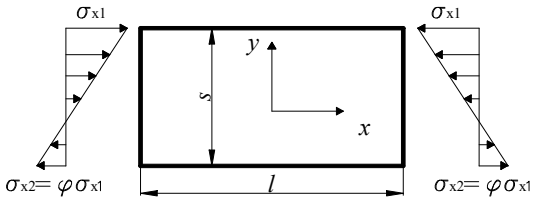
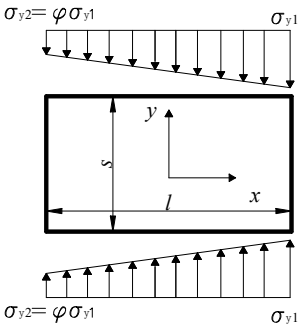
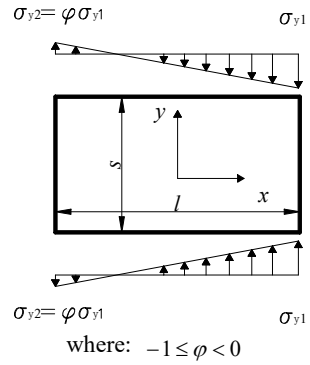
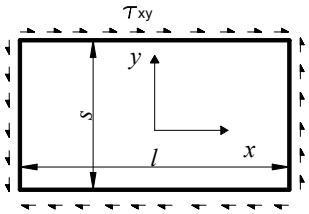
Buckling load condition		Buckling coefficient
Shorter side subject to stress	 where: $0 \le \varphi \le 1$	$k_x = \frac{8.4}{\varphi + 1.1}$
	 where: $-1 \le \varphi < 0$	$k_x = 7.6 - 6.4\varphi + 10\varphi^2$
Longer side subject to stress	 where: $0 \le \varphi \le 1$	$k_y = \left[1 + \left(\frac{s}{l}\right)^2\right]^2 \frac{2.1}{\varphi + 1.1}$
	 where: $-1 \le \varphi < 0$	$k_y = 1.909(1+\varphi)\left[1 + \left(\frac{s}{l}\right)^2\right]^2 - k_p\varphi + 10\varphi(1+\varphi)\left(\frac{s}{l}\right)^2$ where: $k_p = \begin{cases} 24\left(\frac{s}{l}\right)^2 & \frac{l}{s} \le \frac{3}{2} \\ 2 + 16\left(\frac{s}{l}\right)^2 + 8\left(\frac{s}{l}\right)^4 & \frac{l}{s} > \frac{3}{2} \end{cases}$
Edges subject to shear stress		$k_t = 5.34 + 4\left(\frac{s}{l}\right)^2$

Plate Panel Boundary Restraint Coefficients C_1 and C_2 **Table 1.5.9.4(2)**

Boundary	C_1	C_2	
		In double bottom or between double sides	Elsewhere
Angles or T-stiffeners	1.1	1.3	1.2
Flat bars or bulb flats	1.0	1.2	1.1

(2) The elastic critical buckling stress σ_{ycr_e} of the plate panel, of which the longer side is subjected to compression and bending, is defined as follows:

$$\sigma_{ycr_e} = k_y C_2 \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{s}\right)^2 \qquad \text{N/mm}^2$$

where: k_y — buckling coefficient for longer side subjected to compression and bending, to be calculated according to Table 1.5.9.4(1);

C_2 — boundary restraint coefficient, see Table 1.5.9.4(2);

y — axial direction of shorter side of plate panel;

other symbols are the same as in 1.5.9.4(1).

(3) The elastic critical buckling stress τ_{cr_e} of plate panel subject to shear force is defined as follows:

$$\tau_{cr_e} = k_t C_1 \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{s}\right)^2 \qquad \text{N/mm}^2$$

where: k_t — shear buckling coefficient, to be calculated according to Table 1.5.9.4(1);

other symbols are the same as in 1.5.9.4(1) and (2).

1.5.9.5 The elastic critical buckling stress of plate panel is to be corrected as follows:

$$\sigma_{\substack{xcr \\ (ycr)}} = \begin{cases} \sigma_{\substack{xcr_e \\ (ycr_e)}} & \text{when } \sigma_{\substack{xcr_e \\ (ycr_e)}} \le \dfrac{R_{eH}}{2} \\ R_{eH}\left(1 - \dfrac{R_{eH}}{4\sigma_{\substack{xcr_e \\ (ycr_e)}}}\right) & \text{when } \sigma_{\substack{xcr_e \\ (ycr_e)}} > \dfrac{R_{eH}}{2} \end{cases}$$

$$\tau_{cr} = \begin{cases} \tau_{cr_e} & \text{when } \tau_{cr_e} \le \dfrac{\tau_s}{2} \\ \tau_s\left(1 - \dfrac{\tau_s}{4\tau_{cr_e}}\right) & \text{when } \tau_{cr_e} > \dfrac{\tau_s}{2} \end{cases}$$

where:

$\sigma_{xcr_e}, \sigma_{ycr_e}, \tau_{cr_e}$ — respectively as elastic critical buckling compressive stress along axes x and y under uniaxial stress and critical buckling shear stress of plate panel, see 1.5.9.4 of this Section;

R_{eH} — yield stress of material, in N/mm^2;

$\tau_s = \dfrac{R_{eH}}{\sqrt{3}}$.

1.5.9.6 In the buckling strength evaluation, the buckling safety factor λ is to be the ratio of the critical buckling stress of plate panel to actual compressive stress, see Table 1.5.9.6. The σ_x, σ_y, τ_{xy} are considered in their absolute values in calculation. Where the working stress along axes x and y is of tension stress, such stress component is to be taken as zero.

Calculation of λ **Table 1.5.9.6**

Stress condition \ Aspect ratio of plate panel	$1 \le \frac{l}{s} \le \sqrt{2}$	$\sqrt{2} < \frac{l}{s} \le 8$
Biaxial compression	$\dfrac{1}{(1+k_1)}\dfrac{\sigma_{xcr}}{\sigma_x}$	$\dfrac{1}{\sqrt{(1+k_1^2)}}\dfrac{\sigma_{xcr}}{\sigma_x}$
Compression along x axis + edge shear	$\dfrac{1}{\sqrt{(1+k_2^2)}}\dfrac{\sigma_{xcr}}{\sigma_x}$	
Compression along y axis + edge shear	$\dfrac{1}{\sqrt{(1+k_3^2)}}\dfrac{\sigma_{ycr}}{\sigma_y}$	
Biaxial compression + edge shear	$\dfrac{1}{\sqrt{(1+k_1^2+k_2^2)}}\dfrac{\sigma_{xcr}}{\sigma_x}$	

where: $k_1 = \dfrac{\sigma_y / \sigma_{ycr}}{\sigma_x / \sigma_{xcr}}$, $k_2 = \dfrac{\tau_{xy} / \tau_{cr}}{\sigma_x / \sigma_{xcr}}$, $k_3 = \dfrac{\tau_{xy} / \tau_{cr}}{\sigma_y / \sigma_{ycr}}$

Notes:

① σ_{x1} and σ_{y1} are greater values of working stress acting on sides of plate panel along axes x and y, σ_{x2} and σ_{y2} are the lesser values of such stress, and σ_x and σ_y are to be taken as the average values of σ_{x1}, σ_{x2} and σ_{y1}, σ_{y2} respectively; τ_{xy} is the average shear stress, σ_{x1}, σ_{x2}, σ_{y1}, σ_{y2}, τ_{xy} are as shown in Table 1.5.9.4(1) of this Section.

② σ_{xcr}, σ_{ycr} and τ_{cr} are the elastically corrected critical buckling compressive stresses under uniaxial stress and critical buckling shear stress of plate panel along axes *x* and *y* respectively.

Section 6 CORROSION CONTROL FOR HULL STRUCTURES

1.6.1 General requirements

1.6.1.1 Effective means are to be taken for all ships to prevent excessive corrosion of hull members.

1.6.1.2 All seawater ballast tanks having boundaries formed by the hull envelope plating are to have an efficient protective coating, epoxy or equivalent, applied in accordance with the coating manufacturer's recommendation. Dedicated seawater ballast tanks of all types of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of 150 m and over in length, as specified in SOLAS regulation II-1/3-2, are to be coated in accordance with IMO resolution MSC.215(82) on Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in All Types of Ships and Double-Side Skin Spaces of Bulk Carriers (PSPC).

1.6.1.3 For bulk carriers, all internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of cargo holds, excluding the flat tank top areas and the hopper tanks sloping plating approximately 300 mm below the side shell frame and brackets, are to use an efficient protective coating (epoxy coating or equivalent) recommended by the coating manufacturer. In the selection of coatings, due consideration is to be given by the Owner to the intended cargo conditions expected in service.

1.6.1.4 Right before application of coatings to any structure, surface preparation is to be made in accordance with coating manufacturer's workmanship requirements and the surfaces are to be thoroughly cleaned to a corresponding degree. The number of coatings and total dry film thickness are to comply with the design requirements.

1.6.1.5 Where bimetallic connections are made, measures are to be incorporated to preclude galvanic corrosion.

1.6.1.6 Impressed current systems are not permitted in oil cargo tanks.

1.6.2 Primers or coatings

1.6.2.1 Where a primer is used to coat steel during construction, the primer is to be applied right after surface preparation. The composition of the primer is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control for structures. Primers are subject to approval in accordance with the relevant CCS requirements.

1.6.3 Internal cathodic protection in tanks

1.6.3.1 Where a cathodic protection system is to be fitted in tanks or adjacent tanks carrying liquid cargoes having a flash point not exceeding 60℃, a plan showing details of the locations and attachment of anodes is to be submitted for information.

1.6.3.2 When cathodic protection requirements are assessed, the effects of uncoated surfaces (e.g. tank fittings) adjacent to those which require protection are to be taken into account.

1.6.3.3 Aluminium alloy sacrificial anodes, magnesium alloy sacrificial anodes, zinc and zinc alloy sacrificial anodes of oil tankers

(1) Aluminium alloy sacrificial anodes are permitted in tanks used for the carriage of oil and adjacent tanks, but only at locations where the potential energy does not exceed 28 kg•m (200 lb•ft). The weight of the anode is to be taken as the weight at the time of fitting, including any inserts and fitting devices.

(2) The height of the anode is, in general, to be measured from the bottom of the tank to the centre of the anode. Where the anode is located on horizontal surfaces (such as bulkhead girders and stringers) not less than 1 m wide, provided with an upstanding flange or face plate projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured above that surface.

(3) Aluminium anodes are not to be located under tank hatches or Butterworth openings (in order to avoid any metal parts falling on the fitted anodes), unless protected by adjacent structure.
(4) Magnesium alloy sacrificial anodes are not permitted in oil cargo tanks and tanks adjacent to cargo tanks.
(5) Zinc and zinc alloy sacrificial anodes may be located in any position without restriction.
1.6.3.4 Arrangement of sacrificial anodes
(1) Anodes are to be reasonably located in relation to the structural features of the surfaces protected, and particular attention is to be given to the effects of adjacent structures and openings of the tank.
(2) Anodes are to be fitted with steel cores which are to be so designed as to retain the anode even when the latter is wasted. Anodes are to be sufficiently rigid to avoid resonance in the anode support.
(3) Anodes are to be efficiently attached to the structure. The following methods of attachment would be acceptable:

① steel core connected to the structure by continuous welding of adequate section;
② steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts is used at each support;
③ approved means of mechanical clamping.

(4) Sacrificial anodes in tanks are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.
(5) Sacrificial anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating. Where cores or supports are welded to the structure, they are to be arranged so that the welds are clear of stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes be not fitted to face plates of higher tensile steel longitudinals in so far as practicable.

1.6.4 External hull protection

1.6.4.1 Shell plating, particularly the portion between light and loaded load lines, weather decks and hatch covers are to be provided with suitable corrosion protection.
1.6.4.2 Where an impressed current cathodic protection system is fitted, plans or information showing the proposed layout of anodes, reference electrodes, wiring and methods of attaching to the rudder and propeller, are to be submitted.
1.6.4.3 A small cofferdam is to be included in the arrangements for glands, where cables pass through the shell. Cables to anodes are not to be led through tanks intended for the carriage of low flash point oils. Where cables are led through cofferdams or clean ballast tanks of tankers, they are to be enclosed in a substantial steel tube of at least 10 mm thickness.
1.6.4.4 For ships subject to in-water survey instead of drydocking survey, the underwater portion of the hull is to be coated with a high resistant paint. Details of the high resistant paint are to be submitted to CCS for information.

1.6.5 Corrosion allowance

1.6.5.1 Unless otherwise stated in this PART, the scantlings of hull structural members calculated in accordance with this PART are to include the values of corrosion allowance t_c as specified here.
1.6.5.2 Corrosion allowances t_c of hull structural members, including plating and framing, are to be obtained as in Table 1.6.5.2.

Value of Corrosion Allowance t_c **Table 1.6.5.2**

Thickness t (mm)	Corrosion allowance t_c (mm)
≤ 10	1.5
> 10	0.1 t + 0.5, maximum 3.2

1.6.5.3 For boundaries of ballast spaces or cargo tanks, the corrosion allowance is not to be less than 2.5 mm.
1.6.5.4 For dry spaces (cargo spaces in bulk carriers excluded), the corrosion allowances is to be 0.5 t_c (see Table 1.6.5.2), but not less than 1.0 mm.

Section 7 FORE DECK FITTINGS

1.7.1 Strength requirements for fore deck fittings and equipment

1.7.1.1 This Section provides strength requirements for the following items located within the forward 0.25*L*: air pipes, ventilator pipes and their closing devices. However, these requirements do not apply to the cargo tank venting systems and the inert gas systems of oil tankers.

1.7.1.2 All ships of 80 m or over in length, where the height of the exposed deck in way of the items as defined in 1.7.1.1 of this Section is less than 0.1*L* or 22 m above the summer load waterline, whichever is the lesser, are to comply with the relevant requirements of 1.7.1 of this Section.

1.7.1.3 The pressures *p*, acting on air pipes, ventilator pipes and their closing devices may be calculated from:

$$p = 0.5\,\rho\, V^2 C_d C_s\, C_p \quad \text{kN/m}^2$$

where:

ρ — density of seawater, taken as 1.025 t/m^3;

V — velocity of water over the fore deck, in m/s;

= 13.5 m/s, for $h \le 0.5h_1$;

$= 13.5\sqrt{2(1-\frac{h}{h_1})}$ m/s, for $0.5h_1 < h < h_1$;

where: h — distance from summer load waterline to exposed deck, in m;

h_1 — 0.1*L* or 22 m, whichever is the lesser;

C_d — shape coefficient, taken as 0.5 for pipes, 1.3 for air pipe or ventilator heads in general, 0.8 for an air pipe or ventilator head of cylindrical form with its axis in the vertical direction;

C_s — slamming coefficient, taken as 3.2;

C_p — protection coefficient, taken as 0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle, 1.0 elsewhere and immediately behind a bulwark.

1.7.1.4 Forces acting in the horizontal direction on the pipe and its closing device may be calculated from 1.7.1.3 of this Section using the largest projected area of each component.

1.7.1.5 The requirements of 1.7.1.5 to 1.7.1.12 are additional to IACS UR P3 and UI LL36. This does not mean that closing devices of air pipes on all existing ships need to be upgraded to comply with UR P3.

1.7.1.6 Bending moments and stresses in air and ventilator pipes are to be calculated at critical positions: at penetration pieces, at weld or flange connections, at toes of supporting brackets. Bending stresses in the net section are not to exceed 0.8 R_{eH}, where R_{eH} is the specified minimum yield stress or 0.2% proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2.0 mm is then to be applied.

1.7.1.7 For standard air pipes of 760 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 1.7.1.7. Where brackets are required, three or more radial brackets are to be fitted. Brackets are to be of gross thickness 8 mm or more, of minimum length 100 mm, and height according to Table 1.7.1.7 but need not extend over the joint flange for the head. For air pipes of other heights, relevant requirements specified in 1.7.1.5 to 1.7.1.8 of this Section are to be met. Bracket toes at the deck are to be suitably supported.

760 mm Air Pipe Thickness and Bracket Standards **Table 1.7.1.7**

Nominal pipe diameter (mm)	Minimum fitted gross thickness (mm)	Maximum projected area of head (cm^2)	Height① of brackets (mm)
40③	6.0	–	520
50③	6.0	–	520
65	6.0	–	480
80	6.3	–	460
100	7.0	–	380
125	7.8	–	300
150	8.5	–	300
175	8.5	–	300
200	8.5②	1900	300②
250	8.5②	2500	300②
300	8.5②	3200	300②
350	8.5②	3800	300②
400	8.5②	4500	300②

Notes: ① Brackets (see 1.7.1.7) need not extend over the joint flange for the head.

② Brackets are required where the as-fitted (gross) thickness is less than 10.5 mm, or where the tabulated projected head area is exceeded.

③ Not permitted for new ships.

④ For air pipes of other heights, requirements specified in 1.7.1.5 to 1.7.1.12 of this Section are to be met.

1.7.1.8 For other configurations, loads according to 1.7.1.3 and 1.7.1.4 of this Section are to be applied, and means of support determined in order to comply with the requirements of 1.7.1.6 of this Section. Brackets, where fitted, are to be of suitable thickness and length according to their height. Pipe thickness is not to be taken less than as indicated in IACS UI LL36.

1.7.1.9 For standard ventilators of 900 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 1.7.1.9. Brackets, where required, are to be as specified in 1.7.1.7 of this Section.

900 mm Air Pipe Thickness and Bracket Standards **Table 1.7.1.9**

Nominal pipe diameter (mm)	Minimum fitted gross thickness (mm)	Maximum projected area of head (cm^2)	Height of brackets (mm)
80	6.3	–	460
100	7.0	–	380
150	8.5	–	300
200	8.5	550	–
250	8.5	880	–
300	8.5	1200	–
350	8.5	2000	–
400	8.5	2700	–
450	8.5	3300	–
500	8.5	4000	–

Note: For ventilators of other heights, requirements specified in 1.7.1.5 to 1.7.1.12 of this Section are to be met.

1.7.1.10 For ventilators of height greater than 900 mm, brackets or alternative means of support are to be fitted. Pipe thickness is not to be taken less than as indicated in IACS UI LL36.

1.7.1.11 All component parts and connections of the air pipe or ventilator are to be capable of withstanding the loads defined in 1.7.1.3 and 1.7.1.4 of this Section.

1.7.1.12 Rotating type mushroom ventilator heads are unsuitable for application in the areas defined in 1.7.1.1 and 1.7.1.2 of this Section.

1.7.2 Strength and securing of small hatches on the exposed fore deck

1.7.2.1 The provisions of this Section apply to the strength of, and securing devices for, small hatches fitted on the exposed deck over the forward 0.25 *L* ,where the height of the exposed deck in way of the hatch is less than 0.1 *L* or 22 m above the summer load waterline, whichever is the lesser, for all ships of 80 m or over in length. This regulation does not apply to small hatches on container ship giving access to a cargo hold which comply with UI LL64 except the requirement of clauses 4 & 5. Such hatch covers are considered non-weathertight regardless of whether it is actually weathertight or not. However, for scantlings of small hatches, the strength requirements in 1.7.2.4-1.7.2.7 of this Section could be applied instead of clause 6 of UI LL64.

1.7.2.2 Small hatches are hatches designed for access to spaces below the deck and capable of being closed weather-tight or watertight, as applicable. Their opening is normally 2.5 m^2 or less.

1.7.2.3 Hatches designed for emergency escape need not comply with the requirements of 1.7.2.8(1), 1.7.2.8(2), 1.7.2.9(3) and 1.7.2.10 of this Section. Securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g., one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover. The maximum force needed to open the securing device is not to exceed 150 N, and the use of a spring equalizing, counterbalance or other suitable device on the hinge side to reduce the force needed for opening such hatch covers is acceptable. These requirements apply to new vessels, contracted for construction on or after 1 July 2007, by the time of delivery; to vessels contracted for construction prior to 1 July 2007, by the compliance date specified in 5.3.5 of Chapter 5, PART ONE of the Rules, or by the due date of the first special survey after 1 July 2007, whichever is later. Completion prior to 1 July 2007 of a special survey with a due date after 1 July 2007 cannot be used to postpone compliance.

1.7.2.4 For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with Table 1.7.2.4 and Figure 1.7.2.4. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, as required in 1.7.2.9(1) of this Section, see Figure 1.7.2.4. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, see Figure 1.7.2.9 .

Scantlings for Small Steel Hatch Covers on Fore Deck **Table 1.7.2.4**

Nominal size (mm×mm)	Cover plate thickness (mm)	Primary stiffeners	Secondary stiffeners
		Flat bar (mm × mm); number	
630 × 630	8	–	–

Nominal size (mm×mm)	Cover plate thickness (mm)	Primary stiffeners	Secondary stiffeners
		Flat bar (mm × mm); number	
630 × 830	8	100 × 8; 1	–
830 × 630	8	100 × 8; 1	–
830 × 830	8	100 × 10; 1	–
1030 × 1030	8	120 × 12; 1	80 × 8; 2
1330 × 1330	8	150 × 12; 2	100 × 10; 2

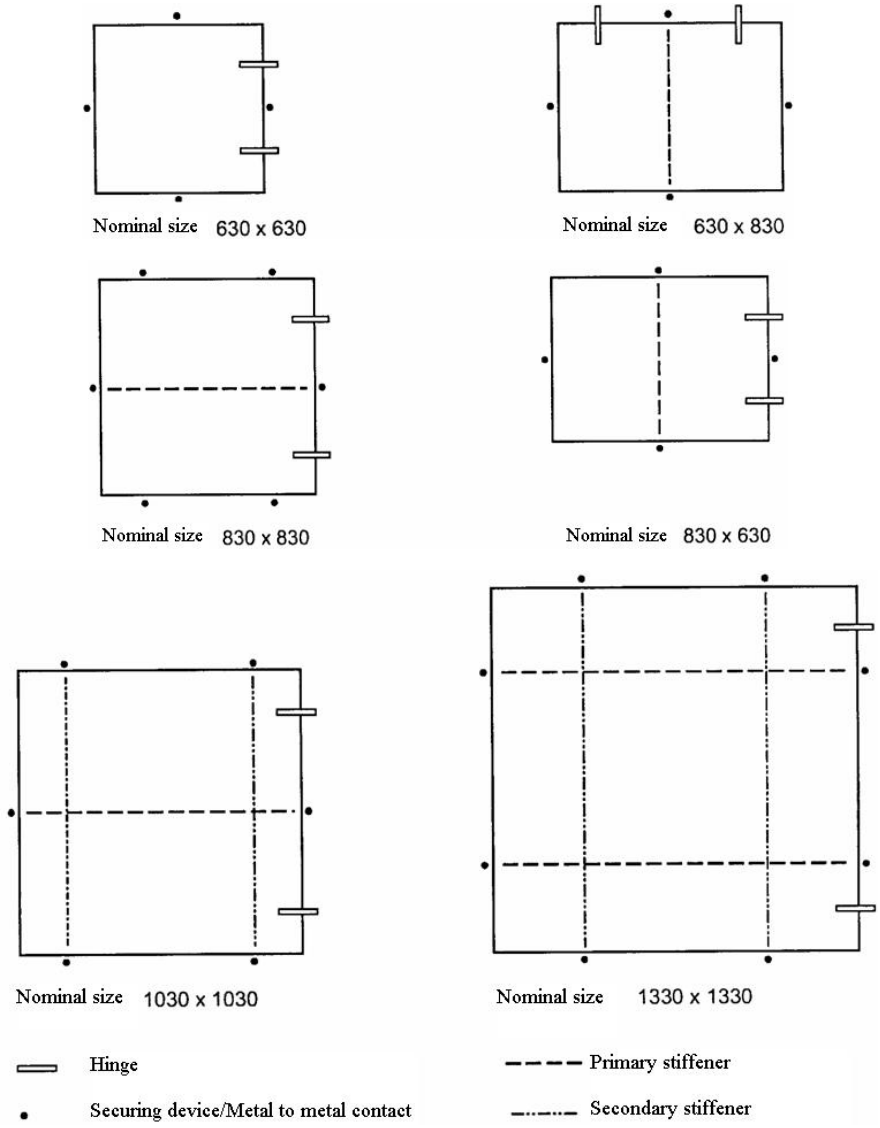


Figure 1.7.2.4 (Unit: mm × mm)

1.7.2.5 The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm from the upper edge of the coamings.

1.7.2.6 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to provide strength equivalent to that of the surrounding structure.

1.7.2.7 For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

1.7.2.8 Small hatches located on exposed fore deck are to be fitted with any one of the following primary securing devices:

(1) butterfly nuts tightening onto forks (clamps);

(2) quick acting cleats; or

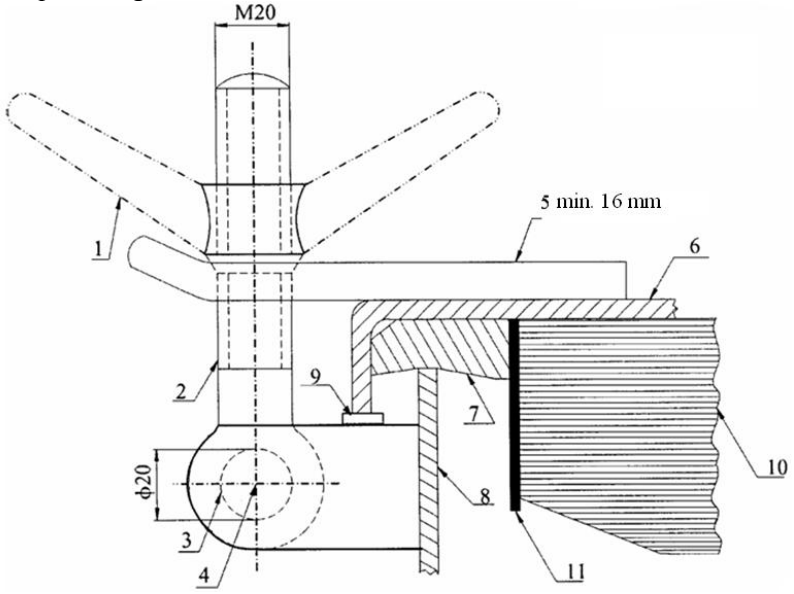
(3) central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

1.7.2.9 The following requirements are to be complied with for primary securing devices:

(1) The hatch cover is to be fitted with a gasket of elastic material. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Figure 1.7.2.4, and of sufficient capacity to

withstand the bearing force. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged.
(2) The primary securing devices are to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.
(3) For a primary securing device using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of forks is not to be less than 16 mm. An example arrangement is shown in Figure 1.7.2.9 .
(4) For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close, which means that the hinges are normally to be located on the fore edge.
(5) On small hatches located between the main hatches, for example between No.1 and No. 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.



1. butterfly nut; 2. bolt; 3. pin; 4. center of pin; 5. fork (clamp) plate; 6. hatch cover; 7. gasket; 8. hatch coaming; 9. bearing pad welded on the bracket of a toggle bolt for metal to metal contact; 10. stiffener; 11. inner edge stiffener

Figure 1.7.2.9

1.7.2.10 Small hatches on the fore deck are to be fitted with an independent secondary securing device e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

Section 8 TANK SLOSHING

1.8.1 General requirements

1.8.1.1 For partially loaded tank, a strength assessment of tank structure under sloshing loads (hereinafter referred to as 'Sloshing Assessment') is to be carried out according to the requirements of this Section.
1.8.1.2 For those not covered by this Section, the requirements of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks are to be met.
1.8.1.3 Unless otherwise specified, for tanks with internal members, partial filling generally means the liquid filling height is greater than 10% of the tank depth but less than 90% of the tank depth. For smooth tank, partial filling generally means the liquid filling height is greater than 5% of the tank depth but less than 95% of the tank depth.
1.8.1.4 Unless specially specified, the sloshing assessment specified in this Section includes both transverse and longitudinal sloshing motions.
1.8.1.5 According to the judgment of the sloshing resonance of ship and tank, the sloshing motion and loads are divided into levels 1, 2 and 3. For tanks complying with sloshing motion level 1, sloshing loads at

sloshing motion level 1 are to be calculated. For tanks complying with sloshing motion level 2, sloshing loads at sloshing motion levels 1 and 2 are to be calculated. For tanks complying with sloshing motion level 3, sloshing loads at sloshing motion levels 1, 2 and 3 are to be calculated.

1.8.1.6 In order to reduce sloshing motion level, internal members may be added for swash or limit on the filling may be taken to avoid sloshing resonance.

1.8.2 Application

1.8.2.1 This Section is applicable to tankers such as oil tankers, chemical tankers, liquefied gas carriers, and bulk carriers, ore carriers and dry cargo carriers etc.

1.8.2.2 This Section is applicable to all cargo tanks, ballast tanks and other tanks where free surface motion is allowed.

1.8.2.3 For ships the length of which is less than 100 m, the level 3 longitudinal sloshing assessment is not to be considered if the tank effective sloshing length does not exceed 0.16 L during the sloshing assessment. If the tank effective sloshing breadth does not exceed 0.6B (B is the ship breadth), level 3 transverse sloshing assessment is not to be considered.

1.8.2.4 Longitudinal sloshing assessment may not be required for tanks meeting one of the following conditions:

(1) the length of ship is less than 65 m and the effective sloshing length does not exceed 0.13L;

(2) the effective sloshing length is less than 0.03L.

1.8.2.5 Transverse sloshing assessment may not be required for tanks meet one of the following conditions:

(1) the length of ship is less than 65 m and the effective sloshing breadth does not exceed 0.56B;

(2) the effective sloshing breadth is less than 0.32B.

1.8.2.6 Sloshing assessment may not be required for tanks meet one of the following conditions:

(1) tank capacity is not greater than 100 m^3;

(2) tanks fitted in double bottom or double skin or other tanks of cellular construction;

(3) dry cargo holds used for ballasting of bulk carriers.

1.8.3 Plans and documents

1.8.3.1 Plans approved by CCS including tank boundary structure plan, internal member structure plan of tank (if any) are to be submitted during the sloshing assessment carried out in accordance with the requirements of this Section.

1.8.3.2 Sloshing loads and hull structural strength assessment report are to be submitted to CCS for information.

1.8.4 Sloshing loads calculation

1.8.4.1 Unless otherwise specified, the sloshing motion and the calculation of the loads specified in this Section are to meet the requirements of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

1.8.4.2 The results of sloshing model test may be taken as the alternative for sloshing design loads when approved by CCS.

1.8.5 Strength assessment

1.8.5.1 Scantling assessment under sloshing loads are to be carried out to the following structural members:

(1) plating forming tank boundaries, stiffeners;

(2) plating and stiffeners on wash bulkheads in the tank;

(3) web of primary support members, web stiffeners in the tank.

1.8.5.2 Unless otherwise specified, scantling assessment under sloshing loads is to meet the requirements of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

Section 9 INTACT STABILITY

1.9.1 General requirements

1.9.1.1 Compliance with the requirements for intact stability is a condition for classification of ships.

1.9.1.2 The intact stability of ships is to comply with the requirements of this Section, or it is to be demonstrated that their intact stability is in compliance with the requirements of the flag State Administration.

1.9.1.3 All bulk carriers of less than 150 m in length are to be fitted with loading instruments capable of providing intact stability information and are to comply with the requirements of Appendixes 1 and 2 of Chapter 2 of this PART.
1.9.1.4 Onboard computers for stability calculation, where fitted, for all ships are to comply with the requirements of Appendixes 1 and 2 of Chapter 2 of this PART.
1.9.1.5 If class notation SGISC(X) is applied for, the provisions of 1.9.6 in this Section are to be complied with, where X means one or more suffixes, the meanings of which are as follows:

PR_N——parametric rolling failure mode;

PL_N——pure loss of stability failure mode;

EA_N——excessive acceleration failure mode;

DS_N——dead ship condition failure mode;

SRB_N——surf-riding/broaching failure mode.

Where: N=1, meaning all loading conditions in compliance with Level 1 vulnerability criteria; N=2, meaning all loading conditions in compliance with Level 2 vulnerability criteria; N=M, meaning that there are loading conditions which do not meet the vulnerability criteria, and information on the stability of ship in waves has been prepared for the master.
1.9.1.6 Ships applying for the ASMW notation are to comply with the provisions of 1.9.7 of this Section.

1.9.2 Application

1.9.2.1 Unless otherwise stated, this Section applies to ships of 24 m and over in length, the types of which are covered by 1.9.4 and 1.9.6 of this Section.
1.9.2.2 For ships of less than 24 m in length, reference may be made to 1.9.2.1 of this Section.
1.9.2.3 For other ship types not covered by 1.9.4 and 1.9.6 of this Section, the criteria acceptable to CCS may be used.

1.9.3 Plans and documents

1.9.3.1 The following plans and documents are to be submitted for approval or confirmation:
(1) Stability calculations for loading conditions or loading manual;
(2) Curves or table of allowable height of center of gravity or allowable initial metacentric height;
(3) Coordinates of opening of flooding angles and curves or table of flooding angles;
(4) Stability information for carriage of grain (capacity of fully and partially filled compartments, curves or table of assumed volumetric heeling moment, curves or table of maximum permissible heeling moment) and stability calculations for loading conditions or loading manual (if applicable);
(5) Operational guidance for ships in high sea conditions (may be included in the loading manual) (if applicable).
1.9.3.2 The following plans and documents are to be submitted for information:
(1) General arrangement;
(2) Lines and offsets;
(3) Hydrostatic curves or table;
(4) Stability cross curves or table;
(5) Capacity curves or table;
(6) Arrangement of bilge keels;
(7) Plan of subdivision draught and load line marks;
(8) Auxiliary calculations for windage area and moment of area, crowding of all passengers towards one side, icing, etc.;
(9) Cross-sectional area (if applicable);
(10) Approved inclining test report or light ship survey report;
(11) Assessment calculations of operational guidance for ships in high sea conditions (if applicable).
1.9.3.3 The above information may be reduced as appropriate for ships of which the intact stability has been approved, except for those of which service has been changed.

1.9.4 Requirements for intact stability

1.9.4.1 The intact stability of ships is to comply with the relevant requirements of IMO resolution MSC.267(85) – International Code on Intact Stability, 2008 (2008 IS Code) and its amendments. For ships with $B/D \geq 2.5$, the requirements of 2.2.3 of Part A of the Code may be substituted by the following criteria:
(1) The heeling angle θ_{max} corresponding to the maximum righting lever GZ is not to be less than 15°.

(2) The area under the curve of righting levers (GZ curve) is not be less than 0.07 m·rad up to an angle of 15° when the maximum righting lever (GZ) occurs at 15º and 0.055 m·rad up to an angle of 30º when the maximum righting lever (GZ) occurs at 30º or above. Where the maximum righting lever (GZ) occurs at angles of between 15º and 30º, the corresponding area under the righting lever curve is to be:

$$0.055+0.001\ (30^\circ - \theta_{max}) \qquad \text{m·rad}$$

1.9.4.2 The intact stability of oil tankers of 5,000 deadweight ton and above is also to comply with the relevant requirements of Regulation 27 of MARPOL Annex I.

1.9.4.3 The intact stability of open-top container ships is to comply with the relevant requirements of MSC/Circ.608/Rev. 1 – Interim Guidelines for Open-Top Container Ships.

1.9.4.4 The intact stability of polar ships having class notation PC and ships intended for navigation in ice and having class notation B1* or B1 are also to comply with the relevant requirements of resolution MSC.385(94) – International Code for Ships Operating in Polar Waters (Polar Code).

1.9.5 Stability of semi-submersible vessels in semi-submerged operation mode

1.9.5.1 Semi-submersible vessels are to operate in semi-submerged mode in the wind and wave conditions not more severe than those specified in 1.9.5.4 below. Such external environmental conditions are to be noted in stability calculations, operating manual and relevant certificates.

1.9.5.2 The stability in semi-submerged mode is to be checked to 10% of fuels, consumables and stores for operational loading conditions of 1.9.5.3 to 1.9.5.6.

1.9.5.3 Immediately before submerging with full deck cargo load, the initial metacentric height as corrected for free surface is not to be less than 1.0 m.

1.9.5.4 During the emerging and submerging of lifting cargo deck with full deck cargo load, the stability is to meet one of the following criteria:

(1) At the normal calm sea area with wind force not exceeding Beaufort scale 3, the initial metacentric height as corrected for free surface is not to be less than 0.05 m, or not less than 0.1 m with wind force not exceeding Beaufort scale 5;

(2) At the sea area with wind force not exceeding Beaufort scale 6 and significant wave height less than 0.5 m or with wind force not exceeding Beaufort scale 4 and significant wave height less than 1 m, the initial metacentric height as corrected for free surface is not to be less than 0.15 m.

1.9.5.5 At the maximum submerged depth, the initial metacentric height as corrected for free surface is not to be less than 0.5 m.

1.9.5.6 Throughout the emerging and submerging without deck cargo load, the initial metacentric height as corrected for free surface is not to be less than 0.15 m.

1.9.5.7 Whenever free liquid surface exists in a tank, the maximum effect of free surface in the tank is to be taken into account.

1.9.5.8 For submerging with large items, ships or offshore installations being carried, their effects on stability may be considered according to their actual positions and floating condition.

1.9.5.9 An appropriate operating manual for operations in semi-submerged mode is to be prepared to specify submerging procedure and operational steps for ensuring compliance with the requirements of 1.9.5.3 to 1.9.5.6. This manual is to be submitted to CCS for information.

1.9.6 Second generation intact stability criteria

1.9.6.1 Ships are to comply with the relevant requirements of CCS Guidelines on Assessment of Ship Second Generation Intact Stability Criteria.

1.9.6.2 Second generation intact stability calculations are to be submitted for information.

1.9.7 Operational guidance for ships in high sea conditions

1.9.7.1 Hydrodynamic-based methods are to be used to analyze the performance and characteristics of the ship, assess the sailing conditions that may affect safety, and prepare operational guidance for ships in potential high sea conditions for the master's reference.

1.9.7.2 Due to the influences of environmental conditions, the ship's own state, human factors and other factors, operating the ship according to the ship's operational guidance in high sea conditions cannot ensure that the ship can completely avoid loss of stability, excessive movement and capsizing accidents when sailing in adverse sea conditions, nor can the master be released from the responsibility of the ship's navigation safety.

1.9.7.3 The likelihood of different modes of navigation safety failures under the combined or separate action of wind and waves is to be assessed, and operational guidance for ships in high sea conditions is to be developed accordingly. Modes of navigation safety failures that are to be assessed include:

(1) excessive roll or excessive acceleration caused by parametric rolling;

(2) excessive roll or excessive acceleration caused by synchronous rolling motion during navigation;
(3) loss of stability caused by pure loss of stability;
(4) excessive roll/capsizing or insufficient stability caused by the combined action of wind and waves in the dead ship condition.
1.9.7.4 Navigation safety assessments are to be carried out for typical loading conditions in sailing conditions as a minimum and operational guidance for ships in high sea conditions is to be developed.
1.9.7.5 The level 2 criteria for parametric rolling in IMO MSC.1/Circ.1627 is to be used to calculate the amplitude of parametric rolling and the resultant lateral acceleration at the bridge when the ship is sailing at typical speed in head waves and following waves. Operational guidance for ships in high sea conditions is to include sailing and sea conditions where the calculated roll amplitude is greater than 25^{o} or lateral acceleration is greater than 4.64 m/s^2.
1.9.7.6 The level 2 criteria for pure loss of stability in IMO MSC.1/Circ.1627 is to be used to calculate the vulnerability index of ship's pure loss of stability. Operational guidance for ships in high sea conditions is to include sea conditions with a calculated vulnerability index of 1.0.
1.9.7.7 The potential flow theory is to be used to calculate the amplitude of parametric rolling and the resultant lateral acceleration at the bridge when the ship is sailing at typical speed in typical waves. Operational guidance for ships in high sea conditions is to include sailing and sea conditions where the calculated roll amplitude is greater than 25^{o} or lateral acceleration is greater than 4.64 m/s^2.
1.9.7.8 The meteorological criteria of the International Code for Intact Stability, 2008, adopted by IMO resolution MSC.267(85), is to be used to calculate the steady wind speed value (beam wind) that meets the requirements of the meteorological criteria, assuming that the ship is in a dead ship condition and that the roll angle caused by wave action is 25^{o}. Operational guidance for ships in high sea conditions is to include the steady wind speed value (beam wind).
1.9.7.9 The potential flow theory is to be used to calculate the amplitude of parametric rolling and the resultant lateral acceleration at the bridge when the ship is in the dead ship conditions in typical waves. Operational guidance for ships in high sea conditions is to include sailing and sea conditions where the calculated roll amplitude is greater than 25^{o} or lateral acceleration is greater than 4.64 m/s^2.
1.9.7.10 Other numerical simulations or model tests may be used as alternatives to navigation safety assessment subject to CCS agreement.
1.9.7.11 Operational guidance for ships in high sea conditions is to be provided in a loading manual or onboard computer-based system in a simple and clear form.

Section 10 DAMAGE STABILITY

1.10.1 General requirements

1.10.1.1 Compliance with the applicable requirements for damage stability is a condition for classification of ships.
1.10.1.2 The damage stability of ships is to comply with the requirements of this Section, or it is to be demonstrated that their damage stability is in compliance with the requirements of the flag State Administration.

1.10.2 Plans and documents

1.10.2.1 The following plans and documents are to be submitted for approval or confirmation:
(1) Calculations of damage stability;
(2) Damage control plan and damage control booklet (for passenger ships and dry cargo ships);
(3) Curves or table of allowable height of center of gravity or allowable initial metacentric height for damage stability (if applicable);
(4) Arrangement of cross-flooding fittings and calculations of cross-flooding duration (if applicable).
1.10.2.2 The following plans and documents are to be submitted for information:
(1) General arrangement of doors and windows;
(2) General arrangement of scuttles, ventilators and air pipes;
(3) Plans and documents stated in 1.9.3 of this Chapter.

1.10.3 Requirements for damage stability

1.10.3.1 The damage stability of ships is to comply with the relevant requirements of applicable regulations as shown in Table 1.10.3.1.
1.10.3.2 The stability of ships carrying timber deck cargo is to comply with the relevant requirements of IACS UI SC 161.

List of Applicable Regulations for Damage Stability **Table 1.10.3.1**

Ship type	Applicable regulation
Passenger ship, type B freeboard dry cargo ship and combination carrier*, type B-60 and type B-100 freeboard cargo ships intended for carriage of deck cargo	Part B-1, Chapter II-1 of International Convention for the Safety of Life at Sea (SOLAS)
Bulk carrier (additional requirements)	Reg. XII/4 of International Convention for the Safety of Life at Sea (SOLAS)
Type B-60, type B-100 and type A freeboard ships	Reg. 27 of the International Convention on Load Lines, 1966 (ICLL), as revised by Protocol of 1988
Chemical tanker	International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code)
Liquefied gas carrier	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
Oil tanker (including combination carrier*)	Reg. 28 of Annex I of International Convention for the Prevention of Pollution from Ships, 1973, as modified by the 1978 Protocols (MARPOL)
Special purpose ship	Code Of Safety For Special Purpose Ships (2008 SPS Code)
Offshore supply vessel of not more than 100 m in length	Guidelines for the Design and Construction of Offshore Supply Vessels, 2006 (2006 OSV Guidelines)
Nuclear ship	Code of Safety for Nuclear Merchant Ships
Ship carrying INF and radioactive wastes	International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-level Radioactive Wastes on Board Ships (INF Code)
Open-top container ship	MSC/Circ.608/Rev.1
Polar ship (notation PC) Ship intended for navigation in ice (class notation B1* or B1)	International Code for Ships Operating in Polar Waters (Polar Code)
Offshore support vessels transporting and handling hazardous and noxious liquid substances in bulk	Code for the Transport and Handling of Hazardous and Noxious Liquid Substances in Bulk on Offshore Support Vessels (OSV Chemical Code)
Ships using gases or other low-flashpoint fuels	International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code)

* Note: Combination carrier is a cargo ship designed to carry both oil and solid cargoes in bulk (see definition of SOLAS Reg. II-2/3.14).

Section 11 LOAD LINE MARKS AND MARKING

1.11.1 Application

1.11.1.1 The requirements of this Section apply to ships engaged on international voyages.

1.11.2 Load line marks

1.11.2.1 The load line mark for ships not carrying timber deck cargoes is shown in Figure 1.11.2.1.

1.11.2.2 The load line mark for ships carrying timber deck cargoes is shown in Figure 1.11.2.2.

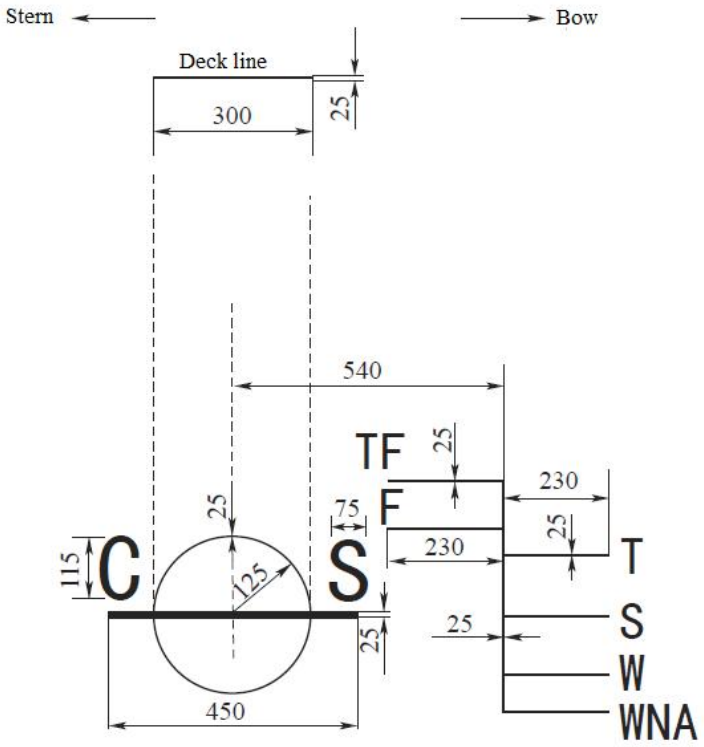


Figure 1.11.2.1 Freeboard Mark for Ships not Carrying Timber Deck Cargoes (in mm)

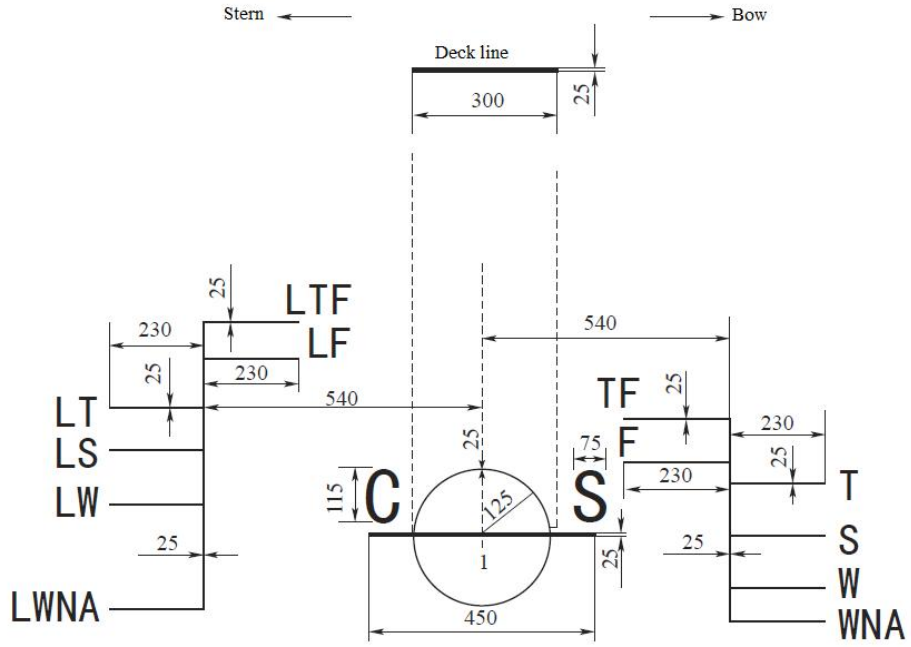


Figure 1.11.2.2 Freeboard Mark for Ships Carrying Timber Deck Cargoes (in mm)

1.11.2.3 Where a ship is assigned a greater than minimum freeboard so that the load line is marked at a position corresponding to, or lower than, the lowest seasonal load line assigned at minimum freeboard as specified in Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966, only the Fresh Water Load Line need be marked. In such a case, the load line mark is as shown in Figure 1.11.2.3.

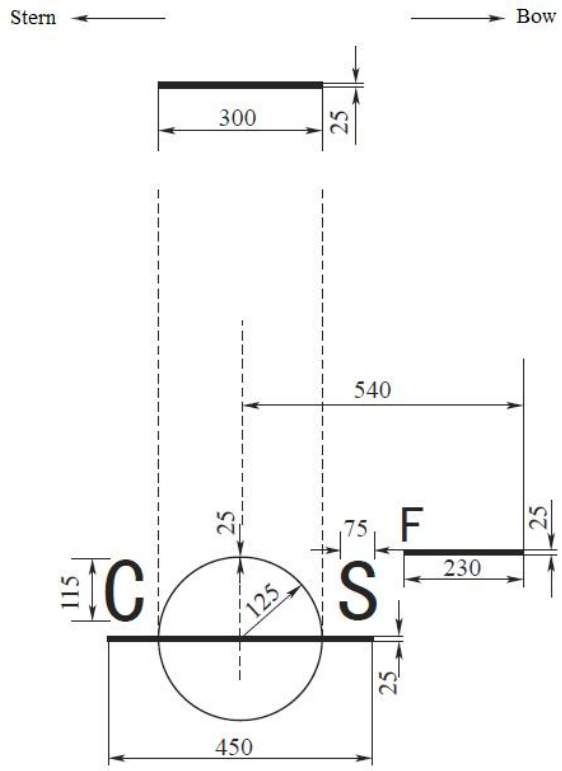


Figure 1.11.2.3 Fresh Water Load Line Only (in mm)

1.11.2.4 The subdivision load line mark for passenger ships is shown in Figure 1.11.2.4.

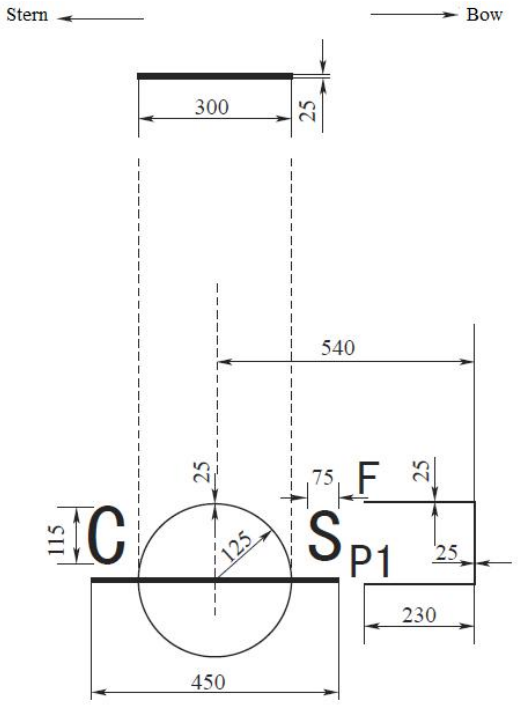


Figure 1.11.2.4 Subdivision Load Line Mark for Passenger Ships (in mm)

The symbols in Figures 1.11.2.1 to 1.11.2.4 are defined as follows:

C, S — China Classification Society;
F — Summer Fresh Water Load Line;
S — Summer Load Line;
WNA — Winter North Atlantic Load Line;
LF — Summer Fresh Water Timber Load
TF — Tropical Fresh Water Load Line;
T — Tropical Load Line;
W — Winter Load Line;
LTF — Tropical Fresh Water Timber Load Line;
LT — Tropical Timber Load Line;

Line;
LS — Summer Timber Load Line;
LW — Winter Timber Load Line;
LWNA — Winter North Atlantic Timber Load Line;
P1 — Passenger Ship Subdivision Load Line.

1.11.3 Marking

1.11.3.1 The Load line mark is to consist of a ring 300 mm in outside diameter and 25 mm wide which is intersected by a horizontal line 450 mm in length and 25 mm in breadth, the upper edge of which passes through the center of the ring. The center of the ring is to be placed on each side of the ship at the middle of the length as defined in the Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966, and at a distance equal to the assigned summer freeboard measured vertically below the upper edge of the deck line. The ring, lines and letters are to be painted in white or yellow on a dark ground or in black on a light ground. They are to be permanently marked on both sides of the ship and clearly visible.

Section 12 STRUCTURAL ARRANGEMENT

1.12.1 General requirements

1.12.1.1 This Section specifies the requirements for the structural arrangement of hull structures of ships engaged in unrestricted service.

1.12.1.2 Unless stated otherwise, this Section applies to mechanically self-propelled ships engaged on international voyages.

1.12.2 Arrangement of watertight bulkheads

1.12.2.1 All ships are to be fitted with at least the following watertight bulkheads:

(1) one collision bulkhead;

(2) one after peak bulkhead;

(3) one bulkhead at both ends of the machinery space;

(4) the number of watertight bulkheads and their distribution along the ship's length for both passenger and cargo ships are to comply with the requirements for subdivision and stability contained in Sections 9 and 10 of this Chapter, in addition to the requirements of (1) to (3) above;

(5) the number of watertight bulkheads and their distribution along the ship's length for oil tankers of 600 deadweight tons and above are to comply with the requirements of Chapters 3 and 4 of MARPOL Annex I, in addition to the requirements of (1) to (3) above.

1.12.3 Arrangement of collision bulkhead

1.12.3.1 A collision bulkhead is to be fitted which is to be watertight up to the bulkhead deck of passenger ships and the freeboard deck of cargo ships. This bulkhead is to be located at a distance from the forward perpendicular (the perpendicular at the intersection of the load waterline L_L with the fore side of the stem) of not less than 0.05 L_L or 10m, whichever is the less, and, except as may be permitted by the Administration, not more than 0.08 L_L or 0.05 L_L + 3 m, whichever is the greater.

1.12.3.2 Where any part of the ship below the waterline extends forward of the forward perpendicular referred to in 1.12.3.1 of this Section, e.g., a bulbous bow, the distances specified in 1.12.3.1 of this Section are to be measured from a point either:

(1) at the mid-length of such extension;

(2) at a distance 0.015 L_L forward of the forward perpendicular; or

(3) at a distance 3m forward of the forward perpendicular,

whichever gives the smallest measurement.

1.12.3.3 The collision bulkhead may have steps or recesses, provided that they are within the limits specified in 1.12.3.1 and 1.12.3.2 of this Section.

1.12.3.4 Where a long forward superstructure is fitted, the collision bulkhead is to be extended weathertight to the deck next above the bulkhead deck of passenger ships and the freeboard deck of cargo ships. The extension need not be fitted directly above the bulkhead below provided it is located within the limits prescribed in 1.12.3.1 and 1.12.3.2 of this Section with the exception permitted by 1.12.3.5 of this Section and that the part of the deck which forms the step is made effectively weathertight.

1.12.3.5 Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the bulkhead deck of passenger ships and the freeboard deck of cargo ships, the ramp is to be weathertight over its complete length. In cargo ships the part of the ramp which is more than

2.3 m above the freeboard deck may extend forward of the limit specified in 1.12.3.1 and 1.12.3.2 of this Section. Ramps not meeting the above requirements are to be disregarded as an extension of the collision bulkhead.

1.12.3.6 The number of openings in the extension of the collision bulkhead above the freeboard deck is to be restricted to the minimum compatible with the design and normal operation of the ship. All such openings are to be capable of being closed weathertight.

1.12.4 Arrangement of after peak and machinery space bulkheads and stern tube

1.12.4.1 Bulkheads are to be fitted separating the machinery space from cargo and accommodation spaces forward and after and made watertight up to the bulkhead deck of passenger ships and the freeboard deck of cargo ships. An aft peak bulkhead is also to be fitted and made watertight up to the bulkhead deck or the freeboard deck. The aft peak bulkhead may, however, be stepped below the bulkhead deck or the freeboard deck, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

1.12.4.2 In all cases, stern tubes are to be enclosed in watertight spaces of moderate volume. In passenger ships the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the bulkhead deck will not be immersed. In cargo ships, other measures to minimize the danger of water penetrating into the ship in case of damage to stern tube arrangements may be taken upon approval.

1.12.5 Arrangement and watertightness of openings and trunks in watertight bulkheads and internal decks

1.12.5.1 The number of openings in watertight bulkheads is to be reduced to the minimum compatible with the design and proper working of the ship.

1.12.5.2 Where pipes, scuppers, electric cables, etc., are carried through watertight bulkheads, arrangements are to be made to ensure the watertight integrity of the bulkheads. Valves not forming part of a piping system are not to be permitted in watertight bulkheads. Lead or other heat-sensitive materials are not to be used in systems which penetrate watertight bulkheads.

1.12.5.3 For passenger ships, no doors, manholes or access openings are permitted in watertight transverse bulkheads dividing a cargo space from an adjoining cargo space, except those agreed. For cargo ships, CCS may permit relaxation of the watertightness requirements for openings above the freeboard deck, where it is demonstrated that any progressive flooding can be easily controlled and that the safety of the ship will not be thereby impaired.

1.12.5.4 No doors, manholes, ventilation ducts or any other openings are to be fitted in the collision bulkhead below the bulkhead deck for passenger ships (except the pipes, provided that the relevant requirements of the Administration are complied with).

1.12.5.5 Watertight ventilators and trunks are to be carried at least up to the bulkhead deck in passenger ships and up to the freeboard deck in cargo ships.

1.12.5.6 The arrangement and watertightness of accesses to spaces below the ro-ro deck (bulkhead deck) in ro-ro passenger ships are to comply with the following requirements:

(1) Subject to (2) and (3) of this paragraph, all accesses that lead to spaces below the bulkhead deck are to have a lowest point which is not less than 2.5 m above the bulkhead deck.

(2) Where vehicle ramps are installed to give access to spaces below the bulkhead deck, their openings are to be able to be closed weathertight to prevent ingress of water below, alarmed and indicated to the navigation bridge.

(3) CCS may permit the fitting of particular accesses to spaces below the bulkhead deck provided they are necessary for the essential working of the ship, e.g. the movement of machinery and stores, subject to such accesses being made watertight, alarmed and indicated to the navigation bridge.

1.12.6 Openings in the shell plating below bulkhead deck of passenger ships and the freeboard deck of cargo ships and their watertightness

1.12.6.1 The number of openings in the shell plating is to be reduced to the minimum compatible with the design and proper working of the ship.

1.12.6.2 Freeing ports are to be capable of rapidly freeing the decks of water and draining them. The freeing port area in bulwarks is to be in accordance with Regulation 24 of the Amendments to Annex I of Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

1.12.6.3 Moving parts penetrating the shell plating below the deepest subdivision draught are to be fitted with an acceptable watertight sealing arrangement. The inboard gland is to be located within a watertight space of such volume that, if flooded, the bulkhead deck of passenger ships and the freeboard deck of cargo ships will not be submerged.

1.12.7 Other openings and their closing appliances

1.12.7.1 All access openings in bulkheads at ends of enclosed superstructures are to comply with the following requirements:

(1) Doors of steel or other equivalent material are to be fitted, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the un-pierced bulkhead and weathertight when closed.

(2) Unless otherwise permitted by the flag Administration, doors are to open outwards so as to be protected against wave impact.

(3) The height of doorsills is to be at least 380 mm above the deck.

1.12.7.2 Cargo and other hatchways, miscellaneous openings in freeboard and superstructure decks are to comply with the following requirements:

(1) The height of coamings of hatchways above the deck is to be at least as follows:

① 600 mm if in Position 1; and

② 450 mm if in Position 2.

(2) The structure of cargo and other hatchways in Positions 1 and 2 and the means for keeping them weathertight are to comply with the relevant requirements of Regulation 15 or 16 of the Amendments to Annex I of Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

(3) Openings in freeboard and superstructure decks are to comply with the relevant requirements of Regulation 18 of the Amendments to Annex I of Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

1.12.7.3 Machinery space openings are to comply with the following requirements:

(1) Machinery space openings are to be efficiently enclosed by steel casings. Access openings in such casings are to be fitted with weathertight doors, the sills of which are to be at least 600 mm above the deck if in Position 1, and at least 380 mm above the deck if in Position 2. Other openings in such casings are to be fitted with covers, permanently attached in their proper positions.

(2) Where machinery casings are not protected by other structures, double doors are to be required for ships assigned freeboards less than those based on relevant requirements. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is to be provided.

(3) Coamings of any machinery space ventilator, the height of which complies with the requirements of 1.12.7.4(6) of this Section, need not be fitted with weathertight closing appliances. Ventilators necessary to continuously supply the emergency generator room, if this is considered buoyant in the stability calculation or protecting opening leading below, are to have coamings of sufficient height to comply with 1.12.7.4(6) of this Section, without having to fit weathertight closing appliances.

(4) Where the height of machinery space and emergency generator room ventilator coamings is less than that required by 1.12.7.4(6) of this Section, weathertight closing appliances are to be fitted.

(5) Engine/boiler openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.

(6) Machinery casings on type "A" ships are to comply with the relevant requirements of Regulations 26(1) and (2) of the Amendments to Annex I of Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

1.12.7.4 Ventilators are to comply with the following requirements:

(1) Ventilators in Position 1 or 2 to spaces below freeboard deck or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck. Where the coaming of any ventilator exceeds 900 mm in height, it is to be specially supported.

(2) Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck.

(3) Ventilators in Position 1 are to have coamings of a height of at least 900 mm above the deck.

(4) Ventilators in Position 2 are to have coamings of a height of at least 760 mm above the deck.

(5) The thickness of ventilator coamings may be taken from Table 1.12.7.4(5), but need not exceed that of the deck.

Thickness of Ventilator Coamings **Table 1.12.7.4(5)**

Internal diameter of coaming (mm)	Thickness of coaming (mm)	Internal diameter of coaming (mm)	Thickness of coaming (mm)
≤200	7.5	350	9.0
250	8.0	400	9.5
300	8.5	≥450	10.0

(6) Ventilators in Position 1 the coamings of which extend to more than 4.5 m above the deck, and in

Position 2 the coamings of which extend to more than 2.3 m above the deck, need not be fitted with closing arrangements.

(7) Except as provided in (6) above, ventilator openings are to be provided with efficient weathertight closing appliances. In ships of not more than 100 m in load line length L_L, the closing appliances are to be permanently attached; in ships of more than 100 m in load line length L_L, they may be conveniently stowed near the ventilators to which they are to be fitted.

1.12.7.5 Air pipes are to comply with the following requirements:

(1) Air pipes are to comply with the requirements of this Section and in addition, the relevant requirements of Chapter 3 of PART THREE of the Rules.

(2) Where air pipes to ballast and other tanks extend above the freeboard or superstructure decks, the height from the deck to the point where water may have access below is to be at least 760 mm on the freeboard deck and 450 mm on the superstructure deck. Where these heights may interfere with the working of the ship, a lower height may be approved, provided that CCS is satisfied that the closing arrangements and other circumstances justify a lower height. The exposed parts of the pipes are to be of substantial construction.

(3) The minimum wall thickness of air pipes above weather deck is to be:

6.0 mm for pipes of 80 mm external diameter or smaller;

8.5 mm for pipes of 165 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation.

(4) Air pipes are to be fitted with automatic closing devices.

1.12.8 Arrangement of double bottoms (not of tankers)

1.12.8.1 For all passenger ships regardless of size and cargo ships of 500 gross tonnage and over, a double bottom is to be fitted and is to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

1.12.8.2 Where a double bottom is required to be fitted, the inner bottom is to be continued out to the ship's side in such a manner as to protect the bottom to the turn of the bilge. The vertical distance h measured from the keel line is in no case to be less than $B/20$, or less than 760 mm, whichever is the greater, and need not be greater than 2,000 mm.

1.12.8.3 Small wells constructed in the double bottom in connection with drainage arrangements are not to extend downward more than necessary. The vertical distance from the bottom of such a well to a plane coinciding with the keel line is not to be less than $h/2$ or 500 mm, whichever is greater. Other wells (e.g. for lubricating oil under main engines) may be permitted if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with this regulation.

1.12.8.4 A double bottom need not be fitted in way of watertight tanks (including dry tanks) of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage.

1.12.8.5 Any part of a passenger ship regardless of size and a cargo ship of 500 gross tonnage and over that is not fitted with a double bottom in accordance with 1.12.8.1 or 1.12.8.4 of this Section is to satisfy the requirements for bottom damages, as specified in SOLAS II-1, in that part of the ship.

1.12.8.6 In case of large lower holds in passenger ships, the double bottom height is to be increased to not more than $B/10$ or 3 m, whichever is less, measured from the keel line. Alternatively, bottom damages may be calculated for these areas, in accordance with 1.12.8.5 of this Section, but assuming an increased vertical extent.

1.12.9 Arrangement of cofferdams

1.12.9.1 A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. A cofferdam is to be properly ventilated and of sufficient size to allow for inspection, maintenance and safety evacuation.

1.12.9.2 Cofferdams are to be provided between compartments intended for fuel oil or lubricating oil and those intended for fresh water (drinking water, water for propelling machinery and boilers).

Cofferdams are to be provided between compartments intended for fuel oil or lubricating oil and tanks

intended for the carriage of liquid foam for fire extinguishing.
Cofferdams are only required between fuel oil tanks in double bottom and tanks immediately above where the inner bottom plating is subjected to the head of fuel oil contained therein, as in the case of a double bottom with its top raised at the sides. Where a corner to corner situation occurs for such tanks, they are not considered to be adjacent.
1.12.9.3 In addition to the requirements of 1.12.9.2 of this Section, the oil fuel tank protection by means of cofferdams in ships is to comply with Regulation 12A of MARPOL Annex I.
1.12.9.4 The separation of cargo oil tanks in tankers is to be arranged in accordance with the requirements of SOLAS Reg. II-2/4.5 regarding cargo areas of tankers.
1.12.9.5 The arrangement of cofferdams is also to comply with 2.8.2 of Section 8, Chapter 2 of PART THREE of the Rules.

1.12.10 Arrangement of bow freeboard deck and compartments forward of collision bulkhead
1.12.10.1 The arrangement of bow freeboard deck and enclosed superstructures (if fitted) is to comply with the requirements for minimum bow height as specified in Regulation 39 of the Amendments to Annex I of Annex B to the Protocol of 1988 relating to the International Convention on Load Lines, 1966.
1.12.10.2 The arrangement of bow freeboard deck and enclosed superstructures (if fitted) of all ships assigned a type B freeboard, other than oil tankers, chemical tankers and gas carrier is to comply with 1.12.9.2 of this Section and in addition, the requirements for bow reserve buoyancy as specified in Regulation 39 of the Amendments to Annex I of Annex B to the Protocol of 1988 relating to the International Convention on Load Lines, 1966.
1.12.10.3 Fuel oil and other flammable oils are not to be carried in forepeak tanks and other compartments located forward of the collision bulkhead.
1.12.10.4 Chain lockers of ships with a load line length of 24 m and above are to comply with the following requirements:
(1) Spurling pipes and cable lockers are to be watertight up to the deck exposed to weather. However, the bulkhead between separate chain lockers (Figure 1.12.10.4(1)) or the common bulkhead between adjacent lockers (Figure 1.12.10.4(2)) need not be watertight.

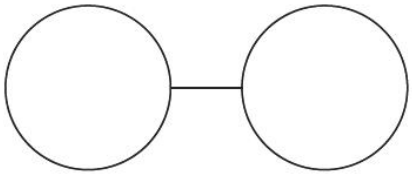


Figure 1.12.10.4(1)

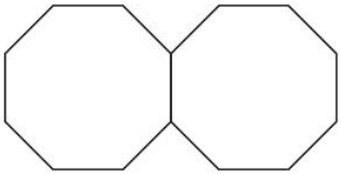


Figure 1.12.10.4(2)

(2) Where means of access are provided, they are to be closed by a substantial cover and secured by closely spaced bolts.
(3) Where a means of access to spurling pipes or cable lockers is located below the weather deck, the manhole covers and securing appliances are to be in consistence with recognized standards① , or equivalent to the watertight manhole covers. The use of butterfly nuts and/or hinged bolts as the securing appliances of manhole covers is prohibited.
(4) Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances (e.g. steel plates in halves hooked over the spurling pipe tops, or canvas covers lashed) to minimize water ingress.

---

① E.g., 1) ISO 5894-2018; 2) China: CB/T4392-2014 “Marine manhole cover”; 3) India: IS 15876-2009 “Ship and Marine Technology manholes with bolted covers”; 4) Japan: JIS F2304:2015, “Ship’s Manholes” and JIS F2329:1975, “Marine Small Size Manhole”; 5) Korea: KS VISO 5894:2012; 6) Norway: NS 6260: 1985 “Manhole cover - overview” ; 7) Russia: GOST 2021-90 “Ship’s steel manholes, Specifications”.

1.12.11 Arrangement of passenger ships above the bulkhead deck

1.12.11.1 Measures are to be taken to limit the entry and spread of water above the bulkhead deck. Such measures may include partial bulkheads or webs. When partial watertight bulkheads and webs are fitted on the bulkhead deck, above or in the immediate vicinity of main subdivision bulkheads, they are to have watertight shell and bulkhead deck connections so as to restrict the flow of water along the deck when the ship is in a heeled damaged condition. Where the partial watertight bulkhead does not line up with the bulkhead below, the bulkhead deck between is to be made of effectively watertight.

1.12.11.2 All openings in the exposed weather deck are to have coamings of ample height and strength and are to be provided with efficient means for expeditiously closing them weathertight. Freeing ports, open rails and scuppers are to be fitted as necessary for rapidly clearing the weather deck of water under all weather conditions.

1.12.11.3 Air pipes terminating within a superstructure which are not fitted with watertight means of closure are to be considered as unprotected openings in damage stability calculation.

1.12.11.4 Side scuttles, gangway, cargo and coaling ports and other means for closing openings in the shell plating above the bulkhead deck are to be of efficient design and construction and of sufficient strength having regard to the spaces in which they are fitted and their positions relative to the deepest subdivision draught.

1.12.11.5 Efficient inside deadlights, so arranged that they can be easily and effectively closed and secured watertight, are to be provided for all side scuttles to spaces below the first deck above the bulkhead deck.

1.12.12 Arrangement of compartments of double hull oil tankers

1.12.12.1 Wing tanks or spaces are to extend either for the full depth of the ship's side or from the top of double bottom to the uppermost deck, disregrading a rounded gunwale where fitted. They are to be so arranged that all cargo tanks are located inboard of the moulded lines of the side shell plating in those tanks or spaces. The entire cargo tank (including slop tank) length of oil tankers of 5,000 tons deadweight and above are to be protected by ballast tanks or spaces other than tanks that carry oil, and the wing tanks and double bottom for such protection within the cargo tank length are to comply with the following requirements:

(1) The vertical distance W between wing tank inner hull and side shell is not to be less than as calculated below:

$W = 0.5 + DW/20000$ m or

$W = 2.0$ m

whichever is the lesser. The minimum value of W = 1.0 m.

where: DW (Deadweight) means the difference in tons between the displacement of a ship in water of a relative density of 1.025 t/m^3 at the load line corresponding to the assigned summer freeboard and the lighweight of the ship.

(2) The depth of double bottom is not to be less than as calculated below:

$h = B/15$ m or

$h = 2.0$ m

whichever is the lesser. The minimum value of h = 1.0 m.

1.12.12.2 The height of double bottom of oil tankers of less than 5,000 tons deadweight are to comply with the following requirements:

$h = B/15$ m; the minimum value of h = 0.76 m

1.12.12.3 Every crude oil tanker of 20,000 tons deadweight and above and every product carrier of 30,000 tons deadweight and above are to be provided with segregated ballast tanks. The capacity of the segregated ballast tanks is to be so determined that the ship may operate safely on ballast voyages without recourse to the use of cargo tanks for water ballast. The capacity of segreated ballast tanks is to be at least such that, in any ballast condition at any part of the voyage, including the conditions consisting of lightweight plus segregated ballat only, the ship's draughts and trim can meet the following requirements:

(1) the moulded draught amidship (d_m), in m, (without taking into account any defomation of the ship) is not to be less than:

$$d_m = 2.0 + 0.02L_L \quad \text{m}$$

(2) the draughts at the forward and after perpendiculars are to correspond to those determined by the draught amidships as specified in (1) above, in association with the trim by the stern of not greater than $0.015L_L$; and

(3) the draught at the after perpendicular is not to be less than that which is necessary to obtain full immersion of the propeller(s).

1.12.12.4 Cargo tanks are to be of such size and arrangement that the hypothetical oil outflow from side and bottom damage, anywhere in the length of the ship, is limited.

For oil tankers of less than 5,000 tons deadweight, the length of each cargo tank is not to exceed 10 m or one of the following values, whichever is the greater:

(1) where no longitudinal bulkhead is provided inside the cargo tanks: $(0.5b_i/B + 0.1)L_L$, but not to exceed $0.2\ L_L$;

(2) where a centerline longitudinal bulkhead is provided inside the cargo tanks: $(0.25b_i/B + 0.15)L_L$;

(3) where two or more longitudinal bulkheads are provided inside the cargo tanks:

① for wing cargo tanks: $0.2\ L_L$

② for centre cargo tanks:

(a) if b_i/B is equal to or greater than 1/5: $0.2\ L_L$

(b) if b_i/B is less than 1/5:

(i) where no centerline longitudinal bulkhead is provided: $(0.5b_i/B + 0.1)L_L$

(ii) where a centerline longitudinal bulkhead is provided: $(0.25b_i/B + 0.15)L_L$

b_i is the minimum distance from the ship's side to the outer longitudinal bulkhead of the tank in question measured inboard at right angles to the centerline at the level corresponding to the assigned summer freeboard.

For oil tankers of less than 5,000 tons deadweight, the capacity of each cargo tank is not to exceed 700 m^3, unless wing tanks or spaces are arranged in accordance with 1.12.12.1(1), complying with the following:

$W = 0.4 + 2.4DW/20000$ m; the minimum value of $W = 0.76$ m.

1.12.12.5 For oil tankers carrying oil having a flash point not exceeding 60℃, the separation of cargo tanks is to comply with the following requirements: Cargo pump-rooms, cargo tanks, slop tanks and cofferdams are to be positioned forward of machinery spaces. Main cargo control stations, control stations, accommodation and service spaces are to be positioned aft of cargo tanks, slop tanks, and spaces which isolate cargo or slop tanks from machinery spaces, but not necessarily aft of fuel oil tanks and ballast tanks.

1.12.12.6 Cofferdams are to be at least gastight. If applicable, means of access for internal inspection are to comply with 1.12.14 to 1.12.16 of this Section.

1.12.12.7 For oil tankers of 5,000 tons deadweight and above, the pump-room is to be provided with a double bottom such that at any cross-section the depth of each double bottom tank or space is to be such that the distance between the bottom of the pump-room and the ship's baseline measured at right angles to the ship's baseline is not less than specified below:

B/15 m or 2 m,

whichever is the lesser.The minimum value is 1 m.

In case of pumo-rooms whose bottom plate is located above the baseline by at least the minimum height required above (e.g. gondola stern design), there will be no need for a double bottom construction in way of the pump-room.

1.12.13 Arrangement of compartments of single hull oil tankers

1.12.13.1 Oil tankers of 600 tons deadweight and above but less than 5,000 tons deadweight are to be fitted with double bottom tanks or spaces, the height of which is to comply with the requirement of 1.12.12.2 of this Section.

1.12.13.2 Oil tankers of less than 600 tons deadweight are not necessarily to be fitted with double bottom and double hull.

1.12.13.3 The length of cargo tanks is to comply with the requirements of 1.12.12.4 of this Section for oil tankers of less than 5,000 tons deadweight.
1.12.13.4 The segregation of cargo tanks is to comply with the requirements of 1.12.12.5 of this Section.

1.12.14 Access and its openings and other requirements

1.12.14.1 Oil tankers as defined in Regulation II-1/2, chemical tankers as defined in Regulation VII/8.2 and gas carriers as defined in Regulation VII/11.2 of the International Convention for the Safety of Life at Sea, 1974, as amended are to be fitted with safe access to bow in accordance with Regulation II-1/3-3 of the Convention.
1.12.14.2 Oil tankers of 500 gross tonnage and over and bulk carriers (as defined in Regulation IX/1 of the International Convention for the Safety of Life at Sea, 1974, as amended) of 20,000 gross tonnage and over are to be fitted with access to and within spaces in, and forward of, the cargo area in accordance with Regulation II-1/3-6 of the Convention.
1.12.14.3 When implementing the provisions of 1.12.14.1 and 1.12.14.2 of this Section, for oil tankers of less than 5,000 tons deadweight, openings of smaller dimesions may be provided subject to the agreement of the flag State Administration, provided that the ability to traverse such openings or to remove an injured person can be proved. However in any case, the size of openings is not to be less than 400 mm × 600 mm or 450 mm × 550 mm.
1.12.14.4 In addition to the requirements of 1.12.14.1 to 1.12.14.3 of this Section, all ships are to be fitted with safe passage of crew in accordance with Regulation 25-1 of the Amendments to Annex I of Annex B to the Protocol of 1988 relating to the International Convention on Load Lines, 1966. Gangway and access fitted on type "A" ships are to be in accordance with Regulations 26(3) and (4) of Annex I. In addition, all ships are to be fitted with guard rails and bulwarks as means for protection of the crew in accordance with Regulations 25(2) and (3) of Annex I.

1.12.15 Arrangement of fuel oil tanks

1.12.15.1 Fuel oil tanks are to be arranged in accordance with the requirements of Regulation 12A of MARPOL Annex I.

Section 13 MARKING OF OPERATING DRAFT OF WORKING SHIPS

1.13.1 General provisions

1.13.1.1 This Section applies to floating cranes, and to open hopper dredgers and barges fitted with means of opening at their bottom (these three types of ships are hereinafter referred to as working ship).
1.13.1.2 For working ships, the maximum operating draught may be assigned and such draught appropriately marked in accordance with this Section.
1.13.1.3 In operational areas defined by the limited sea conditions in 1.13.3 of this Section, the process of hoisting and handling operations of floating cranes, that of dredging operations of dredgers and that of loading, carrying and discharging operations of dredgers and barges are considered as their operating conditions.
1.13.1.4 The intact stability of working ships in operating conditions is to comply with the requirements of 1.13.4 of this Section, or alternatively, their compliance with the requirements of the flag Administration for intact stability regarding assignment of operating draught is to be confirmed.

1.13.2 Assignment of operating draught

1.13.2.1 For working ships intended for assignment of operating draught, the maximum operating draught is to be assigned in accordance with this Chapter, based on the minimum summer freeboard corresponding to type B freeboard as specified in the amendments to the protocol of 1988 relating to the International Convention on Load Lines, 1966 (IMO resolution MSC.143(77)).

1.13.2.2 Where all requirements of this Section are complied with, the maximum draught of working ships in operation may correspond to a freeboard reduced by 2/3 of the minimum summer freeboard referred to in 1.13.2.1.

1.13.3 Limitations on sea conditions for operations

1.13.3.1 For working operations at the maximum operating draught assigned in accordance with this Section, limitations on sea conditions for areas, in which the working ship is to operate, are as follows:

(1) For floating cranes, wind force is not to exceed Beaufort scale 5 and significant wave height is not to exceed 1 m.

(2) For dredgers and barges, wind force is not to exceed Beaufort scale 6 and significant wave height is not to exceed 2 m.

1.13.3.2 Where the environmental limitations as required by design regarding wind and wave for sea areas, in which working ships are to operate, are beyond those specified in 1.13.3.1, relevant technical proof and calculations or model test information for ensuring safe operation are to be submitted for approval or agreement by CCS. And this is to be indicated in the operating draught marking instruction in accordance with 1.13.6.3 of this Section.

1.13.4 Intact stability in operating condition

1.13.4.1 The intact stability of floating cranes in operating condition is to comply with the following requirements:

(1) The stability of floating cranes is to be checked for the following loading conditions:

① maximum lifting load, necessary ballast and all fuels and stores, the ship being at the maximum operating draught;

② maximum lifting load, necessary ballast and 10% of fuels and stores.

(2) Initial metacentric height GM of floating cranes in operating condition:

$$GM \geq \frac{M_f + M_h}{0.1716\theta_c \Delta} \quad \text{m}$$

where: GM — initial metacentric height, in m, taking into account the effects of free surface and suspended objects thereon;

M_f — heeling moment due to wind pressure on the floating crane, in kN·m, calculated according to 1.13.4.2;

M_h — heeling moment due to maximum lifting load and heeling moment due to asymmetrical loading, if any, in kN · m;

θ_c — permissible static limiting heeling angle, (°), taken as 4/5 immersion angle of freeboard deck edge, 4/5 emersion angle of bilge or heeling angle corresponding to 0.3 m of residual freeboard, whichever is the least; not exceeding 5° for floating cranes with slewing booms, and not exceeding 3° for floating cranes with unslewing booms;

Δ — displacement in the loading condition under checking, in t.

(3) Stability criterion numeral K of floating cranes in operating condition:

$$K = \frac{9.81 l_q \Delta}{M_f + M_h} \geq 1$$

where: l_q — minimum capsizing lever, in m, without taking into account the effect of rolling;

Δ, M_f, M_h — the same as in (2).

1.13.4.2 The heeling moment M_f due to wind pressure on the floating crane in operating condition is to be calculated as follows:

$$M_f = 0.001 P \sum C_i A_{f_i} Z_i \quad \text{kN} \cdot \text{m}$$

where: P — wind pressure calculated per unit, taken as 170 N/m^2;

C_i — coefficient for correction of height, as given in Table 1.13.4.3;

A_{fi} — windage area, in m^2;

Z_i — vertical distance, in m, from centre of windage area A_{fi} to half draught d in the loading condition under checking;

Δ — displacement in the loading condition under checking, in t.

Coefficient C_i for Correction of Height **Table 1.13.4.3**

Z_i - d/2 (m)	0 ~ 15	15 ~ 30	30 ~ 45	45 ~ 60	60 ~ 75	75 ~ 90	90 ~ 105	105 ~ 120
C_i	1.00	1.16	1.32	1.44	1.53	1.61	1.68	1.74

1.13.4.3 The intact stability of dredgers and barges in operating condition is to comply with the following requirements:

(1) The stability of dredgers and barges in operating condition is to be checked for the following loading conditions:

① hopper fully loaded, with all fuels and stores;

② hopper fully loaded, with 10% of fuels and stores;

③ hopper partially loaded, with 10% of fuels and stores;

④ hopper unloaded, but being open to sea, with all fuels and stores;

⑤ hopper unloaded, but being open to sea, with 10% of fuels and stores.

When the hopper is fully loaded, spoil is to be loaded to the lower edge of the opening of the means for overflow specified in 1.13.5.2, and the least of the values obtained is to be taken.

When the hopper is partially loaded, an additional layer of seawater is to be assumed on the top of spoil to reach the lower edge of the opening of the means for overflow specified in 1.13.5.2, and the least of the values so obtained is to be taken.

(2) The density of spoil in hopper is to be taken as follows:

① the stability with the density of spoil ρ_{m1}, ρ_{m2} at the maximum operating draught according to (1)①, ② is to be checked;

② the stability is to be checked according to (1)②, density of spoil $\rho = 1.4 – 0.2\ i$, in t/m^3, (i = 0, 1, 2) whichever is the closest to and less than ρ_{m2};

③ the stability is to be checked according to (1)③, density of spoil $\rho = 2.2 – 0.2\ i$, in t/m^3, (i = 0, 1…6) whichever is the closest to and over ρm_2,

where at the maximum operating draught, an additional layer of seawater on the top of spoil is to be regarded as overload.

(3) Characteristic values of righting lever curves for dredgers and barges in operating condition:

① the initial metacentric height is not to be less than 0.15 m;

② the righting lever GZ is to be at least 0.2 m at heeling angles equal to or over 30°;

③ the heeling angle θ_{max} corresponding to the maximum righting lever is to be not less than 15°;

④ up to the heeling angle θ_{max} corresponding to the maximum righting lever, the area under the righting lever curve (GZ curve) is to be not less than 0.055 + 0.001 (30° – θ_{max}) m · rad, and θ_{max} is taken as 30° if greater than 30°;

⑤ the area under the righting lever curve (GZ curve) between the heeling angles of 30° and 40°, or between 30° and immersion angle θ_f (if this angle is less than 40°) is not to be less than 0.03 m · rad.

(4) Weather criterion for dredgers and barges in operating condition:

The weather criterion in 2.3, Chapter 2, Part A of the International Code on Intact Stability, 2008 (2008 IS Code) is to be complied with, where the wind pressure is taken as 215 N/m^2 and the angle of roll may be reduced by 20% but not less than 10°.

(5) For stability calculation, where the density of spoil in the hopper is equal to or less than 1.4 t/m^3, the effects of free surface of spoil on the initial metacentric height and righting lever curves are to be calculated and in this case, the outflow of liquid spoil and inflow of seawater over the upper edge of the hopper coaming by ship's heeling may be taken into account. Where the density of spoil in the hopper is greater than 1.4 t/m^3, the inflow and outflow of seawater through the lower edge of the opening of the means for overflow specified in 1.13.5.2 (and the least of the values obtained is to be taken) by ship's heeling is to be

taken into account. The righting lever curves are to be calculated according to the actual changes of displacement and of centre of gravity of spoil.

(6) For dredgers and barges with bottom doors or similar opening means for the hopper, asymmetric discharging, which is possible due to failure of control mechanism of the door or other opening means, is to be taken into account. 20% of the total hopper load is to be assumed to be discharging only at one side of the longitudinal centre line of the hopper, horizontally and equally distributed at the discharging side, according to the loading condition and the density of spoil respectively specified in (1)② and (2)① above. In this situation, the stability is to comply with the following requirements:

① the angle of equilibrium is not to exceed 25°;

② the range of positive righting lever beyond the angle of equilibrium is not to be less than 30°;

③ the righting lever *GZ* within the range of positive righting lever beyond the angle of equilibrium is to be at least 0.1 m.

(7) Working ships intended for operations in icing areas are to comply with the relevant requirements in Chapter 6, Part B of the International Code on Intact Stability, 2008 (2008 IS Code).

1.13.5 Special requirements for assigning operating draught of dredgers and barges

1.13.5.1 No bulwark is to be fitted on the freeboard deck abreast of any hopper which is an open hopper.

1.13.5.2 Means for overflow of process water is to be arranged for open hoppers as follows:

(1) through the overflow opening of the hopper coaming, the area of which at each side of the coaming is not to be less than 5% of that of that side of the coaming; or

(2) through overflow ducts in the hopper walls, the area of which at each side is not to be less than 0.35 $(L_h)^2/1000$ m^2, or $Q/6$ m^2, whichever is the greater,

where L_h is the maximum length of the hopper, in m;

Q is the total maximum water capacity of the suction dredge pumps, in m^3/sec; or

(3) through adjustable overflows, the area of which at each side is as given in (2) above; or

(4) using upper edge of hopper coaming as overflow opening.

1.13.5.3 In respect to the requirements for piping and valves used in discharging water overboard and the requirements for location of side scuttles or doors, the maximum operating draught is to be considered the uppermost load line or summer load waterline.

1.13.5.4 The spoil dumping system at bottom of the hopper is to be capable of discharging the spoil by gravity, such that the ship is to increase its draught from the maximum operating draught to the summer load waterline within 8 minutes using normal operation of the dumping system.

1.13.5.5 An accurate draught indicator, capable of showing fore, aft and midship draught, is to be fitted at the navigating bridge.

1.13.6 Operating draught mark

1.13.6.1 The permissible maximum operating draught line is to be permanently marked on both sides of the working ship, placed 540 mm aft of the centre of the load line mark. The maximum operating draught mark is to be a line of 25 mm in width and 450 mm in length. The upper edge of the line is to be flush with the maximum operating draught line. The operating draught is indicated by the letter W above the left end and the letter D above the right end of that line, each measuring 115 mm in height and 75 mm in width, as shown in Figure 1.13.6.1.

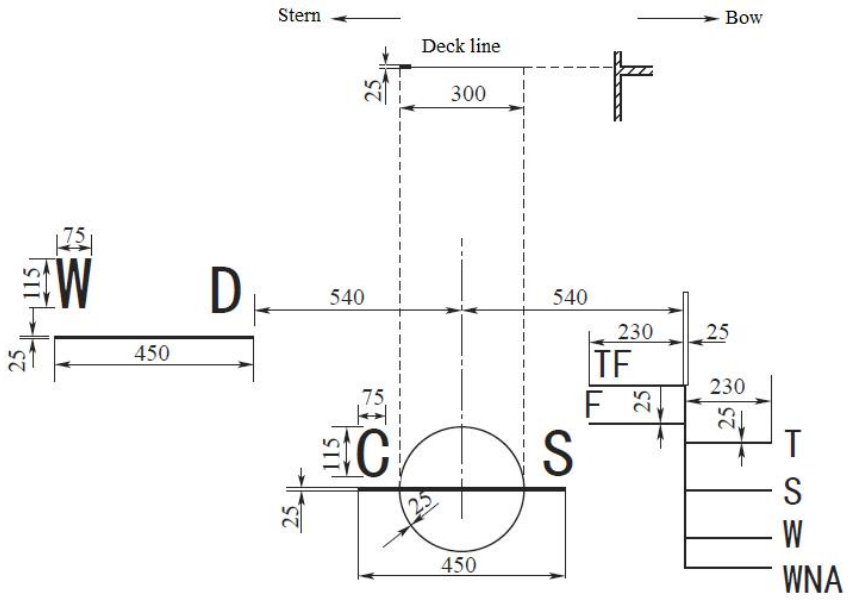


Figure 1.13.6.1 Operating Draught Mark (Starboard)

1.13.6.2 Prior to marking the maximum operating draught of a working ship, compliance of the ship with the stability requirements and other special requirements for operation of working ships is to be confirmed and indicated in the instruction for marking operating draught.

1.13.6.3 Limitations on sea conditions for operations of the working ship are to be clearly defined, compliance of the ship with the stability requirements and other special requirements for its operation summarized in the instruction for marking operating draught, and a marking sketch showing the maximum operating draught line is to be attached thereto.

CHAPTER 2 HULL STRUCTURES

Section 1 GENERAL PROVISIONS

2.1.1 Application

2.1.1.1 This Chapter applies mainly to dry cargo ships. If not covered in this Chapter, the requirements of Chapter 1 of this PART are to be complied with.

2.1.1.2 This Chapter applies to the basic structural configuration of a multi-deck or a single deck hull which includes a double bottom, or a single bottom arrangement, and with the hatch openings of normal dimensions.

2.1.1.3 Longitudinal framing is in general to be adopted at the strength deck outside the line of openings and at the bottom.

2.1.1.4 For ships with self-unloading system, such system is to meet the relevant requirements of CCS Rules for Lifting Appliances of Ships and Offshore Installations.

2.1.2 Class notations

2.1.2.1 General dry cargo ships complying with the requirements of this Chapter will be assigned the class notation General Dry Cargo Ship.

2.1.2.2 Ships which have been strengthened for heavy cargoes and comply with the requirements of Section 22 of this Chapter will be assigned the class notation Strengthened for Heavy Cargoes.

2.1.2.3 Ships which have been strengthened for grabs and comply with the requirements of Section 23 of this Chapter will be assigned the class notation Grab*(X).

2.1.2.4 Ships which comply with the requirements of Section 14, Chapter 8 of this PART will be assigned the class notation Double Side Skin.

2.1.2.5 General dry cargo ships intended to carry cargoes in bulk may be assigned the notation Maximum cargo density x.y t/m^3. When the maximum density of the bulk cargo designed under the bulk cargo loading condition is less than 3.0 t/m^3, this notation is assigned to indicate the limitation and the maximum density value of the bulk cargo allowed to be loaded, see Section 12, Chapter 8 of this PART for detailed requirements.

2.1.2.6 General dry cargo ships intended to carry cargoes in bulk may be assigned the notation No MP. This notation is assigned to show the limitation when the bulk cargo loading condition of general dry cargo ships has not been designed for loading and unloading in multiple ports in accordance with the Rules, see Section 12, Chapter 8 of this PART for detailed requirements.

2.1.2.7 General dry cargo ships intended to carry cargoes in bulk may be assigned the notation Holds a, b, …may be empty. This notation is assigned to specify the empty hold No. when specified empty holds are allowed in the design of bulk cargo loading condition of general dry cargo ships, see Section 12, Chapter 8 of this PART for detailed requirements.

2.1.3 Plans and documents

2.1.3.1 Plans and documents covering the following items are to be submitted to CCS for approval. In the case of special constructions and arrangements, additional plans and documents may be required if considered necessary by CCS:

(1) Principal transverse sections;

(2) Construction profile, including longitudinal sections, decks, inner bottom, superstructures and deckhouses;

(3) Stem;

(4) Stern frame;

(5) Shell expansion;

(6) Oiltight and watertight bulkheads;

(7) Main engine seating and thrust bearing seating;

(8) Propeller shaft bracket;

(9) Hatch coamings;

(10) Cargo hatch covers;

(11) Arrangement of anchoring equipment including equipment number calculations;

(12) Rudder, rudder stock and tiller;

(13) Masts, derrick posts and crane pedestals, together with their support structures;

(14) Ice strengthening with calculations;

(15) Welding, including type and size of welds;

(16) Preliminary and finished loading manuals.

2.1.3.2 The following plans and documents are to be submitted to CCS for information:

(1) General arrangement;

(2) Lines or offsets;

(3) Body plan (frame lines);

(4) Capacity plan;

(5) Specifications for hull and equipment;

(6) Longitudinal strength calculations (where applicable);

(7) Direct strength calculation report (where applicable);

(8) Fatigue strength assessment report (where applicable).

2.1.4 Direct strength calculation and fatigue strength assessment for hull structure

2.1.4.1 For general dry cargo ships of 150 m or over in length, FE direct strength calculation and verification are to be carried out for the strength of primary structural members within cargo area. When containers are carried, reference may be made to applicable requirements of Appendix 2, Chapter 7 of this PART. When bulk cargoes are carried, reference may be made to applicable requirements of Appendix 1, Chapter 8 of this PART.

2.1.4.2 For general dry cargo ships of 150 m or over in length, the fatigue strength check may be carried out for the following structural members in the cargo area. For check method, reference may be made to CCS Guidelines for Fatigue Strength of Ship Structure:

(1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;

(2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;

(3) connections of hopper tank sloping plate or inner shell to inner bottoms (if any);

(4) connections of transverse bulkheads to inner bottoms and girders.

Section 2 LONGITUDINAL STRENGTH

2.2.1 General requirements

2.2.1.1 For ships of 65 m and over in length, their longitudinal strength is to be checked in accordance with the requirements of this Section. For ships of unusual type or special loading and less than 65 m in length, their longitudinal strength may also be checked in accordance with the requirements of this Section.

For container ships of 90 m and over in length or ships dedicated primarily to carry their load in containers, their longitudinal strength is to comply with the requirements of Section 2, Chapter 7 of this PART and of 2.2.5.1 of this Section.

2.2.1.2 For ships complying with the following conditions, special considerations are required for longitudinal strength:

(1) For ships having one or more of the following characteristics, direct calculations are in general to be carried out, of which, direct calculation of wave loads is given in 2.2.9 of this Section:

$L/B \leq 5$

$B/D \geq 2.5$

$L \geq 500$ m

$C_b < 0.6$

(2) For ships having large deck openings, the longitudinal strength at combined bending and torque is to be checked according to the requirements in Section 10, Chapter 7 of this PART.

(3) For ships having large flare, additional bending moment caused by slamming may be considered.

(4) For ships intended for the carriage of special cargoes (e.g. heated cargoes), ships of unconventional type or ships of unconventional design, direct calculations are to be carried out in accordance with properties of cargoes or ship's type; where direct calculations are impracticable, design loads are to be determined by means of model test.

2.2.2 Design still water bending moment and shear force

2.2.2.1 The still water bending moment and shear force at each transverse section along the ship's length are to be calculated from the following conditions:

In loaded conditions: departure, arrival;

In ballast conditions: departure, arrival.

Various loading conditions included in the Loading Manual are also to be taken into account in the calculation.

2.2.2.2 In calculation of still water bending moments and shear forces, the downward loads are to be taken as positive values, the upward loads as negative values, and are to be integrated in the forward direction from the aft end of the length of the ship. The sign conventions of the still water bending moments M_s and shear forces F_s are as shown in Figure 2.2.2.2.

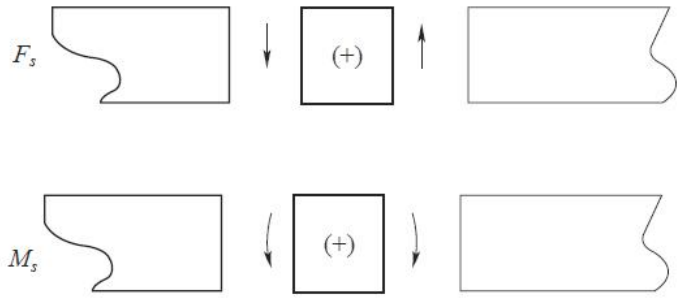


Figure 2.2.2.2

2.2.2.3 In general, the following design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the M_s and F_s calculations.

Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted for information. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting any ballast tank are to be submitted and where reviewed included in the loading manual for guidance.

(1) General cargo ships, container ships, roll-on/roll-off and refrigerated cargo carriers, bulk carriers, ore carriers:

① homogeneous loading conditions at maximum draught;

② ballast conditions;

③ special loading conditions, e.g. container or light load conditions at less than the maximum draught, heavy cargo, empty holds or non-homogeneous cargo conditions, deck cargo conditions, etc., where applicable;

④ short voyage or harbor conditions, where applicable;

⑤ docking condition , afloat;

⑥ instantaneous conditions of loading and unloading, where applicable;

⑦ for bulk carriers to which the harmonized class notation BC-A, BC-B or BC-C is assigned in accordance with the requirements of Section 12, Chapter 8 of this PART, conditions specified in 8.12.4 of Section 12, Chapter 8 of this PART are also to be calculated.

(2) Oil tankers:

① homogeneous loading conditions (excluding dry and clean ballast tanks) and ballast or part-loaded conditions;

② any specified non-uniform distribution of loading;

③ mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions;

④ docking condition, afloat;

⑤ instantaneous conditions of loading and unloading, where applicable.

(3) Chemical tankers:

① conditions as specified for oil tankers;

② conditions for high density or segregated cargo.

(4) Liquefied gas carriers:

① homogeneous loading conditions for all approved cargoes;

② ballast conditions;

③ cargo condition where one or more tanks are empty or partially filled or where more than one type of cargo having significantly different densities are carried;

④ harbor conditions where increased steam pressure is approved;

⑤ docking condition, afloat.

(5) Combination carriers:

① conditions as specified for oil tankers and cargo ships.

2.2.2.4 Where the typical condition during ballast water exchange at sea is to be taken into account, reference may be made to the Guidelines for the Preparation of Ship's Ballast Water Management Plan.

2.2.2.5 Partially filled ballast tanks in ballast loading conditions (relevant recommendations are given in Appendix 3 of this Chapter)

Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

- design stress limits are satisfied for all filling levels between empty and full, and
- for bulk carriers, the requirements in Section 8, Chapter 8 of this PART, as applicable, are complied with for all filling levels between empty and full.

To demonstrate compliance with all filling levels between empty and full, it will be acceptable if, in each condition at departure, arrival and where required by 2.2.2.3 of this Section, any intermediate condition, the tanks intended to be partially filled are assumed to be:

- empty;
- full;
- partially filled at intended level.

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated.

However, for conventional ore carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of these tanks lead to the ship's trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of these one or maximum two pairs of ballast tanks such that the ship's condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks are to be considered between empty and full. The trim conditions mentioned above are:

- trim by stern of 3% of the ship's length, or
- trim by bow of 1.5% of ship's length, or
- any trim that cannot maintain propeller immersion (I/D) not less than 25%, where:

I — the distance from propeller centerline to the waterline;

D — propeller diameter (see Figure 2.2.2.5).

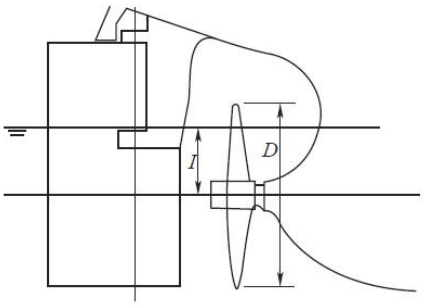


Figure 2.2.2.5

The maximum and minimum filling levels of the above mentioned pairs of side ballast tanks are to be indicated in the loading manual.

2.2.2.6 Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirements in 2.2.2.5 of this Section apply to the peak tanks only.

2.2.2.7 Sequential ballast water exchange

Requirements of 2.2.2.5 and 2.2.2.6 of this Section are not applicable to ballast water exchange using the sequential method. However, bending moment and shear force calculations for each de-ballasting or ballasting stage in the ballast water exchange sequence are to be included in the loading manual or ballast water management plan of any ship that intends to employ the sequential ballast water exchange method.

2.2.3 Wave bending moment and wave shear force

2.2.3.1 The hogging and sagging wave bending moments $M_W(+)$ and $M_W(-)$ at each transverse section along the ship's length are to be obtained from the following formulae:

$$M_W(+) = +190MCL^2BC_b \times 10^{-3} \qquad \text{kN·m}$$

$$M_W(-) = -110MCL^2B(C_b + 0.7) \times 10^{-3} \qquad \text{kN·m}$$

where: M — distribution factor of bending moment, see Figure 2.2.3.1;

L — length of ship, in m;

B — breadth of ship, in m;

C_b — block coefficient, taken not less than 0.60;

C — coefficient to be obtained from the following formulae:

$C = 0.0412L + 4$ for $L < 90$ m;

$C = 10.75 - \left(\frac{300 - L}{100}\right)^{3/2}$ for $90 \le L \le 300$ m;

$C = 10.75$ for $300 < L < 350$ m;

$C = 10.75 - \left(\frac{L - 350}{150}\right)^{3/2}$ for $350 \le L \le 500$ m.

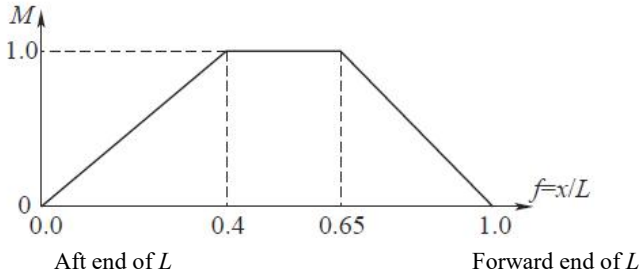


Figure 2.2.3.1

2.2.3.2 The hogging and sagging wave shear forces F_w (+) and F_w (−) at each transverse section along the ship's length are to be obtained from the following formulae:

$$F_w(+) = +30F_1CLB(C_b + 0.7)\times 10^{-2} \quad \text{kN}$$

$$F_w(-) = -30F_2CLB(C_b + 0.7)\times 10^{-2} \quad \text{kN}$$

where: F_1, F_2 — shear force distribution factor given in Figure 2.2.3.2(1) and Figure 2.2.3.2(2);

C — coefficient to be obtained from 2.2.3.1 of this Section;

C_b — see 2.2.3.1 of this Section;

L — length of ship, in m;

B — breadth of ship, in m.

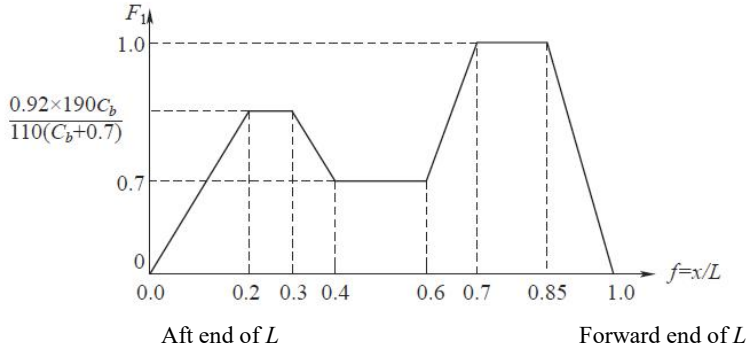


Figure 2.2.3.2(1)

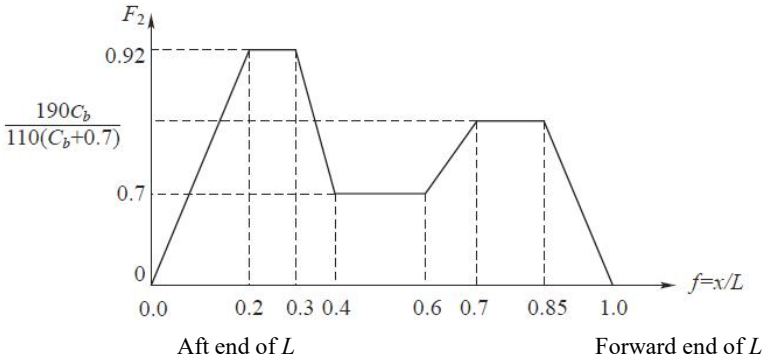


Figure 2.2.3.2(2)

2.2.4 Calculation of hull girder section properties

2.2.4.1 The moment of inertia of the hull girder section about its horizontal neutral axis divided by the vertical distance from the neutral axis to the top of strength deck at side gives the hull girder section modulus W_d at the strength deck; and that divided by the vertical distance from the neutral axis to the top of keel gives the hull girder section modulus W_b at bottom.

2.2.4.2 The strength deck and all continuous longitudinal members below the strength deck within 0.4L amidships may be included in the calculation of hull girder section modulus. The extension of the sheer strake above the strength deck and the continuous stringer angles may be included in the calculation. Where trunck decks or continuous hatch coamings (except inboard coamings of multi-hatch arrangements) above the strength deck are effectively supported by longitudinal bulkheads or deep girders, their sectional area may also be included in the calculation of the hull girder section modulus.

2.2.4.3 For multi-hatch arrangements, the effective sectional area for the inboard continuous hatch coaming and supporting members below is to be determined by direct calculation in accordance with support conditions. The following provision is applicable to cases without detailed calculation:

(1) Where a continuous longitudinal underdeck girder, or girders, are arranged to support the inboard hatch coamings, 50% of their sectional area are to be included in the calculation of the hull girder section modulus. If the girder is fitted in conjunction with a longitudinal bulkhead, 100% of the sectional area may be included. In cases where the girders are enclosed box sections, or where the girders are not enclosed box sections and are adequately supported and effectively tied to the bottom structure, 80% of their sectional area may be included. The slender ratio of the above-mentioned girders is not to be greater than 60.

(2) The percentage of the sectional area to be included for inboard continuous hatch coamings is to be the same percentage as that of the longitudinal girder under.

2.2.4.4 For the cases in 2.2.4.2 and 2.2.4.3 of this Section, when calculating the hull girder section modulus, the lever Z_t, vertical distance from the point considered to the neutral axis, is to be taken as follows, with Z_t being greater than the vertical distance from the neutral axis to the moulded deck line at side:

$$Z_t = Z_c \left(0.9 + 0.2\frac{y}{B_1}\right) \quad \text{m}$$

where: Z_c — vertical distance from the neutral axis to the top of the continuous strength member, in m;

y — horizontal distance from the top of the continuous strength member to the centerline of the ship, in m;

B_1 — breadth of ship at section considered, in m.

In calculation, Z_c and y are to be measured to the point giving the maximum value of Z_t.

2.2.4.5 Where deck longitudinals or deck girders are arranged above the strength deck, the sectional area may be included in the calculation of the hull girder section modulus. The lever Z_t is to be taken as the vertical distance from the neutral axis to the moulded deck line at side amidships plus the depth of the longitudinal member.

2.2.4.6 Deck openings having a length in the fore-and-aft direction exceeding 2.5 m or a breadth exceeding 1.2 m or 0.04B (whichever is the lesser) or scallops where scallop-welding is applied

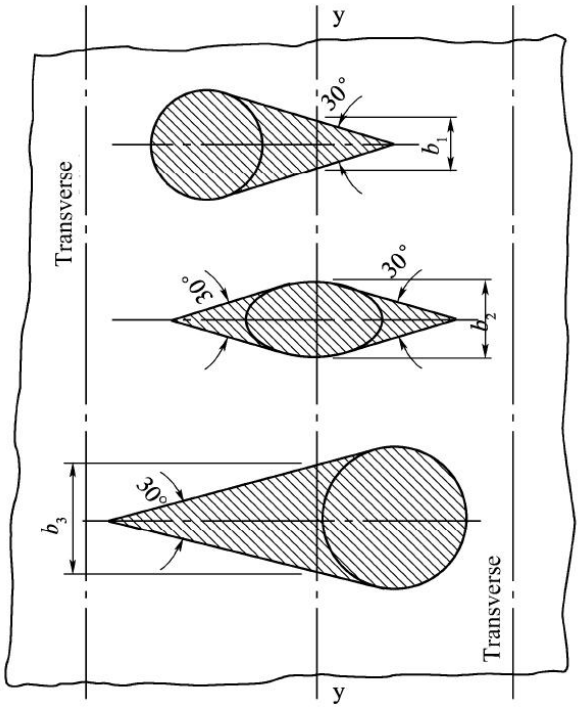
are to be deducted from the sectional areas used in the calculation of the hull girder section modulus.

2.2.4.7 Smaller openings (including manholes, lightening holes, single scallops in way of seams, etc.) smaller than those stated in 2.2.4.6 above need not be deducted from the sectional areas used in the calculation of the hull girder section modulus, provided that the sum b_c of their breadths or shadow area breadths (The shadow area will be obtained by drawing two tangent lines with an opening angle of 30°, as shown in Figure 2.2.4.7) in one transverse section complies with the following or that the section modulus at deck or bottom is not reduced by more than 3%:

$$b_c \le 0.06\left(B_1 - \sum b\right)$$

where: B_1 — breadth of ship at section considered, in m;

Σb — sum of breadths of deductible openings at section considered in accordance with 2.2.4.6 of this Section, in m.



Sum of breadths of small openings at *y-y* section is to be $b_c = b_1 + b_2 + b_3$

Figure 2.2.4.7

2.2.4.8 Openings in longitudinals or longitudinal girders (such as lightening holes, freeing ports, single scallops in way of welds) need not be deducted from the sectional areas used in the calculation of the hull girder section modulus, if their depth does not exceed 25% of the web depth (with a maximum depth of 75 mm for scallops).

2.2.5 Hull girder bending strength

2.2.5.1 The minimum midship section modulus① W_0 at deck and keel is not to be less than that obtained from the following formula:

$$W_0 = CL^2B(C_b + 0.7)K \quad \text{cm}^3$$

where: C — coefficient②, to be taken in accordance with 2.2.3.1 of this Section;

C_b — the same as that in 2.2.3.1 of this Section;

L — length of ship, in m;

B — breadth of ship, in m;

K — material factor.

Scantlings of all continuous longitudinal members of the hull girder based on the minimum midship section modulus W_o are to be maintained within 0.4L amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0.4L amidships, bearing in mind the desire not to inhibit the vessel's loading flexibility. In ships where part of the longitudinal strength material in the deck or bottom area are forming boundaries of tanks for oil cargoes or ballast water and such tanks are provided with an effective corrosion protection system, certain reductions in the scantlings of these boundaries are allowed. These reductions, however, are in no case to reduce the minimum hull girder section modulus for a new ship by more than 5%.

2.2.5.2 The moment of inertia of midship section about the horizontal neutral axis I is not to be less than that obtained from the following formula:

$$I = 3W_0L / K \quad \text{cm}^4$$

where: W_0 — the minimum midship section modulus, in cm³, calculated in accordance with 2.2.5.1 of this Section;

L — length of ship, in m;

K — material factor.

2.2.5.3 The hull girder bending strength outside 0.4L amidships is to comply with the requirements of 2.2.5.4 of this Section and also the following requirements:

(1) As a minimum, hull girder bending strength checks are to be carried out at the following locations:

— in way of the forward end of the engine room;

— in way of the forward end of the foremost cargo hold;

— at any locations where there are significant changes in hull cross-section;

— at any locations where there are changes in the framing system.

(2) Buckling strength of members contributing to the longitudinal strength and subjected to compressive and shear stresses is to be checked, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur.

(3) Continuity of structure is to be maintained throughout the length of the ship. Where significant changes in structural arrangement occur, adequate transitional structure is to be provided.

(4) For ships with large deck openings such as container ships, sections at or near to the aft and forward quarter length positions are to be checked. For such ships with cargo holds aft of the

---

① The minimum midship section modulus applies to ships in unrestricted service. However, it may not be applicable to ships of unusual type or design, e.g. for ships of unusual main proportions and/or weight distributions, and special consideration is to be given.

② For ships in service, C is 0.9 times the value calculated in 2.2.3.1.

superstructure, deckhouse or engine room, strength checks of sections in way of the aft end of the aft-most holds, and the aft end of the deckhouse or engine room are to be performed.

2.2.5.4 The designer is to provide permissible hogging and sagging still water bending moments $\overline{M}_s$ (+) and $\overline{M}_s$ (−) of hull girders at each transverse section along the ship's length, provided that the following conditions are satisfied:

(1) The permissible hogging and sagging still water bending moments $\overline{M}_s$ of hull girders are to cover the most severe hogging and sagging design still water bending moments calculated for any navigation condition given in the loading manual, see 2.2.2 of this Section.

(2) The permissible hogging and sagging still water bending moments $\overline{M}_s$ of hull girders are not to be greater than the values obtained from the following formulae:

$$\overline{M}_s(+)_{max} = \overline{M} - M_W(+) \quad \text{kN·m}$$

$$\overline{M}_s(-)_{min} = -\overline{M} - M_W(-) \quad \text{kN·m}$$

where: M_W — wave bending moment, see 2.2.3.1 of this Section;

$\overline{M}$ — combined permissible bending moment, in kN · m, to be taken as one of the values obtained from the following formulae, whichever is the lesser:

$$\overline{M} = F_d W_d [\sigma] \times 10^{-3} \quad \text{kN·m}$$

$$\overline{M} = F_b W_b [\sigma] \times 10^{-3} \quad \text{kN·m}$$

where: F_d, F_b — determined in accordance with 2.2.5.6(1);

W_d — section modulus at deck, in cm^3;

W_b — section modulus at keel, in cm^3;

Permissible bending stress of hull girder $[\sigma]$① is determined in accordance with the following requirements:

$[\sigma] = 175/K$, in N/mm^2, for 0.4 L amidships;

$[\sigma] = 125/K$, in N/mm^2, for 0.1 L from the ship's ends;

for other areas, to be obtained by linear interpolation, where K is material factor.

2.2.5.5 Longitudinal bending stress is to be calculated in accordance with the following formula:

$$\sigma = \frac{\left|\overline{M}_s + M_W\right|}{W_c} \times 10^3 \quad \text{N/mm}^2$$

where: $\overline{M}_s$ — permissible still water bending moment, in kN·m, see 2.2.5.4 of this Section;

M_W — wave bending moment, in kN·m, calculated in accordance with 2.2.3.1 of this Section;

W_c — hull girder section modulus at the point considered, in cm^3.

2.2.5.6 The reduction factor of scantlings of local members is to comply with the following:

(1) Where the maximum longitudinal bending stresses at deck and keel are less than the permissible bending stress [σ], appropriate reduction factors F_d and F_b may be taken to reduce the scantlings of local member provided the following conditions are met:

① Permissible bending stress of hull girder outside 0.4L amidships is generally in accordance with this paragraph.

$$F_d \geq \frac{\sigma_d}{[\sigma]}$$

$$F_b \geq \frac{\sigma_b}{[\sigma]}$$

where: σ_d — longitudinal bending stress at deck, in N/mm^2;

σ_b — longitudinal bending stress at keel, in N/mm^2;

$[\sigma]$ — permissible bending stress, see 2.2.5.4(2) of this Section.

In calculation of the thickness of shell plating t_1 and deck t_1, reduction factor F_d may be calculated based on sagging bending moment and F_b may be calculated based on the hogging bending moment.

For shell plating and deck, reduction factors F_d and F_b are not to be less than 0.67; for framing, reduction factors F_d and F_b are not to be less than 0.75.

(2) For ships less than 65 m in length, 1 is to be taken for both F_d and F_b.

(3) For containerships of 90 m in length and over, see Section 2 of Chapter 7 for the longitudinal bending stress and permissible bending stress in calculation of F_d and F_b.

2.2.5.7 Where higher tensile steel is used in some portions of hull, the vertical extent of application of the higher tensile steel is not to be less than:

Where higher tensile steel is applied to the strength deck, the region y_1 $(1 - K/F_d)$ below the deck line is to be made of higher tensile steel; where applied to the bottom, the region y_2 $(1 - K/F_b)$ above the keel is to be made of higher tensile steel. y_1 and y_2 are the vertical distances from the neutral axis to the deck line at side and to the plate keel respectively, in m, as shown in Figure 2.2.5.7. K is material factor, F_d and F_b are as defined in 2.2.5.6 above.

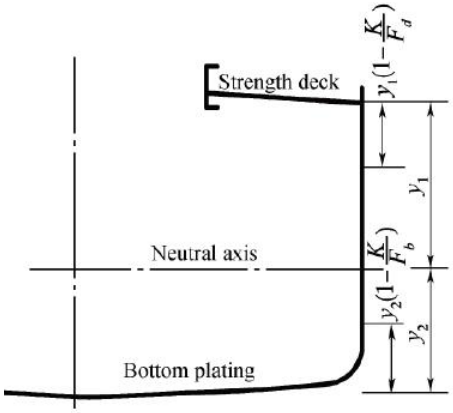


Figure 2.2.5.7

2.2.5.8 Where higher tensile steel is used amidships and low carbon steel at the ends of the ship, the region in which higher tensile steel is used is to be extended to the points where the thickness required for low carbon steel is equal to that of the higher tensile steel (see Figure 2.2.5.8).

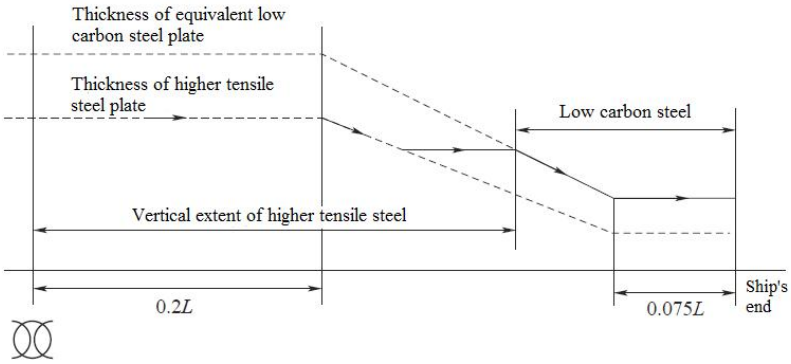


Figure 2.2.5.8

2.2.5.9 Where higher tensile steel is applied to strength deck structure, corresponding higher tensile steel is usually to be applied to the continuous members (e.g. stiffening members of hatch coamings and deck openings) welded to strength deck.

2.2.6 Hull girder shearing strength

2.2.6.1 Design still water shear force

(1) Under different loading conditions, the design still water shear force at each transverse section along the ship's length is to meet the following conditions:

$$F_s(+) \le \overline{F_s}(+)$$

$$\left| F_s(-) \right| \le \left| \overline{F_s}(-) \right|$$

where: F_s — design still water shear force under the conditions considered, in kN;

$\overline{F_s}$ — permissible still water shear force, in kN, calculated in accordance with 2.2.6.2.

(2) For type 1 and type 2 hull sections as shown in Table 2.2.6.2, the still water shear force F_s at transverse bulkhead is to be corrected in respect to alternate or significantly non-homogeneous hold loading conditions. The correction of shear force is as shown in Figure 2.2.6.1. The values N_k and N_m of shear force correction are to be calculated in accordance with the following formulae respectively:

$$N_k = F\,|F_{sA} - F_{sB}| \quad \text{kN}$$

$$N_m = F|F_{sA} - F_{sC}| \quad \text{kN}$$

where: F_{sA}, F_{sB}, F_{sC} — shear force in kN, obtained by calculation based on hull girder at transverse bulkheads A, B and C respectively;

F — correction factor of still water shear force, calculated in accordance with the following formula:

$$F = \frac{B_0}{2.2(B + l_H)}$$

where: B_0 — average breadth of the flat part of inner bottom of the hold considered, in m;

B — breadth of ship, in m;

l_H — length of hold, in m.

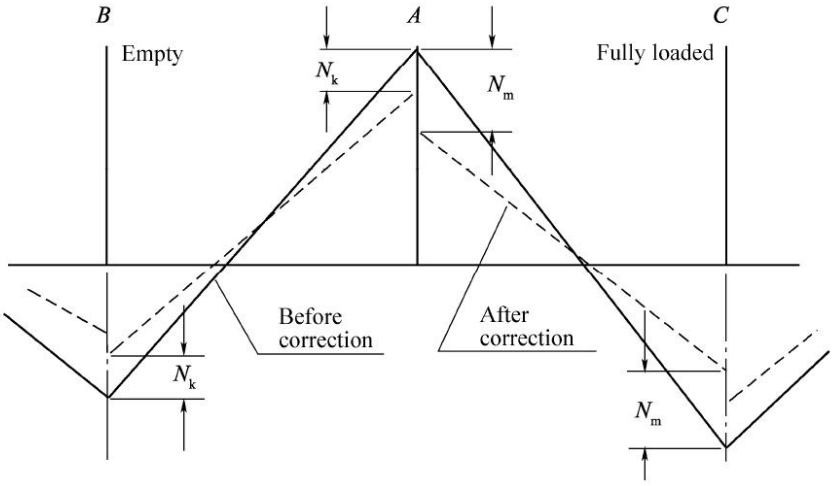


Figure 2.2.6.1

2.2.6.2 The designer is to provide permissible still water shear forces $\overline{F}_s$ (+) and $\overline{F}_s$ (−) of hull girders at each transverse section along the ship's length, provided that the following conditions are satisfied:

(1) The positive and negative permissible still water shear forces $\overline{F}_s$ of hull girders are to cover the most severe positive and negative design still water shear forces calculated for any navigation condition given in the loading manual, see 2.2.2 of this Section.

(2) The positive and negative permissible still water shear forces $\overline{F}_s$ of hull girders are not to be greater than the values obtained from the following formulae:

$$\overline{F_s}\,(+)_{\max}=[\tau]\frac{I\delta}{S}\times 10^{-2}-F_w(+) \quad \text{kN}$$

$$\overline{F_s}\,(-)_{\min}=-[\tau]\frac{I\delta}{S}\times 10^{-2}-F_w(-) \quad \text{kN}$$

where: F_w — wave shear force, in kN, calculated in accordance with 2.2.3.2;

I — moment of inertia about the horizontal neutral axis at the transverse section under consideration, in cm^4;

S — static moment, in cm^3, about the horizontal neutral axis, of the area of the effective longitudinal members above the horizontal neutral axis, taken at the transverse section under consideration;

Permissible shearing stress $[\tau] = 110/K$, in N/mm^2, where K is material factor;

δ — the lesser of δ_1 and δ_2, calculated in accordance with the following formulae:

$$\delta_1=\frac{t_1}{f_1+m_1}$$

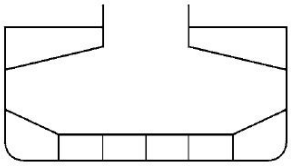
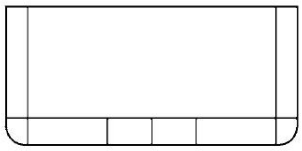
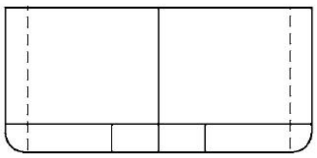
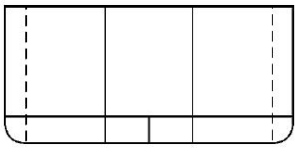
$$\delta_2=\frac{t_2}{f_2+m_2}$$

t_1 — thickness (the total thickness of inner and outer plating for double hull-skin ship) of side shell at the horizontal neutral axis of the section under consideration, in mm;

t_2 — thickness of longitudinal bulkhead plating at the horizontal neutral axis of the section under consideration, in mm;

f_1, f_2, m_1, and m_2 — factors, see Table 2.2.6.2.

Factors f_1, f_2, m_1 and m_2 **Table 2.2.6.2**

No.	Hull configuration	Factor f_i	Factor m_i
1		$f_1 = 0.5$	$m_1 = 0$
2		$f_1 = 0.5$	$m_1 = 0$
3		$f_1 = 0.261 + 0.058\, A_1 / A_2$ $f_2 = 0.478 - 0.116\, A_1 / A_2$	$m_1 = 0.5\, m_2$ $m_2 = 0.5(0.1 + \gamma)$
4		$f_1 = 0.154 + 0.08\, A_1 / A_2$ $f_2 = 0.346 - 0.08\, A_1 / A_2$	$m_1 = m_2$ $m_2 = (0.1 + \gamma)\ \frac{b}{B}$

Notes: A_1, A_2— shear areas of side shell and longitudinal bulkhead plating respectively, in cm^2, at one side of the section under consideration. The area for the centreline bulkhead is actual area and not to be reduced for symmetry around the centreline;

b — horizontal distance from longitudinal bulkhead to side shell plating, in m;

B — breadth of ship, in m;

γ — for transversely non-homogeneous loading condition, γ = 0.15; for transversely homogeneous loading condition, γ = 0.

2.2.6.3 For hull configurations not included in Table 2.2.6.2, e.g. ships with three or four longitudinal bulkheads, the shearing stresses at side shell and longitudinal bulkhead plating may be determined by direct calculation.

2.2.6.4 Shearing stress①

(1) The shearing stress τ at side shell is to be calculated in accordance with the following formula:

$$\tau = \frac{\left|\overline{F_s} + F_w\right| S}{I\delta_1} \times 10^2 \quad \text{N/mm}^2$$

where: $\overline{F_s}$ — permissible still water shear force, in kN, see 2.2.6.2 of this Section;

S — static moment, in cm^3. Where the point considered is above the horizontal neutral axis, S is to be taken as the static moment, about the horizontal neutral axis, of the area of all longitudinal members passing through the point above the neutral axis. Where the point considered is below the horizontal neutral axis, S is to be taken as the static moment, about the horizontal neutral axis, of the area of all longitudinal members passing through the point below the neutral axis;

F_w, I and δ_1 — see 2.2.6.2 of this Section.

① Direct shearing stress calculation may be used, subject to approval by CCS.

(2) Shearing force τ at longitudinal bulkhead plating is to be calculated in accordance with the following formula:

$$\tau = \frac{\left|\overline{F}_s + F_w\right| S}{I\delta_2} \times 10^2 \quad \text{N/mm}^2$$

where: $\overline{F}_s$, S — see 2.2.6.4 (1) of this Section;

F_w, I and δ_2 — see 2.2.6.2 of this Section.

2.2.7 Buckling strength

2.2.7.1 For ships of 90 m and over in length, where the plate panels and longitudinals are subject to hull girder bending and shear stresses, the buckling strength is to be checked according to the following requirements.

2.2.7.2 The working stress σ in compression of the plate panels and longitudinals as calculated in 2.2.5.5 of this Section (taken not less than 30/K, in N/mm^2, where K is material factor) is to comply with the following formula:

$$\sigma \le \frac{1}{\beta}\sigma_c$$

where: β = 1, for plating and for web plating of stiffeners (local buckling);

β = 1.1, for stiffeners;

σ_c — critical buckling stress in compression, calculated according to 2.2.7.6 of this Section.

2.2.7.3 The working shear stress τ of plate panels as calculated in 2.2.6.4 of this Section is to comply with the following formula:

$$\tau \le \tau_c$$

where: τ_c — critical buckling stress in shear, calculated according to 2.2.7.7 of this Section.

2.2.7.4 The ideal elastic buckling stresses of the plates are to be obtained from the following formulae:

(1) The ideal elastic buckling stress σ_E of the compression plate panel is to be obtained from the following formula:

$$\sigma_E = 0.9\, K_c E \left(\frac{t_b}{1000s}\right)^2 \quad \text{N/mm}^2$$

where: E — modulus of elasticity of material, in N/mm^2;

s — shorter side of plate panel, in m;

t_b — net thickness, in mm, of plating, considering standard deductions equal to the values given in Table 2.2.7.4;

Standard Deduction of Thickness **Table 2.2.7.4**

Structure	Standard deduction (mm)	Limit values min-max (mm)
Compartments carrying dry bulk cargoes: One side exposure to ballast or liquid cargo, vertical surfaces and surfaces sloped at an angle greater than 25º to the horizontal line.	0.05 t	0.5 ~ 1
One side exposure to ballast or liquid cargo, horizontal surfaces and surfaces sloped at an angle less than 25º to the horizontal line;	0.10 t	2 ~ 3

Two side exposure to ballast or liquid cargo, vertical surfaces and surfaces sloped at an angle greater than 25º to the horizontal line.		
Two side exposure to ballast or liquid cargo, horizontal surfaces and surfaces sloped at an angle less than 25º to the horizontal line.	0.15 t	2 ~ 4

Note: t is the designed thickness of plating, in mm.

K_c – coefficient, calculated according to the following:

$K_c = \dfrac{8.4}{\psi + 1.1}$ for plating with longitudinal stiffeners (parallel to compressive stress);

$K_c = C\left[1+\left(\dfrac{S}{l}\right)^2\right]^2 \dfrac{2.1}{\psi + 1.1}$ for plating with transverse stiffeners (perpendicular to compressive stress);

where:

l — longer side of plate panel, in m;

C = 1.3 when plating stiffened by floors or deep girders;

C = 1.21 when stiffeners are angles or T-sections;

C = 1.10 when stiffeners are bulb flats;

C = 1.05 when stiffeners are flat bars;

ψ — ratio between smallest and largest compressive stress, $0 \le \psi \le 1$ (see Figure 2.2.7.4).

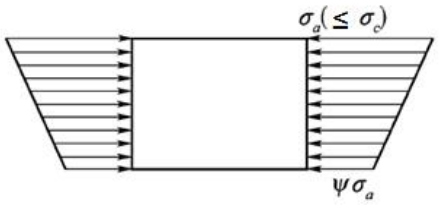


Figure 2.2.7.4

(2) The ideal elastic buckling stress τ_E in shear of plate panels subjected to shearing forces is to be obtained from the following formula:

$$\tau_E = 0.9K_t E\left(\frac{t_b}{1000s}\right)^2 \quad \text{N/mm}^2$$

where: $K_t = 5.34 + 4\left(\dfrac{s}{l}\right)^2$;

for E, t_b, s and l, see (1) above.

2.2.7.5 The ideal elastic buckling stresses of longitudinals are to be obtained from the following formulae:

(1) For the column buckling mode (perpendicular to plane of plating) without rotation of the cross section, the ideal elastic buckling stress σ_E of longitudinals is to be obtained from the following formula:

$$\sigma_E = 0.001E\frac{I_a}{Al^2} \quad \text{N/mm}^2$$

where: I_a — moment of inertia, in cm^4, of longitudinal, including plate flange and calculated with thickness as specified in Table 2.2.7.4 of this Section;

A — cross-sectional area, in cm^2, of longitudinal, including plate flange and calculated with thickness as specified in Table 2.2.7.4 of this Section;

l — span, in m, of longitudinal.

(2) The ideal elastic buckling stress σ_E of longitudinals for the torsional buckling mode is to be obtained from the following formula:

$$\sigma_E = \frac{\pi^2 EI_W}{I_p l^2 \times 10^4}\left(n^2 + \frac{K_B}{n^2}\right) + 0.385\,E\,\frac{I_t}{I_p} \quad \text{N/mm}^2$$

where: $K_B = \frac{Cl^4}{\pi^4 EI_W}\times 10^6$;

n — number of half waves, given by Table 2.2.7.5:

Number of Half Waves **Table 2.2.7.5**

	$0 < K_B \le 4$	$4 < K_B \le 36$	$36 < K_B \le 144$	$(n-1)^2\,n^2 < K_B \le n^2\,(n+1)^2$
n	1	2	3	n

I_t — St Venant's moment of inertia, in cm^4, of profile (without plate flange), to be obtained by the following formula:

$I_t = \frac{h_w t_w^3}{3} \times 10^{-4}$, for flat bars;

$I_t = \frac{1}{3}\left[h_w t^3{}_w + b_f t^3{}_f\left(1 - 0.63\frac{t_f}{b_f}\right)\right]\times 10^{-4}$ for flanged profiles;

I_p — polar moment of inertia, in cm^4, of profile about connection of stiffener to plate:

$I_p = \frac{h^3{}_w t_w}{3} \times 10^{-4}$ for flat bars;

$I_p = (\frac{h^3{}_w t_w}{3} + h_w^2 b_f t_f)\times 10^{-4}$ for flanged profiles;

I_w — sectional moment of inertia, in cm^6, of profile about connection of stiffener to plate:

$I_w = \frac{h^3{}_w t^3{}_w}{36} \times 10^{-6}$ for flat bars;

$I_w = \frac{t_f b_f^3 h_w^2}{12} \times 10^{-6}$ for Tee profiles;

$I_w = \frac{b_f^3 h_w^2}{12\left(b_f + h_w\right)^2}\left[t_f\left(b_f^2 + 2b_f h_w + 4h_w^2\right) + 3t_w b_f h_w\right] \times 10^{-6}$ for angles and bulb profiles;

l — span of longitudinal, in m;

E — modulus of elasticity of material, in N / mm^2;

where: h_w — web height, in mm;

t_w — web thickness, in mm, considering standard deductions as specified in Table 2.2.7.4 of this Section;

b_f — flange width, in mm;

t_f — flange thickness, in mm, considering standard deductions as specified in Table 2.2.7.4 of this Section. For bulb profiles the mean thickness of the bulb may be used;

C — spring stiffness exerted by supporting plate panel, obtained by the following formula:

$$C = \frac{K_p E t_p^3}{3s\left(1 + \frac{1.33 K_p h_w t_p^3}{1000 s t_w^3}\right)} \times 10^{-3}$$

s — spacing of profiles, in m;

t_p — panel thickness, in mm, considering standard deductions as specified in Table 2.2.7.4 of this Section;

$K_p = 1 - \eta_P$, not to be taken less than zero. For flanged profiles, K_p need not be taken less than 0.1;

$$\eta_p = \frac{\sigma}{\sigma_{EP}};$$

σ — working pressure in compression, calculated in accordance with 2.2.5.5 of this Section, but not to be taken as less than $30/K$, in N/mm², where K is material factor;

σ_{EP} — elastic buckling stress of supporting plate as calculated in 2.2.7.4 of this Section.

(3) Web and flange buckling of longitudinals

① For web plate of longitudinals, the ideal elastic buckling stress σ_E is to be obtained from the following formula:

$$\sigma_E = 3.8E\left(\frac{t_w}{h_w}\right)^2 \quad \text{N/mm}^2$$

where: t_w, h_w, E — see (2).

② For flanges on angles and T-sections of longitudinals, buckling is taken care of by the following requirement:

$$\frac{b_f}{t_f} \le 15$$

where: b_f — flange width, in mm, for angles, half the flange width for T-sections;

t_f — flange thickness, in mm.

2.2.7.6 The critical buckling stress in compression σ_c is determined as follows:

$$\sigma_c = \sigma_E \qquad \text{for } \sigma_E \le \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \qquad \text{for } \sigma_E > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of material, in N/mm²;

σ_E — ideal elastic buckling stress, in N/mm², calculated according to 2.2.7.4(1) and 2.2.7.5 of this Section.

2.2.7.7 The critical buckling stress in shear τ_c is determined as follows:

$$\tau_c = \tau_E \qquad \text{for } \tau_E \le \frac{\tau_s}{2}$$

$$\tau_c = \tau_s\left(1 - \frac{\tau_s}{4\tau_E}\right) \qquad \text{for } \tau_E > \frac{\tau_s}{2}$$

where: $\tau_s = \frac{R_{eH}}{\sqrt{3}}$;

R_{eH} — yield stress of material, in N/mm^2;

τ_E — ideal elastic buckling stress in shear, in N/mm^2, calculated according to 2.2.7.4(2) of this Section.

2.2.8 Loading manual and loading instrument

2.2.8.1 On completion of construction of the ship, a Loading Manual is to be formulated in time and submitted by the designer to CCS for approval. CCS Guidelines for Preparation of Loading Manuals may be referred to for formulating the Loading Manual.

2.2.8.2 The ship is to be loaded in accordance with the requirements specified in the Loading Manual to avoid the creation of unacceptable stresses in the hull structures.

2.2.8.3 The Loading Manual is to contain the following:

(1) The loading conditions on which the design of the ship has been based, including curves of permissible still water bending moment and shear force along the length of the ship.

(2) The results of the calculations of still water bending moments and shear forces under various loading conditions and where necessary, limitations due to torsional and lateral loads.

(3) The allowable local loading for local structures (such as hatch covers, decks and double bottom, etc.).

2.2.8.4 Loading instruments are to comply with the following specifications:

(1) A loading instrument is either an analog or a digital instrument, by means of which it can be easily and quickly ascertained that the still water bending moment, shear forces and where applicable, the still water torsional moments and lateral loads at specified read-out points will not exceed the specified permissible values in any loading or ballasting condition.

(2) The loading instrument is generally to be provided with an operation manual.

(3) Single-point loading instruments are not acceptable.

(4) The detailed requirements for loading instruments are referred to Appendix 1 of this Chapter.

2.2.8.5 Those ships complying with one of the following provisions are Category I ships:

(1) Ships with large deck openings where combined stresses due to vertical and horizontal hull girder bending as well as torsional and lateral loads are to be considered.

(2) Ships possibly with non-homogeneous loadings, where the cargo and/or ballast may be unevenly distributed. Ships less than 120 m in length, when uneven distribution of cargo and/or ballast is considered in design, belong to Category II.

(3) Chemical tankers and gas carriers.

2.2.8.6 Those ships complying with one of the following provisions are Category II ships:

(1) ships with such arrangements that would allow only a small possibility for variation in the distribution of cargo and ballast, and ships operating on a regular and fixed tradeing pattern where the loading manual gives sufficient guidance;

(2) ships for which an exception is given under Category I.

2.2.8.7 A loading manual approved by CCS is to be supplied to all ships except those of Category II with length less than 90 m of which the deadweight does not exceed 30% of the displacement at the summer load line draft.

2.2.8.8 An approved loading manual is to be supplied to all ships of Category I with 100 m or over in length.

2.2.8.9 Bulk carriers, ore carriers and combination carriers of 150 m or over in length are to be provided with a loading manual and a loading instrument in accordance with the requirements of Section 7, Chapter 8 of this PART.

2.2.8.10 Conditions for approval of loading manuals:

(1) The approval of the loading manual is to be based on the final data of the ship. The manual is to include the design loading and ballasting conditions upon which the approved scantlings of hull structures are approved.

(2) In case of modifications resulting in changes to the main data of the ship, a new approved loading manual is to be issued.

(3) The loading manual must be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

2.2.8.11 Conditions for approval of loading instruments:

(1) The following are to be included in loading instruments and approved:

① Confirmation of type approval, if any;

② Confirming that the final data of the ship have been used;

③ Confirmation of the number and positions of read-out points;

④ Confirmation of relevant limits for all read-out points;

⑤ Checking of proper installation and operation of the instrument on board, in accordance with the approved test report of loading calculation, and that a copy of the operation manual is available.

(2) In case of modifications implying changes in the main data of the ship, the loading instrument is to be modified accordingly and reapproved.

(3) The operation manual and the instrument output must be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

(4) The operation of the loading instruments is to be verified upon installation. It is to be checked that the operation manual and the approved test loading conditions are available on board.

2.2.9 Direct calculation of wave loads

2.2.9.1 The direct calculation of wave loads is to be based on the following assumptions:

(1) The calculation software is to be based on the three-dimensional linear or non-linear wave theory and approved by the classification society.

(2) Wave statistics based on the marine environment of the North Atlantic, as given in IACS REC34, are used in the prediction of wave loads.

(3) The requirements for wave frequencies, wave heading angles and the considered ship speed are given in Section 5, Chapter 1 of this PART.

(4) The wave spectrum and energy spread function under consideration are given in Section 5, Chapter 1 of this PART.

(5) The long-term prediction results at the probability level of 10^{-8} are taken as calculation results.

2.2.9.2 The hydrodynamic models used in calculation are to comply with the following requirements:

(1) The mass model is to correctly reflect the mass and its distribution of the real ship, ensuring that the error between mass of the model and that of the real ship is not greater than 0.1% and that the error between position of center of gravity of the model and that of the real ship is not greater than 0.1%L.

(2) The model of wetted surface is to be sufficiently refined for an accurate simulation of the shape of the real ship from the hydrodynamic perspective. The error between displacement of the model and that of the real ship is not to be greater than 0.1%, the error between position of center of buoyancy of the model and that of the real ship is not to be greater than 0.1% L, and the number of elements is generally not to be less than 2,000.

2.2.9.3 The wave bending moments and shear forces obtained by the linear wave theory are to be subject to non-linear correction as follows:

(1) The hogging wave bending moment M_W (+) and the sagging wave bending moment M_W (–) are to be calculated by the following formulas:

$$M_W(+)=Mf_{nl\text{-}h}M_{W,cal} \quad \text{kN·m}$$

$$M_W(-)=-Mf_{nl\text{-}s}M_{W,cal} \quad \text{kN·m}$$

where: $M_{W,\,cal}$ — maximum vertical wave bending moment between 0.4L and 0.6L, obtained by direct calculation based on linear wave theory;

M — distribution factor of bending moment along ship's length, see Figure 2.2.3.1 of this Chapter;

f_{nl-h} , f_{nl-s} — non-linear correction factor, determined by the following formulas:

$$f_{nl-h}=\frac{190C_b}{95C_b+55(C_b+0.7)}$$

$$f_{nl\text{-}s}=\frac{110(C_b+0.7)}{95C_b+55(C_b+0.7)}$$

where: C_b — block coefficient, taken not less than 0.6.

(2) The hogging wave shear force F_W (+) and the sagging wave shear force F_W (−) are to be calculated by the following formulas:

$$F_W(+)=F_{nl,1}F_{WV,\,\max}\text{kN}$$

$$F_W(-)=-F_{nl,2}F_{WV,\,\max}\text{kN}$$

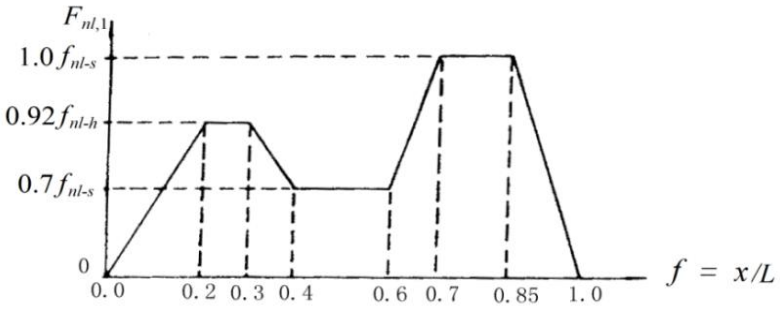
where: $F_{nl,1}$, $F_{nl,2}$ — distribution factors taking non-linear correction into account, see Figures 2.2.9.3(1) and 2.2.9.3(2) respectively. For f_{nl-h}, f_{nl-s} in the Figures, see (1) above.

$F_{WV,\,\max}$ is to be calculated by the following formula:

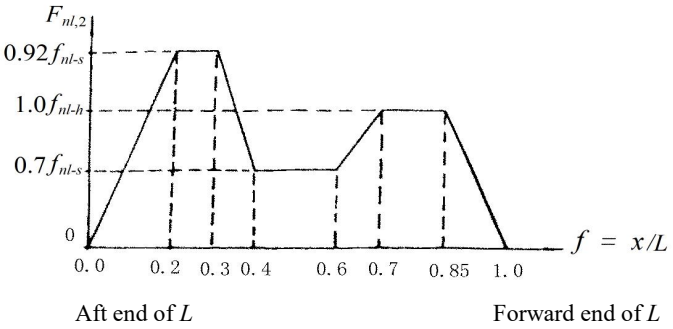
$$F_{WV,\max}=\max\left(\frac{\max\left|F_{WV,CAL,A}\right|}{0.92},\frac{\max\left|F_{WV,CAL,F}\right|}{1.0}\right)\text{kN}$$

where: $F_{WV,\,CAL,\,A}$ — wave shear force, in kN, directly calculated for sections with $x/L < 0.5$;

$F_{WV,\,CAL,\,F}$ — wave shear force, in kN, directly calculated for sections with $x/L \geq 0.5$.



Figures 2.2.9.3(1) Distribution of Factor $F_{nl,1}$ along Ship's Length



Figures 2.2.9.3(2) Distribution of Factor $F_{nl,2}$ along Ship's Length

2.2.9.4 For specific ships, e.g. engineering ships which need to carry out short-term operation, short-term prediction of wave loads is to be used to determine wave loads in the operating condition based on the most severe short-term sea state provided by the designer. The period of short-term prediction is generally taken as 3 hours or the operating hours provided by the designer, whichever is greater.

Section 3 SHELL PLATING

2.3.1 Bottom shell

2.3.1.1 Bottom shell means the shell plating between the plate keel and the bilge strake.

2.3.1.2 In a ship with transverse bottom framing, the thickness t of bottom shell plating within 0.4L amidships is not to be less than the following:

$$t_1 = 0.072sE^{-1}(L+170)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 7.0s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

d — draught, in m;

L — length of ship, in m, to be taken as not greater than 200 m;

F_b — reduction factor, see 2.2.5.6 of this Chapter;

$E = 1+\frac{s^2}{S^2}$, where S is spacing of girders or keelsons, in m;

h_1 = 0.26 C, to be taken as not greater than 0.2 d;

C — coefficient, see 2.2.3.1 of this Chapter;

K — material factor.

2.3.1.3 In a ship with longitudinal bottom framing, the thickness t of bottom shell plating within 0.4L amidships is not to be less than the values obtained from the following:

$$t_1 = 0.043s(L+230)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 5.6s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

d — draught, in m;

L — length of ship, in m, to be taken as not greater than 190 m;

F_b, h_1 — see 2.3.1.2 of this Section;

K — material factor.

2.3.1.4 The thickness t of bottom shell plating within the regions of 0.075L from the ship's ends is not to be less than that obtained from the following formula:

$$t = (0.035L + 6)\sqrt{\frac{sK}{0.7}} \quad \text{mm}$$

where: L — length of ship, in m, L need not be taken as greater than 300 m;

s — spacing of frames or longitudinals, in m, to be taken as not less than 0.7;

K — material factor.

2.3.1.5 The thickness of bottom shell plating is not to be less than that obtained by the following formula:

$$t = (0.035L + 6)\sqrt{K} \quad \text{mm}$$

where: L — length of ship, in m;

K — material factor.

The thickness of bottom shell plating beyond 0.4L amidships is to be tapered gradually to the end thickness of bottom shell plating.

2.3.1.6 The thickness of bottom shell plating at fore end is, in addition, to comply with the relevant requirements of Section 15 of this Chapter.

2.3.2 Plate keel

2.3.2.1 The width b of the plate keel is not to be less than that obtained from the following formula:

$$b = 900 + 3.5L \quad \text{mm}$$

where: L — length of ship, in m.

The width of the plate keel need not be greater than 1,800 mm, and is to be maintained over the whole length of the ship.

2.3.2.2 The thickness of the plate keel is not to be less than that of the bottom shell plating calculated according to 2.3.1 of this Section in accordance with its structural configuration plus 2.0 mm nor less than that of the adjacent bottom shell plating.

2.3.3 Bilge strake

2.3.3.1 Where the bilge is framed transversely, the thickness of the bilge plating is not to be less than the value obtained from 2.3.1.2 of this Section, and where the bilge is framed longitudinally, the thickness of the bilge plating is not to be less than the value obtained from 2.3.1.3 of this Section.

2.3.3.2 Where both the bottom and side shells are framed longitudinally and the bilge longitudinals are omitted, and where transverse strength members or corresponding bilge brackets are fitted in accordance with the requirements of 2.6.15.5 of this Chapter, the thickness of the bilge strake is neither to be less than $\frac{rF_b}{165K}$ (r being the radius of bilge, in mm, K being material factor and F_b being reduction factor of bottom), nor to be less than that of the adjacent bottom plating.

2.3.4 Side shell plating

2.3.4.1 Side shell plating means the shell plating between the bilge strake and the sheer strake.

2.3.4.2 Where the side shell is framed transversely, the thickness t of side shell plating within $0.4L$ amidships is to be as follows:

(1) The thickness t of side shell plating above $\frac{3}{4}D$ from base is not to be less than the following:

$$t_1 = 0.073sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 4.2s\sqrt{(d+h_2)K} \quad \text{mm}$$

(2) The thickness t of side shell plating within $\frac{1}{2}D$, the centre point of which is $0.5D$ from base, is not to be less than the following:

$$t_1 = 0.06s(L+110)\sqrt{\frac{F_m}{K}} \quad \text{mm}$$

$$t_2 = 5.1s\sqrt{(d+h_2)K} \quad \text{mm}$$

(3) The thickness t of side shell plating below $\frac{1}{4}D$ from base is not to be less than the following:

$$t_1 = 0.072sE^{-1}(L+110)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 6.3s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: s — spacing of frames, in m; to be taken as not less than the standard spacing of frames;

L — length of ship, in m, L need not be taken as greater than 190 m;

d — draught, in m;

F_d, F_b — reduction factors, see 2.2.5.6 of this Chapter;

F_m — reduction factors, to be taken as F_d or F_b, whichever is the greater;

$E = 1+\frac{s^2}{S^2}$, where S is the spacing of side stringers, in m;

$h_2 = 0.5C$, to be taken as not greater than $0.36d$;

h_1, C — see 2.3.1.2 of this Section;

K — material factor.

(4) In calculation of t_1, except the minimum range of high tensile steel stipulated in Section 2 of this Chapter, the material factor K may be taken as 1.

2.3.4.3 Where the side shell is framed longitudinally, the thickness t of side shell plating within 0.4L amidships is to be as follows:

(1) The thickness t of side shell plating above $\frac{1}{2}D$ from base is not to be less than the following:

$$t_1 = 0.06s(L+110)\sqrt{F_d / K} \quad \text{mm}$$

$$t_2 = 4.2s\sqrt{(d+h_2)K} \quad \text{mm}$$

(2) The thickness t of side shell plating below $\frac{1}{4}D$ from base is not to be less than the following:

$$t_1 = 0.06s(L+110)\sqrt{F_b / K} \quad \text{mm}$$

$$t_2 = 5.4s\sqrt{(d+h_1)F_b K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

L — length of ship, in m, L need not be taken as greater than 190 m;

d — draught, in m;

F_d, F_b— reduction factors, see 2.2.5.6 of this Chapter;

h_1 — see 2.3.1.2 of this Section;

h_2 — see 2.3.4.2 of this Section;

K — material factor.

(3) The thickness t of side shell plating between $\frac{1}{4}D$ and $\frac{1}{2}D$ from base is to be obtained by interpolation between the values of t_2 in (1), (2) above, but not less than t_1 in (2) above.

(4) For the calculation of t_1, except the minimum range of high tensile steel stipulated in Section 2 of this Chapter, the material factor K may be taken as 1.

2.3.4.4 The thickness of side shell plating within 0.075L from the ship's ends is to comply with the requirements of 2.3.1.4 of this Section.

2.3.4.5 The thickness of side shell plating is not to be less than that obtained by the following formula:

$$t = (0.035L+6)\sqrt{K} \quad \text{mm}$$

where: L — length of ship, in m;

K— material factor.

The thickness of side shell plating beyond 0.4L amidships is to be tapered gradually to the end thickness of side shell plating.

2.3.5 Sheer strake

2.3.5.1 The width of the sheer strake is not to be less than:

b = 800 + 5L mm, but need not be greater than 1,800 mm

where: L — length of ship, in m.

2.3.5.2 Where the side shell is framed transversely, the thickness t of the sheer strake within 0.4L amidships is not to be less than the following:

$$t_1 = 0.085sE^{-1}(L_1+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 1.05s\sqrt{(L+75)K} \quad \text{mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

L — length of ship, in m;

L_1 = L, in m, need not be taken as greater than 200 m;

F_d, E — see 2.3.4.2 of this Section;

K — material factor.

2.3.5.3 Where the side shell is framed longitudinally, the thickness t of the sheer strake within 0.4L amidships is not to be less than the following:

$$t_1 = 0.06s(L_1+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s\sqrt{(L+75)K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

L — length of ship, in m;

L_1 = L , in m, need not be taken as greater than 200 m in calculation;

F_d — reduction factors, see 2.2.5.6 of this Chapter;

K — material factor.

2.3.5.4 The thickness of sheer strake within 0.4L amidships is in any case not to be less than 0.8 times that of the stringer plate of the strength deck, nor less than that of adjacent side shell plating, and may be gradually tapered to the end thickness of the side shell plating.

2.3.5.5 Where the sheer strake is connected to the stringer plate by welding, the upper edge of the sheer strake is to be dressed smooth, and any fittings welded to the top of the sheer strake within 0.5L amidships are to be avoided. Scupper openings are not to be cut in the sheer strake which is protruded above the deck within 0.5L amidships or in way of breaks of superstructures.

Where a rounded sheer strake is adopted, the radius is not to be less than 15 times the thickness of the plate. The thickness of rounded sheer strake is to be at least equal to that of deck plating. Effective measures are to be taken to maintain the required properties of material after shaping. Deck fittings welded directly to the rounded sheer strake within 0.5L amidships are to be avoided, wherever possible.

2.3.6 Local strengthening

2.3.6.1 The thickness of shell plates connected to the stern frame or fitted in way of the shaft bossing in single screw ships and in way of the palms of propeller struts in multi-screw ships, is neither to be less than 1.5 times the thickness of shell plating at ends, nor to be less than the thickness of the shell plating amidships.

2.3.6.2 The shell plating in way of hawse pipe and one plate below are to be increased in thickness or to be fitted with doubler plates. The outlet of hawse pipe is to have adequate corner

radius. It is recommended that the corner radius of chafing lips made of steel plate or cast steel be not less than 12 times the diameter of anchor chain.

2.3.7 Openings in shell plating

2.3.7.1 Openings cut in the turn of the bilge strake within 0.5*L* amidships are to be avoided as far as possible, but if necessary, the openings are to be elliptical with the major axis arranged in the fore and aft direction.

2.3.7.2 In general, compensation will not be required for circular openings in the sheer strake which are clear of the gunwale and the deck openings outside the line of hatchways and whose depth does not exceed 20% of that of the sheer strake or 380 mm, whichever is the lesser. Circular openings in sheer strake are to be kept well clear of the ends of superstructures. Openings cut in a rounded gunwale are not allowed.

2.3.7.3 Sea inlets and other openings are to have well rounded corners. The thickness of sea inlet box plating and its steel grade are not to be lower than the adjacent shell. For ships of 90 m or over in length, this thickness is not to be less than 12 mm, but need not exceed 25 mm.

2.3.7.4 Cargo door openings are to have well rounded corners, and are to be kept clear of the ends of superstructures and the deck openings outside the line of hatchways. Such openings within 0.5*L* amidships are to be fully compensated by insert plates or doubler plates with a sufficient length in the fore and aft direction.

2.3.8 Bilge keels

2.3.8.1 Where bilge keels are fitted, they are to be attached to a continuous flat bar which may be welded to the shell. All butts of bilge keels, flat bars and shell plating are to be properly shifted from one another. Bilge keels and flat bars are not to be interrupted abruptly, but to be gradually tapered at their ends and terminated on a suitably stiffened panel.

Section 4 DECKS

2.4.1 General requirements

2.4.1.1 This Section applies to all decks with longitudinal or transverse framing.

2.4.1.2 Where the platform decks terminate within 0.4*L* amidships, horizontal brackets are to be provided at their ends and are to extend over a suitable length.

2.4.2 Strength deck

2.4.2.1 The thickness t of strength deck plating outside the line of openings within 0.4*L* amidships is, in addition to complying with the requirements for midship section modulus, not to be less than the following:

(1) For transverse framing:

$$t_1 = 0.085sE^{-1}\,(L_1+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 1.05s\sqrt{(L+75)K} \quad \text{mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

L — length of ship, in m;

L_1 = L, in m, need not be taken as greater than 200 m in calculation;

F_d — reduction factor, see 2.2.5.6 of this Chapter;

$E = 1 + \frac{s^2}{S^2}$, where S is spacing of deck longitudinals;

K — material factor.

(2) For longitudinal framing:

$$t_1 = 0.06s(L_1+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s\sqrt{(L+75)K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

L — length of ship, in m;

L_1 = L in m, need not be taken as greater than 200 m;

F_d — reduction factor, see 2.2.5.6 of this Chapter;

K — material factor.

2.4.2.2 The thickness t of strength deck plating inside the line of openings and within 0.075L from the ship's ends, irrespective of longitudinal or transverse framing, is not to be less than that obtained from the following formula:

$$t = 0.9s\sqrt{(L+75)K} \quad \text{mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

L — length of ship, in m;

K — material factor.

2.4.2.3 The minimum thickness t of the strength deck plating (including deck plating at ends) is not to be less than 6 mm.

2.4.2.4 Where the long bridge deck within 0.5L amidships is regarded as the strength deck, the midship section modulus and the minimum thickness are to comply with the requirements of 2.2.5 and 2.4.2.1 of this Chapter.

2.4.2.5 The thickness of strength deck plating is to be maintained for 0.4L amidships and is to be gradually tapered to the end thickness.

2.4.2.6 Where the strength deck at the ship's fore end is not protected by a forecastle, the plate thickness of strength deck forward of 0.15L from the fore perpendicular is to meet the requirements for forecastle deck.

2.4.3 Stringer plates

2.4.3.1 The thickness of strength deck stringer plates is not to be less than the thickness of strength deck plating. The breadth of strength deck stringer plates within 0.4L amidships is to comply with the relevant requirements of Section 3, Chapter 1 of this PART. The breadth of strength deck stringer plates at ends of the ship is not to be less than 65% of that amidships.

2.4.4 Deck openings

2.4.4.1 Where the corners of engine/boiler room or hatch openings in the strength deck are parabolic or elliptical, insert plates are not required, but the requirements as shown by Figure 2.4.4.1 are to be complied with.

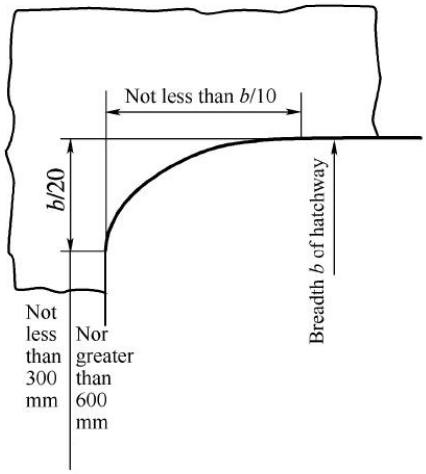


Figure 2.4.4.1

2.4.4.2 Where the corners of engine/boiler room or hatch openings in the strength deck are rounded, insert plates are required, and the radius of the rounded corner is not to be less than 1/20 of the breadth of the opening, but not less than 1/10 provided that deck girders are not fitted in way of the hatch coamings. Rounded corners are to have a minimum radius of 300 mm if the deck plating extends inside the coaming, or 150 mm if the coamings are welded to the inner edge of the deck plating in the form of a spigot.

The extension of the insert plates is to be as shown in Figure 2.4.4.2 (R is the radius of hatch corners, e is not to be less than 760 mm and for longitudinal framing, not to be less than one longitudinal spacing). The butt of the insert plate is to be kept well clear of the butt in coaming and the fillet welds of deck framing. The thickness of the insert plate is to be 4 mm greater than the thickness of strength deck framing. If the thickness or extension of the insert plate can not meet above requirements, direct calculation covering yield, buckling and fatigue is to be adopted for verification.

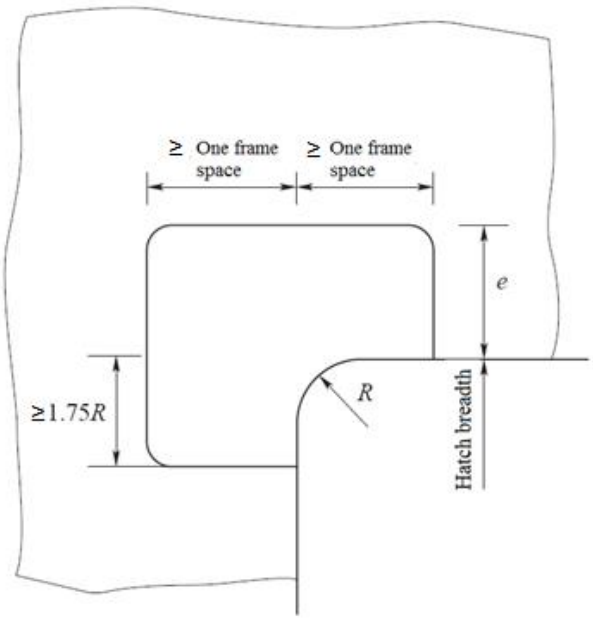


Figure 2.4.4.2

2.4.4.3 Openings in the strength deck outside the line of hatchways are to be kept to a minimum and are to be arranged clear of hatch corners. The corners of all openings are to be well rounded and with the edges smoothed.

Openings in the strength deck between midship bridge or deckhouse end bulkheads and hatches are to be avoided so far as possible.

2.4.4.4 Compensation is not required for openings in the strength deck outside the line of hatchways and situated within 0.5*L* amidships provided that they comply with the provisions of 2.2.4.7 of this Chapter. Edge reinforcement will not be required for:

(1) elliptical openings having their major axis in the fore and aft direction and an aspect ratio not less than 2;

(2) openings of other shapes provided that it has been shown by suitable tests that the stress concentration factor does not exceed 2 for low carbon steel and 1.5 for higher tensile steel.

2.4.4.5 Where the openings in the strength deck within 0.5*L* amidships and outside the line of hatchways do not comply with the provisions of 2.2.4.7 of this Chapter, compensation is required. Compensation is normally arranged by increasing the deck plate thickness. Where the openings do not comply with the provisions of 2.4.4.4(1) or (2) of this Section, the edge reinforcement in the form of a spigot as shown in Figure 2.4.4.5 is to be adopted, or alternative arrangements will be considered. Where a spigot is adopted, the sectional area *A* of the ring plate is not to be less than that obtained from the following formula:

$$A = 0.5rt \quad \text{mm}^2$$

where: r — radius of opening, in mm, and to be taken as the half breadth of the openings for elliptical openings;

t — thickness of deck plating, in mm.

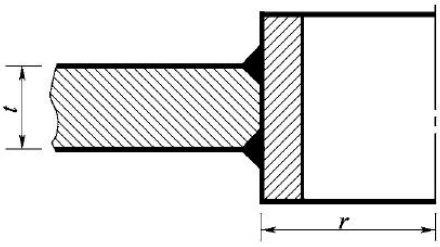


Figure 2.4.4.5

2.4.4.6 Lower deck openings are to comply with the following requirements:

(1) Inserts are required for machinery spaces and cargo hatch opening corners on second tier decks, and the thickness of inserts is to be 2.5 mm greater than the deck thickness. Insert plates will not generally be required for hatch corners on third tier decks and decks below (including platform decks).

(2) Openings outside the line of hatchways are to be as far as practicable kept clear of hatch corners and other areas of high stress. The provisions of 2.4.4.4 and 2.4.4.5 of this Section are generally also applicable to openings in lower decks, but compensation will not be required unless the total breadth of openings (see shadow areas as shown in Figure 2.2.4.7 of this Chapter) in such decks exceeds 15% of the breadth of deck plating used in midship section modulus calculation.

2.4.4.7 The above requirements for deck openings are, in general, also applicable to regions outside 0.5*L* amidships.

2.4.5 Lower decks and platform decks with loading not exceeding 40 kPa

2.4.5.1 The thickness *t* of second tier deck plating outside the line of hatchways and within 0.4*L* amidships is not to be less than that obtained from the following formula:

$$t = 12s\sqrt{K} \quad \text{mm, and not less than 6 mm}$$

The thickness *t* of second tier deck plating inside the line of hatchways and within 0.075*L* from the ship's ends is not to be less than that obtained from the following formula:

$$t = 10s\sqrt{K} \quad \text{mm, and not less than 6 mm}$$

where: *s* — spacing of frames, in m, to be taken as not less than the standard spacing of frames.

2.4.5.2 The thickness *t* of third tier deck or platform deck plating is not to be less than that obtained from the following formula:

$$t = 10s\sqrt{K} \quad \text{mm, and not less than 6 mm}$$

where: *s* — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

K — material factor.

2.4.6 Raised quarter decks

2.4.6.1 For the requirements for raised quarterdecks, see 2.17.8 of this Chapter.

2.4.7 Superstructure ends

2.4.7.1 The deck strengthening at ends of superstructures is to comply with the requirements of 2.17.6 of this Chapter.

2.4.8 Deck coverings

2.4.8.1 The deck coverings are to be of materials which are not corrosive to steel, or they are to be effectively insulated from the steel by a noncorrosive protective coating.

2.4.8.2 Wood sheathing on exposed steel deck is to have a thickness not less than 50 mm for pine and 45 mm for teak wood in ships less than 120 m in length, and 60 mm and 50 mm respectively in ships of 120 m or over in length. For enclosed spaces, the thickness of pine sheathing on the steel deck is not to be less than 40 mm.

The thickness of steel deck plating sheathed with wood planks may be reduced by 1 mm, but each plank is to be well secured to the deck plating at every beam by studs.

2.4.8.3 Where chemical covering is used as a substitute for wood sheathing, the thickness of the steel deck plating is not to be reduced.

Section 5 SINGLE BOTTOMS

2.5.1 Application

2.5.1.1 This Section applies to transversely framed single bottom ships of not greater than 90 m in length.

2.5.2 Centre keelson

2.5.2.1 The centre keelsons are to be provided in way of the central longitudinal section of the ship. The depth of the centre keelson is to be the same as that of floors, and the web thickness t and the sectional area A of the face plate of the centre keelson are not to be less than the following:

Within 0.4L amidships: $t = \sqrt{LK} + 2$ mm, and not less than 6 mm

$A = 0.67LK$ cm^2, and not less than 12.5 cm^2

Within 0.075L from the ship's ends: $t = \sqrt{LK} + 0.5$ mm, and not less than 6 mm

$A = 0.52LK$ cm^2, and not not less than 12.5 cm^2

where: L — length of ship, in m;

K— material factor.

In the forepeak tank, the centreline keelson may have the same depth and thickness and the same sectional area of face plate as the floor.

2.5.2.2 The centre keelson is normally to extend as far forward and aft as practicable. Where the centre keelson is cut in way of a bulkhead, it is to be connected to the bulkhead by one of the following means:

(1) The web plate of the centre keelson is to be gradually raised, within one frame spacing to 1.5 times the original web depth at the bulkhead, and the face plate of the centre keelson is to extend and to be welded to the bulkhead, as shown in Figure 2.5.2.2(1).

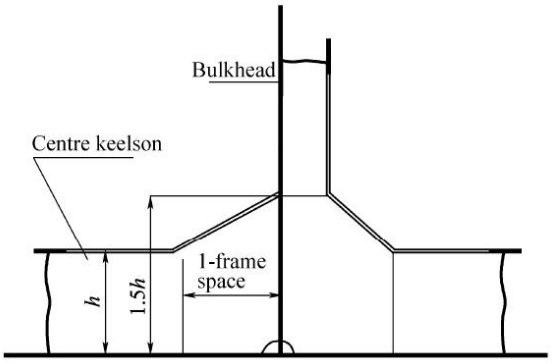


Figure 2.5.2.2(1)

(2) The centre keelson is to be attached to the bulkhead by brackets having a face plate or flange, and the depth and length of the brackets are to be equal to the depth of the keelson. In this case, the face plate of the centre keelson may not be welded to the bulkhead. The thickness of the brackets is to be the same as that of the web of the centre keelson, as shown in Figure 2.5.2.2(2).

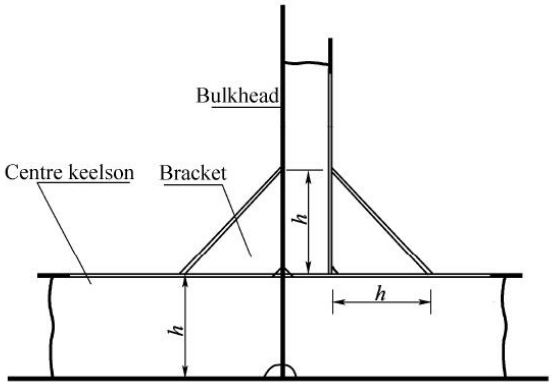


Figure 2.5.2.2(2)

(3) The face plate of the centre keelson is, within one frame spacing, to be gradually widened to twice its original width at the bulkhead, and to be welded to the bulkhead, as shown in Figure 2.5.2.2(3).

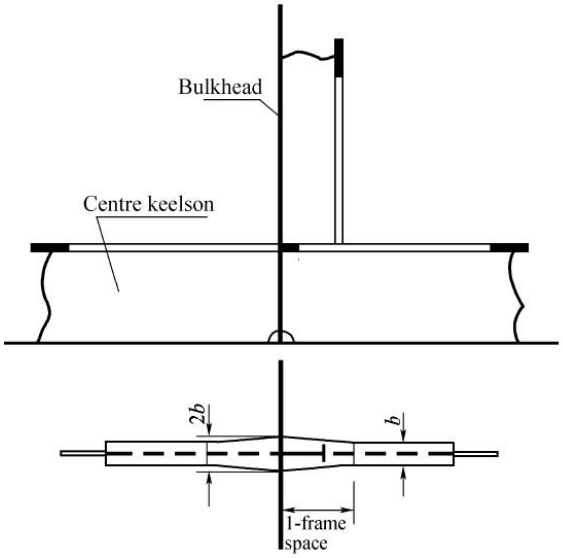


Figure 2.5.2.2(3)

2.5.2.3 In the machinery space the thickness of the centre keelson web is to be equal to the value obtained from 2.5.2.1 of this Section plus 1 mm. Where a single main engine is fitted, the centre keelson may be omitted in the machinery space provided that the longitudinal girders under the engine seating extend over the whole length of the engine room and brackets are fitted at the outside of both end bulkheads of the engine room for transition. Within the engine room where the centre keelson is cut, however, gradually tapered brackets having a length not less than two frame spaces are to be fitted for transition, as shown in Figure 2.5.2.3.

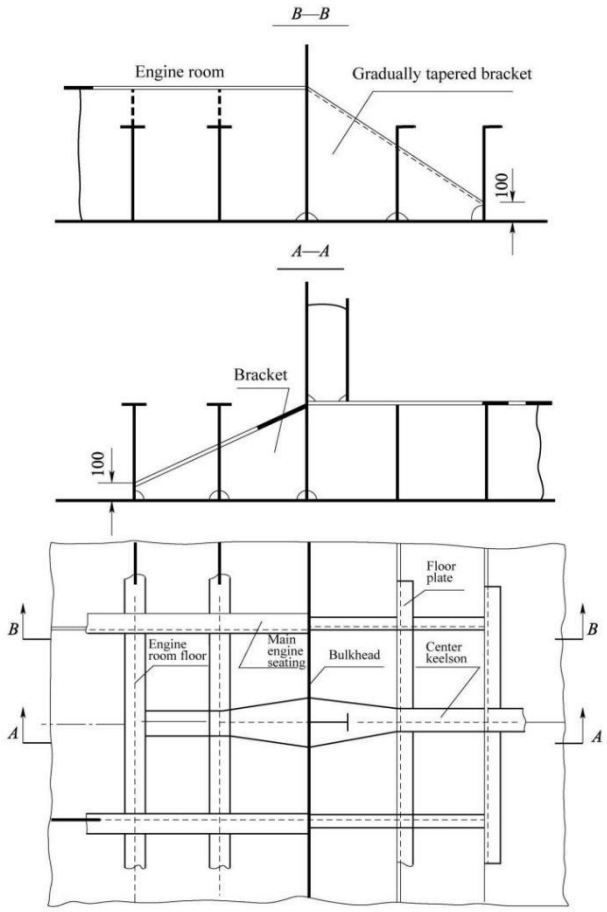


Figure 2.5.2.3

In machinery spaces situated at the aft end, such engine seating girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses. Where it is impracticable to provide transition brackets abaft the aft peak bulkhead because the aft body of the ship is too fine, such brackets may be dispensed with.

2.5.3 Side keelsons

2.5.3.1 The depth of side keelsons is to be the same as that of floors, and the web thickness t and the face plate sectional area A of side keelsons are not to be less than the following:

$$t = \sqrt{LK} \quad \text{mm, and not less than 6 mm}$$

$$A = 0.25L + 5 \text{ cm}^2, \text{ and not less than 10 cm}^2$$

where: L — length of ship, in m;

K— material factor.

In the machinery space, the web thickness of side keelsons is not to be less than that of the centre keelson as required in 2.5.2.1 of this Section.

2.5.3.2 One side keelson at least is to be fitted on each side of the centre keelson where the breadth of ship is equal to 9 m or less, and two at least where the breadth exceeds 9 m but does not exceed 16 m. In addition, continuous or intercostal longitudinal stiffeners are to be fitted where the panel aspect ratio exceeds 4. Side keelsons are to be uniformly fitted and are to extend as far forward and aft as practicable. Outboard of the main engine seating girders, side keelsons as

required in 2.5.3.1 of this Section are to be fitted, and attention is to be given to structural continuity. In the case of ships having duplicate main engines situated at the aft end, where it is impracticable to fit the side keelsons owing to the confined space in the engine room, such keelsons may be dispensed with.

2.5.3.3 The attachment of side keelsons to the bulkheads is to be the same as required for the centre keelson (see 2.5.2.2 of this Section).

2.5.4 Floors

2.5.4.1 Plate floors are to be fitted at every frame and are, at the centreline, to have a web depth h, a web thickness t and a sectional area A of face plate not less than:

$$h = 42(B + d) - 70 \quad \text{mm}$$

$$t = (0.01h+3)\sqrt{K} \text{ mm, but not less than 6 mm and need not be greater than 14 mm}$$

$$A = (4.8d-3)\,K \quad \text{cm}^2$$

where: B — breadth of ship, in m;

d — moulded draught, in m;

K — material factor.

2.5.4.2 The thickness of the face plate of the floor is not to be less than that of its web plate. The breadth of the face plate is not to be less than 10 times its thickness, but need not exceed 15 times.

2.5.4.3 In ships having considerable rise of floor (or towards fore and aft ends), the depth of floor plates is to be increased. The floor plates forming part of a watertight, deep tank or tank bulkhead are not to be less than 900 mm in depth measured at the centreline, and have a thickness not less than that required for the bottom strake of a bulkhead.

For small ships, the depth of the floor plates at the centreline may be suitably reduced.

2.5.4.4 In machinery spaces the web thickness of floors is not to be less than that of the centre keelson as required in 2.5.2.1 of this Section. In way of machinery spaces situated amidships, the depth of the web plate and the face plate sectional area of floors are to be increased by 10% above those obtained from 2.5.4.1 of this Section. In way of machinery spaces situated astern, the face plate area of floors is to be increased by 10% above those obtained from 2.5.4.1 of this Section. The floors are not to be flanged instead of having face plates.

In way of machinery spaces situated aft or where there is considerable rise of floor, the depth of floors is to be appropriately increased in accordance with the ship's lines and strength.

2.5.5 Bilge brackets

2.5.5.1 Floors are to be connected to the frames by bilge brackets. The depth of the bilge brackets measured from the base line is to be twice that of the floors in way of the centreline, and the length of the brackets, measured from the inner edge of frames, is to be equal to the floor depth on the centreline. The thickness of the brackets is to be equal to that of floors. The brackets are to have a flange or face plate. When flanged, the width of the flange is neither to exceed 10 times the thickness of the bracket nor to be less than 50 mm.

2.5.5.2 Where it is impracticable to arrange the bilge brackets due to the ship's lines or other reasons, the floors are to extend to the ship's side and to be raised to the required depth for bilge brackets.

2.5.5.3 Where bilge brackets or floors are connected to the frames by means of a welded lap joint, the length of overlap is to be as follows:
(1) when the depth of frames is 100 mm or less, the length of overlap is not to be less than twice the depth of frames;
(2) when the depth of frames exceeds 100 mm, the length of overlap is neither to be less than 1.5 times the depth of the frame nor less than 200 mm.

2.5.6 Drain holes

2.5.6.1 Drain holes are to be cut in the floors and side keelsons in way of the bottom. Provision is to be made for the free passage of water from all parts of the bottom to the suctions, taking into account the pumping rates required.

Section 6 DOUBLE BOTTOMS

2.6.1 General requirements

2.6.1.1 Double bottoms are to comply with the requirements of this Section and in addition, the relevant requirements of Section 12, Chapter 1 of this PART.
2.6.1.2 Where the double bottom is interrupted, the continuity of bottom longitudinal members is to be maintained. The centre and side keelsons within the single bottom in way of the break are to be the continuation of the centre and side girders of the double bottom. The inner bottom plating is to extend beyond the break of the double bottom and to be gradually tapered for a length of not less than three frame spaces to form the face plate of the keelsons, and the breadth of the face plate at the break of the double bottom is not to be less than half the spacing of side keelsons. The margin plate is also to extend not less than three frame spaces beyond the break of the double bottom. Where the margin plate is inclined, the extension portion is to have a face plate or flange, and the width of the margin plate may be reduced gradually. Within the single bottom, side keelsons, which are not the direct continuation of the girders in the double bottom, are to be extended into the double bottom and to be gradually tapered off over a length of not less than three frame spaces with their free edges flanged.
2.6.1.3 Sufficient girders are to be arranged in way of the main machinery and structural continuity is to be maintained. In midship machinery spaces, these girders are to extend for the full length of the space and are to be carried for at least three frame spaces beyond the fore and after bulkheads of the engine room. However, the extension beyond the after bulkhead is also to support the foremost shaft tunnel bearing; in machinery spaces situated at the aft end such girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses.
Outboard of the main engine seating girders, side girders are to be arranged and attention is to be given to the structural continuity.
2.6.1.4 Manholes are to be cut in the floors and side girders. Except for lightened floors, the depth of manholes is not to exceed 50% of that of the double bottom, unless edge reinforcement is provided. Manholes cut in floors are to be arranged along a straight line in the fore and aft direction for easy access. Manholes or lightening holes are not permitted within the range of floor

ends (generally taken as 1 spacing of longitudinals in way of the longitudinal bulkhead or 600 mm, whichever is greater) and in the side girders for one frame space from transverse bulkheads, unless the edges of holes are strengthened. The edges of all holes are to be smoothed.

2.6.1.5 Air and drain holes are to be cut in floors, side girders and bottom and inner bottom longitudinals to ensure the free passage of air and water from all parts of the tanks to the air pipes and suctions, account being taken of the pumping rates required.

2.6.1.6 The minimum thickness of floors and girders of double bottoms is to be 6 mm.

2.6.1.7 The strake connecting the inner bottom plating to the shell plating is the margin plate.

2.6.2 Centre girders

2.6.2.1 Centre girders are to be provided in way of the central longitudinal section of the ship. The depth h_0 of centre girders is to comply with the requirements for the depth of double bottoms in Section 12, Chapter 1 of this PART and not to be less than that calculated by the following formula:

$$h_0 = 25B + 42d + 300 \quad \text{mm, nor less than 760 mm}$$

where: B — breadth of ship, in m;

d — draught, in m.

For double hull ships (with double bottom and double side skin), the distance from midpoint between outer and inner shells at one side to that at the other side may be taken as equivalent breadth in lieu of the breadth B of ship (see Figure 2.6.2.1). B_e is generally not to be less than $0.9B$, and if the double bottom strength is in compliance with the CCS criteria for direct strength calculations, not to be less than $0.8B$.

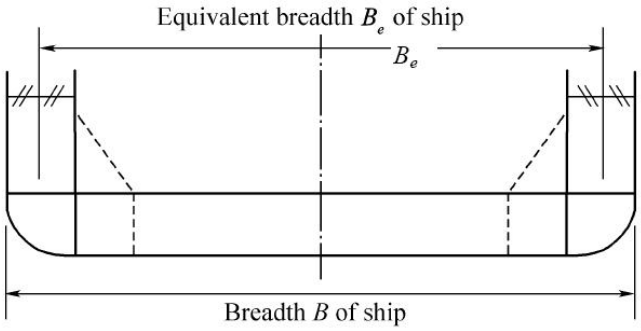


Figure 2.6.2.1

2.6.2.2 The thickness t of centre girders is not to be less than:

(1) For $0.4L$ amidships:

$$t = (0.0077h_0+4)\sqrt{K} \quad \text{mm}$$

where: h_0 — considered height of double bottom, in mm;

K — material factor.

(2) For $0.075L$ from the ship's ends, the thickness t of centre girders may be decreased by 2 mm from that required in (1) above.

(3) The thickness of centre girders in boiler spaces is to be increased by 2.5 mm above that required for centre girders within $0.4L$ amidships.

2.6.2.3 The centre girders within $0.75L$ amidships are to be continuous and to extend as far as practicable to the stem and stern frame.

2.6.2.4 Manholes or lightening holes are not to be cut in the centre girders within 0.75L amidships, but if such holes are essential in exceptional cases, suitable compensation is to be provided.

Outside 0.75L amidships, holes may be cut in centre girders (excluding one frame space forward and aft of a transverse bulkhead) with a depth not exceeding 40% of that of the centre girders at that place.

2.6.3 Duct keels

2.6.3.1 Duct keels (pipe tunnels) may be substituted for centre girders. The thickness of side plates of the duct keel is not to be less than that of the watertight floors. The side plates are in general not to be spaced more than 2 m apart; for ships of 150 m or above in length, the side plates may be spaced not more than 3 m apart upon verification by direct calculation.

The bottom shell and inner bottom within the region of duct keels are to be suitably increased in thickness.

2.6.3.2 The framing members of the duct keel are to be as follows:

(1) Bottom and inner bottom stiffening members are to be fitted to the duct keel at every frame, and the section modulus W of these framing members is not to be less than that obtained from the following formula:

$$W = 22sdl^2K \qquad \text{cm}^3$$

where: s — spacing of frames, in m;

d — draught, in m;

l — span, in m, to be taken as the distance between side plates;

K — material factor.

(2) Bottom and inner bottom stiffening members are to be gradually increased in scantlings at both ends and are to be connected to the side plates of the duct keel. The enlarged portions are to have a length and depth not less than 1.5 times the depth of the members. In such a case, brackets having the same thickness as the plate floors are to be fitted outside the side plates at each frame where no floor is fitted, and are to be attached to the longitudinals.

(3) Bottom longitudinals are to be fitted within the duct keel on the centreline of the ship, which may be intercostal in way of transverse framing members.

2.6.3.3 At the connection between the duct keel and the ordinary centre girder, they are to be overlapped over a length not less than 3 frame spaces for transition.

2.6.4 Transverse framing — side girders

2.6.4.1 The thickness of side girders is not to be less than that obtained from the following formula:

$$t = (0.0077h_0+1)\sqrt{K} \qquad \text{mm}$$

where: h_0 — considered height of double bottom, in mm.

K — material factor.

The thickness of watertight side girders is to be increased by 1 mm above that obtained from the above formula. Where the double bottom tanks are interconnected with side tanks or cofferdams, the thickness of side girders is to be as required for deep tanks.

2.6.4.2 At least one side girder is to be fitted on each side of the centreline when the breadth of the ship exceeds 10 m, and at least two side girders spaced apart generally not more than 4 m are

to be fitted on each side of the centreline when the breadth of the ship exceeds 18 m. But forward of 0.2L from the F.P., the spacing of side girders is not to be greater than 3 frame spaces. Side girders are to be equally spaced as far as practicable.

2.6.5 Transverse framing — plate floors

2.6.5.1 The thickness t of plate floors in cargo holds or machinery spaces is not to be less than that obtained from the following formula, but need not exceed 15 mm:

$$t = (0.0077h_0+1)\sqrt{K} \quad \text{mm}$$

where: h_0 — considered height of double bottom, in mm;

K — material factor.

The thickness of plate floors in boiler rooms and in way of the bilge wells is to be 2.5 mm greater than that given by the above formula.

2.6.5.2 Plate floors are to be fitted at least 4 frame spaces apart at a spacing not exceeding 3.2 m. Where the length of ships exceeds 90 m or the depth of floors exceeds 0.9 m, vertical stiffeners spaced not more than 1.5 m apart are to be fitted on the plate floors, generally having the same thickness as that of floors and the width of which is not to be less than 150 mm. For ships less than 90 m in length, the width of such stiffeners is not to be less than 1.65L, with a minimum of 50 mm.

Plate floors are to be fitted at every frame in the engine room and under the boiler bearers, thrust seatings, transverse bulkheads and heels of pillars. Plate floors are to be fitted at every frame forward of 0.2L from the F.P.

2.6.6 Transverse framing — watertight floors

2.6.6.1 The thickness of watertight floors is to be as follows:

(1) The thickness of watertight floors is to be 2 mm greater than that of the plate floors in cargo holds, but generally need not exceed 15 mm.

Watertight floors are to be fitted below transverse watertight bulkheads wherever practicable.

(2) The thickness of oiltight floors in oil tanks is to be the same as required for the above watertight floors.

2.6.6.2 Where the depth of watertight floors is greater than 0.9 m but does not exceed 2 m, they are to be fitted with vertical stiffeners spaced not more than 0.9 m apart. Both ends of stiffeners are to be snipped, the thickness and depth are to comply with the requirements of 2.6.5.2 of this Section, and the section modulus W of which is not to be less than that obtained from the following formula:

$$W = 5.5shl^2K \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, from the inner bottom to the top of overflow;

l — span of stiffener, in m, i.e. the considered height of double bottom;

K — material factor.

The section modulus of the stiffeners on the oiltight floors in oil tanks is to be the same as required in the above formula.

2.6.6.3 Where the double bottom tanks are interconnected with side tanks or cofferdams, or the depth of the plate floor is greater than 2 m, the scantlings of the watertight floors are not to be less than those required for deep tanks, furthermore, vertical stiffeners are to be bracketed at both ends.

2.6.7 Bracket floors

2.6.7.1 Where transverse framing is adopted in the double bottom, bracket floors are to be fitted at every frame where no plate floor is fitted. The breadth of the brackets attaching the frames and the reversed frames to the centre girder and margin plate is not to be less than 75% of the depth of the centre girder, and the thickness of the brackets is to be the same as that of plate floors in that region. Where the depth of the double bottom is equal to 800 mm or more, the brackets are to have a flange or face plate on the unsupported edge and the breadth of the flange or face plate is to be 10 times the thickness but need not exceed 90 mm. Stiffeners having the same scantlings as the reversed frames are to be fitted on one side of the side girders (see Figure 2.6.7.1). Where l as shown in the Figure is greater than 2.5 m, struts as required in 2.6.7.2 of this Section are to be fitted.

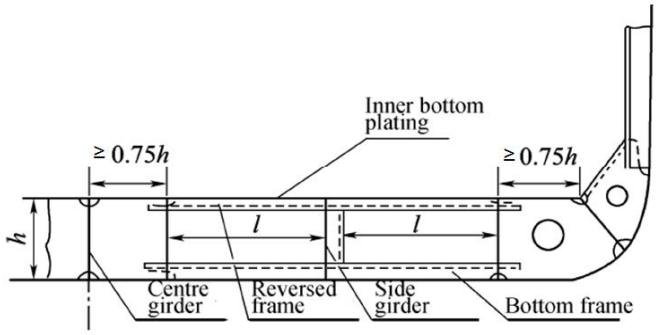


Figure 2.6.7.1

2.6.7.2 The bottom frames of bracket floors are to have a section modulus W not less than that obtained from the following formula:

$$W = (15 - 2.5l_1)sdl^2K \quad \text{cm}^3$$

where: s — spacing of frames, in m;

d — draught, in m;

l — span of bottom frames, in m, measured from the edge of the bracket to the side girder (see Figure 2.6.7.1);

l_1 — the same as l, but l_1 is to be taken as 2.5 m for $l > 2.5$ m;

K — material factor.

Where struts are fitted at the mid-point of the span l, the section modulus W of the bottom frames is not to be less than half of that given by the above formula. The cross sectional area A of the struts is not to be less than the following:

$$A = 23.8 + 0.04W \text{ cm}^2 \quad \text{for } W > 85 \text{ cm}^3$$

$$A = 0.32W \text{ cm}^2 \quad \text{for } W \leq 85 \text{ cm}^3$$

where: W — section modulus of bottom frames, in cm³.

The reversed frames are to have a section modulus not less than 85% of that given above for the bottom frames.

In boiler rooms, the thickness of the bottom frames, reversed frames and struts is to be increased by 2 mm.

2.6.7.3 The attachment of bottom frames and reversed frames to brackets is to be the same as required in 2.5.5.3 of this Chapter for the attachment of frames to bilge brackets.

2.6.8 Lightened floors

2.6.8.1 Where transverse framing is adopted in the double bottom, lightened floors may be fitted at every frame where no plate floor is fitted, as substitutes for bracket floors. The thickness of the web plate of lightened floors is not to be less than that of the plate floor in the same region. The distance from the edge of the lightening hole to bottom and inner bottom is not to be less than 0.2 times the depth of the centre girder; the distance from the edge of the lightening hole to the centre girder and margin plate is not to be less than 0.5 times the depth of the centre girder; the distance from the edge of the lightening hole to the side girder is not to be less than 0.25 times the depth of the centre girder; and the length of the the lightening hole is not to exceed 1.2 times the depth of the centre girder, as shown in Figure 2.6.8.1.The dimensions of the vertical stiffeners on the floors are to comply with the requirements of 2.6.5.2 of this Section, and the spacing of the stiffeners is not to be more than 2.2 m.

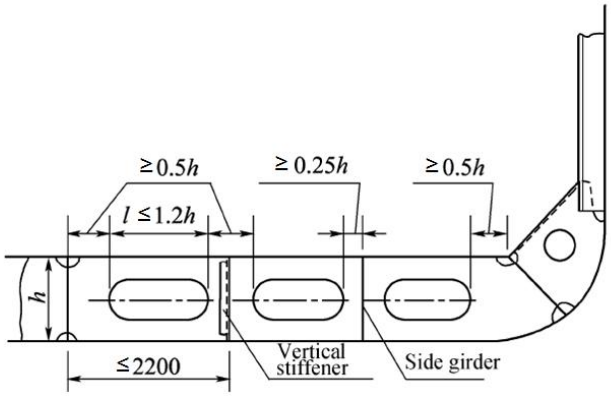


Figure 2.6.8.1

2.6.9 Transverse framing — inner bottom plating and margin plate

2.6.9.1 The thickness t of the inner bottom plating is not to be less than the following:

$t = (0.04L+5s+2.1)\sqrt{K}$ mm for 0.4L amidships

$t = (0.055L+4.8)\sqrt{K}$ mm for engine spaces

where: L — length of ship, in m, to be taken as not greater than 400 m;

s — spacing of frames, in m;

K — material factor.

For 0.075L from the ship's ends, the thickness is to be 0.9 times that required for 0.4L amidships. The thickness of the inner bottom plating in other regions is to be tapered gradually to the end thickness from the thickness within 0.4L amidships.

2.6.9.2 Local strengthening of inner bottom plating:

(1) Where the double bottom tanks are used to carry oil fuel, the thickness of the inner bottom plating is not to be less than 8 mm.

(2) The thickness of the inner bottom plating under hatchways is to be increased at least by 2 mm if no wood ceiling is fitted. If cargo is regularly discharged by grabs or other similar means and where no wood ceiling as required in 3.3.1.5 of this PART is fitted, the thickness of the inner bottom plating under hatchways is to be increased at least by 5 mm.

2.6.9.3 Where the margin plate is inclined downwards, the breadth of the margin plate is not to be less than 80% of the depth of the centre girder. Where the margin plate is horizontal, the breadth is not to be less than that of bilge brackets plus 50 mm.

Where the margin plate is inclined downwards, the thickness of the margin plate throughout the hold is to be 1.5 mm greater than that required for the inner bottom plating when the length of the ship is equal to 110 m or less, and 2 mm when the length of the ship is greater than 110 m. In engine rooms and boiler rooms, the thickness of the margin plate is not to be less than that required for the inner bottom plating within such spaces respectively.

2.6.10 Longitudinal framing — bottom girders

2.6.10.1 The depth and thickness of the centre girder are to be the same as required in 2.6.2.1 and 2.6.2.2 of this Section. Between plate floors, brackets having the same thickness as the plate floors are to be fitted on each side of the centre girder, extending to the adjacent longitudinals. Such brackets are in general to be spaced not more than 1.20 m apart. Where the centre girder is watertight, vertical stiffeners spaced not more than 0.9 m apart are to be fitted between the plate floors and brackets (when the distance between them is greater than one frame space). For these stiffeners, the section modulus is to comply with the requirements of 2.6.6.2, the thickness is to be the same as that of the center girder web and in general, the breadth is to comply with the requirements of 2.6.5.2.

2.6.10.2 At least one side girder is to be fitted on each side of the centreline when the breadth of the ship exceeds 12 m but not greater than 20 m, and at least two side girders spaced apart generally not more than 5 m are to be fitted on each side of the centreline when the breadth of the ships exceeds 20 m. Forward of 0.2L from the F.P. the spacing of side girders is not to be greater than four longitudinal spaces. The side girders are to be equally spaced as far as practicable.

The thickness of side girders and watertight side girders are to comply with the requirements of 2.6.4.1 of this Section. Where the double bottom tanks are interconnected with side tanks or cofferdams, the thickness of side girders is to be as required for deep tanks.

Side girders and watertight side girders are in general to be fitted with vertical stiffeners. Vertical stiffeners of side girders are to be spaced not more than 1.5 m apart, having the same thickness as that of side girder webs and generally, a breadth is to comply with the requirements of 2.6.5.2. Vertical stiffeners of watertight side girders are to be spaced not more than 0.9 m apart, the thickness is to be the same as that of watertight side girder web and generally, the breadth is to comply with the requirements of 2.6.5.2 and the section modulus W is to comply with the requirements of 2.6.6.2.

Where side girders and watertight side girders are fitted with horizontal stiffeners, the thickness of stiffeners is generally the same as that of side girder webs and the breadth is to comply with the requirements of 2.6.5.2. The section modulus W of horizontal stiffeners on watertight side girders is to comply with the requirements of 2.6.6.2.

2.6.11 Longitudinal framing — plate floors

2.6.11.1 In machinery spaces, plate floors are to be fitted at least at alternate frames, and are to be fitted at every frame under the main engine seating, boiler bearers, thrust seatings, transverse bulkheads and heels of pillars.

Plate floors are to be fitted at alternate frames within the region forward of 0.2L from the F.P. Elsewhere, the spacing of the plate floors is not to exceed 3.6 m.

2.6.11.2 The thickness of plate floors for longitudinally framing is to be 10% greater than that required in 2.6.5.1 of this Section, but need not exceed 15 mm, and the thickness of watertight and oiltight floors is to be the same as required in 2.6.6.1 of this Section.

Vertical stiffeners are to be fitted at each longitudinal. The thickness of vertical stiffeners for floors is to be the same as that of the floors and the width of which is to comply with the requirements of 2.6.5.2. In addition, the scantlings of vertical stiffeners for watertight floors are to comply with the requirements of 2.6.6.2 of this Section. Vertical stiffeners are to be attached to the inner bottom and shell longitudinals by welding.

The ratio of thickness to depth of the floors is not to be less than 1/130. Where the double bottom tanks are interconnected with side tanks or cofferdams, the thickness of watertight floors and the stiffeners are to be as required for deep tanks.

2.6.12 Longitudinal framing — bottom longitudinals

2.6.12.1 The spacing of bottom longitudinals is not to be greater than 1 m.

2.6.12.2 The section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = \frac{8.5f}{1.73 - F_b}(d + h_1)sl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinal, in m, but not less than 1.5 m;

d — draught, in m;

f — factor, taken as 0.52 when intermediate vertical struts are fitted, or 1.0 when no intermediate vertical strut is fitted;

F_b — reduction factor, see 2.2.5.6 of this Chapter;

h_1 — see 2.3.1.2 of this Chapter;

K — material factor.

Where the spacing of plate floors is greater than 2.5 m, vertical struts connecting the bottom longitudinals and inner bottom longitudinals may be fitted at the midpoint of the spacing, and the cross sectional area A of the vertical struts is not to be less than the following:

$A = 23.8 + 0.04W$ cm² for $W > 85$ cm³

$A = 0.32W$ cm² for $W \leq 85$ cm³

where: W — section modulus of longitudinals, in cm³.

2.6.12.3 The section modulus of inner bottom longitudinals is to be equal to 85% of that of the bottom longitudinals. In boiler rooms, the thickness of the longitudinals, struts and brackets is to be increased by 2 mm.

2.6.12.4 Where longitudinals pass through non-watertight floors, they are to be welded to the floors and the vertical stiffeners on the floors in way. Where longitudinals are cut in way of watertight floors, they are to be bracketed to the watertight floors. The scantlings of the brackets are to comply with the requirements of 1.2.6 of this PART. Where the length of the ship exceeds 200 m or higher tensile steel is used, the bottom longitudinals are to be continuous in way of watertight floors, or alternative arrangements may be considered.

2.6.13 Longitudinal framing — inner bottom plating and margin plate

2.6.13.1 The thickness of the inner bottom plating is to comply with the requirements of 2.6.9 of this Section. But for the calculation of the thickness of the inner bottom plating within 0.4*L* amidships, the *s* in the formula is to be taken as the spacing of longitudinals, and the value considered may be reduced by 1 mm.

2.6.13.2 The thickness of the margin plate is to comply with the requirements in 2.6.13.1 of this Section and in addition, is to be increased in accordance with the requirements of 2.6.9.3 of this Section.

2.6.13.3 The margin plate is to be provided with brackets at every frame, extending to the adjacent longitudinal, as shown in Figure 2.6.13.3. The edges of the brackets are to be strengthened, and the thickness of the brackets is to be the same as that of floors.

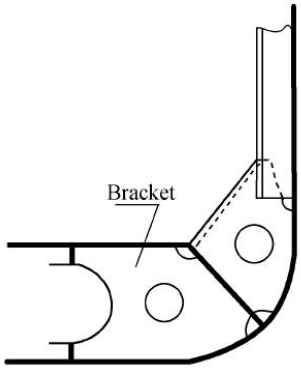


Figure 2.6.13.3

2.6.14 Reinforcement for using fork lift trucks in cargo holds

2.6.14.1 Where fork lift trucks are used for handling cargo in holds, the inner bottom plating and framing are to comply with the relevant requirements of Section 21 of this Chapter for vehicle decks.

2.6.15 Tank side brackets

2.6.15.1 Tank side brackets are to be fitted at every frame and their thickness is to be the same as that of plate floors. Circular lightening holes may be cut in the tank side brackets and the distance from any point of hole edges to the side of brackets is not to be less than 1/3 breadth of the bracket.

2.6.15.2 Tank side brackets are to be flanged or provided with a face plate on the free edge, and the breadth of the flange or face plate is generally to be 10 times the thickness of the bracket.

2.6.15.3 The standard depth and breadth of tank side brackets are to be as follows:

The depth of tank side brackets connecting secondary members is to be equal to 10% of the distance between the inner bottom and nearest deck or 2.2 times the depth of the web of frames, whichever is the greater. The depth of tank side brackets connecting primary members is to be equal to 1.65 times the depth of the web of web frames. The breadth of tank side brackets is to be equal to their depth. The breadth and depth of tank side brackets are to be measured in accordance with Figure 2.6.15.3. Where the inner bottom margin plate of the double bottom is horizontal, vertical stiffeners are to be fitted to the floors under the toes of the brackets (as shown in Figure 2.6.15.3). The requirements for the stiffeners are to be the same as required in 2.6.5.2 of this Section.

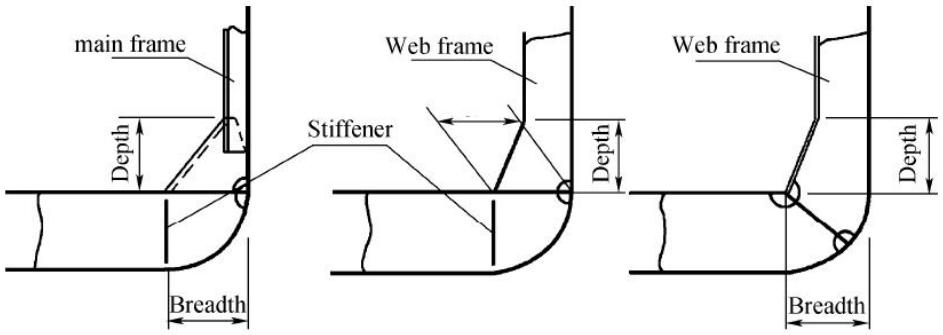


Figure 2.6.15.3

2.6.15.4 Where lap joint is adopted for the connection of tank side brackets to frames, the length of overlap is to comply with the requirements of 2.5.5.3 of this Chapter.

2.6.15.5 Where bottom and sides of the ship are framed longitudinally and no bilge longitudinals are fitted, the transverse strength members or corresponding bilge brackets in way are to have a spacing S not exceeding:

$$S = 8 \times 10^6 \frac{t^2}{Dr}\sqrt{\frac{t}{r}} \quad \text{mm}$$

where: t — thickness of bilge plating, in mm;

D — moulded depth, in m;

r — radius of the bilge, in mm.

Furthermore, a suitable number of intermediate bilge brackets connected to the longitudinals situated at the upper and lower turns of the bilge are to be fitted between the plate floors.

Section 7 SIDE FRAMING

2.7.1 General requirements

2.7.1.1 The maximum spacing of frames or side longitudinals is not to be greater than 1.0 m.

2.7.2 Frames

2.7.2.1 The section modulus W of main frames (except those in fore and after peaks) is not to be less than that obtained from the following formula:

$$W = cc_1 sdl^2 K \quad \text{cm}^3$$

where: s — spacing of frames, in m;

d — draught, in m;

l — span of frames, but in no case is it to be taken as less than $\sqrt{D}$ (D being moulded depth), in m. For frames between collision bulkhead and 0.2L from F.P., it is to be the greatest frame span of the similar structural arrangment in that region:

$$c = \frac{2 + \frac{0.65d}{D}}{1.45 - \frac{\sqrt{D}}{l}}$$

c_1 — coefficient: $c_1 = 1.05$ for $L < 90$ m; $c_1 = 1.00$ for $L \geq 90$ m;

K — material factor.

2.7.2.2 Corrections to the section modulus of main frames:

(1) Where the depth of tank side brackets is less than that required in 2.5.5.1 or 2.6.15.3 of this Chapter, the section modulus of main frames is to be increased by 2.7% of the value required in 2.7.2.1 of this Section for each reduced 100 mm.

(2) Where the arm length of the brackets connecting main frames to beams or deck longitudinals at side is greater than that required in 1.2.6.7 of this PART, the section modulus of main frames may be decreased by 1.3% of the value required in 2.7.2.1 of this Section for each increased 100 mm of difference.

2.7.2.3 Where side stringers are uniformly fitted in compliance with the requirements of 2.7.3.1 of this Section, the section modulus of main frames may be reduced in accordance with the following:

(1) Where one stringer is fitted, the section modulus of main frames may be 1/2 of the value required in 2.7.2.1 or 2.7.2.2 of this Section.

(2) Where two stringers are fitted, the section modulus of main frames may be 2/7 of the value required in 2.7.2.1 or 2.7.2.2 of this Section.

(3) Where three stringers are fitted, the section modulus of main frames may be 1/5 of the value required in 2.7.2.1 or 2.7.2.2 of this Section.

2.7.2.4 The section modulus of the main frames under hatch end beams is not to be less than 1.67 times that of normal main frames as required in this Section.

2.7.2.5 In midship machinery spaces where web frames are not fitted in accordance with 2.7.4.2 of this Section, the section modulus of mains frames in the machinery spaces is to be 50% greater than that normally required.

2.7.2.6 The scantlings of main frames are in no case to be less than those of 'tween decks above, and the main frame section modulus is not to be less than 20 cm^3.

2.7.2.7 The moment of inertial I of main frames is not to be less than that obtained from the following formula:

$$I = 3.2Wl/K \quad cm^4$$

where: W — section modulus of main frames as required in this Section, in cm^3;

l — span of frames, in m, as required in 2.7.2.1 of this Section where fitted with no side stringer, or being the vertical distance measured from the upper edge of floor or top of inner bottom to the side stringer or between side stringers or from the side stringer to the lowest deck at side where fitted with side stringers;

K — material factor.

2.7.2.8 The frames in fore and after peaks are to comply with the following requirements:

(1) The section modulus W and the moment of inertia I of frames below the lowest deck in fore and after peaks are to be respectively not less than the values obtained from the following formulae:

$$W = 4.6sdDK \quad cm^3$$

$$I = 3.5Wl/K \qquad \text{cm}^4$$

where: s — spacing of frames, in m;

d — draught, in m;

D — moulded depth, in m;

L — span of frames, in m, being the vertical distance measured from the upper edge of floor to the side stringer (perforated flat), or distance between side stringers (perforated flats) or from the side stringer (perforated flat) to the lowest deck;

K— material factor.

(2) Where the lowest deck in the fore peak is below 1.0 m above the full-load waterline, the 'tween deck frames fitted from the lowest deck up to 1.0 m above the full-load waterline are also to comply with the requirements of (1) above.

(3) Other 'tween deck frames in the fore peak are also to comply with the requirements of 2.7.2.9 of this Section.

2.7.2.9 The section modulus W of the frames in 'tween decks and superstructures is not to be less than that obtained from the following formula:

$$W = CC_1sdl\sqrt{D}\,K \quad \text{cm}^3$$

where:

s — spacing of frames, in m;

d — draught, in m;

l — span of frame, in m. For frames in 'tween deck space where the actual span is less than 2.6 m, l = 2.6 m is to be taken and for those in superstructures where the actual span is less than 2.3 m, l = 2.3 m is to be taken;

D — moulded depth, in m;

C — coefficient, to be taken as $C = 0.7 + 4\frac{d}{D}$;

C_1 — coefficient, to be determined by the position of frame: C_1 = 1.0 for those in the first 'tween deck below the upper deck; C_1 = 1.1 for those in the second 'tween deck; C_1 = 1.45 for those in the third and lower 'tween decks; C_1 = 0.90 for those in forecastle; C_1 = 0.80 for those in bridge and poop;

K — material factor.

2.7.2.10 The section modulus of the frames under hatch end beams in 'tween deck spaces is not to be less than 1.67 times that of normal 'tween deck frames, as required in this Section.

2.7.2.11 In midship machinery spaces where web frames are not fitted in accordance with 2.7.4.2 of this Section, the section modulus of the 'tween deck frames under the lowest deck above the load waterline is to be 50% greater than that normally required.

2.7.2.12 Where the length of the forecastle or poop exceeds 0.25L, the scantlings of the two frames fitted at the after end of the forecastle or at the fore end of the poop are to be calculated by the formula used for 'tween deck frames located below the upper deck in way of the forecastle or poop.

2.7.2.13 The scantlings of four frames fitted at each end of the bridge are to be calculated by the formula used for 'tween deck frames located below the upper deck in way of the bridge.

2.7.2.14 The end connections of frames are to comply with the following:

(1) The scantlings of brackets connecting beams to upper ends of frames are to comply with 1.2.6 of this PART. Where decks are framed longitudinally, the brackets at the upper end of frames are to be extended to the nearest deck longitudinal and welded to it.
(2) The tank side brackets at the lower ends of main frames are to comply with the relevant requirements in Sections 5 and 6 of this Chapter.
(3) Where 'tween deck frames terminate at lower decks, their lower ends are to be bracketed. The scantlings of the brackets are to be the same as those at the upper end of 'tween deck frames. Where the 'tween deck frames and the frames thereunder are directly attached to the lower deck by welding, the lower end of the 'tween deck frames may not be bracketed.

2.7.3 Side stringers

2.7.3.1 Where side stringers are fitted to support the main frames and 'tween deck frames, the section modulus W and the moment of inertia I of the side stringers are not to be less than those obtained from the following formulae respectively:

$$W = 7.8hbl^2K \quad \text{cm}^3$$
$$I = 2.5Wl/K \quad \text{cm}^4$$

where: b — width of areas supported by the side stringers, in m;
h — vertical distance, in m, measured from the mid-span of side stringer to upper deck at side;
l — span of side stringers, in m;
K — material factor.

2.7.3.2 Brackets are to be fitted at the connection between side stringers and transverse bulkheads, and the requirements of 1.2.7 of this PART are to be complied with. Side stringers and web frames are to be so connected that an adequate continuity of the face plate or flange of side stringers is kept.

2.7.3.3 In transversely framed machinery spaces, side stringers are to be fitted to support main frames where the main frame span exceeds 6 m and their section modulus and moment of inertia are to comply with 2.7.3.1 of this Section and their web depth is not to be less than 2.5 times that of main frames.

2.7.3.4 In transversely framed machinery spaces, an arrangement of intercostal side stringers spaced generally 2.5 m apart may be accepted as an alternative to the side stringers specified in 2.7.3.3 of this Section and their web depth is to be the same as that of main frames, their web thickness t and sectional area A are to be respectively not less than those obtained from the following formulae:

$$t = 0.023L + 6 \quad \text{mm}$$
$$A = (0.14L + 1)K \quad \text{cm}^2$$

where: L — length of ship, in m, to be taken as not greater than 215 m in calculation;
K — material factor.

2.7.4 Transverse framing − web frames

2.7.4.1 The scantlings of web frames supporting side stringers are to be determined by direct calculation based on the assumptions that their both ends are rigidly fixed and that they are subject to concentrated loadings transmitted by side stringers (the considered pressure head being the distance from the mid-span of side stringers to upper deck at side, in m), with the permissible

bending stress being taken as 93.2/K, in N/mm² and the allowable shear stress as 83.4/K, in N/mm².

2.7.4.2 Where machinery spaces are situated aft and the ship's sides are transversely framed, web frames are to be fitted and spaced not more than five frame spaces apart in the machinery spaces, extending from the inner bottom to the upper deck.

2.7.4.3 In the areas of transversely framed machinery spaces, the scantlings of web frames supporting side stringers are to be determined in accordance with 2.7.4.1 of this Section.

2.7.4.4 In the areas of transversely framed machinery spaces, the section modulus W of web frames not supporting side stringers is not to be less than that obtained from the following formulas:

$$W = 5Shl^2K \quad \text{cm}^3 \quad \text{for spaces below the lowest deck}$$

$$W = 3.5Sdl\sqrt{D}\,K \quad \text{cm}^3 \quad \text{for 'tween decks}$$

where: S — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of web frame to upper deck at side;

l — span of web frame, in m;

d — draught, in m;

D — moulded depth, in m;

K — material factor.

2.7.4.5 In the areas of transversely framed machinery spaces, the web depth of web frames is not to be less than 2.5 times the depth of adjacent frames.

2.7.4.6 The end connections of web frames for transverse framing are to comply with the relevant provisions in 2.6.15 and 2.8.7.9 of this Chapter.

2.7.5 Side longitudinals

2.7.5.1 The section modulus W of side longitudinals below the upper deck (including bilge longitudinals) is not to be less than that obtained from the following formula:

$$W = \frac{8.5}{f} hsl^2 K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinals, in m;

f — factor, to be taken in accordance with following two formulae, and to be taken as not greater than 1.077:

$$f = 1.73 - F_d \frac{Z - Z_n}{D - Z_n} \quad \text{for } Z \geq Z_n$$

$$f = 1.73 - F_b \frac{Z_n - Z}{Z_n} \quad \text{for} < Z_n$$

h — design pressure head, to be taken from the following formula:

$$h = 0.26C + d - \frac{Z}{D}(0.06C + d)$$

Z_n — the height of horizontal neutral axis, from base line, of hull cross section, in m;

D — moulded depth, in m;

d — draft, in m;

C — coefficient, see 2.2.3.1 of this Chapter;

F_b, F_d — reduction factors, see 2.2.5.6 of this Chapter;

Z — height of longitudinals from base line, in m;

K — material factor.

2.7.5.2 Within the region between $0.2L$ from the F.P. and the forepeak bulkhead, the section modulus of side longitudinals below the upper deck is to be in accordance with 2.7.5.1 of this Section and also in accordance with 2.7.5.4 of this Section.

2.7.5.3 For machinery spaces situated aft, the section modulus of side longitudinals in the areas of the machinery spaces is to be in accordance with 2.7.5.1 of this Section and in addition, not less than 0.8 times that obtained from the formula in 2.7.5.5.

2.7.5.4 In the forepeak, the section modulus W of side longitudinals is to be taken as not less than that obtained from the following formula:

$$W = 7.5shl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

h —vertical distance, in m, measured from the longitudinal to 3 m above the minimum bow height required by the load line, not less than the vertical distance from the longitudinal to upper deck at side;

l — span of longitudinals, in m, but taken as not less than 1.5 m;

K — material factor.

2.7.5.5 In the aft peak, the section modulus W of side longitudinals is to be taken as not less than that obtained from the following formula:

$$W = 8.5sl^2(h + 0.167D)K \quad \text{cm}^3$$

where:

s — spacing of longitudinals, in m;

l — span of longitudinals, in m, but taken as not less than 1.5 m;

h — vertical distance from the longitudinal to upper deck at side, in m, but not to be less than 3 m;

D — moulded depth, in m, but taken as not greater than 20 m;

K — material factor.

2.7.5.6 The section modulus of side longitudinals (including bilge longitudinals) need not be greater than that of bottom longitudinals with the same spacing.

2.7.5.7 The side longitudinals are to penetrate web frames and the intersections of longitudinal webs and frame webs are to be welded. Where a side longitudinal is cut in way of a transverse bulkhead, brackets are to be fitted at the connection between the longitudinal and the bulkhead, and the brackets are to comply with the relevant provisions in 1.2.6 of this PART.

2.7.6 Longitudinal framing — web frames

2.7.6.1 Where the side is framed longitudinally, web frames supporting side stringers are to be fitted in line with plate floors. In general, the spacing of web frames is not to be greater than 3.6 m for ships of 100 m in length or less, and not greater than $0.006L + 3.0$ m (L being length of ship) for ships more than 100 m in length. In the forepeak and aft peak, the spacing of web frames is not to be greater than 2.5 m for ships of 100 m in length or less, and not greater than 3.5 m for ships of 300 m or over in length. The intermediate values are to be obtained by interpolation.

2.7.6.2 Other than in machinery spaces and forepeak and aft peak, the section modulus W of web frames is not to be less than that obtained from the following formula:

$$W = 10Shl^2K \quad \text{cm}^3$$

where: S — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of the web frame to upper deck at side;

l — span of web frame, in m;

K — material factor.

2.7.6.3 In longitudinally framed machinery spaces, the section modulus W of web frames is not to be less than that obtained from the following formula:

$$W = 10Shl^2K \quad \text{cm}^3 \qquad \text{below the lowest deck}$$

$$W = 4.4Sdl\sqrt{D}\,K \quad \text{cm}^3 \qquad \text{in 'tween decks}$$

where: S — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of the web frame to upper deck at side;

l — span of web frame, in m;

d — draught, in m;

D — moulded depth, in m;

K — material factor.

The web depth of web frames is not to be less than 2.5 times that of the side longitudinal supported by it.

2.7.6.4 In the longitudinally framed forepeak, the section modulus W and the moment of inertia I of web frames are respectively not to be less than those obtained from the following formulae:

$$W = 14Shl^2K \quad \text{cm}^3$$

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: S — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of the web frame to tank top or half of the vertical distance from the mid-span of the web frame to the top of overflow, whichever is the greater;

l — span of web frame, in m;

K — material factor.

Where struts are fitted, the web frames and struts are to comply with the relevant provisions of Section 5 of Chapter 6 of this PART.

2.7.6.5 In the longitudinally framed aft peak, the section modulus W is not to be less than that obtained from the following formula:

$$W = 10Shl^2K \quad \text{cm}^3$$

where: S — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of the web frame to upper deck at side;

l — span of web frame, in m;

K — material factor.

2.7.6.6 The end connections of web frames for longitudinal framing are to comply with the relevant provisions in Sections 6 and 8 of this Chapter and Chapter 5 of this PART.

Section 8 DECK FRAMING

2.8.1 General requirements

2.8.1.1 The design head h of decks is to be determined according to Table 2.8.1.1, and the corresponding design load p is to be calculated by the following formula:

$$p = \frac{9.81h}{\gamma} \quad \text{kPa}$$

where: h — design head, in m, see Table 2.8.1.1 of this Section;

γ — stowage rate, in m^3/t, taken as the standard rate of 1.39 m^3/t.

For decks in deep tanks, the relevant requirements in Section 13 of this Chapter are also to be complied with, and the corresponding design load P is to be calculated by the following formula:

$$p = 9.81\rho h \quad \text{kPa}$$

where: h — design head, in m, see Section 13 of this Chapter;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025 t/m^3.

Design Heads of Decks Table 2.8.1.1

Name and location of deck	Design head h (m)	Permissible cargo load (kPa)
Weather decks (minimum sizes of structural members):		
Forward of 0.075L from F.P.	Primary members: $h_0 + 3$; Secondary members: 1.5 h_0	8.5
Between 0.075L and 0.15L from F.P.	Primary members: $h_0 + 2$; Secondary members: 1.25 h_0	8.5
Aft of 0.15L from F.P.	h_0	8.5
Weather decks (specified cargo load):		
Forward of 0.075L from F.P.	$0.49p + h_0 - 1.2$	p (> 8.5)
Between 0.075L and 0.15L from F.P.	$0.37p + h_0 - 1.2$	p (> 8.5)
Aft of 0.15L from F.P.	$0.14p + h_0 - 1.2$	p (> 8.5)
Cargo decks not exposed to weather	0.14p, but not to be less than mean height H, in m, of 'tween decks	Max (p, 7.06H)
Accommodation decks	1.2	—
Decks for stores	2.0	—
Decks for E.R. platform, workshop and stores	2.6	—
Superstructure decks:		
1st tier	0.90, increased for exposed portion $h_0 - 1.2$	—
2nd tier	0.60, increased for exposed portion $h_0 - 1.2$	—
3rd tier and above	0.45, increased for exposed portion $h_0 - 1.2$	—
Forecastle deck forward of 0.2L from F.P.	Same as weather decks in corresponding locations	—

Notes: ① h_0 in the Table is not to be less than that obtained from the following formula, but it is neither to be less than 1.2 m, nor greater than 1.5 m:

$$h_0 = 1.20 + \frac{2}{1000}\left(\frac{100 + 3L}{D - d} - 150\right) \quad \text{m}$$

where: L — length of ship, in m;
D — moulded depth, in m;
d — draught, in m.

② For ships less than 90 m in length, the design head of primary members within the areas of fore and aft ends of ships may be appropriately reduced, but not less than that of secondary members at the same location.

③ The superstructure deck is defined in 2.17.1.6 of this Chapter.

2.8.2 Deck beams

2.8.2.1 The section modulus W of deck beams is not to be less than that obtained from the following formula:

$$W = (C_1C_2Dd + C_3shl^2)K \quad \text{cm}^3$$

where: C_1 — coefficient, dependent on the number of decks (including bridge, poop decks and engine room platform) at the position of the beam under consideration: C_1 = 2.0 for 1st tier, C_1 = 1.33 for 2nd tier, C_1 = 1.05 for 3rd tier, C_1 = 0.93 for 4th tier and above, C_1 = 1.33 for forecastle deck;

C_2, C_3 — coefficients, see Table 2.8.2.1;

D — moulded depth, in m;

d — draught, in m;

s — spacing of beams, in m;

h — design head, in m, see 2.8.1.1 of this Section;

l — span of beam, in m, to be taken not less than 2 m;

K — material factor.

Coefficients C_2 and C_3 **Table 2.8.2.1**

Location of deck	C_2	C_3
Weather/strength deck or exposed forecastle deck forward of 0.075L from F.P.	0.8	0.54B
Weather/strength deck or exposed forecastle deck between 0.075L and 0.15L from F.P.	0.8	Beams connected to ship side: 0.36B
Weather/strength deck or exposed forecastle deck aft of 0.15L from F.P.	0.54	Beams elsewhere: 0.33B
Short bridge and poop deck where exposed to the weather	0.14	
Cargo decks and other decks (engine room, forepeak tank and aftpeak tank platforms)	0.40	4.0
Accommodation strength decks or lower decks	0.52	4.0

Note: B in the Table is the breadth of ship, in m.

2.8.2.2 The section modulus W of weather deck beams need not be greater than that obtained from the following formula:

$$W = Bshl^2K \quad \text{cm}^3$$

where: B — breadth of ship, in m, to be taken as not greater than 21.5 m;

s, h, l — see 2.8.2.1 of this Section;

K — material factor.

2.8.2.3 The web depth of deck beams is not to be less than 60 mm.

2.8.2.4 The connections between beams and frames are to comply with the requirements in 1.2.6 of this PART.

2.8.2.5 Beams are to pass through deck girders, and they are to be connected to the girder web by welding. Where beams are to be cut in way of the web of hatch side girders or deck girders, the beams are to be bracketed to the girders and the scantlings of brackets are to comply with the provisions in 1.2.6 of this PART. The brackets are to be extended to the face plate of deck girders.

2.8.3 Transverse framing — deck girders

2.8.3.1 For weather strength deck forward of 0.075*L* from F.P., the spacing of deck girders supporting beams is not to be greater than 3.6 m. For the upper and lower decks after the aft peak bulkhead, the spacing of deck girders supporting beams is not to be greater than 3 m.

2.8.3.2 The section modulus *W* of deck girders supporting beams is not to be less than that obtained from the following formula:

$$W = 4.75bhl^2K \quad \text{cm}^3$$

where: *b* — mean width, in m, of deck area supported by deck girders;

h — design head of deck, in m, see 2.8.1.1 of this Section;

l — span of deck girder, in m;

K — material factor.

2.8.3.3 Where deck girders arranged to support beams are subject to a concentrated load, their section modulus *W* is to be not less than that obtained from the following formula:

$$W = 0.102cPlK \quad \text{cm}^3$$

where: *P* — concentrated load, in kN;

l — span of deck girder, in m;

c — coefficient, to be obtained from Table 2.8.3.3 where *a* is the distance, in m, between the application point of concentrated load *P* and the farther one of two supports of the girder;

K — material factor.

Coefficient *c* **Table 2.8.3.3**

a/l	0.94	0.90	0.85	0.80	0.75	0.70	0.60	0.50
c	1.44	3.36	5.68	7.36	8.64	9.20	9.60	10

2.8.3.4 Where deck girders arranged to support beams are subject to two or three point loads, their section modulus *W* is to be determined by direct calculations assuming fixed ends and using an allowable bending stress of 124/*K*, in N/mm².

2.8.3.5 The section moment of inertia *I* of deck girders is not to be less than that obtained from the following formula:

$$I = 2Wl/K \quad \text{cm}^4$$

where: *W* — section modulus of deck girders required in this Section, in cm³;

l — span of deck girder, in m;

K — material factor.

2.8.3.6 The web depth of deck girders is not to be less than 1.6 times the depth of cut-outs for the passage of beams. The cut-outs in deck girders are to be designed to minimize the creation of stress concentration on the web. The web thickness of deck girders is not to be less than 1% of the web depth plus 4 mm.

2.8.3.7 Holes cut for the passage of pipes or cables in the web of deck girders are to have a depth not greater than 25% of that of the web and a width not exceeding 60% of the spacing of beams or

the web depth, whichever is the greater, otherwise compensation is required. Normally the compensation is achieved by fitting doublers, spigots or insert plates for strengthening, and the cross-sectional area of such strengthening pieces is to be not less than that lost from the web due to openings. The strength level of the material of strengthening pieces is not to be lower than that of the web material. The edges of holes are not to be less than 40% of the web depth from the face plate of girders. The edges of the holes are to be smooth and well rounded. The holes are not to be concentrated in the adjacent frame spaces. No holes are to be cut on the girder web within 200 mm from the toe of girder brackets.

2.8.3.8 The ends of deck girders are to be connected to transverse bulkheads in accordance with the relevant provisions in 1.2.7 of this PART. For deck girders contributing to the longitudinal strength, special attention is to be paid to the longitudinal structural continuity at transverse bulkheads.

2.8.4 Transverse framing — deck transverses

2.8.4.1 For deck transverses supporting deck girders, the scantlings are to be determined by direct calculations assuming fixed ends and the function for sustaining concentrated loads transmitted by deck girders and using an allowable bending stress of $124/K$, in N/mm².

2.8.4.2 The section moment of inertia I of deck transverses supporting deck girders is not to be less than that obtained from the following formula:

$$I = 2Wl/K \quad \text{cm}^4$$

where: W — section modulus of deck transverses, in cm³, obtained according to 2.8.4.1 of this Section;

l — span of deck transverse, in m;

K — material factor.

2.8.4.3 The thickness and cutouts of the web of deck transverses supporting deck girders are to comply with the provisions in 2.8.7.7 and 2.8.7.8 of this Section.

2.8.4.4 The connections between deck transverses supporting deck girders and frames or web frames or longitudinal bulkheads are to comply with the provisions of 2.8.7.9 of this Section.

2.8.5 Deck longitudinals

2.8.5.1 The section modulus W of weather/strength deck longitudinals is not to be less than the greater obtained from the following formulae:

$$W = c_1 shl^2 K \quad \text{cm}^3$$

$$W = (c_2 sh + c_3 sl^2 L^2 \times 10^{-4})K \quad \text{cm}^3$$

where:

s — spacing of longitudinals, in m;

h — design head of deck, in m, to be determined according to 2.8.1.1 of this Section, but outside the line of deck openings within $0.4L$ amidships:

$$h \geq \frac{22.6L}{1780 - L};$$

l — span of longitudinal, in m, to be taken as not less than 2 m;

c_1, c_2, c_3 — coefficients, to be determined according to Table 2.8.5.1;

L — length of ship, in m, L need not be taken as greater than 200 m;

K — material factor.

Coefficients c_1, c_2, c_3 **Table 2.8.5.1**

Item	Location of deck longitudianl	Region	c_1	c_2	c_3
1	Forward of 0.075L from F.P.		12.5	63.5	7.8
2	Between 0.075L ~ 0.15L from F.P.		12.5	57	7.2
3	At 0.15L from F.P.	Outside the line of openings	9	48.5	6.2
		Inside the line of openings	7.5	40	5.5
4	Between 0.15L ~ 0.3L from F.P.	Outside the line of openings	See note		
		Inside the line of openings	7.5	40	5.5
5	0.4L amidships	Outside the line of openings	10.5	–	–
		Inside the line of openings	7.5	40	5.5
6	Between 0.075L ~ 0.3L from A.P.	Outside the line of openings	See note		
		Inside the line of openings	7.5	40	5.5
7	Aft of 0.07L from A.P.		7.5	40	5.5

Note: The section modulus W of deck longitudinals in way of the region may be determined after tapering the section moduli of amidships and end deck longitudinals.

2.8.5.2 The section modulus W of cargo deck longitudinals (including longitudinals of decks/platforms within the engine room, fore and aft peaks) is not to be less than the following:

$$W = (2.5shl^2 + 0.6sL)K \quad \text{cm}^3 \text{ for } L \geq 90 \text{ m}$$

$$W = 5shl^2K \quad \text{cm}^3 \text{ for } L < 90 \text{ m}$$

where: s, h, l, L, K — see those in 2.8.5.1 of this Section.

2.8.5.3 The section modulus W of accommodation and superstructure deck longitudinals is not to be less than the following:

$$W = (2.5shl^2 + 0.52sL)K \quad \text{cm}^3 \text{ for } L \geq 90 \text{ m}$$

$$W = 4.4shl^2K \quad \text{cm}^3 \text{ for } L < 90 \text{ m}$$

where: s, h, l, L, K — see those in 2.8.5.1 of this Section.

2.8.5.4 The web depth of deck longitudinals is in no case to be less than 60 mm.

2.8.5.5 The deck longitudinals outside the line of deck openings are to pass through deck transverses and to be connected to the deck transverse webs by welding. Where the deck longitudinals are cut in way of the web plates of hatch end beams or deck transverses (only for those inside the line of deck openings or at the ship's ends), brackets are to be fitted at the connection between deck longitudinals and hatch end beams or deck transverses and the scantlings of the brackets are to comply with the relevant provisions in 1.2.6 of this PART. The brackets are to be extended to the face plate of hatch end beams or deck transverses along the web plates of hatch end beams or deck transverses.

2.8.5.6 Where deck longitudinals are cut in way of transverse bulkheads, brackets are to be fitted at the connection between deck longitudinals and transverse bulkheads and the scantlings of the brackets are to comply with the relevant provisions in 1.2.6 of this PART. Where the ship's length exceeds 200 m or higher tensile steel is adopted, the deck longitudinals outside the line of deck openings are to be continuous through the transverse bulkheads, but alternative arrangements may be considered.

2.8.5.7 The deck longitudinals outside the line of deck openings are not to be terminated at the same transverse section and their ends are to be suitably shifted from one another. These ends are to extend to the adjacent transverse members.

2.8.6 Longitudinal framing — deck girders

2.8.6.1 For deck girders supporting deck transverses, the scantlings are to be determined by direct calculations assuming fixed ends and the function for sustaining concentrated loads transmitted by deck transverses and using an allowable bending stress of $124/K$, in N/mm^2.

2.8.6.2 The section moment of inertia I of deck girders supporting deck transverses is not to be less than that obtained from the following formula:

$$I = 2Wl/K \quad \text{cm}^4$$

where: W — section modulus of deck girders, in cm^3, obtained according to 2.8.6.1 of this Section;

l — span of deck girder, in m;

K — material factor.

2.8.6.3 The thickness and cutouts of the web of deck girders supporting deck transverses are to comply with the relevant provisions in 2.8.3.6 and 2.8.3.7 of this Section respectively.

2.8.6.4 The connections between deck girders supporting deck transverses and transverse bulkheads are to comply with the relevant provisions of 2.8.3.8 of this Section.

2.8.7 Longitudinal framing — deck transverses

2.8.7.1 Where the deck is framed longitudinally, deck transverses supporting the deck longitudinals are to be fitted in line with plate floors. In general, the spacing of deck transverses is not to be greater than 3.6 m for ships of 100 m in length or less and not greater than $0.006L + 3.0$ m (L being length of ship) for ships more than 100 m in length, In the forepeak and aft peak, the spacing of deck transverses is not to be greater than 2.5 m for ships of 100 m in length or less and not greater than 3.5 m for ships of 300 m or over in length. The intermediate values are to be obtained by interpolation.

2.8.7.2 In the machinery spaces and aft peak tank, deck transverses supporting deck longitudinals are to be fitted in frames spaces of web frames.

2.8.7.3 The section modulus W of deck transverses supporting deck longitudinals is not to be less than that obtained from the following formula:

$$W = 5Shl^2K \quad \text{cm}^3$$

where: S — spacing of deck transverses, in m;

h — design head of deck, in m, to be determined according to 2.8.1.1 of this Section;

l — span of deck transverses, in m;

K — material factor.

2.8.7.4 The section modulus of deck transverses in single deck ships is to be 15% greater than that obtained from the formula in 2.8.7.3 of this Section.

2.8.7.5 Where the deck transverses supporting deck longitudinals are subject to concentrated loads, their increased section modulus may be determined by calculations in accordance with the requirements for deck girders in 2.8.3.3 or 2.8.3.4 of this Section.

2.8.7.6 The section moment of inertia I of deck transverses supporting deck longitudinals is not to be less than that obtained from the following formula:

$$I = 2Wl/K \quad \text{cm}^4$$

where: W — section modulus of deck transverses, in m³, as required in this Section;

l — span of deck transverses, in m;

K — material factor.

2.8.7.7 The web depth of deck transverses is not to be less than 1.6 times the depth of cut-outs for the passage of deck longitudinals. The cutouts in deck transverses are to be designed to minimize the creation of stress concentration on the web. The web thickness of deck transverses is not to be less than 1% of the web depth plus 4 mm.

2.8.7.8 Holes cut for the passage of pipes or cables in the web of deck transverses are to have a depth not greater than 25% of that of the web and a width not exceeding 60% of the spacing of deck longitudinals or the web depth, whichever is the greater, otherwise compensation is required. Normally the compensation is achieved by fitting doublers, spigots or insert plates for strengthening, and the cross-sectional area of such strengthening pieces is to be not less than that lost from the web due to openings. The strength level of the material of strengthening pieces is not to be lower than that of the web material. The edges of holes are not to be less than 40% of the web depth from the face plate of deck transverses. The edges of the holes are to be smooth and well rounded. The holes are not to be concentrated in the spacings of adjacent longitudinals. No holes are to be cut on the web of deck transverses within 200 mm from the bracket toe of deck transverses.

2.8.7.9 The ends of deck transverses are to be bracketed to frames or web frames or longitudinal bulkheads, and the scantlings of brackets are to comply with the relevant provisions in 1.2.7 of this PART. Where the connection between deck transverses and web frames or longitudinal bulkhead vertical webs is designed as an integral structure, a ring system is generally to be formed and connecting brackets are to have the form of an circular arc with a radius generally not less than the web depth of deck transverses or web frames or longitudinal bulkhead vertical webs, whichever is the smallest. The brackets are to be provided with a face plate to connect the face plate of deck transverses and that of web frames or longitudinal bulkhead vertical webs, and the scantlings of the face plate are to be the same as those of the face plate of deck transverses.

2.8.8 Deck hatch side girders

2.8.8.1 Where weather deck hatch side girders (including weather deck hatch side coamings) act as deck girders and are supported at both ends of the hatchway, their section modulus W and section moment of inertia I are not to be less than those obtained from the following formulae respectively:

$$W = 7hbl^2K \quad \text{cm}^3$$

$$I = 2.6Wl/K \quad \text{cm}^4$$

where: h — design head of deck, in m, see 2.8.1.1 of this Section;

b — mean width, in m, of deck area supported by deck hatch side girders;

l — span of deck hatch side girder, in m;

K — material factor.

2.8.8.2 The section modulus W and section moment of inertia I of 'tween deck hatch side girders are not to be less than those obtained from the following formulae respectively:

$$W = 5.2hbl^2K \quad \text{cm}^3$$

$$I = 2Wl/K \quad \text{cm}^4$$

where: h — design head of deck, in m, see 2.8.1.1 of this Section;

b — mean widdth, in m, of deck area supported by 'tween deck hatch side girders;

l — span of 'tween deck hatch side girder, in m;

K — material factor.

2.8.8.3 Where 'tween deck hatch side girders are subject to concentrated loads, the section modulus is to be increased to 1.1 times that obtained according to 2.8.3.3 or 2.8.3.4 of this Section.

2.8.8.4 The depth of the web of deck hatch side girders below deck is not to be less than that of the beam web to which it is connected.

2.8.8.5 The thickness of the web of deck hatch side girders is not to be less than 1% of its depth plus 4 mm. The thickness and structure of hatch coamings are to comply with the requirements of 2.20.3.2 of this Chapter.

2.8.8.6 In the calculation of the section modulus and section moment of inertia of deck hatch side girders (including hatch coamings), the upper edge of the horizontal face plate (excluding holes in the face plate) of hatch coamings may be included; or only the upper edge of the horizontal stiffener is to be included if no horizontal face plate is fitted.

2.8.8.7 A gradual transition in depth is to be made for the extension of deck hatch side girders.

2.8.8.8 Where the deck is framed longitudinally, deck hatch side girders are to be bracketed to deck transverses. Where the web depth of deck hatch side girders below deck is the same as that of deck transverses, the girders and transverses are to be directly connected. Where the spacing of deck transverses is greater than two frame spaces, an additional tripping bracket is to be fitted between the transverses. This tripping bracket is to extend to the face plate of the deck hatch side girder and to the adjacent deck longitudinals. The thickness of the bracket is to be the same as that of the web plate of adjacent deck transverses, and the flange or face plate of the bracket is to comply with the provisions in 1.2.6.6 of this PART.

2.8.8.9 Where the deck is framed transversely, a bracket is to be fitted at the connection between each beam and deck hatch side girders. These brackets are to extend to the face plate of deck hatch side girders, and the scantlings of the brackets are to comply with the provisions in 1.2.6 of this PART.

2.8.9 Hatch end beams

2.8.9.1 Hatch end beams are to be fitted in accordance with the following requirements:

(1) Where a pillar complying with the requirements of Section 10 of this Chapter is fitted at each corner of the hatchway (i.e. hatch end beams do not support hatch side girders), the section modulus of hatch end beams is to meet the requirements of 2.8.2.1 of this Section, but in this case, s in the formula is to be the actual width of deck area supported by hatch end beams.

(2) Where hatch end beams support the full load of hatch side girders, pillars are fitted below the beams at the longitudinal centerline of deck and deck longitudinal girders or longitudinal bulkheads are also fitted at the longitudinal centerline, hatch end beams are to be continuous within the breadth of ship and their section modulus W and section moment of inertia I are not to be less than those obtained from the following formulae respectively:

$$W = 4.6chAlK \quad \text{cm}^3$$

$$I = 3Wl/K \quad \text{cm}^4$$

where: l — span of hatch end beams, in m;

K — material factor;

A — load area, in m^2, to be determined according to the following conditions:

① Where the deck is framed longitudinally and the extension of hatch side girders supports one or more deck transverses, see Figure 2.8.9.1(1):

$$A = F_1 + 2F_3 + F_4 + F_5$$

② Where the deck is framed longitudinally and the extension of hatch side girders does not support any deck transverse, see Figure 2.8.9.1(2):

$$A = F_1 + F_2 + F_3$$

③ Where the deck is framed transversely without additional girders, see Figure 2.8.9.1(3):

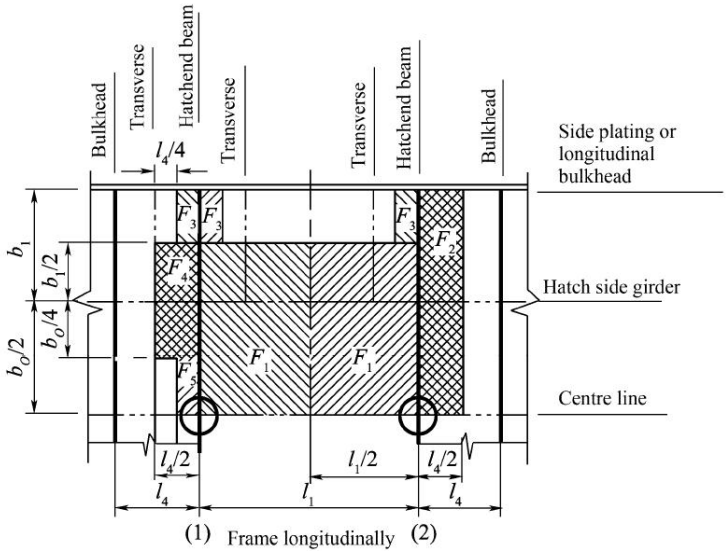
$$A = F_1 + F_4$$

④ Where the deck is framed transversely and with fitted with additional girders, see Figure 2.8.9.1(4):

$$A = F_1 + F_4;$$

h — design head of deck, in m, see 2.8.1.1 of this Section;

c — coefficient, to be taken according to the distance a between the hatch side girder and the longitudinal centreline: c = 1.6 for a ≥ l/2 (l being span of hatch end beams), c = 1.5 for a ≤ l/3, and c is to be obtained by interpolation for l/3 < a < l/2.



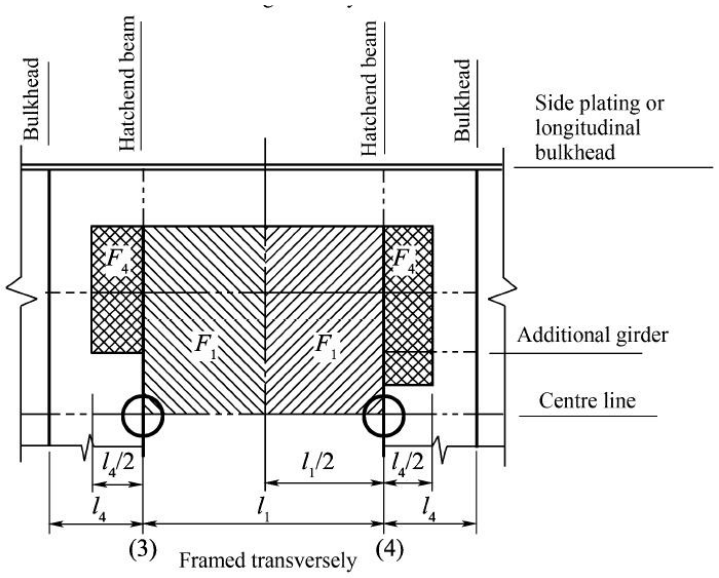


Figure 2.8.9.1

2.8.9.2 The connections between hatch end beams and frames or web frames or longitudinal bulkheads are to comply with the requirements of 2.8.7.9 of this Section.

Section 9 CANTILEVERS

2.9.1 General requirements

2.9.1.1 Cantilevers covered by this Section are the deck transverses extending from ship side to the deck hatch side girders supported by them. The structural configuration of cantilevers and their supporting frames is as shown in Figure 2.9.1.1.

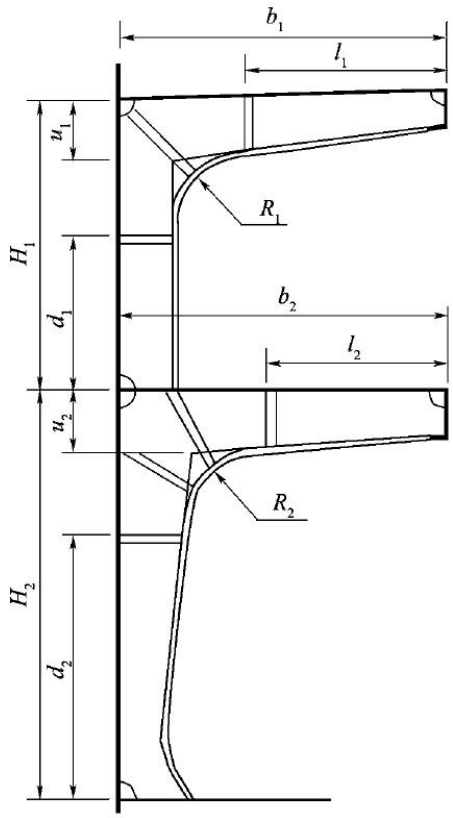


Figure 2.9.1.1

2.9.1.2 The considered sections of the cantilever and its supporting frame are to be the corresponding sections at the toe of the connecting bracket (i.e. at the tangential point of the arc of the bracket).

2.9.1.3 The requirements of this Section are applicable to ships having cantilevers approximately equally arranged, hatch side girders supported by cantilevers and uniform loading on decks and hatch covers.

2.9.2 Cantilevers

2.9.2.1 The section modulus W_i of the considered section of cantilevers is not to be less than the respective values given below:

(1) Where cantilevers are not supported by hatch side girders:

$$W_i = 30.6Sl_i(l_i\, h_1 + b_0\, h_2)K \quad \text{cm}^3$$

where: S — load width of cantilever, in m;

l_i — span of cantilever, in m;

b_0 — width of hatch, in m;

h_1 — design head of deck outside the line of hatch openings, in m, see 2.8.1.1 of this Chapter;

h_2 — design head of deck or hatch cover inside the line of hatch openings, in m, see 2.8.1.1 or 2.20.2 of this Chapter;

K — material factor.

(2) Where both ends of hatch side girders are fitted with the hatch end beams complying with the requirements of 2.8.9 of this Chapter and cantilevers are partially supported by hatch side girders:

$$W_i = W_0 - G \quad \text{cm}^3$$

where: $W_0 = 30.6\, S\, l_i(l_i\, h_1 + b_0\, h_2)K$ cm^3

where: S, l_i, b_0, h_1, h_2 — see (1) above;

$$G = \frac{8l_i}{(n+1)l_h}(W_h + W_P) \quad \text{cm}^3$$

where: W_h — section modulus of the hatch side girder derived from 2.8.8.1 or 2.8.8.2 of this Chapter, in cm³, and the span of cantilevers taken as the spacing of cantilevers;

W_p — section modulus of deck girders on the extension line of hatch side girders, in cm³, derived from 2.8.3 of this Chapter, and W_p is to be taken not greater than W_h;

n — number of cantilevers between hatch end beams;

l_h — length of hatch, in m;

l_i — span of cantilevers, in m.

(3) Where both ends of hatch side girders are supported by transverse bulkheads and cantilevers are partially supported by hatch side girders:

$$W_i = \frac{n+1}{n}\left[0.5\left(1+\frac{1}{Q}\right)W_o - QG - (1-Q)E\right] \quad \text{cm}^3$$

where: W_o, G, n — see (2) above;

$$Q = \frac{l_h}{l_b};$$

where: l_h, l_b — See Figure 2.9.2.1(1) of this Section;

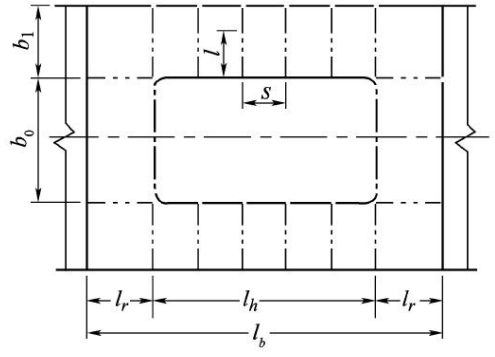
$E = \frac{4}{n+1}(W_1 + W_2)$ in cm³ for hatch end beams the midpoint of which is not supported by pillars, etc., or

$E = \frac{4}{n+1}\left[(W_1 + W_2) + \frac{2l_i}{b_o}(W_2 + W_3)\right]$ in cm³, for hatch end beams the midpoint of which is supported by pillars or bulkheads;

where: W_1, W_2 and W_3 are section moduli of hatch end beams, in cm³, as shown in Figure 2.9.2.1(2), W_2 is to be taken as the lesser of the section moduli of hatch end beams at both sides of the line of hatch openings;

l_i, b_0 — see Figure 2.9.2.1(1) of this Section.

And in addition, the section modulus W_i of the cantilever is not to be less than that obtained from (2) above.



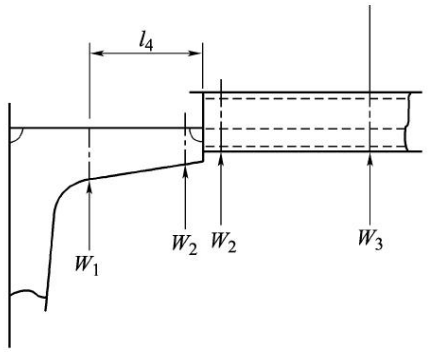


Figure 2.9.2.1(1) **Figure 2.9.2.1(2)**

(4) Where loading is concentrated at hatch side girders and cantilevers are partially supported by hatch side girders:

$$W_i = W'_0 - \frac{3.5 l_i}{S} W_h \quad \text{cm}^3$$

where: W'_0 — section modulus, in cm³, of the cantilever when subjected to concentrated loading and uniform loading, with no support from hatch side girders. In the calculation, the cantilever is to be assumed fixed at one end, and the allowable bending stress is to be taken as 115.2 N/mm²;

l_i, S, W_h — see (1) and (2) above.

And in addition, the section modulus W_i of the cantilever is not to be less than those obtained from (2) and (3) above.

2.9.2.2 The moment of inertia I of the cantilever at the section under consideration is not to be less than that obtained from the following formula:

$$I = 9\ W_i l_i / K_i \quad \text{cm}^4$$

where: W_i — section modulus of cantilevers, in cm³, derived from the formula in 2.9.2.1 of this Section;

l_i — span of cantilevers, in m;

K_i — material factor.

2.9.2.3 The net sectional area A_x of the cantilever web is not to be less than that obtained from the following formula:

$$A_x = 0.43\ S\left(2 h_i X + b_o h_2 + \frac{0.283}{S} P_c\right)\frac{W_i}{W_o} \quad \text{cm}^2$$

where: S, b_0, h_1, h_2 — see 2.9.2.1(1) of this Section;

X — distance, in m, between the section of cantilever under consideration and the hatch side girder;

W_o — see 2.9.2.1(2) of this Section, in cm³;

W_i — section modulus of cantilevers, in cm³, as required in 2.9.2.1 of this Section;

P_c — concentrated loading, in kN, applied on the hatch side girder for calculation in accordance with 2.9.2.1(4) of this Section. P_c = 0, if no concentrated loading is applied.

2.9.3 Supporting frames

2.9.3.1 The section modulus W_{fi} at the considered section of supporting frames is not to be less than that obtained from the following formula:

$$W_{fi} = \frac{d_i}{H_i}\left[\frac{b_i}{l_i} W_i - W_{f(i-1)}\right] \quad \text{cm}^3$$

where: d_i, H_i, b_i, l_i — see Figure 2.9.1.1 of this Section;

$W_{f(i-1)}$ — section modulus of supporting frames of the cantilevers on the $i-1$ tier deck, in cm³, and $W_{f(i-1)} = 0$ for the upper deck;

W_i — section modulus of cantilevers, in cm³, as required in 2.9.2.1 of this Section;

i — tier sign of decks, i = 1 for upper deck, i = 2 for 2nd tier deck and so on.

2.9.3.2 The scantlings of the supporting frames of the lower deck are, in general, not to be less than those of the supporting frames of the 'tween deck above.

2.9.4 Structural requirements

2.9.4.1 Cantilevers and supporting frames are to be connected by brackets. The radius of the arc of the bracket is not to be less than u_i. The sectional area of the face plate and the web thickness of the bracket are not to be less than those of the larger one of connected members. Tripping brackets are to be fitted at the toes of the brackets (i.e. in way of the considered section of the cantilever and supporting frame), and an adequate number of stiffeners is to be fitted to the web connecting the bracket. See Figure 2.9.1.1.

2.9.4.2 Where the deck is framed longitudinally, cantilevers are to be provided with tripping brackets in accordance with the requirements of 1.2.5.4 of this PART; where the deck is framed transversely, the tripping brackets of cantilevers are to be generally spaced 3 m apart.

2.9.4.3 The minimum thickness of the web plate of cantilevers and supporting frames is not to be less than 1% of the web depth plus 4.5 mm. Where the web depth is greater than 700 mm, vertical stiffeners are to be fitted and spaced not greater than 1.5 times the web depth apart.

2.9.4.4 The web depth and the sectional area of face plates of cantilevers and supporting frames may be gradually tapered from the considered section to the ends, but the minimum web depth at ends is not to be less than 50% of the web depth at the considered section, and the sectional area of face plates at ends is not to be less than 60% of that at the considered section. Longitudinals passing through cantilevers and supporting frames are, in addition, to comply with the relevant requirements of 2.8.7.7 of this Chapter.

2.9.4.5 The effective area of the attached plating of cantilevers and supporting frames is to be calculated according to the requirements of 1.2.2.1 of this PART.

2.9.4.6 Where cantilevers and supporting frames consist of two or three combined members having a T-shaped cross section, they are to be regarded as a single cantilever, and the section modulus of such combined cantilevers is to be determined according to 2.9.2.1 of this Section, and the individual modulus of each cantilever is then determined by dividing this modulus by the actual number of cantilevers.

2.9.4.7 The supporting frames in holds are to be securely connected to the inner bottom by brackets. Plate floors or other stiffening arrangements are to be provided in the double bottom in line with cantilevers and supporting frames.

2.9.4.8 The web depth of hatch side girders below the deck is in general not to be less than that of the web plate at the end of cantilevers. Cantilevers and hatch side girders are to be securely connected with each other.

Section 10 PILLARS

2.10.1 Load supported by pillars

2.10.1.1 The load P supported by the pillar is to be calculated according to the following formula:

$$P = 7.06abh + P_0 \quad \text{kN}$$

where: a — length of deck area supported by the pillar, in m, as shown in Figure 2.10.1.1;

b — mean width of deck area supported by the pillar, in m, as shown in Figure 2.10.1.1;

h — design head of the deck supported by the pillar, in m, see 2.8.1.1 of this Chapter;

P_0 — load transmitted from the pillar above, in kN.

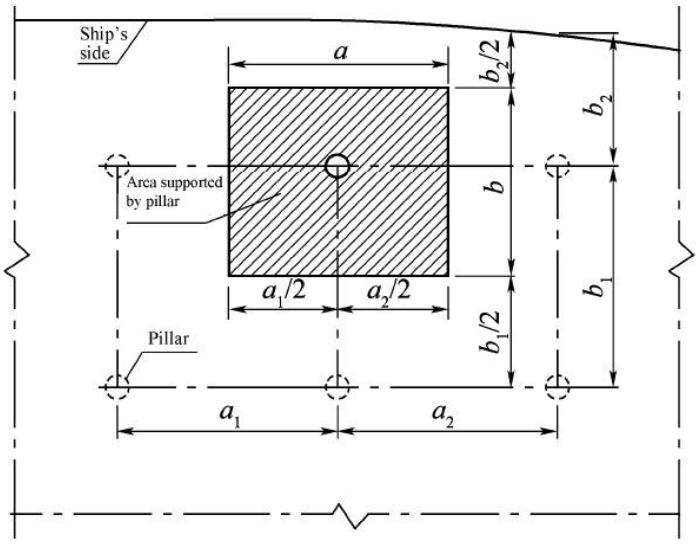


Figure 2.10.1.1

2.10.2 Cross-sectional area of pillars

2.10.2.1 The cross-section area A of pillars is not to be less than that obtained from the following formula:

$$A = \frac{KP}{12.26 - 5.10\dfrac{l}{r\sqrt{K}}} \quad \text{cm}^2$$

where: P — see 2.10.1.1 of this Section;

l — the effective length of pillars, in m, to be taken as 0.8 times the whole length of pillars;

r — minimum radius of gyration of the cross section of pillars, in cm;

K — material factor, but it is not to be taken less than 0.72.

2.10.3 Minimum wall thickness of pillars

2.10.3.1 The wall thickness t of tubular pillars is not to be less than the following:

$$t = \frac{P}{0.392d_p - 4.9l} \quad \text{mm}$$

$$t = \frac{d_p}{40} \quad \text{mm}$$

where: P — see 2.10.1.1 of this Section;

l — see 2.10.2.1 of this Section;

d_p — mean diameter of tubular pillars, in mm.

The minimum wall thickness of tubular pillars is to be 5 mm for ship's length $L < 60$ m; 6 mm for 60 m $\leq L <$ 90 m and 7 mm for $L \geq 90$ m.

2.10.3.2 The built or rolled-section pillars are to comply with the following requirements:

(1) The wall thickness t of hollow rectangular pillars or the web thickness t of I-shaped or channel-section pillars is not to be less than the lesser of the following:

$$t = \frac{br}{60l} \quad \text{mm}$$

$$t = \frac{b}{55} \quad \text{mm}$$

where: b — length of hollow rectangular pillars or web depth of I-shaped or channel-section pillars, in mm;

l, r — see 2.10.2.1 of this Section.

The minimum wall thickness of hollow rectangular pillars or the minimum web thickness of I-shaped or channel-section pillars is not to be less than 5 mm for ship's length $L < 60$ m, 6 mm for 60 m $\leq L <$ 90 m and 7 mm for $L \geq 90$ m.

(2) The side thickness t of angular pillars and the face plate thickness t of channel-section pillars are not to be less than the lesser of the following:

$$t = \frac{br}{20l} \quad \text{mm}$$

$$t = \frac{b}{18} \quad \text{mm}$$

where: b — side length of angular pillars or face plate breadth of channel-section pillars, in mm;

l, r — same as defined in 2.10.2.1 of this Section.

(3) The thickness t of face plate of I-shaped pillars is not to be less than the lesser of the following:

$$t = \frac{br}{40l} \quad \text{mm}$$

$$t = \frac{b}{36} \quad \text{mm}$$

where: b — breadth of face plate of I-shaped pillars, in mm;

l, r — same as defined in 2.10.2.1 of this Section.

2.10.4 Strengthening of structures at heads and heels of pillars

2.10.4.1 The structures at the heads and heels of pillars are to be so arranged that loads are reasonably supported and transmitted. Tubular and hollow rectangular pillars are to be attached at their heads to plates supported by efficient brackets. Longitudinal and transverse brackets are to be fitted at the heads and heels of the built or rolled-section pillars. Doubler or insert plates are to be fitted below pillars.

2.10.4.2 Pillars are to be fitted on plate floors or girders, and these plate floors or girders are to be fitted with vertical stiffeners. Widely spaced pillars are to be fitted at the intersection of plate floors and girders and if they are not fitted at the intersection, partial floors or girders are to be fitted below such pillars. Manholes are not to be cut in the floors and girders below pillars.

2.10.4.3 Where pillars are fitted on a shaft tunnel or any weak framing, structural strengthening is required in way of the pillars.

2.10.4.4 For pillars fitted inside ballast tanks or other tanks, attention is to be given to the effects of possible tensions.

2.10.4.5 Tubular or hollow rectangular pillars are not to be used inside oil tanks.

Section 11 NON-WATERTIGHT PILLAR BULKHEADS

2.11.1 General requirements

2.11.1.1 The minimum thickness of bulkhead plating is to be 7 mm in lower holds and 6 mm in 'tween decks and where the ship's length is less than 90 m, the minimum thickness is to be 5 mm.

2.11.1.2 The maximum spacing of bulkhead stiffeners is to be 1,500 mm.

2.11.1.3 The sectional area A of bulkhead stiffeners (including attached plating not exceeding 600 mm in width), which support beams, longitudinals, girders, transverses, etc., is not to be less than the following:

$$A = \frac{KP}{12.26 - 5.1\frac{l}{r\sqrt{K}}} \quad \text{cm}^2 \quad \text{for } \frac{s}{t} \leq 80$$

$$A = \frac{KP}{4.86 - 1.475\frac{l}{r\sqrt{K}}} \quad \text{cm}^2 \quad \text{for } \frac{s}{t} \geq 120$$

A is to be obtained by interpolation for $80 < \frac{s}{t} < 120$

where: P, r — see 2.10.2.1 of this Chapter;

l — span of stiffeners, in m;

s — spacing of stiffeners, in mm;

t — thickness of bulkhead plating, in mm;

K — material factor, to be taken not less than 0.72.

2.11.1.4 The minimum web depth of stiffeners is to be 150 mm in lower holds and 100 mm in 'tween decks and where the ship's length is less than 90 m, the minimum depth is to be 100 mm and 75 mm respectively.

Section 12 WATERTIGHT BULKHEADS

2.12.1 General requirements

2.12.1.1 Watertight bulkheads are to comply with the requirements of this Section and in addition, the relevant requirements of Section 12, Chapter 1 of this PART.

2.12.1.2 The total number of transverse watertight bulkheads is, in general, not to be less than that given in Table 2.12.1.2. For ships over 190 m in length, this number is to be determined by direct calculation.

Total Number of Transverse Watertight Bulkheads **Table 2.12.1.2**

Ship's length / Ship type	$L \leq 60$	$60 < L \leq 85$	$85 < L \leq 105$	$105 < L \leq 125$	$125 < L \leq 145$	$145 < L \leq 165$	$165 < L \leq 190$

Machinery amidships	4	4	5	6	7	8	9
Machinery aft	3	4	5	6	6	7	8

2.12.1.3 Transverse watertight bulkheads are to be fitted in accordance with the following requirements:

(1) All transverse watertight bulkheads are to extend to the bulkhead deck, except collision bulkheads and after peak bulkheads.

(2) The bulkheads in the holds are to be spaced at uniform intervals. Where the length of a hold is greater than 0.15*L* or 30 m, whichever is the greagter, transverse structures are to be strengthened and relevant supporting documents are to be submitted.

(3) Where it is impracticable for the arrangement of transverse watertight bulkheads to comply with Table 2.12.1.2 due to the requirements of a special trade, one or more of these bulkheads may be dispensed with, subject to suitable structural compensation and demonstration by direct calculation that the transverse strength is adequate.

2.12.1.4 Where the bulkheads form the boundaries of deep tanks, the bulkhead structures are also to satisfy the requirements of Section 13 of this Chapter for the deep tank bulkheads.

2.12.1.5 The bulkheads may be of the plane, symmetrically corrugated or double-plated type.

2.12.2 Collision bulkhead

2.12.2.1 For the calculation of structural members of collision bulkheads, the value h is to be 1.25 times the height required accordingly.

2.12.3 Plane bulkhead plating

2.12.3.1 The thickness t of the plane watertight bulkhead plating is not to be less than that obtained from the following formula, nor less than 5.5 mm:

$$t = 4s\sqrt{hK} \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of the plate in a strake to the bulkhead deck at side, to be taken as not less than 2.5 m;

K — material factor.

2.12.3.2 The thickness of bulkhead plating in way of bilges or bilge wells is to be increased by 2.5 mm, and the thickness of bulkhead plating in way of the passage of the stern tube is to be doubled.

2.12.3.3 The lowest strake of bulkheads is not to be less than 900 mm in height measured from the inner bottom, or from the bottom in the case of single bottom. Where a double bottom is provided on one side and a single bottom on the other side of the bulkhead, the lowest strake is to extend at least 300 mm above the flat portion of the double bottom.

2.12.3.4 Where the difference in thickness between the bulkhead and the web of longitudinal girders attached to the bulkhead is too great, the thickness of bulkhead plating in way is to be increased.

2.12.4 Plane bulkhead stiffeners

2.12.4.1 The section modulus W of bulkhead stiffeners is not to be less than that obtained from the following formula:

$$W = Cshl^2K \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the mid-span of stiffeners to the bulkhead deck at side, but not to be taken as less than 2 m;

l — span of stiffener, in m;

C — coefficients, to be taken as follows:

$C = 6$, for stiffeners unattached at both ends, or directly attached to unstiffened plating;

$C = 3$, for stiffeners bracketed at ends; stiffeners directly lapped to longitudinal members at ends; stiffeners directly connected to longitudinally framed deck plating (inner bottom) at ends, and the stiffeners are in line with the webs of longitudinals; stiffeners directly connected to deck plating or girder web at ends, provided that the other side of the deck plating or girder is connected to an adjacent member having at least the same cross section as and in line with the said stiffener;

K — material factor.

2.12.4.2 Where a transverse bulkhead supports deck girders, bulkhead stiffeners are to be fitted in way of the deck girders. The sectional area of these stiffeners together with attached plating is also to comply with the requirements of Section 11 of this Chapter for non-watertight pillar bulkheads.

2.12.4.3 The scantlings of end brackets of bulkhead stiffeners are to comply with the provisions in 1.2.6 of this PART. Stiffeners unattached at ends are applicable only in the upper 'tween deck spaces.

2.12.4.4 The brackets at the ends of stiffeners are to be extended and efficiently welded to the beams or floors adjacent to the bulkhead respectively. Where the deck or bottom is framed longitudinally and where the brackets at ends of stiffeners are not in line with longitudinals, stiffening bars are to be fitted between the ends of brackets and longitudinals.

2.12.4.5 The minimum web depth of stiffeners is to meet the requirements of 2.11.1.4 of this Chapter, and the thickness t of the web is to meet the following requirements:

For rolled or combined stiffeners with flange or face plate: $t \geq \dfrac{d_w}{60\sqrt{K}}$ mm

For flat bar stiffeners: $t \geq \dfrac{d_w}{18\sqrt{K}}$ mm

where: d_w — depth of stiffener webs, in mm;

K — material factor.

2.12.5 Bulkheads with symmetrical corrugations

2.12.5.1 Symbols for the dimensions of corrugations are as shown in Figure 1.2.4.3, Chapter 1 of this PART.

2.12.5.2 Dimensions of corrugations are to comply with the following requirements:

(1) The section modulus W of a corrugation over a spacing is not to be less than that obtained from the following formula:

$$W = Cshl^2K \quad cm^3$$

where: l — span of corrugation, in m;

h — vertical distance, in m, measured from the mid-span of the corrugation to the bulkhead deck at side, but not to be taken as less than 2 m;

s — spacing of corrugations, in m;

C — coefficient, to be taken according to the end fixity as specified in Table 2.12.5.2;

K — material factor.

(2) The angle α between web and flange of corrugations is not to be less than 40°.

(3) Where the span of corrugation exceeds 15 m, a diaphragm plate is to be arranged near the mid-span or equivalent measures for strengthening are to be taken.

Value of Coefficient *C* **Table 2.12.5.2**

Upper end / Lower end	Directly connected to deck	As shown in Figure 2.12.5.2(2) or (3)
As shown in Figure 2.12.5.2(1) or (2) or (3)	5.04	3.84

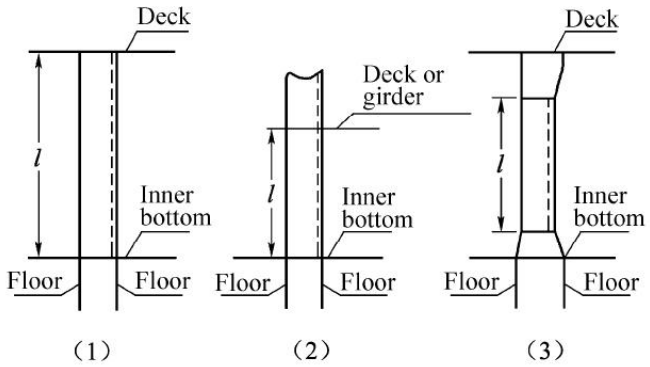


Figure 2.12.5.2

2.12.5.3 The plating thickness t of bulkheads with symmetrical corrugations is to comply with the requirements of 2.12.3.1 of this Section, and the following formula is to be complied with:

$$t \geq \frac{a}{85\sqrt{K}} \quad mm \qquad \text{at top}$$

$$t \geq \frac{a}{70\sqrt{K}} \quad mm \qquad \text{at bottom}$$

where: a — width of corrugation flange, in mm;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

2.12.5.4 The plating thickness at the mid-span of corrugated bulkheads is to be kept up to not less than $0.2l$ above the mid-span.

2.12.6 Double plate bulkheads

2.12.6.1 The section modulus W of webs of double plate bulkheads is not to be less than that obtained from the following formula:

$$W = Cshl^2K \quad cm^3$$

where: s — spacing of webs, in m, see Figure 1.2.4.4 of Chapter 1 of this PART;

h — vertical distance, in m, measured from the mid-span to the bulkhead deck at side, but to be taken as not less than 2 m;

l — span of webs, in m;

C — coefficient, to be taken according to the end fixity as specified in Table 2.12.6.1;

K — material factor.

Value of coefficient *C* **Table 2.12.6.1**

Upper end / Lower end	Directly connected to deck	As shown in Figure 2.12.5.2(2) or (3)
As shown in Figure 2.12.5.2(1) or (2) or (3)	3.96	3.00

2.12.6.2 The scantlings of double plate bulkheads are to comply with the requirements of 2.12.3.1 and 2.12.6.1 of this Section and in addition, the following requirements:

(1) The plating thickness t_p of double plate bulkheads is to comply with the following requirements:

$$t_p \geq \frac{s}{75\sqrt{K}} \quad mm \quad \text{at top}$$

$$t_p \geq \frac{s}{65\sqrt{K}} \quad mm \quad \text{at bottom}$$

where: s — spacing of webs, in mm;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

(2) The plating thickness t_w and the shear area A_w of the web of double plate bulkheads are to comply with the following requirements:

$$t_w \geq \frac{b}{85\sqrt{K}} \quad mm \quad \text{at top}$$

$$A_w \geq 0.12\frac{W}{l} \quad cm^2$$

$$t_w \geq \frac{b}{75\sqrt{K}} \quad mm \quad \text{at bottom}$$

$$A_w \geq 0.18\frac{W}{l} \quad cm^2$$

where: b — spacing of plates of double plate bulkheads, in mm;

W — section modulus required in 2.12.6.1 of this Section, in cm³;

l — span of webs, in m;

K — material factor. In the case of higher tensile steel where the material factor for a lower

strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

2.12.6.3 The plating thickness at the mid-span of double plate bulkheads is to be kept up to not less than $0.2l$ above the mid-span. Manholes or similar openings are not to be cut in the webs of double plate bulkheads within one-third of their length from either end.

2.12.7 Girders

2.12.7.1 The section modulus W of girders is not to be less than that obtained from the following formula:

$$W = 6.6bhl^2K \quad \text{cm}^3$$

where: b— breadth of the area supported by the girder, in m;

h— vertical distance, in m, measured from the mid-span of girders to the bulkhead deck at side, but to be taken not less than 2 m;

l — span of girder, in m;

K— material factor.

2.12.7.2 The web depth of girders is not to be less than 2.5 times that of the supported bulkhead stiffeners, and the breadth of the face plate of girders is not to be more than the web depth or 35 times the thickness of the face plate.

2.12.7.3 The girder ends are to be connected by brackets. The brackets are to extend to the adjacent frames or bulkhead stiffeners. The scantlings of brackets are to comply with the relevant provisions in 1.2.7 of this PART.

2.12.8 Watertight bulkhead steps

2.12.8.1 The section modulus W of beams of decks or flats forming the steps in bulkheads is not to be less than that obtained from the following formula:

$$W = 4.2shl^2K \quad \text{cm}^3$$

where:

s — spacing of beams, in m;

h — vertical distance, in m, measured from the deck or flat forming bulkhead steps to the bulkhead deck at side, but to be taken not less than 2 m;

l — span of beams, in m, but to be taken not less than 2 m;

K — material factor.

2.12.8.2 The thickness of plating of the deck or flat forming the steps in bulkheads is to be 1 mm thicker than that required in 2.12.3.1 of this Section, and in this case s in the formula is to be taken as the spacing of beams.

2.12.8.3 The thickness of plating of the deck or flat forming the steps in bulkheads and the scantlings of beams are in no case to be less than those required, as appropriate, in Sections 4 and 8 of this Chapter for deck plating and beams.

Section 13 DEEP TANKS

2.13.1 General requirements

2.13.1.1 The deep tanks referred to in this Section are those loaded with liquids, such as water, oil fuel, vegetable oil, spoil, etc., which form a part of hull within tank or 'tween deck.

2.13.1.2 For ballast tanks with ballast water exchange by overflow method, the design pressure head h is, in addition to complying with the requirements of this Section, not to be less than the vertical distance from the calculation point to the overflow point.

2.13.2 Plane bulkheads

2.13.2.1 The thickness t of plane bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.95 s \sqrt{\rho h K} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of the plate in a strake to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

K — material factor.

The thickness of bulkhead plating is not to be less than 8 mm for $L \geq 90$ m; not to be less than 7 mm for 60 m $\leq L <$ 90 m; and not to be less than 6 mm for $L <$ 60 m.

2.13.2.2 The thickness of bulkhead plating in way of bilges or bilge wells is to be increased by 2.5 mm.

2.13.2.3 The section modulus W of stiffeners of bulkheads is not to be less than that obtained from the following formula:

$$W = 8 s \rho h l^2 K \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

l — span of stiffener, in m;

h — vertical distance, in m, measured from the mid-span of the stiffener to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater. The ends of stiffeners are to be connected by brackets, and the scantlings of these brackets are to be in accordance with the relevant requirements in 1.2.6 of this PART. The ends of the stiffeners may also be connected directly to the deck plating or girders provided that the other side of the deck plating or girder is connected to an adjacent member having at least the same cross section as and in line with the said stiffener;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

K — material factor.

The section moment of inertia I of stiffeners is not to be less than that obtained from the following formula:

$$I = 2.3 W l / K \quad \text{cm}^4$$

where: W, l — same as defined above.

2.13.3 Bulkheads with symmetrical corrugations

2.13.3.1 The scantlings of the bulkheads are to be in accordance with the following requirements:

(1) The section modulus W of a corrugation over a spacing is not to be less than that obtained from the following formula:

$$W = Cs\rho hl^2K \quad \text{cm}^3$$

where: l — span of stiffener, in m;

h — vertical distance, in m, measured from the mid-span of the corrugation to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

s — spacing of corrugation, in m;

C — coefficient, to be taken according to the end fixity as specified in Table 2.13.3.1;

K — material factor.

Value of coefficient *C* **Table 2.13.3.1**

Upper end / Lower end	Directly connected to deck	As shown in Figure 2.12.5.2(2) or (3) of this Chapter
As shown in Figure 2.12.5.2(1) or (2) or (3) of this Chapter	13.3	10.3

(2) The angle α between web and flange of corrugations is not to be less than 40°.

(3) Where the span of corrugations exceeds 15 m, a horizontal girder is to be arranged near the mid-span.

2.13.3.2 The plating thickness t of corrugated bulkheads is to comply with the requirements of 2.13.2.1 of this Section, and the following formula is to be complied with:

$$t \geq \frac{a}{70\sqrt{K}} \quad \text{mm}$$

where: a — width of corrugation flange, in mm;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

2.13.3.3 The plating thickness at the mid-span of corrugated bulkheads is to be kept up to not less than 0.2l above the mid-span.

2.13.4 Double plate bulkheads

2.13.4.1 The section modulus W of webs and the spacing b of plates of double plate bulkheads are not to be less than those obtained from the following formulae:

$$W = Cs\rho hl^2K \quad \text{cm}^3$$

$$b = 40l \quad \text{mm}$$

where: s — spacing of webs, in m;

h — vertical distance, in m, measured from the mid-span to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

l — span of web, in m;

C — coefficient, to be taken according to the end fixity as specified in Table 2.13.4.1;

K — material factor.

Value of coefficient *C* **Table**

2.13.4.1

Upper end / Lower end	Directly connected to deck	As shown in Figure 2.12.5.2(2) or (3) of this Chapter
As shown in Figure 2.12.5.2(1) or (2) or (3) of this Chapter	10.2	8

2.13.4.2 The plating thickness t_p of double plate bulkheads is to comply with the requirements of 2.13.2.1 of this Section and in addition, the following formulae are to be complied with:

$$t_p \geq \frac{s}{75\sqrt{K}} \quad \text{mm} \quad \text{at top}$$

$$t_p \geq \frac{s}{65\sqrt{K}} \quad \text{mm} \quad \text{at bottom}$$

where: s — spacing of webs, in mm;

K— material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

2.13.4.3 The plating thickness t_w and shear area A_w of webs of double plate bulkheads are to comply with the following requirements:

$$t_w \geq \frac{b}{85\sqrt{K}} \quad \text{mm} \quad \text{at top}$$

$$A_w \geq 0.07\frac{W}{l} \quad \text{cm}^2$$

$$t_w \geq \frac{b}{75\sqrt{K}} \quad \text{mm} \quad \text{at bottom}$$

$$A_w \geq 0.10\frac{W}{l} \quad \text{cm}^2$$

where: b — spacing of plates of double plate bulkheads, in mm;

W — section modulus required in 2.13.4.1 of this Section, in cm³;

l — span of webs, in m;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

2.13.4.4 The plating thickness at the mid-span of double plate bulkheads is to be kept up to not less than $0.2l$ above the mid-span.

Manholes or similar openings are not to be cut in the webs of double plate bulkheads within one-third of their length from either end.

2.13.5 Girders

2.13.5.1 The section modulus W of girders is not to be less than that obtained from the following formula:

$$W = 11.7bph l^2 K \quad \text{cm}^3$$

where: b — breadth of the area supported by the girder, in m;

h — vertical distance, in m, measured from the mid-span of girder to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

l — span of girder, in m;

K — material factor.

2.13.5.2 The section moment of inertia I of girders is not to be less than that obtained from the following formula:

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: W, l, K — same as defined in 2.13.5.1 of this Section.

2.13.5.3 The web depth of girders is not to be less than 2.5 times that of the supported bulkhead stiffeners, and the breadth of the face plate of girders is not to be more than the web depth or 35 times the thickness of the face plate.

2.13.5.4 The girder ends are to be connected by brackets. The brackets are to extend to the adjacent frames or bulkhead stiffeners. The scantlings of the brackets are to comply with the relevant provisions in 1.2.7 of this PART.

2.13.6 Transverse side framing

2.13.6.1 Frames are to comply with the following requirements:

(1) The section modulus of frames other than those of forepeak and aft peak tanks is to be increased by 15% above that required in Section 7 of this Chapter.

(2) The section modulus W and section moment of inertia I of frames are to be not less than those obtained from the following formulae in addition to the requirement mentioned above:

$$W = 6.8s\rho hl^2K \quad \text{cm}^3$$

$$I = 3.5Wl/K \quad \text{cm}^4$$

where: s — spacing of frames, in m;

l — span of frame, in m, the vertical distance measured from the upper edge of floor or inner bottom to the side stringer, or between side stringers or from the side stringer to the 'tween deck;

h — vertical distance, in m, measured from the mid-span of frame to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

K — material factor.

(3) The arm length of end brackets of frames is to be increased by 20% above that required in 1.2.6 of this PART.

2.13.6.2 Side stringers supporting the frames are to comply with the requirements of 2.13.5.3 to 2.13.5.4 of this Section and in addition, to have a section modulus W and a moment of inertia I not less than those obtained from the following formulae:

$$W = 11.7b\rho hl^2K \quad \text{cm}^3$$

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: b — breadth of the area supported by the stringer, in m;

h — vertical distance, in m, from the mid-span of stringer to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater, but not less than the distance measured from the mid-span of stringer to the upper deck, or to a point

1.4d (d being the draught, in m) above the plate keel, whichever is the lesser;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

l — span of stringer, in m;

K — material factor.

2.13.6.3 In deep tanks forward of 0.2L from F.P., side stringers are to be fitted and spaced not more than 5 m apart, or perforated flats having scantlings complying with the requirements of 2.15.1.11 of this Chapter are to be fitted. Where the length of the tank exceeds 14 m and perforated flats are fitted in lieu of the side stringers, web frames or transverse wash bulkheads are to be fitted.

2.13.6.4 The scantlings of web frames supporting the side stringers are to be calculated according to 2.7.4.1 of this Chapter. But the design head h is to be taken as the vertical distance measured from the side stringer to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater, in m; but not to be less than the distance measured from stringers to the upper deck or to a point 1.4d (d being the draught, in m) above the plate keel, whichever is the lesser.

2.13.7 Longitudinal side framing

2.13.7.1 In addition to complying with the requirements of Section 7 of this Chapter, the section modulus W of side longitudinals is not to be less than that obtained from the following formula:

$$W=8.8s\rho hl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

h — vertical distance, in m, measured from the longitudinal to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

l — span of longitudinal, in m;

K — material factor.

The end connections of side longitudinals are to comply with the relevant requirements of 2.7.5.7. The arm length of the end brackets is to be increased by 20% above that required in 1.2.6 of this PART.

2.13.7.2 The section modulus W of the web frames supporting the side longitudinals is not to be less than that obtained from the following formula:

$$W=11.7s\rho hl^2K \quad \text{cm}^3$$

where: s — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of web frame to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

l — span of web frame, in m;

K — material factor.

2.13.7.3 The section moment of inertia I of web frames is not to be less than that obtained from the following formula:

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: W, l, K — same as defined in 2.13.7.2 of this Section.

2.13.7.4 In deep tanks forward of 0.2L from F.P., the section modulus of web frames supporting the side longitudinals is to be increased by 20% above that obtained from 2.13.7.2 of this Section.

In general, the spacing of web frames is not to be greater than 3.0 m for ships of 100 m in length or less and not greater than 4.2 m for ships of 300 m or over in length, and the intermediate values are to be obtained by interpolation. Where the depth of the tank exceeds 16 m, perforated flats are to be fitted, and transverses are to be fitted in way of the web frames.

2.13.8 Deck plating and framing

2.13.8.1 In addition to complying with the requirements of Section 4 of this Chapter, the plating thickness t of the deck (or flat) of deep tanks is not to be less than that obtained from the following formula:

$$t = 3.95s\sqrt{\rho hK} + 3.5 \quad \text{mm}$$

where: s — spacing of frames, in m;

h — vertical distance, in m, measured from deck (or flat) to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

K — material factor.

The plating thickness t of the deck (or flat) is not to be less than 8 mm for ship's length $L \geq 90$ m; 7 mm for 60 m $\leq L <$ 90 m; 6 mm for $L <$ 60 m.

2.13.8.2 In addition to complying with the requirements of Section 8 of this Chapter, the section modulus W of longitudinals or beams of the decks (or flats) in deep tanks is not to be less than that obtained from the following formula:

$$W = 8.8s\rho hl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals or beams, in m;

h — vertical distance, in m, measured from deck (or flat) to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

l — span of longitudinal or beam, in m;

K — material factor.

The section moment of inertia I is not to be less than that obtained from the following formula:

$$I = 2.3Wl/K \quad \text{cm}^4$$

where: W, l, K — same as defined above.

2.13.8.3 In addition to complying with the requirements of Section 8 of this Chapter, the section modulus W of girders or transverses of decks (or flats) in deep tanks is not to be less than that obtained from the following formula:

$$W = 11.7S\rho hl^2K \quad \text{cm}^3$$

where: S — spacing of girders or transverses, in m;

h — vertical distance, in m, measured from deck (or flat) to the top of the deep tank, or half the distance to the top of the overflow, whichever is the greater;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

l — span of girder or transverse, in m;

K — material factor.

The section moment of inertia I is not to be less than that obtained from the following formula:

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: W, l, K — same as defined above.

2.13.8.4 The web depth of deck girders or transverses is to comply with the relevant requirements of Section 8 of this Chapter.

2.13.8.5 In deep tanks forward of 0.2L from F.P., the spacing of deck transverses supporting the deck longitudinals is to be the same as that of web frames as provided in 2.13.7.4 of this Section.

2.13.9 Bottom framing

2.13.9.1 The transversely framed single bottom in deep tanks forward of 0.2L from F.P. is to comply with the following requirements:

(1) Plate floors are to be fitted at every frame space, and the scantlings of floors are not to be less than those required in 2.15.1.1 of this Chapter. In way of web frames, the depth of floors and scantlings of face plates are not to be less than those of web frames.

(2) The section modulus W of the centerline girder is not to be less than the greater of those obtained from the following formulae:

$$W = 9sh_1l^2K \quad \text{cm}^3$$

$$W = 9.8\,s\,\rho h_2 l^2 K \quad \text{cm}^3$$

where: s — mean spacing supported by centerline girder, in m;

l — span of centerline girder, in m;

h_1 — vertical distance, in m, measured from the mid-span to upper deck at side; for the region forward of 0.15L from F.P., to 3 m above the deck for measuring minimum bow height (see Regulation 39 of the International Convention on Load Lines, 1966);

h_2 — vertical distance, in m, measured from the mid-span to the top of the deep tank, or half the vertical distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3, to be taken not less than 1.025;

K — material factor.

The section moment of inertia I is not to be less than that obtained by the following formula:

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: W, l, K — same as defined above.

(3) Intercostal side girders are to be fitted and spaced not more than three frame spaces apart. The scantlings of intercostal side girders are to be the same as those of floors.

2.13.9.2 For longitudinally framed single bottom in deep tanks forward of 0.2L from F.P., the spacing of plate floors supporting longitudinals is to be the same as that of the web frames as provided in 2.13.7.4 of this Section. The plate floors are to be supported by a continuous centreline girder or a longitudinal bulkhead. The scantlings of plate floors and centreline girders are to comply with the relevant requirements of Section 3, Chapter 6 of this PART.

2.13.10 Wash bulkheads

2.13.10.1 Where a deep tank extends from side to side of the ship, a wash bulkhead is to be fitted on the centreline. Where the widest breadth of the tank exceeds 0.5B within the region forward of 0.3L from F.P., a wash bulkhead is to be fitted on the centreline of the tank. Where the widest breadth of the tank exceeds 0.7B, it is recommended that a longitudinal bulkhead be fitted on the centreline of the tank.

2.13.10.2 The thickness of the wash bulkhead is to be the same as that required for the bulkheads mentioned in this Section. The section modulus of the stiffeners of the wash bulkhead is to be equal to 50% of that of those bulkheads, but h is to be measured to the top of the deep tank. The stiffeners are to be connected by brackets at both ends. The area of perforations is not to be less than 5% nor more than 10% of the total area of the bulkhead.

Section 14 STEMS, STERN FRAMES, BULBOUS BOWS AND PROPELLER SHAFT BRACKETS

2.14.1 Stems

2.14.1.1 The cross-sectional area A of bar stems up to 0.5 m above the summer load waterline is not to be less than the following:

$$A = 1.2L \quad \text{cm}^2 \text{ for } L < 90 \text{ m}$$
$$A = 1.63L - 38 \quad \text{cm}^2 \text{ for } L \geq 90 \text{ m}$$

where: L — length of ship, in m.

From a position above 0.5 m from the summer load waterline, the cross-sectional area may be gradually tapered to the stem head where the area may be reduced by 25%.

2.14.1.2 The thickness t of plate stems up to 0.5 m above the summer load waterline is not to be less than that obtained from the following formula:

$$t = (0.08L + 5.5)\sqrt{K} \quad \text{mm}$$

where: L — length of ship, in m, but not to be taken greater than 230 m;

K — material factor.

From a position above 0.5 m from the summer load waterline, the plate thickness may be gradually tapered to the stem head where the thickness may be the same as that of the shell at ends.

Plate stems are to be supported by horizontal webs spaced not more than 1 m apart, and the web thickness is not to be less than the thickness of the adjacent shell plating. The webs are to be extended aft to be connected to frames or side stringers, but at least beyond the butts of stem plates and shell plating.

Where the radius of curvature of the stem is large, a centreline vertical web is to be fitted, having the same thickness as the horizontal webs.

2.14.1.3 Cast steel stems are to be easy for manufacture, and all fillets are to have adequate radii. The sectional area of cast steel stems is not to be less than that of bar stems required in 2.14.1.1 of this Section. Cast steel stems are to be provided with rib reinforcement.

2.14.2 Stern frames without rudder post

2.14.2.1 The stern frame without rudder post is composed of sole piece, propeller post and propeller boss.

2.14.2.2 The scantlings of fabricated propeller posts (as shown in Figure 2.14.2.2) are not to be less than those obtained from the following formulae:

Length of stern frame: $a = 46\sqrt{L}$ mm

Thickness of stern frame: $t = 2.3\sqrt{L} + 3$ mm

where: L — length of ship, in m.

2.14.2.3 The scantlings of cast propeller posts (as shown in Figure 2.14.2.3) are not to be less than those obtained from the following formulae:

Length of stern frame: $a = 41\sqrt{L}$ mm

Thickness of stern frame: $t_1 = 3\sqrt{L}$ mm

$t_2 = 4\sqrt{L}$ mm

Radius of fillet: $R = 4.9\sqrt{L}$ mm

where: L — length of ship, in m.

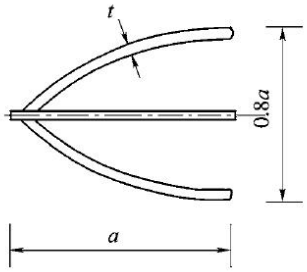


Figure 2.14.2.2(1)

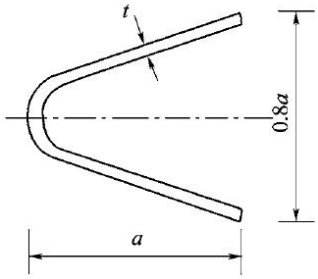


Figure 2.14.2.2(2)

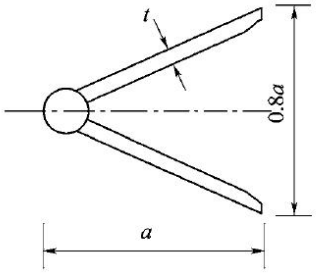


Figure 2.14.2.2(3)

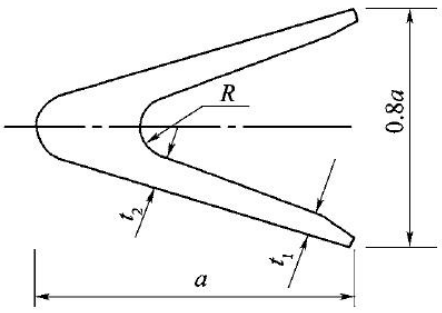


Figure 2.14.2.3

2.14.2.4 Fabricated or cast propeller posts are to be strengthened by horizontal brackets at positions depending upon the hull framing and the structural arrangements of propeller posts, but the spacing of the webs is not to exceed 650 mm. Cast steel stern frames are to be easy for manufacture, and all fillets are to have adequate radius; where the radius of curvature is large, a vertical web is to be fitted.

2.14.2.5 The section modulus W_z of sole pieces (see Figure 2.14.2.5) about the vertical neutral axis (z-axis) at any considered section, is not to be less than that obtained from the following formula:

$$W_z = \frac{K}{80} Px \quad \text{cm}^3$$

where: P — supporting force exerting by the sole piece on rudder blade, in N, to be calculated according to the relevant provisions of Section 1, Chapter 3 of this PART;

K — material factor according to 1.3.1.7 of this PART for fabricated sole pieces; material factor according to 3.1.1.3 of this PART for cast sole pieces;

x — distance between the axis of rudder stock and the section under consideration, in m, to be taken not less than $0.5l_s$, l_s being the maximum distance, in m, (see Figure 2.14.2.5).

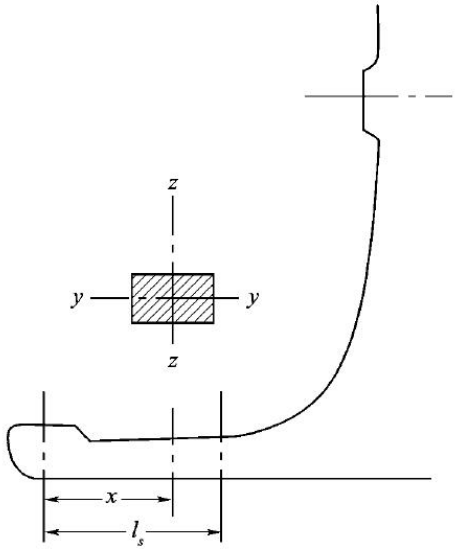


Figure 2.14.2.5

2.14.2.6 The section modulus W_y of sole pieces about the horizontal neutral axis (y-axis) at any considered section is not to be less than that obtained from the following formula:

$$W_y = 0.5W_z \quad \text{cm}^3$$

where: W_z — section modulus, in cm³, to be calculated according to 2.14.2.5 of this Section.

2.14.2.7 The sectional area A_s at any section of the sole piece is not to be less than that obtained from the following formula:

$$A_s = \frac{K}{48}P \quad \text{mm}^2$$

where: P, K — see 2.14.2.5 of this Section.

2.14.2.8 Within the length l_s, the equivalent stress σ_e of any section of sole pieces is to be determined from following formula:

$$\sigma_e = \sqrt{\sigma^2 + 3\tau^2} \le 115/K \quad \text{N/mm}^2$$

where: $\sigma = \frac{Px}{W_z}$, in N/mm², where: P, x — see 2.14.2.5 of this Section, W_z being the section modulus of the considered section about z-axis, in cm³;

$\tau = \frac{P}{A_s}$, in N/mm², where: P — see 2.14.2.5 of this Section, A_s being the sectional area of the section under consideration, in mm²;

K — see 2.14.2.5 of this Section.

2.14.2.9 In fabricated sole pieces, transverse webs are to be fitted and spaced not more than 760 mm apart. Where the breadth of the fabricated sole pieces exceeds 900 mm, a centreline vertical web is to be fitted.

2.14.2.10 The sole piece is to extend forward from the fore end of the propeller boss for at least 3 frame spaces and to be efficiently connected to the plate keel. The sectional area of the extended portion may be reduced gradually to the area required for effective connection with the plate keel.

2.14.2.11 The stern tube shaft is to be efficiently connected to the floor or bulkhead, and the thickness of the floor is to be increased by 3 mm.

2.14.2.12 The finished thickness t of the propeller boss in way of the passage of the stern tube shaft or propeller shaft is not to be less than that obtained from the following formula:

$$t = 0.1d_s + 60 \quad \text{mm, but not greater than } 0.3d_s$$

where: d_s — diameter of stern tube shaft or propeller shaft, in mm.

2.14.3 Propeller posts of twin screw ships

2.14.3.1 The dimensions of propeller posts which are built integral with the hull of twin screw ships (see Figures 2.14.3.1(1), (2)) are not to be less than as given below:

Breadth of section:	$b = 33\sqrt{L}$	mm
Thickness of section:	$t_1 = 3.3\sqrt{L}$	mm
	$t_2 = 3.7\sqrt{L}$	mm
	$t_3 = 4.5\sqrt{L}$	mm
Radius of fillet:	$R = 4.4\sqrt{L}$	mm

where: L — length of ship, in m.

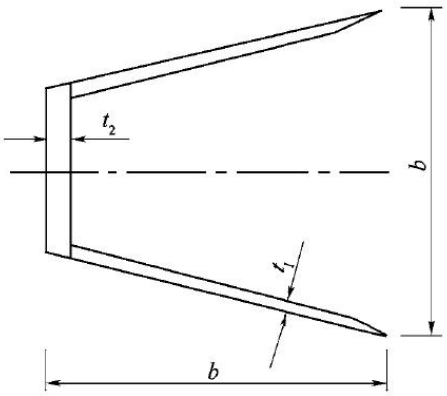


Figure 2.14.3.1(1)

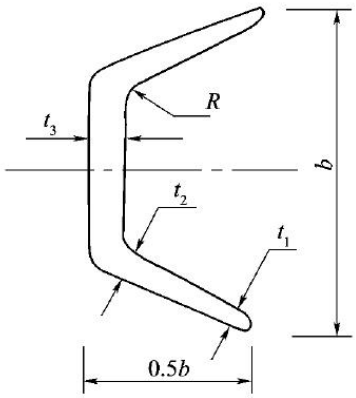


Figure 2.14.3.1(2)

2.14.4 Propeller clearances

2.14.4.1 It is recommended that the minimum clearances (see Figure 2.14.4.1) between the propeller and the stern frame or between the propeller and the rudder be not less than the following:

$$a = 0.12D \quad \text{m}$$
$$b = 0.20D \quad \text{m}$$
$$c = 0.14D \quad \text{m}$$
$$d = 0.04D \quad \text{m}$$

where: D — diameter of propeller, in m.

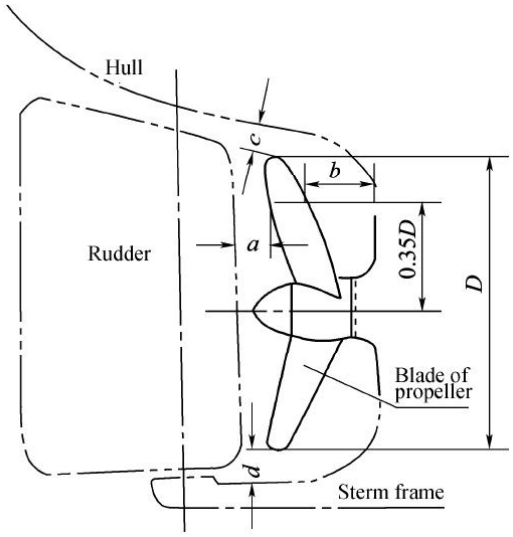


Figure 2.14.4.1

2.14.5 Bulbous bows

2.14.5.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure. The bulb is in general to be strengthened as follows:

(1) At the fore end of the bulb, the structure is to be supported by horizontal diaphragm plates spaced about 1 m apart in conjunction with the center girder;

(2) Vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing;

(3) In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or web frames spaced about 5 frame spaces apart are generally to be fitted;

(4) In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted;

(5) The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness may be the same as that required for plate stems.

2.14.6 Propeller shaft brackets

2.14.6.1 Propeller shaft brackets may be made of steel castings or fabricated from plates, or made of cast or forged pieces connected by welding. The connection of the arms to the bearing boss is to be made by full penetration welding.

2.14.6.2 The scantlings of each arm and shaft bossing of herringbone propeller shaft bracket are not to be less than as given below:

Thickness of arm:	$t = 0.45d_s$	mm
Cross sectional area of arm:	$A = 0.45\,d_s^2$	mm²
Thickness of shaft bossing:	$t = 0.33d_s$	mm
Length of shaft bossing:	$l = 3d_s$	mm

where: d_s — diameter of stern tube shaft or propeller shaft at the location of shaft bracket, in mm.

2.14.6.3 The hull framing in way of the bracket palm is to be strengthened and the shell plating in way is to be increased in thickness as required in 2.3.6.1 of this Chapter. Bracket arms are to be carried through the shell plating and efficiently attached to floors, girders and shell plating.

Section 15 STRENGTHENING AT ENDS OF SHIP

2.15.1 Fore peak strengthening

2.15.1.1 Solid floors are to be fitted at every frame. The web depth h and thickness t and the face plate sectional area A of the floors are not to be less than those obtained from the following formulae:

$$h = 85D + 140 \quad \text{mm, but need not be greater than 1500 mm}$$

$$t = (0.03L+6)\sqrt{K} \quad \text{mm}$$

$$A = 0.85BK \quad \text{cm}^2$$

where: B — breadth of ship, in m;

D — moulded depth of ship, in m;

L — length of ship, in m, to be taken as not greater than 200 m;

K — material factor.

2.15.1.2 Centreline keelson is to be fitted at the longitudinal centreline section. The web depth and thickness and the face plate sectional area are to be as those required in 2.15.1.1 of this Section for solid floors.

2.15.1.3 For the extremely narrow bottom, the centreline keelson not extended to the bottom may be accepted, but the depth of the keelson is to be approximately equal to 1/3 of the floor depth. Or alternatively, the centreline keelson may be entirely omitted provided that the web of floors is fitted with horizontal stiffeners and that a perforated flat, instead of a face plate, is fitted at the top edge of the web.

2.15.1.4 In the case as mentioned in 2.15.1.3 of this Section, a centreline keelson gradually tapered off over several frame spaces is to be fitted forward of the collision bulkhead as the continuation of the centreline girder or centreline keelson abaft the collision bulkhead.

2.15.1.5 Where the side shell is framed transversely, panting beams spaced not more than 2 m apart vertically are to be fitted at alternate frames, from the top of floors up to the lowest deck, and at least to 1 m above the full-load waterline. The cross-sectional area A and minimum section moment of inertia I of the panting beams are not to be less than:

$$A = (0.27L + 8)K \quad \text{cm}^2$$

$$I = ceh_i l^2 \quad \text{cm}^4$$

where: L — length of ship, in m, to be taken as not greater than 250 m;

c — horizontal spacing of panting beams, in m;

e — vertical spacing of panting beams, in m;

h_i — vertical distance, in m, measured from the beam to 3 m above the minimum bow height required by load line, and not to be less than that to upper deck;

l — span of panting beam, in m;

K — material factor.

2.15.1.6 Where a fore peak space is used as a tank and the breadth of the tank at its widest point exceeds 0.5B (B being the breadth of ship), efficient supporting members or wash bulkheads are to be fitted to support the panting beams. The wash bulkheads are to comply with the requirements of 2.13.10.2 of this Chapter.

2.15.1.7 Where the length of the fore peak space exceeds 10 m, additional transverse strengthening in the form of transverse wash bulkheads or web frames is to be provided. Transverse wash bulkheads are to comply with the provisions in 2.13.10.2 of this Chapter while web frames are to comply with the provisions in 2.7.2.8 of this Chapter.

2.15.1.8 Where the side shell is framed transversely, side stringers with flange or face plate are to be fitted at each panting beam, and are to have a web depth h and thickness t not less than:

$$h = 5.6L + 166 \quad \text{mm} \quad \text{for } L < 90\text{m}$$
$$h = 3.0L + 400 \quad \text{mm} \quad \text{for } L \geq 90\text{m}$$
$$t = 0.023L + 6 \quad \text{mm}$$

where: L — length of ship, in m, to be taken as not greater than 250 m.

2.15.1.9 Brackets are to be fitted at the lower edge of connections between side stringers and frames, the thickness of brackets is not to be less than that of the side stringer web and the brackets are to be extended to the flange or face plate of side stringers. Where panting beams are fitted, the arm length of brackets along the frames is not to be less than 75% the web depth of side stringers, and where no panting beams are fitted, the arm length is not to be less than 50% the web depth of side stringers. The webs of side stringers are to be welded to the frames.

2.15.1.10 Where the side shell is framed transversely and if perforated flats are fitted in lieu of the panting beams in association with stringers, the flats are to be spaced not more than 2.5 m apart and are to be fitted vertically from the top of floors to the lowest deck above the full-load waterline, but not below 1.0 m above the full-load waterline.

2.15.1.11 Where the side shell is framed transversely, the perforated flats are to comply with the following requirements:

(1) The area of perforations in each flat is not to be less than 10% of the total area of the flat.

(2) The plate thickness t of the perforated flat is not to be less than that obtained from the following formula:

$$t = 0.023L + 5 \quad \text{mm}$$

where: L — length of ship, in m.

(3) Where the perforated flat is framed transversely, one beam is at least to be fitted at alternate frames below the perforated flat, and their sectional area A without attached plating is not to be less than that obtained from the following formula:

$$A = (0.13L + 4)CK \quad \text{cm}^2$$

where: L — length of ship, in m.

C — coefficient, C =1 when beams are fitted at alternate frames; C =0.5 when beams are fitted at every frame;

K — material factor.

Where the perforated flat is framed longitudinally, an appropriate number of transverses are to be fitted below the perforated flat, and the size of transverses and longitudinals is to be specially considered.

(4) Scantlings of the brackets connecting the beams of the perforated flat to the frames are to comply with the requirements in 1.2.6 of this PART.

2.15.1.12 Where the side shell is framed longitudinally and the depth of the forepeak exceeds 10 m, one or more perforated flats are to be provided at suitable positions, or one or more panting beams as required in 2.15.1.5 of this Section are to be provided in way of each web frame.

2.15.1.13 Where the side shell is framed longitudinally, an adequate number of transverses are to be arranged at the top of the forepeak and at perforated flats (if fitted). The brackets connecting transverses to web frames are to be in accordance with the requirements of 1.2.7 of this PART.

2.15.1.14 Where the side shell is framed longitudinally, the perforated flats are to comply with the requirements of 2.15.1.11(1) to (3) and brackets are to be fitted at the connection between the beams of perforated flats and the side plating and extended to the adjacent side longitudinals.

2.15.1.15 Brackets are to be fitted in way of fore edge of the connection between web frames and side longitudinals. The thickness of brackets is not to be less than the web thickness of web frames and the brackets are to be extended to the face plate of web frames. Where panting beams are fitted, the arm length of brackets along the side longitudinals is not to be less than 75% of the web depth of web frames and where no panting beams are fitted, the arm length of brackets along the side longitudinals is not to be less than 50% of the web depth of web frames.

2.15.1.16 Longitudinally framed bottom structure is to be specially considered.

2.15.2 Strengthening at sides abaft the fore peak tank

2.15.2.1 Where the side shell is framed transversely, side framing within the region from 0.15L from F.P. to the collision bulkhead is to be strengthened as follows:

(1) Where the span of main frames does not exceed 9 m, intercostal side stringers are to be fitted in line with the side stringers or perforated flats in the fore peak tank.

(2) Where the span of main frames does not exceed 9 m and if intercostal side stringers are omitted, the side shell plating in the region concerned is to be increased in thickness by the percentages given below:

where $L \leq 150$ m, by 15% of the thickness as required in this Chapter;

where $L \geq 200$ m, by 5% of the thickness as required in this Chapter.

For intermediate values of L, the percentage increase is to be obtained by interpolation.

(3) Where the span of main frames exceeds 9 m, intercostal side stringers are to be fitted and to extend abaft to 0.2L from the F.P. in line with the side stringers or perforated flats in the fore peak tank.

(4) Where the span of frames exceeds 2.6 m in the lower 'tween deck or 3 m in the upper 'tween deck, intercostal side stringers are to be fitted. Where the shell plating is increased according to the requirements in (2) above, the side stringers may be omitted.

2.15.2.2 The web depth of intercostal side stringers as required in 2.15.2.1 of this Section may be the same as that of frames. However, the web plate of such stringers is to be gradually increased in depth for at least two frame spaces to the collision bulkhead so that the depth at the bulkhead is the same as that of the side stringers in the fore peak tank. Where perforated flats are fitted in the fore peak tank, the depth of the web of side stringers is to be calculated according to 2.15.1.8 of this Section. The web thickness t and the face plate sectional area A of the intercostal side stringers are not to be less than those obtained from the following formulae:

$$t = 0.023L + 6 \quad \text{mm, but need not be greater than 12 mm}$$

$$A = 0.14L + 1 \quad \text{cm}^2\text{, but not to be less than 7 cm}^2$$

where: L — length of ship, in m.

2.15.3 Strengthening of bottom forward

2.15.3.1 Where the length L of the ship is equal to 65 m or over and the draught forward in navigation is less than $0.04L$, the flat portion of bottom from F.P. is to be strengthened. The transverse extent of strengthening is not to be less than $0.014B$ (B being the breadth of the ship) above the base line, but need not be greater than 0.28 m, and the length X from the end line of the longitudinal extent of strengthening to F.P. is not to be less than that obtained from the following formula:

$$X = \left(0.65 - \frac{C_b}{2}\right)L \quad \text{m}$$

where: L — length of ship, in m;

C_b — block coefficient, to be taken as 0.7 for $C_b < 0.7$, and 0.8 for $C_b > 0.8$.

For every oil tanker subject to Regulation 18 of MARPOL Annex I, the minimum forward draught is to be determined according to the conditions in which only segregated ballast tanks are used.

2.15.3.2 Where strengthening is required, double bottom framed transversely is to be strengthened as follows:

(1) Plate floors are to be fitted at every frame space.

(2) Side girders are in general to be fitted not more than three frame spaces apart, and half-depth flanged side girders are to be fitted midway between the side girders. The side girders and half-depth side girders are to be extended as far forward as practicable.

2.15.3.3 Where strengthening is required, double bottom framed longitudinally is to be strengthened as follows:

(1) Plate floors are to be fitted at alternate frames, and spaced not more than 2.5 m apart.

(2) The section modulus of bottom longitudinals is to be increased by 10% above that obtained from the formula in 2.6.12.2 of this Chapter, and in this case, l in the formula is not to be less than 1.85 m.

(3) Side girders are in general to be fitted not more than three times the spacing of longitudinals apart and are to be extended as far forward as practicable.

2.15.3.4 Where strengthening is required, single bottom framed transversely is to be strengthened as follows:

(1) In addition to complying with the requirements of 2.15.1.1 of this Section, floors are to be increased gradually in depth towards the fore end as far as practicable, and the floor web is to be adequately increased in thickness so as to ensure its stability. The sectional area of the face plate of floors is to be increased by 50% over the value required in 2.15.1.1 of this Section and flanges are not to be substituted for face plates of floors.

(2) Side keelsons are to be fitted not more than three frame spaces apart, and half-depth side keelsons or other equivalent bottom longitudinal stiffening members are to be fitted midway between the side keelsons and extended as far forward as practicable.

2.15.3.5 In the Where strengthening is required, the forward bottom plating is to be strengthened as follows:

(1) The thickness t of the forward bottom plating is not to be less than that obtained from the following formula:

$$t = CC_1\left(1.8 - 26\frac{d_1}{L}\right)\sqrt{\frac{seK}{s_b}} \quad \text{mm}$$

where: L — length of ship, in m;

d_1 — minimum draught forward in navigation, in m;

s — spacing of frames, in m;

s_b — standard spacing of frames, in m;

e — correction coefficient of longitudinal position, see Table 2.15.3.5;

C — coefficient: $C = 7.3 + 0.081L$ for $65 \text{ m} \le L \le 145$ m;

$C = 19.0$ for $145 < L \le 200$ m;

$C = 23.6 - 0.023L$ for $200 < L \le 300$ m;

$C = 16.7$ for $L > 300$ m;

$C_1 = 1.2 - \frac{s}{2l}$, where l is the spacing of primary members, C_1 is to be taken as 1 for $C_1 > 1$;

K — material factor.

Correction Coefficient *e* **Table 2.15.3.5**

Position	e
Between $X - 0.125L$ to X from F.P.	$\frac{2f-1}{0.05 - C_b}$
Between F.P. and $X - 0.2L$ from F.P.	$0.5 + \frac{f}{0.9 - C_b}$
Others	1

where: C_b — see 2.15.3.1 of this Section;

f — the ratio of the distance of x, in m, from F.P. and length of ship L, in m, i.e. $f = X/L$;

X — see 2.15.3.1 of this Section.

(2) The strengthened forward bottom plating is to be gradually tapered to adjacent shell plating.

2.15.3.6 The forward bottom strengthening is to be verified by direct calculation assessment as specified in Appendix 4 of this Chapter if any of the following conditions applies:

(1) where the minimum forward draught of a ship is less than $0.01L$;

(2) where the arrangements of primary members do not comply with the relevant requirements of 2.15.3 of this Section.

2.15.3.7 In the strengthening region for single bottom framed longitudinally:

(1) Plate floors complying with the provisions of 2.15.3.4 (1) are to be fitted at alternate frames.

(2) The section modulus of bottom longitudinals is to be increased by 10% above that obtained from the formula in 2.6.12.2 of this Chapter, and in this case, l in the formula is not to be less than 1.85 m; side keelsons are to be fitted not more than three times the spacing of longitudinals apart and extended as far forward as practicable.

2.15.4 Aft peak strengthening

2.15.4.1 Plate floors are to be fitted at every frame space, the thickness of which is to be 1.5 mm thicker than that in the fore peak as required in this Section. In single screw ships, floors are to be carried well above the stern tube. In way of propeller posts, propeller shaft brackets and rudder

horns, the floors are generally to be carried to the top of the space and are to be increased in thickness.

2.15.4.2 Where the side shell is framed transversely, panting beams and side stringers spaced vertically not more than 2.5 m apart are to be fitted above the floors, or alternatively, perforated flats complying with the requirements of 2.15.1.11 of this Section are to be provided. The panting beams and side stringers as well as the connection of these members to frames are to comply with the requirements for the fore peak.

2.15.4.3 Where the side shell is framed longitudinally, suitable transverses are to be arranged at the top of the tank and the brackets connecting the transverses to web frames are to comply with the requirements of 1.2.7 of this PART.

2.15.4.4 A centreline wash bulkhead is in general to be arranged in tanks, the upper part of the after peak space and counter or cruiser stern. Where the overhang is very large, additional longitudinal wash bulkheads may be required port and starboard. The wash bulkheads are to comply with the requirements of 2.13.10.2 of this Chapter, and stiffeners are to be fitted at every frame space.

2.15.5 Side strengthening above the aft peak

2.15.5.1 Where the side shell of 'tween deck spaces above the after peak tank is transversely framed and the height of such spaces is more than 3 m, intercostal panting stringers are to be provided, of which the web depth is to be the same as that of frames. The web thickness and the sectional area of face plates of these intercostal stringers are to comply with the requirements of 2.15.2.2 of this Section. Where no intercostal side stringer is fitted, the thickness of shell plating within the region is to be increased in accordance with the requirements of 2.15.2.1(2) of this Section.

2.15.5.2 Where the side shell of 'tween deck spaces above the after peak tank is transversely framed, web frames are to be fitted not more than 4 frame spaces apart. The section modulus W of web frames is not to be less than that obtained from the following formula:

$$W = 3.5Sdh\sqrt{D}\,K \quad \text{cm}^3$$

where: S — spacing of web frames, in m;

d — draught of ship, in m;

h — height of 'tween deck spaces, in m;

D — moulded depth, in m;

K — material factor.

2.15.5.3 Where the side shell of 'tween deck spaces above the after peak tank is framed longitudinally, web frames supporting longitudinals are to be fitted. The spacing of web frames is not to be greater than 2.5 m for ships of 100 m in length or less; and not greater than 3.5 m for ships of 300 m or over in length; the intermediate values are to be obtained by interpolation. The section modulus W of the frames is not to be less than that obtained from the following formula:

$$W = 4.4Sdh\sqrt{D}\,K \quad \text{cm}^3$$

where: S, d, h, D and K — the same as those in 2.15.5.2 of this section.

2.15.6 Structural strengthening for bow flare

2.15.6.1 For container ships, ro-ro ships, passenger ships, car carriers and the ships with the similar bow flare, the side structural strengthening at bow is to meet the requirements of Section 8, Chapter 7 of this PART.

Section 16 ENGINE SEATINGS AND SHAFT TUNNELS

2.16.1 Main engine seatings

2.16.1.1 The main engine seating is to be of ample strength and rigidity. It is generally to consist of two longitudinal girders with transverse diaphragms and transverse brackets fitted at every frame space. Transverse diaphragms are to be fitted between longitudinal girders and are to extend to the face plate of girders as far as practicable. Transverse brackets, the width of which is generally not to be less than their depth, are to be fitted at the outside of the longitudinal girders and welded to the face plate of the girders.

2.16.1.2 The longitudinal girders of the seating are to be in line with the bottom side girders. If it is impracticable to do so, partial girders of the same thickness as the bottom side girders are to be fitted under the longitudinal girders.

In particular cases, the partial girder may be in the form of a half-depth girder welded to the inner bottom plating and floors only.

2.16.1.3 Scantlings of structural members of main engine seatings

(1) For large low-speed diesel engines having a power of more than 1,470 kW, the horizontal face plate thickness t and the web thickness t_1 of longitudinal girders, and the thickness t_2 of transverse diaphragms and transverse brackets are not to be less than the values given below:

$$t = 1.44\sqrt[3]{p} + 10s \quad \text{mm}$$

$$t_1 = 0.65t\left(1+\frac{h-1}{10}\right) \quad \text{mm for } L \geq 90 \text{ m}$$

$$t_1 = 0.70t \quad \text{mm for } L < 90 \text{ m}$$

$$t_2 = 0.77t_1 \quad \text{mm for } L \geq 90 \text{ m}$$

$$t_2 = 0.80\ t_1 \quad \text{mm for } L < 90 \text{ m}$$

where: P — main engine power, in kW;

s — spacing of frames, in m;

h — web depth of longitudinal girders, in m.

(2) For main engines having a power of 1,470 kW or less, the web thickness of longitudinal girders is to be increased by 60% above that of the bottom side girders (for double bottom) or side keelsons (for single bottom) in way of the engine room in the case of diesel engines, and by 30% in the case of turbines or propulsion motors. In both cases, the longitudinal girders are to be provided with a continuous horizontal face plate having a thickness 40% greater than their web thickness. The longitudinal girders are to be gradually tapered off at their ends.

The thickness of the transverse diaphragms and transverse brackets is to be increased by 40% above that of the floors in the case of diesel engines, and by 30% in the case of turbines or propulsion motors. The transverse diaphragms and transverse brackets are to be provided with a face plate or flange.

(3) The scantlings of main engine seatings may be suitably reduced in the case of high-powered turbines, propulsion motors or medium/high speed diesel engines.

2.16.1.4 The horizontal face plates of longitudinal girders are to be stiffened in way of holding-down bolts by a suitable number of vertical brackets, and the depth of the brackets is to be twice their breadth.

2.16.1.5 Where the main engine seating or the thrust seating is directly bolted to the inner bottom, the thickness t_3 of the inner bottom plating in way is not to be less than that required as follows:

(1) for large low-speed diesel engines having a power of more than 1,470 kW, $t_3 = t$, t as defined in 2.16.1.3(1) of this Section;

(2) for main engines having a power of 1,470 kW or less, t_3 is to be equal to twice the thickness of the inner bottom plating in the region, but is not to be less than 20 mm;

(3) for high-powered turbines, t_3 will be specially considered.

The double bottom tanks within the above regions are not to be used for carrying oil fuel or water. Partial or half-depth girders are to be fitted close to holding-down bolts. The longitudinal division bulkheads and side girders in the adjacent oil or water tanks may be regarded as the partial girders at holding-down bolts.

2.16.2 Shaft tunnels

2.16.2.1 Shaft tunnels are to be of watertight construction.

2.16.2.2 The thickness of tunnel plating is to comply with the requirements of 2.12.3.1 of this Chapter for watertight bulkheads. If the top plating is curved, the thickness may be reduced by 10% in dry cargo holds. If the top plating is flat, it is not to be less than 1.1 times the thickness required for the watertight bulkheads.

The thickness of top plating of the tunnel under hatchways is to be increased by at least 2 mm, unless covered with wood ceiling as required in 3.3.1.5 of this PART.

2.16.2.3 Stiffeners of shaft tunnels are to be in line with the frames wherever possible, and their section modulus W is not to be less than that obtained from the following formula:

$$W = 6shl^2K \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

h — the vertical distance, in m, measured from the mid-point of the vertical part of the stiffener to bulkhead deck;

l — the length of the vertical part of the stiffener, in m;

K — material factor.

Where the tunnel top is flat, the scantlings of the top beams are not to be less than those required for the beams in way of the steps in watertight bulkheads (see 2.12.8 of this Chapter).

The lower end of the vertical part of stiffeners is to be welded to the inner bottom.

2.16.2.4 Where shaft tunnels pass through or are adjacent to deep tanks, the adjacent bulkheads and their stiffeners are to comply with the requirements of Section 13 of this Chapter for deep tanks.

2.16.2.5 The structure of the thrust and tunnel recesses is to comply with the requirements for the steps in watertight bulkheads. Where these recesses are enclosed by deep tanks, the requirements for bulkheads and stiffeners of deep tanks are to be complied with.

2.16.2.6 The shaft tunnel is to be provided with an emergency exit leading to the weather deck, and the construction of the trunk of the exit is to comply with the requirements for watertight bulkheads. The closing appliance for the exit is to be capable of being operated from both sides.

Section 17 SUPERSTRUCTURES AND DECKHOUSES

2.17.1 General requirements

2.17.1.1 All ships are to be provided with forecastles or increased sheer to such a minimum bow height as to meet the requirements of their respective flag Administrations. The forecastles of bulk carriers, ore carriers and combination carriers are to be also in compliance with Section 13, Chapter 8 of this PART.

2.17.1.2 Where superstructures and deckhouses are subject to loading in excess of that as specified in this Section, the scantlings of their structural members are to be appropriately increased in addition to complying with the requirements of this Section.

2.17.1.3 Where long superstructures are provided within 0.5L midships, the deck structure of the 1st tier is to comply with the requirements for strength decks and side shell is to comply with the requirements for shell plating.

2.17.1.4 Where long deckhouses are provided within 0.5L midships, the thickness of plating and the size of framing of the 1st tier is to be increased according to the contribution of these deckhouses to the longitudinal bending of hull girders.

2.17.1.5 The deckhouses on forecastle deck of offshore supply ships are to comply with the requirements of Section 5, Chapter 11 of this PART.

2.17.1.6 Definitions of tiers of superstructures/deckhouses: The lowest, or first tier, is normally that tier which is directly situated on the uppermost continuous deck to which the Rule moulded depth D is to be measured. The second tier is the next tier above the lowest tier and so on.

2.17.1.7 The deck plating of No.N tier of superstructure/deckhouse is the top plating of this tier of superstructure/deckhouse.

2.17.1.8 Where a freeboard corresponding to or exceeding the uncorrected tabular values of the International Convention on Load Lines, 1966 can be obtained for a ship with excessive freeboard, i.e. by considering the ship to have a virtual moulded depth D' at least one standard superstructure height less than the Rule moulded depth D (see Figure 2.17.1.8), the 1st tier erection may be treated as the 2nd tier, and the 2nd tier as the 3rd tier when applying the requirements of this Section. The standard superstructure height h_s is to be obtained as follows:

$$h_s = 1.05 + 0.01L_L \quad \text{m, and } 1.8 \leq h_s \leq 2.3$$

where: L_L — load line length of ship, in m.

However, this does not apply to type ‘B’ ships with reduced freeboard.

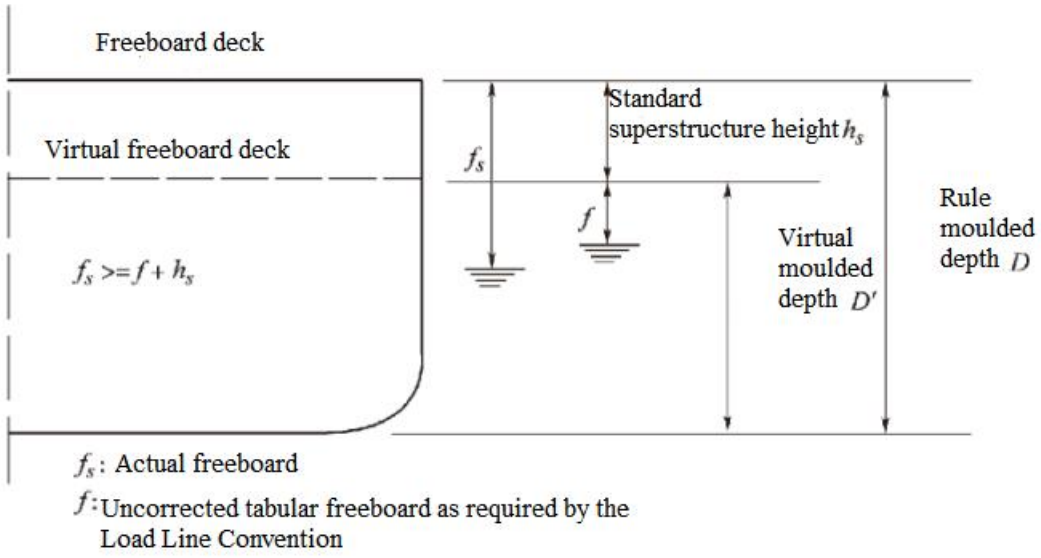


Figure 2.17.1.8

2.17.2 Design pressure head

2.17.2.1 The design pressure head h for end bulkheads of exposed superstructures and boundary bulkheads (end and side bulkheads) of deckhouses is to be obtained as follows and not less than the minimum value in Table 2.17.2.1:

$$h = \alpha\delta(\beta\lambda - \gamma) \quad \text{m}$$

where: α, β, λ and δ — coefficients, to be determined respectively according to 2.17.2.2, 2.17.2.3, 2.17.2.4 and 2.17.2.5 of this Section;

γ — vertical distance, in m, measured from summer load waterline to mid-span of stiffener or mid-point of panel.

Table 2.17.2.1

Length of ship L (m)	Design pressure head h_{min} (m)	
	Lowest tier of unprotected fronts	Elsewhere
$L \leq 50$	3.0	1.5
$50 < L < 250$	$0.01L + 2.5$	$0.005L + 1.25$
$L \geq 250$	5.0	2.5

2.17.2.2 Coefficient α is to be determined as follows:

$\alpha = 0.0083L_1 + 2.0$, lowest tier of unprotected fronts

$\alpha = 0.0083L_1 + 1.0$, second tier of unprotected fronts

$\alpha = 0.0067L_1 + 0.5$, third tier of unprotected fronts and above, protected fronts and sides of all tiers

$\alpha = 0.001L_1 - 0.8\,(X/L) + 0.7$, aft ends of all tiers where aft of amidships

$\alpha = 0.001L_1 - 0.4\,(X/L) + 0.5$, aft ends of all tiers where forward of amidships

where: L, L_1 — length of ship, in m; L_1 need not be taken greater than 300 m;

X — distance, in m, between bulkhead considered and A.P. When determining sides of a deckhouse, the deckhouse is to be subdivided into parts of approximately equal

length, not exceeding 0.15L each and X is to be taken as the distance between A.P. and the centre of each part considered.

2.17.2.3 Coefficient β is to be determined as follows:

$$\beta = 1.0 + \left(\frac{X/L - 0.45}{C_b + 0.2} \right)^2 \text{, for } X/L \le 0.45$$

$$\beta = 1.0 + 1.5\left(\frac{X/L - 0.45}{C_b + 0.2} \right)^2 \text{, for } X/L > 0.45$$

where: L — length of ship, in m;

X — see 2.17.2.2;

C_b — block coefficient, where $C_b < 0.6$, to be taken as 0.6; where $C_b > 0.8$, to be taken as 0.8; where the aft end bulkhead of the superstructure is forward of amidships, C_b used in determining the value β for the aft end bulkhead is not to be taken as less than 0.8.

2.17.2.4 Coefficient λ is to be determined as follows:

$$\lambda = \frac{L}{10} e^{-L/300} - [1 - (\frac{L}{150})^2] \quad \text{for } L < 150 \text{ m}$$

$$\lambda = \frac{L}{10} e^{-L/300} \quad \text{for } 150 \text{ m} \le L < 300 \text{ m}$$

$$\lambda = 11.03 \quad \text{for } L \ge 300 \text{ m}$$

where: L — length of ship, in m.

2.17.2.5 Coefficient δ is to be determined as follows:

$$\delta = 0.7 \frac{b}{B_1} + 0.3 \text{, and not less than 0.475}$$

where: b — breadth of deckhouse at the position considered, in m;

B_1— actual maximum breadth of ship on the exposed weather deck at the position considered, in m.

For exposed parts of superstructures, machinery casings and deckhouses protecting pump room openings, δ is to be taken as 1.

2.17.3 End bulkheads of superstructures and boundary bulkheads of deckhouses

2.17.3.1 The thickness t of end bulkhead plating of superstructures and boundary bulkhead plating of deckhouses is not to be less than:

$$t = 3s\sqrt{hK} \quad \text{mm}$$

The minimum thickness of the plate, t_{min}, is to comply with the following requirements:

If $L_1 \ge 65$ m: $t = (0.01L_1 + 5.0)\sqrt{K}$ mm, for lowest tier

$$t = (0.01L_1 + 4.0)\sqrt{K} \text{ mm, for upper tiers, and not less than 5 mm}$$

If $L_1 < 65$ m: $t_{min} = 5.0$ mm, for the lowest unprotected front

$t_{min} = 4.0$ mm ,for all other cases

where: s — spacing of stiffeners, in m;

h — design pressure head, in m, to be calculated according to 2.17.2 of this Section;

L_1 — length of ship, in m, L_1 need not be taken greater than 300 m;

K — material factor.

2.17.3.2 The section modulus W of end bulkhead stiffeners of superstructures and boundary bulkhead stiffeners of deckhouses is not to be less than:

$$W=3.5shl^2K \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

l — span of stiffener, in m; to be taken as height of deckhouse, but not less than 2.0 m in any case;

h — calculated pressure head, in m, to be obtained according to 2.17.2 of this Section;

K — material factor.

Except as required in 2.17.3.3 and 2.17.3.4 of this Section, the end of stiffeners of enclosures of the deckhouse may not be fitted with brackets, provided that the webs of stiffeners are welded to the deck effectively. The section modulus of house side stiffeners need not be greater than that of side frames on the deck situated directly below, taking account of spacing and span.

2.17.3.3 The ends of following stiffeners are to be bracketed or connected by equivalent arrangements. The scantlings of brackets are to be determined according to the relevant provisions of 1.2.6 of this PART:

(1) Front stiffeners of the lowest tier;

(2) Front stiffeners of upper tiers in ships over 150 m in length;

(3) Side stiffeners of single tier deckhouse;

(4) Aft stiffeners of the lowest aft deckhouse;

(5) Side stiffeners of upper deckhouses when the length of ship is greater than 150 m, side stiffeners of the lowest deckhouse if two or more tiers of deckhouses are fitted; where such stiffeners are not bracketed but directly welded to the deck, their section modulus is to be increased by 20%.

2.17.3.4 For exposed machinery and pump-room casings, the front stiffeners on amidships casing and all stiffeners on aft end casings which are situated on the deck to which the moulded depth D is measured are to be bracketed at top and bottom. Where such stiffeners are not bracketed but directly welded to the deck, their section modulus is to be increased by 20% above that required for the stiffeners of deckhouses in the corresponding positions. All other stiffeners on exposed machinery and pump-room casings are to be welded to the decks at top and bottom.

2.17.4 Sides of superstructures

2.17.4.1 The side framing of superstructures is to comply with the following requirements:

(1) Where the side shell is framed transversely, the relevant requirements of Section 7 of this Chapter are to be complied with.

(2) Where the sides of superstructures are framed longitudinally and located within the range of 0.3L from A.P. forward the bow, the section modulus of longitudinals is not to be less than:

$$W = 6.5sl^2(0.6+0.167D_1)K \quad \text{cm}^3$$

where: s— spacing of longitudinals, in m;

l — span of longitudinal, in m, not less than 1.5 m;

$D_1 = d + H_b$, in m, not greater than 20 m,

where: H_b— the minimum bow height as required by load line assignment, in m;

d — draught, in m;

K— material factor.

The section modulus of web frames supporting the side longitudinals is not to be less than:

$$W = 8.8Sl^2(0.6 + 0.167D_1)K \qquad \text{cm}^3$$

where: D_1, K — the same as those in the above formula;

S — spacing of web frames, in m;

l — span of web frames, in m.

(3) Where the sides of superstructures are framed longitudinally and located beyond the range of 0.3L from A.P forward the bow, the section modulus of longitudinals is not to be less than:

$$W = 7.5sl^2(0.6 + 0.167D_2)K \quad \text{cm}^3$$

where: s— spacing of longitudinals, in m;

l— span of longitudinal, in m, not less than 1.5 m;

$D_2 = d + H_b$, in m;

where: H_b— the minimum bow height as required by load line assignment, in m;

d — draught, in m;

K— material factor.

The section modulus of web frames supporting the side longitudinals is not to be less than:

$$W = 10Sl^2(0.6 + 0.167D_2)K \qquad \text{cm}^3$$

where: D_2, K — the same as those in the above formula;

S — spacing of web frames, in m;

l — span of web frames, in m.

Where the superstructure is located within the range of 0.4L amidships and contributes to the longitudinal strength, the relevant requirements of 2.2.7, Section 2 of this Chapter are also to be complied with.

2.17.4.2 The side plating of superstructures is to comply with the following requirements:

(1) The thickness t of side plating of forecastles is not to be less than:

$$t = (0.028L + 5.5)\sqrt{\frac{sK}{s_b}} \qquad \text{mm}$$

where: L — length of ship, in m;

s — spacing of frames or longitudinals, in m, to be taken as not less than s_b;

s_b — standard spacing of frames or longitudinals, in m;

K — material factor.

(2) The thickness t of side plating of bridge and poop is not to be less than:

$$t = (0.025L + 5)\sqrt{\frac{sK}{s_b}} \qquad \text{mm}$$

where: L — length of ship, in m;

s — spacing of frames or longitudinals, in m, to be taken as not less than s_b;

s_b — standard spacing of frames or longitudinals, in m;

K — material factor.

2.17.5 Decks

2.17.5.1 The deck framing of superstructures is to comply with the relevant requirements of Section 8 of this Chapter. The deck framing of the forecastle is also to comply with the following requirements:

(1) Within the region forward of 0.075L from F.P., the spacing of deck girders supporting the beams is generally not to be more than 3.5 m, and that of the transverses supporting the deck longitudinals is generally not to be more than 2.5 m;

(2) The web depth of deck girders and transverses is not to be less than twice the depth of cutouts for the passage of beams or longitudinals being supported.

2.17.5.2 The section modulus W of the deck longitudinals or beams of deckhouses is not to be less than:

$$W = 5shl^2K \quad \text{cm}^3, \text{ and not less than } 25s$$

where: s — spacing of deck longitudinals or beams, in m;

l — span of deck longitudinals or beams, in m;

h — design pressure head, in m, to be determined as follows:

0.9 m, for those on first tier deck;

0.6 m, for those on second tier deck;

0.45 m, for those on third tier deck and above;

K — material factor.

2.17.5.3 The scantlings of deck girders and transverses of deckhouses are to be calculated in accordance with the relevant requirements of Section 8 of this Chapter, but the design pressure head is to be as specified in 2.17.5.2 of this Section. The web thickness of girders of deckhouses is not to be less than 1% of their depth plus 2 mm, but not to be less than 4 mm.

2.17.5.4 The thickness t of deck plating of superstructures (except the forecastle) and deckhouses is not to be less than:

$$t = (0.02L + C)\sqrt{\frac{sK}{s_b}} - t_c \quad \text{mm, and not less than 5 mm}$$

where: L — length of ship, in m; not to be taken as greater than 100 m;

s — spacing of deck longitudinals or beams, in m, to be taken as not less than s_b;

s_b — standard spacing of deck longitudinals or beams, in m;

C — coefficient, to be taken as follows:

5.5, for the first tier deck;

5.0, for the second tier deck;

4.5, for the third tier deck and above;

t_c — t_c = 1 for decks of dry spaces within superstructures or deckhouses; t_c = 0 in other cases;

K — material factor.

2.17.5.5 The thickness t of forecastle deck plating is not to be less than:

$$t = (0.02L + 6)\sqrt{\frac{sK}{s_b}} \quad \text{mm}$$

where: L — length of ship, in m;

s — spacing of deck longitudinals or beams, in m, to be taken as not less than s_b;

s_b — standard spacing of deck longitudinals or beams, in m;

K — material factor.

2.17.6 Local strengthening of superstructures

2.17.6.1 Web frames or partial bulkheads spaced about 9 m apart are to be fitted within the poop or bridge that have large deckhouses or other erections above, to support side and end bulkheads of the deckhouses.

Appropriate strength members are also to be fitted in other areas under high loading.

2.17.6.2 The web frames or partial bulkheads within superstructures are to be arranged, where practicable, in line with the watertight bulkheads or other strength members below.

2.17.6.3 Pillars, diaphragms, bulkheads or other strength members are to be arranged under the ends of superstructures for support.

2.17.6.4 To reduce stress concentration in main hull structure in way of ends of superstructures which are flush with ship's side, the side plating of the superstructures is to extend beyond their ends and the height of the side plating is to be gradually reduced to that of the sheer strake in a smooth transition (free edges of extension plating generally in an oval shape with horizontal axis, see Figure 2.17.6.4). This plating is to be supported by stiffened brackets and to be efficiently stiffened at the upper edge by a face plate having the same thickness as the extension plating and a breadth not less than 10 times its thickness. The extension plating is to comply with the following requirements:

(1) For end bulkheads of superstructures situated within 0.5L amidships, the length of the extension plating is not to be less than 1.5 times that of the superstructure and its thickness is to be increased by 25%;

(2) For end bulkheads of superstructures situated within 0.2L from the ship's ends, the length of the extension plating is not to be less than the height of the superstructure and its thickness need not be increased;

(3) For end bulkheads of superstructures situated between 0.2L and 0.25L from the ship's ends, the increased length and thickness of the extension plating is to be obtained by interpolation.

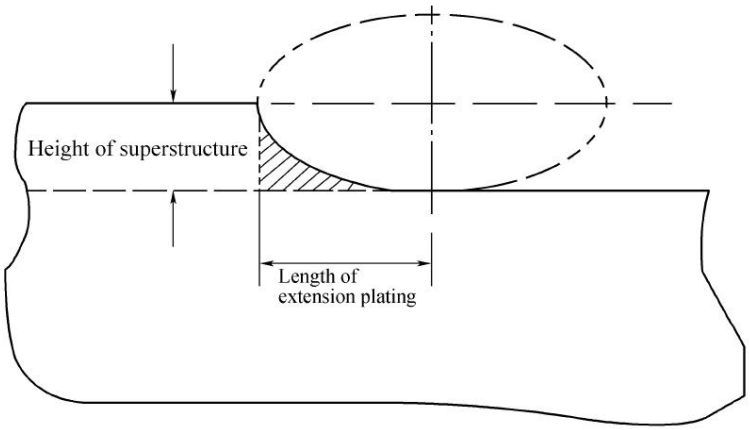


Figure 2.17.6.4

2.17.6.5 The thickness of the upper deck stringer plate and the sheer strake is to be increased at the ends of the superstructure from at least two frame spaces inside the superstructure to two frame spaces beyond the extension of side plating (see Figure 2.17.6.5) in accordance with the following requirements:

(1) Where the end bulkheads of the superstructure are situated within 0.5*L* amidships, the thickness of stringer plates and sheer strakes is to be increased by 20%;

(2) Where the end bulkheads of the superstructure are situated within 0.2*L* from the ship's ends, the thickness of stringer plates and sheer strakes need not be increased;

(3) Where the end bulkheads of the superstructure are situated between 0.2*L* and 0.25*L* from the ship's ends, the increased thickness of stringer plates and sheer strakes is to be obtained by interpolation.

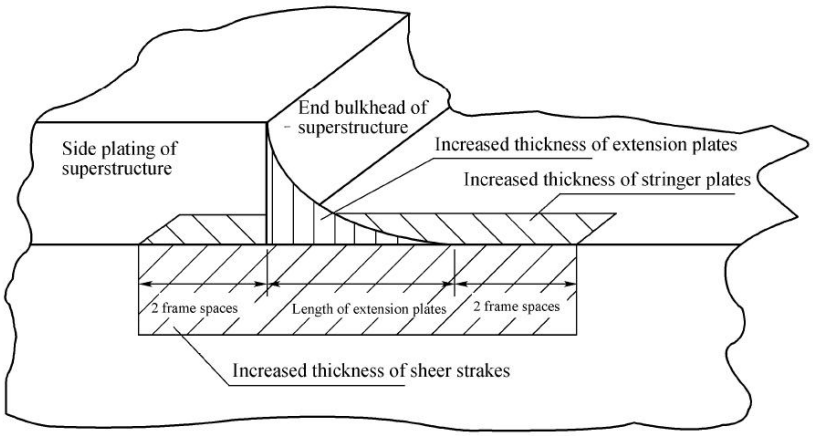


Figure 2.17.6.5

2.17.7 Local strengthening of deckhouses

2.17.7.1 Adequate support under the ends of deckhouses is to be provided in the form of pillars, diaphragms, bulkheads or other strength members. At the corners of houses and in way of supporting structures, attention is to be given to the connection to the deck, and inserts or equivalent arrangements are generally to be fitted.

2.17.7.2 All openings cut in the sides of long deckhouses are to be adequately strengthened and have well rounded corners. Continuous coamings with adequate height are to be fitted below and above doors or similar openings. House tops are to be strengthened in way of boats and davits. Special care is to be taken to minimize the size and number of openings in the side bulkheads in the region of the ends of deckhouses within 0.5*L* amidships.

2.17.7.3 The sides and ends of the long deckhouses on the lowest tier deck are generally to be strengthened by partial bulkheads or vertical webs spaced about 9 m apart, and these stiffening members are, as far as practicable, to be arranged in line with the strengthening members within the 'tween deck space below the deckhouse.

2.17.8 Raised quarterdecks

2.17.8.1 The scantlings of the main frames in way of the raised quarter deck are to be determined according to the requirements of Section 7 of this Chapter. In this case the span of the frame is to be measured to the raised quarter deck.

The scantlings of the deck frames in way of the raised quarter deck are to be determined in accordance with the relevant requirements for the strength deck as specified in Section 8 of this Chapter.

The thickness of the raised quarter deck sheer strake is to be determined according to the requirements of Section 3 of this Chapter, and the thickness of deck plating is to be determined in accordance with the relevant requirements for strength deck as specified in Section 4 of this Chapter. In such cases the moulded depth is to be taken as that at the raised quarter deck.

The thickness of break bulkheads and the scantlings of stiffeners are to be determined in accordance with the requirements for end bulkheads of corresponding superstructures.

2.17.8.2 Strengthening at the break within 0.5*L* amidships

(1) For $L < 65$ m, the strength deck stringer plate and the raised quarter deck stringer plate are to extend respectively for 3 or 4 frame spaces on either side of the break bulkhead and are to be gradually tapered off;

(2) For $L \geq 65$ m, the upper and raised deck plating at the break is to overlap for 2 or 3 frame spaces, and in this case the stringer plates of both decks are to extend forward for 2 or 3 frame spaces beyond the end of overlapped plating. Vertical diaphragm plates spaced not more than 1.5 m apart in parallel with the longitudinal centreline are to be fitted between the overlapped deck plating. The thickness of the diaphragm plates is to be the same as that of the break bulkhead plating, and the diaphragms are to be efficiently stiffened and their free edges are to be flanged or provided with a face plate.

2.17.8.3 Where the break is located outside of 0.5*L* amidships, the strength deck stringer plate is to extend for 3 frame spaces beyond the break and is to be gradually tapered off.

2.17.8.4 The sheer strake is to be increased in thickness by 30% for a distance of 3 to 5 frame spaces on either side of the break bulkhead. Where a raised quarter deck is connected to a long bridge, the sheer strake of side plating within the raised quarter deck area is to be increased in thickness by 25% for a distance of at least 2 frame spaces on either side of the break, and the side plating of the bridge is to be gradually tapered in a curve line from the end of the bridge deck stringer plate into the sheer strake of side plating within raised quarter deck area over a length more than 1.5 times the height of the bridge above the raised quarter deck.

2.17.9 Machinery casings

2.17.9.1 Machinery space openings in the exposed deck are to be protected by strong steel casings. Machinery casings situated on the freeboard or raised quarter deck are to be enclosed in the superstructures or deckhouses so far as practicable.

2.17.9.2 Doors in machinery casings are to be of steel and rigid construction, and are to be capable of being operated from both sides.

2.17.9.3 The scantlings of boundary bulkheads of exposed casings are to be determined in accordance with the requirements for those of the deckhouses in the corresponding positions.

2.17.9.4 The scantlings of boundary bulkheads of non-exposed casings are to comply with the following requirements:

(1) The minimum thickness of boundary bulkheads of the casings is not to be less than 6.5 mm in way of cargo spaces and not to be less than 5 mm in way of accommodation spaces;

(2) The section modulus *W* of the stiffeners of boundary bulkheads of the casings is not to be less than that obtained from the following formula:

$$W = 8slK \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

l — span of stiffener, in m;

K— material factor.

For ships of 65 m or over in length, the depth of stiffeners is not to be less than 60 mm.

2.17.9.5 Where casing stiffeners support the deck transverses or girders or where they are in line with pillars below, they are to be suitably strengthened.

2.17.9.6 Where the casing sides act as girders supporting decks above, the openings for doors, windows, etc., in the sides are to be effectively strengthened. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

2.17.10 Breakwater

2.17.10.1 The load under consideration is to be determined with the requirements for fronts of superstructures in 2.17.2 of this Section as reference.

2.17.10.2 The thickness of breakwater plating and the scantlings of breakwater stiffeners are to be determined according to 2.17.3 of this Section.

2.17.10.3 The scantlings of main members (horizontal girders and vertical webs) supporting breakwaters are to be determined by direct calculations, and the permissible stress is as follows:

$$[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 235/K \quad \text{N/mm}^2$$

where: K — material factor.

Section 18 HELICOPTER DECKS

2.18.1 General requirements

2.18.1.1 This Section applies to all ships fitted with areas and facilities for normal takeoff and landing of helicopters.

2.18.1.2 Helicopter decks covered by this Section mean helicopter deck structure only.

2.18.1.3 For helicopter deck connected by bolts and splice other than welding, special consideration is to be given to the requirements for structural strength.

2.18.2 Plans and documents

2.18.2.1 The following plans and documents are to be submitted for approval:

(1) Detailed arrangement of helicopter deck, including overall dimensions, landing area/securing area, if any;

(2) Structural plan for helicopter deck (appropriate strength calculations are submitted for information).

2.18.2.2 Loading manual is to include information on models and parameters of helicopters to be used, including maximum takeoff weight, overall length of helicopter (including rotation of rotor), size of wheel print and tracking width.

2.18.3 Arrangement of helicopter deck

2.18.3.1 The arrangement and construction of helicopter deck is to meet the applicable standards accepted by the flag Administration, such as the annex to IMO MSC/Circ.895 and MSC.1/Circ.1524—Recommendation on Helicopter Landing Areas on Ro-Ro Passenger Ships, International Chamber of Shipping (ICS)- Guide to Helicopter/Ship Operations, International Aeronautical and Maritime Search and Rescue Manual (IAMSAR) and Offshore Helicopter Landing Areas-Guidance on Standards (CAP437).

2.18.4 Design conditions

2.18.4.1 The supporting structure of the helicopter platform is to be designed to the following three conditions: overall distributed loading, helicopter landing impact loading and stowed helicopter loading (if provisions are made to accommodate the helicopter secured to the deck in a predetermined position):

(1) Overall distributed loading:

① a minimum distributed loading of 2 kN/m^2 is to be taken over the entire helicopter deck.

(2) Helicopter landing impact loading: Combination of the following loads is to be taken into account:

① for normal landing, vertical impact loading P_H = 1.5P (P being the maximum takeoff weight), uniformly distributed on both wheel prints when landing (landing of both wheels at the same time is generally assumed). Where no data on actual size of wheel prints are available, the size of each print may be taken as a square area of 0.30 m × 0.30 m. The structural members are to be designed according to the worst landing position with regard to forces acting on them.

Where the upper deck of a superstructure or deckhouse is used as a helicopter platform deck and the spaces below are normally manned (control room, quarters, etc.), the above vertical impact loading P_H = 1.75P;

② the structural weight of the helicopter deck;

③ where necessary, a uniformly distributed loading of 0.5 kN/m^2, representing wet snow, ice or other environmental loading, is to be considered.

(3) Stowed helicopter loading: Combination of the following loads is to be taken into account:

① wheel loading at maximum takeoff weight, with landing area being assumed as that for helicopter landing impact loading;

② the structural weight of the helicopter deck;

③ where necessary, a uniformly distributed loading of 0.5 kN/m^2, representing wet snow, ice or other environmental loading, is to be considered;

④ in addition, where stowage of helicopters is possible, the inertial forces of helicopter and helicopter platform due to ship's motion under corresponding environmental conditions are to be considered. If no proper data are available, both the horizontal and vertical inertial forces may be taken as 0.5 times the loading corresponding to the weight of helicopter and helicopter platform structure.

2.18.4.2 For helicopters fitted with landing gear other than wheels, the landing area is to be determined according to the data provided by manufacturers.

2.18.5 Helicopter deck plating

2.18.5.1 The initial plate thickness of the helicopter deck may be calculated in accordance with

2.21.2.1(1) of this Chapter, with loading being the wheel impact loading required for the above design conditions.

2.18.5.2 Where the helicopter deck is the strength deck within 0.4L amidships, the wheel impact loading obtained according to 2.18.5.1 of this Section is to be multiplied by a factor of 1.18. This factor is linearly reduced to 1.00 within 0.4L amidships aft or forward along ship's length.

2.18.5.3 The helicopter deck plate thickness is to be based on the initial thickness calculated according to 2.18.4.1 or 2.18.4.2, and is to comply with the strength verification of the entire helicopter deck structure by direct calculation.

2.18.5.4 Hatch covers used as helicopter deck are to comply with this Section and in addition, Section 20 of this Chapter.

2.18.5.5 Where the helicopter deck forms part of a weather deck or other decks, the scantlings are not to be less than those required for decks in the same position.

2.18.6 Strength verification by direct calculation

2.18.6.1 Direct calculation of helicopter deck structure is to be preformed by 3-dimensional finite element structural analysis, and recognized programs and structural idealization methods are to be used.

2.18.6.2 The permissible bending stress [σ], shear stress [τ] of helicopter deck plating, deck framing and their supporting structure and the permissible stress [σ_{cb}] of compressed components are as follows:

(1) The permissible bending stress [σ] is to be determined according to Table 2.18.6.2.

Permissible Bending Stress [σ] **Table 2.18.6.2**

Structural member / Design condition	Deck plating	Longitudinals, transverses and other secondary deck members	Girders, web beams and other main deck members Stanchions, supports and other truss supports of platform
Overall distributed loading	$0.6R_{eH}$ ③	$0.6R_{eH}$	$0.6R_{eH}$ ①
Helicopter landing impact loading	R_{eH} ②	R_{eH}	$0.9R_{eH}$ ①
Stowed helicopter loading	R_{eH}	$0.9R_{eH}$	$0.9R_{eH}$ ①

Notes: R_{eH} — yield stress of material, in N/mm^2; for aluminium alloy, taken as $R_{p0.2}$, see Section 3, Chapter 1 of this PART.

① Components under axial compression are to be checked to the lesser of permissible bending stress and permissible critical buckling stress.

② For helicopter landing impact loading, where the stress of helicopter deck plating is obtained according to a four-sides supported plate subjected to vertically distributed loading, the permissible stress may be taken as 1.1 R_{eH}.

③ For overall distributed loading, the helicopter deck plating thickness is not to be less than the minimum thickness required by 2.18.5 and the Rules.

(2) Permissible shear stress [τ]: $[\tau] = [\sigma] / \sqrt{3}$.

(3) Permissible compressive stress [σ_{cb}] is to be calculated according to 2.2.7.5(1) and 2.2.7.6 of this Chapter.

2.18.6.3 The value of the permissible bending stress for framing and girders of strength deck used as helicopter deck is to be multiplied by a reduction factor in Table 2.18.6.3.

Reduction Factor **Table 2.18.6.3**

Location of helicopter deck	Reduction factor	Location of helicopter deck	Reduction factor

Area 0.4*L* amidships	0.7	A.P./F.P. area	1.0
Area between A.P. and F.P.	Linear interpolation		

Section 19 BULWARKS AND GUARDRAILS

2.19.1 General requirements

2.19.1.1 Guardrails or bulwarks are to be fitted around all exposed decks. The height of the bulwarks or guardrails is to be at least 1 m from the deck, provided that where this height would interfere with the normal operation of the ship, a lesser height may be approved, if the Administration is satisfied that adequate protection is provided.

2.19.1.2 The ship designed for the carriage of timber deck cargoes is to be fitted either with permanent bulwarks at least 1 m in height, specially stiffened on the upper edge and supported by strong bulwark stays attached to the deck and provided with necessary freeing ports, or with efficient rails of the same height and of specially strong construction.

2.19.2 Bulwarks

2.19.2.1 The plating thickness of bulwarks on freeboard decks is not to be less than 5 mm for ships having a length less than 65 m and not to be less than 6 mm for ships having a length equal to 65 m or over. The plating thickness of bulwarks elsewhere may be suitably reduced.

2.19.2.2 The top edge of bulwarks is to be stiffened by a flat bar or profile steel.

2.19.2.3 Bulwarks are to be supported by stays with flange or face plate from the deck in line with the beams or beam webs. Where the frame spacing does not exceed 620 mm, the spacing of stays is not to exceed 3 frame spaces. Where the frame spacing exceeds 620 mm or where the ship is intended for the carriage of timber deck cargoes, the spacing of stays is not to be greater than 2 frame spaces. Where the bulwarks on the forecastle deck have a great flare, stays are to be fitted at every frame.

2.19.2.4 The section modulus W at the bottom of bulwark stays is not to be less than that obtained from the following formula:

$$W = (30 + 0.45L)SH^2K \quad \text{cm}^3$$

where: S— spacing of stays, in m;

L— length of ship, in m, not to be taken as greater than 100 m;

H— height of bulwark, in m;

K— material factor.

Where the flange of the stay is not welded to the deck, such a flange is not to be considered for the section modulus.

2.19.2.5 Bulwarks are to be adequately strengthened in way of mast shrouds or eyeplates for cargo gear and in way of fairleaders.

2.19.2.6 Where bulwarks are cut to form a gangway or other openings, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

2.19.2.7 Bulwarks are as far as practicable not to be welded to the sheer strake amidships so as to ensure their freedom from the longitudinal bending of the hull.

2.19.3 Guardrails

2.19.3.1 Guardrails fitted on superstructure and freeboard decks are to have at least three courses. The opening below the lowest course of the guardrails is not to exceed 230 mm. The other courses are to be not more than 380 mm apart. In the case of ships with rounded gunwales the guardrail supports are to be placed on the flat of the deck. In other locations, guardrails with at least two courses are to be fitted.

2.19.3.2 Where external glass balustrades are fitted, reference may be made to relevant requirements of Section 8, Chapter 9 of this PART.

Section 20 HATCHWAYS AND HATCH COVERS

2.20.1 General requirements

2.20.1.1 In addition to the requirements of this Section, exposed hatchways and hatch covers are to comply with the relevant requirements of the Amendments to Annex I to Annex B of the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

2.20.1.2 The structural scantlings of non-exposed hatch covers may be determined according to the relevant requirements of this Section, depending on their structural configuration and with only permissible cargo loads being taken into account.

2.20.1.3 The scantlings of steel hatch covers for deep tanks may be determined according to the relevant requirements of this Section and depending on the position of hatch covers, but in no case are to be less than those required in Section 13 of this Chapter for deep tank deck and its framing.

2.20.1.4 Where wheeled vehicles are to be stowed on hatch covers or used for cargo handling, the scantlings of hatch covers are also to comply with the requirements for vehicle deck in Section 21 of this Chapter.

2.20.1.5 The scantlings of hatch covers used as helicopter deck are also to comply with the requirements for helicopter decks in Section 18 of this Chapter.

2.20.1.6 Except as otherwise provided, the width of the attached plating of hatch cover stiffeners and girders is to be determined according to 1.2.2 of Section 2, Chapter 1 of this PART. However, the areas of stiffeners are not to be included in the area of the attached plating of girders.

2.20.1.7 For the hatch covers on the lower deck within cargo holds, the strength is to be checked according to the requirements of 2.20.3.

2.20.1.8 Height of hatch coamings

(1) at Position 1, the height is not to be less than 600 mm;

(2) at Position 2, the height is not to be less than 450 mm;

(3) for ships provided with steel weathertight hatch covers, with the consent of the flag State Administration, the height of hatch coamings may be suitably reduced provided that efficient measures have been taken and that the safety of the ship is not impaired;

(4) for hatchways on unexposed freeboard decks or exposed superstructure decks, hatchway coamings with a suitable height may be provided depending upon the position of the hatchways and the protection necessitated by such hatchways.

2.20.1.9 Hatch cover types

(1) Single skin cover

A hatch cover made of steel or equivalent material that is designed to comply with ICLL Regulation 16. The cover has continuous top and side plating, but is open underneath with the stiffening structure exposed. The cover is to be weathertight and fitted with gaskets and clamping devices unless specifically exempted from such fittings.

(2) Double skin cover

A hatch cover as above but with continuous bottom plating such that all the stiffening structure and internals are protected from the environment.

(3) Pontoon type cover

A special type of portable cover, secured weathertight by tarpaulins and battening devices. Such covers are to be designed in accordance with ICLL Regulation 15.

Note: Modern designs of lift-away hatch covers are in many cases called pontoon covers. This definition does not fit to the (3) above. Modern lift-away hatch covers are to fall into one of the two categories of single skin covers and double skin covers.

2.20.2 Weathertight steel hatch covers

2.20.2.1 General requirements

(1) These requirements apply to all ships except CSR bulk carriers, and are for all cargo hatch covers and coamings on exposed decks. As specified in this Section, parts of the requirements are for some specific ship types as categorized below:

① Type-1 ships, including all ships except bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers.

② Type-2 ships, including all bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers.

(2) The strength requirements are applicable to hatch covers and hatch coamings of stiffened plate construction and their closing arrangements.

(3) These requirements are applicable to hatch covers and coamings made of steel. The materials of hatch covers and hatch coamings are to meet the relevant requirements of Section 3, Chapter 1 of this PART. The material class I is to be applied for top plate, bottom plate and primary supporting members of hatch covers. Equivalent materials and novel designs subject to approval by CCS.

(4) Primary supporting members and secondary stiffeners of hatch covers are to be continuous over the breadth and length of hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to provide sufficient load carrying capacity.

The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed 1/3 of the span of primary supporting member. When strength calculation is carried out by FE analysis using plane strain or shell elements, this requirement may be relaxed appropriately.

Secondary stiffeners of hatch coamings are to be continuous over the breadth and length of hatch coamings.

(5) Unless stipulated otherwise, the thickness t in these requirements is net thickness.

The net thicknesses are the member thicknesses necessary to obtain the minimum net scantlings required by 2.20.2.3 to 2.20.2.6 and 2.20.2.8 of this Section.

The required gross thickness is obtained by adding the corrosion addition t_s, given in 2.20.2.10 of this Section, to the net thickness t_s.

Strength calculations using FEM are to be performed with net scantlings.

2.20.2.2 Hatch cover and coaming load model

The structural strength evaluation of hatch covers and hatch coamings is to be carried out using the design loads defined as follows:

Definitions:

L = length of ship, in m;

L_L = load line length, in m;

x = longitudinal distance measured from midpoint of structural member to the aft end of L or L_L, in m;

$D_{\min}$ = the least moulded depth, in m, as defined in Regulation 3 of ICLL Annex I;

h_N = standard superstructure height, in m, to be calculated as follows:

$$h_N = 1.05 + 0.01L_L \text{, and} 1.8 \le h_N \le 2.3 .$$

(1) Vertical weather design load

The pressure p_H, in kN/m², on the hatch cover panel is given by ICLL. This may be taken from Table 2.20.2.2(1). The vertical weather design load is not to be combined with cargo loads in 2.20.2.2(3) and (4).

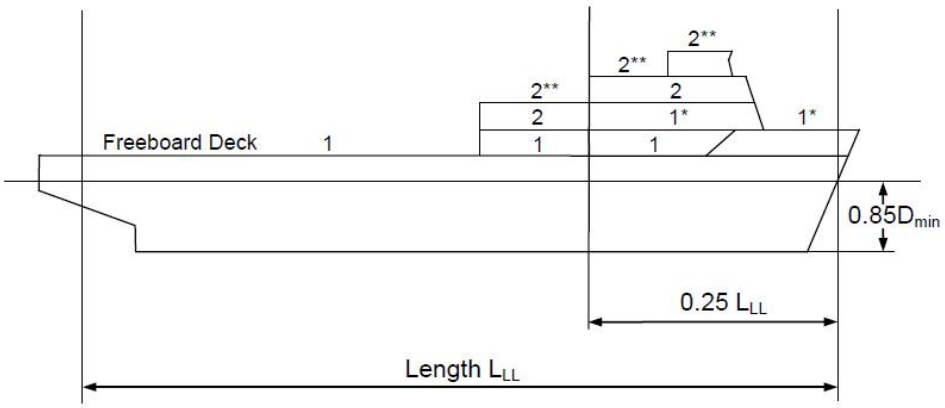
For Position 1 and Position 2, see Figure 2.20.2.2(1).

Where an increased freeboard is assigned, the design load for hatch covers on the actual freeboard deck may be as required for a superstructure deck, provided that the summer freeboard is such that the resulting draught will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance at least equal to the standard superstructure height h_N below the actual freeboard deck, see Figure 2.20.2.2(2).

Vertical Design Load p_H of Weather Deck Hatches Table 2.20.2.2(1)

<table>
<tr><td rowspan="2">Position</td><td colspan="2">Vertical design load p_H , kN/m^2</td></tr>
<tr><td>$\frac{x}{L_L} \le 0.75$</td><td>$0.75 < \frac{x}{L_L} \le 1.0$</td></tr>
<tr><td rowspan="4">1</td><td colspan="2">For $24\text{m} \le L_L \le 100\text{m}$</td></tr>
<tr><td rowspan="2">$\frac{9.81}{76}(1.5L_L + 116)$</td><td>On freeboard deck: $\frac{9.81}{76}\left[(4.28L_L + 28)\frac{x}{L_L} - 1.71L_L + 95\right]$</td></tr>
<tr><td>Upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck: $\frac{9.81}{76}(1.5L_L + 116)$</td></tr>
<tr><td colspan="2">For L_L>100 m</td></tr>
<tr><td>9.81×3.5</td><td>On freeboard deck for type B ships according to ICLL:
$9.81\left[(0.0296L_1 + 3.04)\frac{x}{L_L} - 0.0222L_1 + 1.22\right]$</td></tr>
</table>

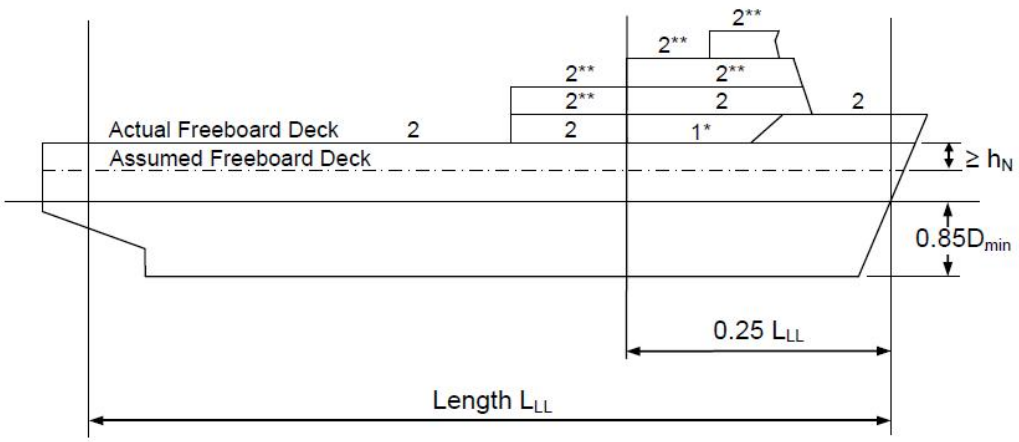
		On freeboard deck for ships with less freeboard than type B according to ICLL: $9.81\left[(0.1452L_1 - 8.52)\frac{x}{L_L} - 0.1089L_1 + 9.89\right]$ L_1=L_L, but not more than 340 m
		Upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck: 9.81×3.5
2	For $24\text{ m} \le L_L \le 100\text{ m}$	
	$\frac{9.81}{76}(1.1L_L + 87.6)$	
	For L_L>100 m	
	9.81×2.6	
	Upon exposed superstructure decks located at least one superstructure standard height above the lowest Position 2 deck: 9.81×2.1	



* — reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck;

** — reduced load upon exposed superstructure decks of vessels with L_L > 100 m located at least one superstructure standard height above the lowest Position 2 deck.

Figure 2.20.2.2(1) Positions 1 and 2



*— reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck;

** — reduced load upon exposed superstructure decks of vessels with L_L > 100 m located at least one superstructure standard height above the lowest Position 2 deck.

Figure 2.20.2.2(2) Positions 1 and 2 for an Increased Freeboard

(2) Horizontal weather design load

① General horizontal weather design load

The horizontal weather design load p_A , in kN/m^2, for determining the scantlings of outer edge girders (skirt plates) of weather deck hatch covers and of hatch coamings is to be calculated by the following formula:

$$p_A = ac(bfc_L - z) \quad \text{kN/m}^2$$

where: $f = \frac{L}{25} + 4.1$, for L< 90 m;

$f = 10.75 - \left(\frac{300 - L}{100}\right)^{1.5}$, for $90\text{m} \le L < 300\text{m}$;

$f = 10.75$, for $300\text{m} \le L < 350\text{m}$;

$f = 10.75 - \left(\frac{L - 350}{150}\right)^{1.5}$, for $350\text{m} \le L \le 500\text{m}$;

$c_L = \sqrt{\frac{L}{90}}$, for $L < 90$ m;

$c_L = 1$, for $L \ge 90\text{m}$;

$a = 20 + \frac{L_1}{12}$, for unprotected front coamings and hatch cover skirt plates;

$a = 10 + \frac{L_1}{12}$, for unprotected front coamings and hatch cover skirt plates, where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard according to ICLL by at least one standard superstructure height;

$a = 5 + \frac{L_1}{15}$, for side and protected front coamings and hatch cover skirt plates;

$a = 7 + \frac{L_1}{100} - \frac{8x'}{L}$, for aft ends of coamings and aft hatch cover skirt plates abaft amidships;

$a = 5 + \frac{L_1}{100} - \frac{4x'}{L}$, for aft ends of coamings and aft hatch cover skirt plates forward of amidships;

L_1=L, but need not be taken as greater than 300 m;

$b = 1.0 + \left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2}\right)^2$, for $\frac{x'}{L} < 0.45$;

$b = 1.0 + 1.5\left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2}\right)^2$, for $\frac{x'}{L} \ge 0.45$;

C_b — block coefficient, $0.6 \le C_b \le 0.8$, when determining scantlings of aft ends of coamings and aft hatch cover skirt plates forward of amidships, C_b need not be taken less than 0.8;

x' — distance in m, between the transverse coaming or hatch cover skirt plate considered and aft end of the length L . For side coamings or side hatch cover skirt plates, the side is to be subdivided into parts of approximately equal length, not exceeding 0.15 L each, and "x" is to be taken as the distance between aft end of the length L and the centre of each part considered;

z — vertical distance, in m, from the summer load line to the midpoint of stiffener span, or to the middle of the plate field;

$c = 0.3 + 0.7\frac{b'}{B'}$, the $\frac{b'}{B'}$ is not to be less than 0.25;

b' — breadth of coaming, in m, at the position considered;

B' —actual maximum breadth of ship, in m, on the exposed weather deck at the position considered.

The horizontal design load is not to be taken less than the minimum values given in Table 2.20.2.2(2).

Minimum Horizontal Design Load P_{Amin} Table 2.20.2.2(2)

L	P_{Amin} kN/m²	
	Unprotected fronts	elsewhere
≤ 50m	30	15
> 50m	$25+\frac{L}{10}$	$12.5+\frac{L}{20}$
< 250m		
≥ 250m	50	25

② Horizontal weather design load applicable to coamings of Type-2 ships

The pressure P_{coam}, in kN/m², on the No. 1 forward transverse hatch coaming is given by:

$P_{coam} = 220$ kN/m², when a forecastle is fitted in accordance with Section 13, Chapter 8 of this PART;

$P_{coam} = 290$ kN/m² in the other cases;

The pressure P_{coam}, in kN/m² , on the other coamings is given by:

$P_{coam} = 220$ kN/m²

Note: The horizontal weather design loads p_A and P_{coam} need not be included in the direct strength calculation of the hatch cover, unless it is utilized for the design of substructures of horizontal support according to 2.20.2.9(2)③.

(3) Cargo loads

① Distributed loads

The uniform cargo load on hatch covers due to cargo loads p_L, resulting from heave and pitch (i.e. ship in upright condition) is to be determined according to the following formula:

$$p_L = p_C(1 + a_V) \quad \text{kN/m}^2$$

where: p_C — uniform cargo load, in kN/m²;

a_V — vertical acceleration addition as follows:

$a_V = Fm$;

$F = \frac{0.11 v_0}{\sqrt{L}}$;

$m = m_0 - 5(m_0 - 1)\frac{x}{L}$ for $0 \le \frac{x}{L} \le 0.2$;

$m = 1.0$ for $0.2 < \frac{x}{L} \le 0.7$;

$m = 1 + \frac{m_0 + 1}{0.3}\left[\frac{x}{L} - 0.7\right]$ for $0.7 < \frac{x}{L} \le 1.0$;

$m_0 = 1.5 + F$;

v_0 — maximum speed at summer load line draught, is not to be taken less than $\sqrt{L}$, in kn.

② Point loads

The load P, in kN, due to a concentrated force P_S, in kN, except for container load, resulting from heave and pitch (i.e. ship in upright condition) is to be determined as follows:

$$P = P_S(1 + a_V) \quad \text{kN}$$

(4) Container loads

① The loads defined in ② to ④ are to be applied where containers are stowed on the hatch cover.

② Corner loads for ship in upright condition

The load P, in kN, applied at each corner of a container stack, and resulting from heave and pitch (i.e. ship in upright condition) is to be determined as follows:

$$P = 9.81\frac{M}{4}(1 + a_V) \quad \text{kN}$$

where: a_V — vertical acceleration addition according to (3)①;

M — maximum designed mass of container stack, in t.

③ Corner loads for ship in heel condition

Where containers are stowed on hatch covers, the loads due to heave, pitch and the ship's rolling motion are to be determined as follows (see Figure 2.20.2.2(4)):

$$A_z = 9.81\frac{M}{2}(1 + a_V)\left(0.45 - 0.42\frac{h_m}{b}\right) \quad \text{kN}$$

$$B_z = 9.81\frac{M}{2}(1 + a_V)\left(0.45 + 0.42\frac{h_m}{b}\right) \quad \text{kN}$$

$$B_y = 2.4M \quad \text{kN}$$

where:

a_V — vertical acceleration addition according to 2.20.2.2(3);

M — maximum designed mass of container stack, in t;

h_m — designed height of centre of gravity of stack above hatch cover top, in m, may be calculated as weighted mean value of the stack, where the centre of gravity of

each tier is assumed to be located at the centre of each container, $=\sum(z_i \cdot W_i)/M$;

z_i — distance from hatch cover top to the centre of *i*th container, in m;

W_i — mass of *i*th container, in t;

b — distance between foot points, in m;

A_z, B_z — support forces in *z*-direction at the forward and aft stack corners;

B_y — support forces in *y*-direction at the forward and aft stack corners.

Values of A_z and B_z applied for the hatch cover strength evaluation are to be shown in the drawings of the hatch covers.

Note: It is recommended that container loads as calculated above are considered as limit for foot point loads of container stacks in the calculations of cargo securing (container lashing).

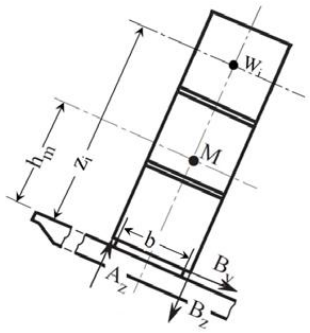


Figure 2.20.2.2(4)

④ Load cases with partial loading

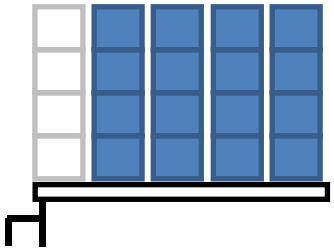
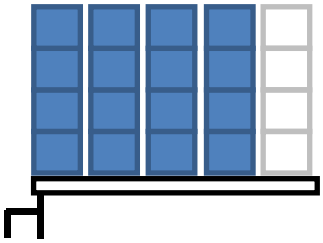
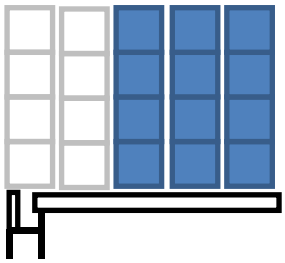
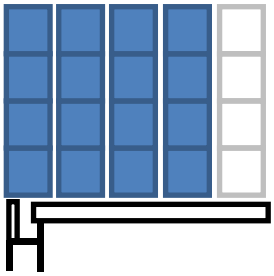
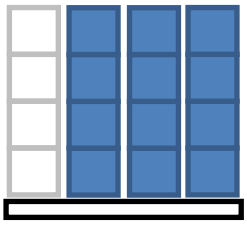
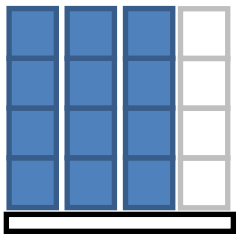
The load cases in ② and ③ above are also to be considered for partial non-homogeneous loading which may occur in practice, e.g. where specified container stack places are empty. For each hatch cover, the heel directions, as shown in Table 2.20.2.2(4), are to be considered. The load case of partial loading of container hatch covers may be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks that are located completely on the hatch cover. If there are additional stacks that are supported partially by the hatch cover and partially by container stanchions then the loads from these stacks may be neglected, refer to Table 2.20.2.2(4) Partial loading of container hatch covers.

In addition, the case where only the stack places supported partially by the hatch cover and partially by container stanchions are left empty is to be assessed in order to consider the maximum loads in the vertical hatch cover supports.

It may be necessary to also consider partial load cases where more or different container stack places are left empty. Therefore, CCS may require that additional partial load cases other than those in Table 2.20.2.2(4) be considered.

Partial loading of container hatch covers **Table 2.20.2.2(4)**

Heel direction	←	→

Heel direction	←	→
Hatch covers supported by the longitudinal hatch coaming with all container stacks located completely on the hatch cover		
Hatch covers supported by the longitudinal hatch coaming with the outermost container stack supported partially by the hatch cover and partially by container stanchions		
Hatch covers not supported by the longitudinal hatch coaming (center hatch covers)		

⑤ Mixed stowage of 20’ and 40’ containers on hatch cover

In the case of mixed stowage (20'+40' container combined stack), the foot point forces at the fore and aft end of the hatch cover are not to be higher than resulting from the design stack weight for 40’ containers, and the foot point forces at the middle of the cover are not to be higher than resulting from the design stack weight for 20’ containers.

(5) Hatch covers, which in addition to the loads according to (1) to (4) above are loaded in the ship’s transverse direction by forces due to elastic deformations of the ship’s hull, are to be designed such that the sum of stresses does not exceed the allowable value given in 2.20.2.5.

2.20.2.3 The net structural scantling of weathertight steel hatch covers is to be in compliance with the following requirements:

(1) Local net plate thickness

The local net plate thickness of the hatch cover top plating is not to be less than that obtained from the following formulae, and not less than 6 mm:

$$t = 0.0158 F_p s \sqrt{\frac{p}{0.95 R_{eH}}} \quad \text{mm}$$

$$t = 0.01 s \quad \text{mm}$$

where: F_p — factor for combined membrane and bending response, calculated as follows:

$F_p = 1.5$ in general;

$F_p = 1.9 \frac{\sigma}{\sigma_a}$ for $\frac{\sigma}{\sigma_a} \geq 0.8$ for the attached plate flange of primary supporting members;

s — stiffener spacing, in mm;

p — pressure p_H and p_L, calculated according to 2.20.2.2 of this Section, in kN/m^2;

σ — maximum normal stress of hatch cover top plating, in N/mm^2, determined according to Figure 2.20.2.3;

σ_a——permissible stress, see Table 2.20.2.5,, in N/mm^2;

R_{eH} — yield stress of materials, in N/mm^2.

For flange plates under compression, the buckling strength requirements of 2.20.2.6 of this Section are to be complied with.

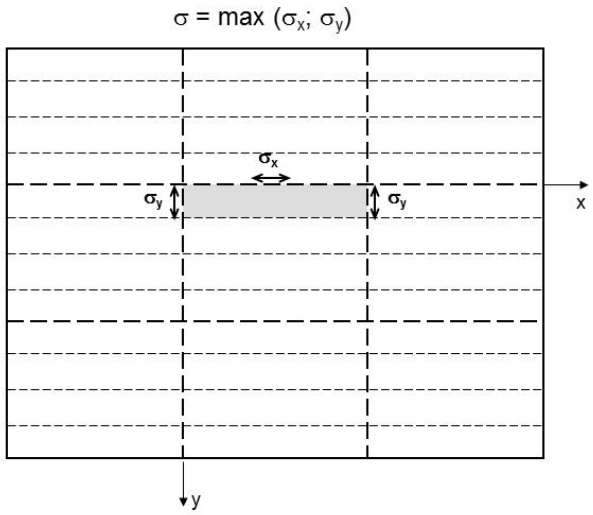


Figure 2.20.2.3

① The local net plate thickness of hatch covers for wheel loading is also to meet the relevant requirements of Section 21 of this Chapter.

② The local net plate thickness of lower plating of double skin hatch covers and box girders are to comply with the following requirements:

The thickness to fulfill the strength requirements is to be obtained from the calculation according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section. When the lower plating is taken into account as a strength member of the hatch cover, the net thickness, in mm, of lower plating is to be taken not less than 5 mm. When project cargo is intended to be carried on a hatch cover, the net thickness is not to be less than:

$$t = 6.5s \times 10^{-3} \quad \text{mm}$$

where: s— stiffener spacing, in mm.

When the lower plating is not considered as a strength member of the hatch cover, the thickness of the lower plating is not to be less than 5 mm.

Note:

Project cargo means especially large or bulky cargo lashed to the hatch cover. Examples are parts of cranes or wind power stations, turbines, etc. Cargoes that may be considered as uniformly distributed over the hatch cover, e.g. timber, pipes or steel coils need not to be considered as project cargo.

(2) The stiffeners of hatch covers are to comply with the following requirements:

The net section modulus Z and net shear area A_{shr} of uniformly loaded hatch cover stiffeners constrained at both ends are not to be less than:

$$Z = \frac{psl^2}{f_{bc}\sigma_a} \quad \text{cm}^3$$

$$A_{shr} = \frac{8.7\,psl}{\sigma_a}10^{-3} \quad \text{cm}^2$$

where: l — secondary stiffener span, in m, to be taken as the spacing of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all stiffener spans, the secondary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the unsupported span, for each bracket;

s — spacing of stiffeners, in mm;

p — p_H and p_L, to be calculated according to 2.20.2.2 of this Section, in kN/m^2;

f_{bc} — boundary coefficient of stiffener, taken equal to:

f_{bc} = 8, in the case of stiffener simply supported at both ends or simply supported at one end and clamped at the other end;

f_{bc} = 12, in the case of stiffener clamped at both ends.

σ_a — allowable stress as defined in Tab.2.20.2.5, in N/mm^2.

For secondary stiffeners of lower plating of double skin hatch covers, requirements mentioned above are not applied due to the absence of lateral loads. For double skin hatch covers of holds designed for ballast or liquid cargo, the stiffeners on lower plating are to be strengthened according to CCS requirements.

The net thickness, in mm, of the stiffener (except U-beams/trapeze stiffeners) web is not to be less than 4 mm.

The net section modulus of secondary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

Stiffeners parallel to primary supporting members are to be continuous at crossing primary supporting members, and may be considered for calculations regarding cross-sectional properties of primary members. It is to be verified that the combined stress of those stiffeners induced by the bending of primary supporting members and lateral pressures does not exceed the allowable stresses according to 2.20.2.5 of this Section. When the lower plating is not taken into account as a strength member of the hatch cover, the requirements of this paragraph are not necessary for the stiffeners of lower plating.

For hatch cover stiffeners under compression, sufficient safety against lateral and torsional buckling according to 2.20.2.6 of this Section is to be verified.

For hatch covers subject to wheel loading, the relevant requirements of Section 21 of this Chapter are to be complied with. For hatch covers subject to point loads, stiffener scantlings are to be determined by direct calculations under consideration of the allowable stresses as required in 2.20.2.5 of this Section.

(3) The net scantlings of primary supporting members are to comply with the following requirements:

① Scantlings of primary supporting members are to be obtained from direct calculations according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section.

For all components of primary supporting members sufficient safety against buckling is to be verified according to 2.20.2.6 of this Section. For biaxially compressed flange plates, the buckling strength is to be verified within the effective width according to 2.20.2.6(3)② of this Section.

The net thickness, in mm, of webs of primary supporting members is not to be less than:

$$t = 6.5s \times 10^{-3} \quad \text{mm}$$

$$t = 5 \quad \text{mm}$$

where: s— spacing of stiffeners, in mm.

② The net scantlings of edge girders are to comply with the following requirements:

Scantlings of edge girders are to be verified according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section.

The net thickness of the outer edge girders exposed to wash of seawater is not to be less than the largest of the following values:

$$t = 0.0158s\sqrt{\frac{p_A}{0.95R_{eH}}} \quad \text{mm}$$

$$t = 8.5s \times 10^{-3} \quad \text{mm}$$

$$t = 6 \quad \text{mm}$$

where: s — spacing of stiffeners, in mm;

P_A — horizontal weather design pressure, calculated according to 2.20.2.2 of this Section, in kN/m^2;

For the required moment of inertia of edge girders, refer to 2.20.2.9(1)④.

2.20.2.4 Strength calculation

The stresses in hatch covers are to be determined by FE analysis.

The stress calculation model in this section is to be used for both yielding and buckling strength assessments in accordance with 2.20.2.5 and 2.20.2.6, respectively.

The net scantlings as defined in 2.20.2.1(5) are to be used.

(1) General requirements for FEM calculations

For strength calculations of hatch covers by means of finite elements, the cover geometry is to be idealized as realistically as possible. In no case element width is to be larger than stiffener spacing. In way of force transfer points and cutouts the mesh has to be refined where applicable. The ratio of element length to width is not to exceed 3.

The element height of webs of primary supporting members is not to exceed one-third of the web height. Stiffeners, which support plates subjected to lateral pressure loads, are to be included in the FE model idealization. Stiffeners may be modelled by using beam elements, or shell/plate elements. Buckling stiffeners may be disregarded for the stress calculation.

Hatch covers fitted with U-type stiffeners as shown in Figure 2.20.2.4(1) are to be assessed by means of FE analysis.The geometry of the U-type stiffeners is to be accurately modelled using shell/plate elements. Nodal points are to be properly placed on the intersections between the webs

of a U-type stiffener and the hatch cover plate, and between the webs and flange of the U-type stiffener.

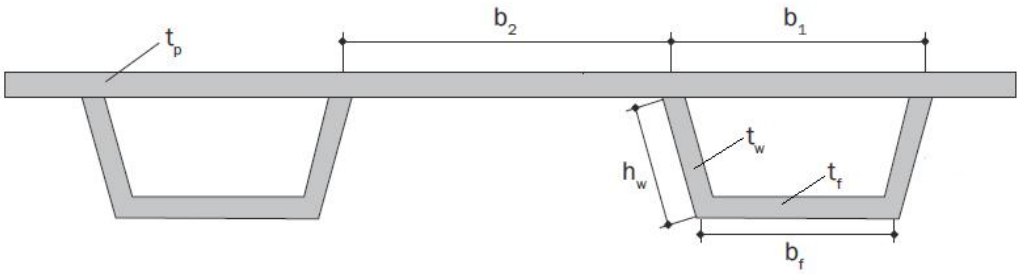


Figure. 2.20.2.4(1) Example of hatch cover fitted with U-type stiffeners

① A right-handed coordinate system is to be used with:
the *x*-axis measured in the longitudinal direction, positive forward;
the *y*-axis measured in the transverse direction, positive to port from the centerline;
the *z*-axis measured in the vertical direction, position upward.

② The FEM is to be performed with net scantlings.

③ The finite element model is to be limited as follows:

(a) for symmetry of the hatch cover girders, loads and supporting boundary conditions about only the x-axis or y-axis, it may be limited to a half of the hatch cover for check;

(b) for non-symmetry of hatch cover girders, loads or supporting boundary conditions about any of the axes, the whole hatch cover may be taken for strength evaluation, see Figure 2.20.2.4(2).

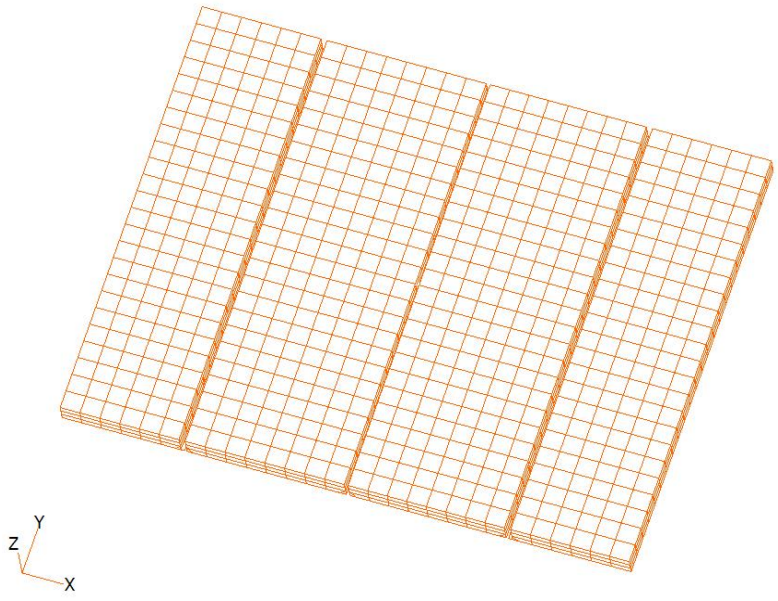


Figure 2.20.2.4(2) Finite Element Hatch Cover Model

④ The model element is to comply with the following requirements:

(a) all plating, including girders and stiffeners, is to be represented by the finite element model;

(b) all plating, such as top plates, bottom plates, brackets, and girder webs, face plates of primary supporting members is to modeled using plate elements, triangular elements are to be avoided where possible;

(c) all stiffeners are to be modeled using beam, rod or plate elements.

⑤ The element mesh size is to be controlled as follows:

(a) the mesh size is not to be greater than the spacing of stiffeners;

(b) the girders are to be represented by at least 3 elements in the depth;

(c) triangular and distorted quadrilateral elements with corner angles less than 60 degrees and greater than 120 degrees are to be avoided.

⑥ Boundary conditions are to be determined as follows:

(a) for symmetry of the hatch cover girders and loads about the xz-plane, the longitudinal displacement of nodes in the symmetric plane and the rotations about the *y* and *z* axes are to be taken as 0 respectively, i.e. $\delta_x = \theta_y = \theta_z = 0$, as shown in Figure 2.20.2.4(3);

(b) for symmetry of the hatch cover girders and loads about the yz-plane, the transverse displacement of nodes in the symmetric plane and rotation about the *x* and *z* axes are to be taken as 0 respectively i.e. $\delta_y = \theta_x = \theta_z = 0$, as shown in Figure 2.20.2.4(3);

(c) boundary nodes in way of bearing pads on the hatch coamings are generally to be fixed against displacement in the *z* direction, i.e. $\delta_z = 0$;

(d) lifting stoppers are to be fixed against displacements in the direction determined by the stoppers;

(e) hinges in folding type hatch covers are to be represented as rigid links which tie together displacements in the *z* direction.

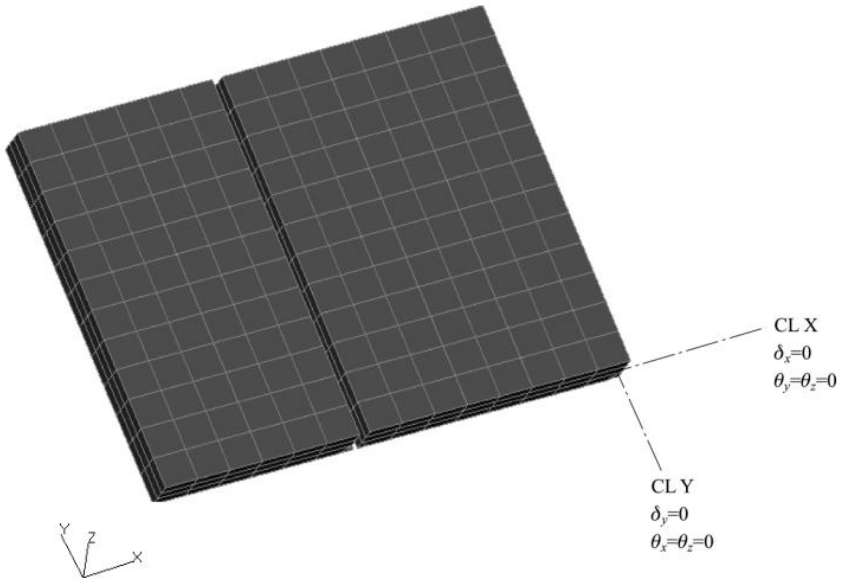


Figure 2.20.2.4(3) Boundary Conditions of Hatch Cover Model

2.20.2.5 Yield strength and deflection criteria of hatch cover structures

(1) Allowable stresses

All hatch cover structures are to comply with the following formulae:

$\sigma_{vm} \leq \sigma_a$, for shell element;

$\sigma_{axial} \leq \sigma_a$, for rod or beam elements.

where: σ_a ——allowable stress in Table 2.20.2.5;

R_{eH} ——yield stress of the material;

σ_{vm} —— the equivalent stress may be taken as follows:

$$\sigma_V = \sqrt{\sigma_x^{\,2} - \sigma_x \cdot \sigma_y + \sigma_y^{\,2} + 3\tau^2} \qquad \text{N/mm}^2$$

where: σ_x — normal stress, in N/mm^2, in x-direction;

σ_y — normal stress, in N/mm^2, in y-direction;

τ — shear stress, in N/mm^2, in the x-y plane;

σ_{axial} —axial stress in rod or beam elements, in N/mm^2.

In case of FEM calculations using shell elements, the stresses are to be read from the centre of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element centre may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or, the stress at the element edges is not to exceed the allowable stress. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

For steels with a yield stress of 390 N/mm^2, it is taken as 368 N/mm^2 for calculation.

Stress concentrations are to be evaluated according to the actual conditions.

Allowable stress Table 2.20.2.5

Members of	Subject to	σ_a , in N/mm^2
Hatch cover structure	External pressure, as defined in 2.20.2.2(1)	$0.80R_{eH}$
	Other loads, as defined in 2.20.2.2(2)~(5)	$0.90R_{eH}$ for static+dynamic load case $0.72R_{eH}$ for static load case

(2) Deflection

The vertical deflection of primary supporting members due to the load stipulated in 2.20.2.2 of this Section is to be not more than 0.0056 l_g, where l_g is the greatest span of primary supporting member.

Note: Where containers are arranged on hatch covers and mixed stowage is allowed, i.e., a 40'-container stowed on top of two 20'-containers, particular attention is to be paid to the deflections of hatch covers. Further the possible contact of deflected hatch covers with cargo in hold has to be considered.

2.20.2.6 Buckling strength of hatch cover structures

(1) General

Buckling strength of all hatch cover structures is to be checked. Buckling assessments are to be performed in compliance with the requirements in Appendix 5.

The net scantlings as defined in 2.20.2.1(5) are to be used for buckling check.

(2) Slenderness requirements

The slenderness requirements are to be in accordance with those specified in Sec 2 of Appendix 5.

The slenderness requirements need not be applied to the lower boundary of double skin hatch covers unless the cargo hold is designed for carriage of ballast or liquid cargo.

The breadth of the primary supporting member flange is to be not less than 40% of their depth for laterally unsupported spans greater than 3.0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

(3) Buckling requirements

① These requirements apply to the buckling assessment of hatch cover structures subjected to compressive and shear stresses and lateral pressures. The buckling assessment is to be performed for the following structural elements:

- Stiffened and unstiffened panels, including curved panels and panels stiffened with U-type stiffeners.
- Web panels of primary supporting members in way of opening.

The buckling strength assessment of coaming parts is to be done according to this paragraph.

For rule application, the panel types and assessment methods, the applied lateral pressure and stresses, safety factors and buckling check criteria are defined in 2.20.2.6(3)②-2.20.2.6(3)⑤, respectively. The procedure and detailed requirements for buckling assessment are given in Section 4 of Appendix 5, including idealization of irregular plate panels, definition of reference stresses and buckling criteria.

Unless otherwise specified, the symbols used in 2.20.2.6(3) are defined in Appendix 5.

② Panel types and assessment methods

The plate panel of a hatch cover structure is to be modelled as stiffened panel (SP) or unstiffened panel (UP) as defined in 4.2, Section 4 of Appendix 5. Assessment Method A (-A) and Method B (-B) as defined in 1.3, Section 1 of Appendix 5 are to be used in accordance with Table 2.20.2.6(3)①, Figure 2.20.2.6(3)① and Figure 2.20.2.6(3)②. For a web panel with opening, the procedure for opening should be used for its buckling assessment.

For a hatch cover fitted with U-type stiffeners, the additional buckling assessment requirements specific for panels with U-type stiffeners in 5.2.5, Section 5 of Appendix 5 are also to be followed.

Structural members and assessment methods **Table 2.20.2.6(3)①**

Structural elements	**Assessment method**[(1)(2)]	**Normal panel definition**
Hatch cover top/bottom plating structures, see Figure 2.20.2.6(3)①		

Hatch cover top/bottom plating	SP-A	Length: between transverse girders Width: between longitudinal girders
Irregularly stiffened panels	UP-B	Plate between local stiffeners/PSM
Hatch cover web panels of primary supporting members, see Figure 2.20.2.6(3)②		
Web of transverse/longitudinal girder (single skin type)	UP-B	Plate between local stiffeners/face plate/PSM
Web of transverse/longitudinal girder (double skin type)	SP-B(3)	Length: between PSM Width: full web depth
Web panel with opening	Procedure for opening	Plate between local stiffeners/face plate/PSM
Irregularly stiffened panels	UP-B	Plate between local stiffeners/face plate/PSM
Note 1: SP and UP stand for stiffened and unstiffened panel respectively. Note 2: A and B stand for Method A and Method B respectively. Note 3: In case that the buckling carlings/brackets are irregularly arranged in the web of transverse/longitudinal girder, UP-B method may be used.		

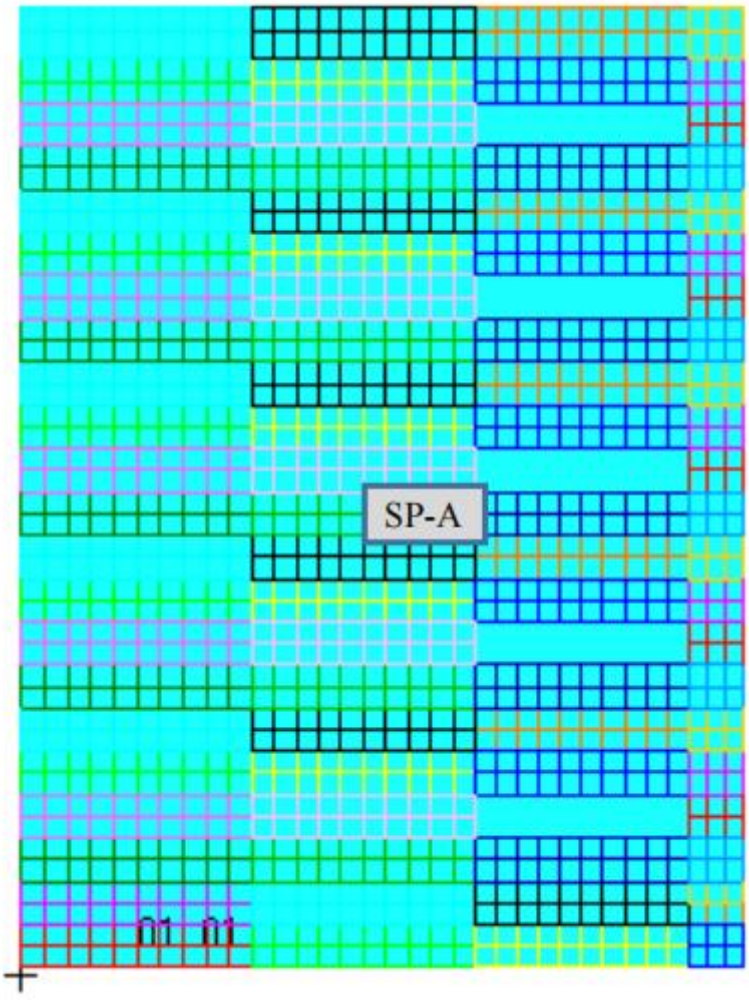


Figure 2.20.2.6(3)①

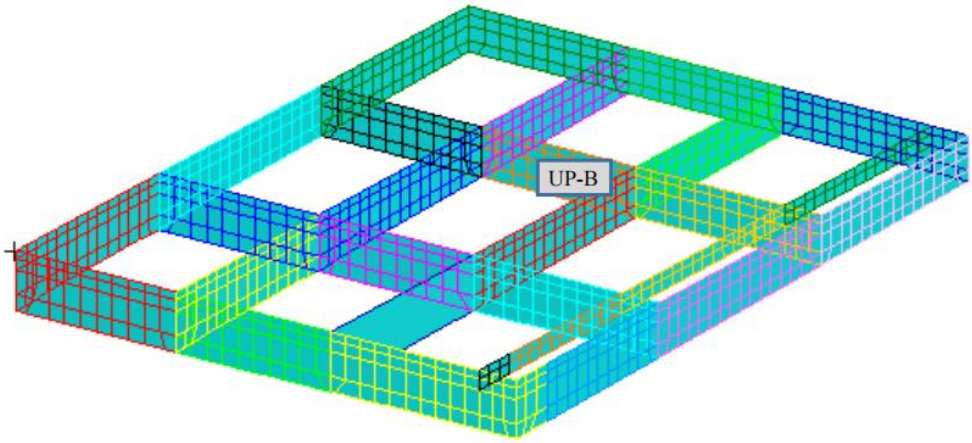


Figure 2.20.2.6(3)②

③ Applied lateral pressure and stresses

The buckling assessment of hatch covers is based on the lateral pressure as defined in 2.1 and 2.2, and stresses obtained from FE analysis, refer to 2.20.2.4.

④ Safety factors

For all hatch cover structural members, safety factor S=1.0 is to be applied to both of the plating and stiffener buckling capacity formulas as defined in 5.2.2, Section 5 of Appendix 5 and 5.2.3, Section 5 of Appendix 5, respectively.

⑤ Buckling acceptance criteria

A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where: η_{act} —— Buckling utilisation factor based on the applied stress, as defined in 1.3.2.2, Section 1 of Appendix 5 and Section 4 of Appendix 5, and calculated per Section 5 of Appendix 5.

η_{all} —— Allowable buckling utilisation factor, taken as given in Tab.2.20.2.6(3)⑤.

Allowable buckling utilisation factors **Table 2.20.2.6(3)⑤**

Structural component	Subject to	η_{all}, allowable buckling utilisation factor
Plates and stiffeners Web of PSM	External pressure, as defined in 2.20.2.2(1)	0.80
	Other loads, as defined in 2.20.2.2(2)~(5)	0.90 for static+dynamic load case 0.72 for static load case

2.20.2.7 Details of hatch covers

(1) Container foundation on hatch covers

Container foundations on hatch covers are to be in compliance with the relevant requirements of Appendix 1 of Chapter 7 of this PART. The calculated stresses of substructures of container

foundations under cargo and container loads according to 2.20.2.2 of this Section are to comply with the requirements of 2.20.2.5 of this Section.

(2) Weathertightness

In addition to the following requirements, the hatch covers are also to meet the relevant requirements of IACS REC14.

① Packing material (general)

The packing material is to be suitable for all expected service conditions of the ship and is to be compatible with the cargoes to be transported. The packing material is to be selected with regard to dimensions and elasticity in such a way that expected deformations may be carried. Forces are to be carried by the steel structure only.

The packings are to be compressed so as to give the necessary tightness effect for all expected operating conditions. Special consideration is to be given to the packing arrangement in ships with large relative movements between hatch covers and coamings or between hatch cover sections.

② Dispensation of weathertight gaskets

For hatch covers of cargo holds intended solely for the transport of containers, upon request by the Owner and subject to compliance with the following conditions, the fitting of weathertight gaskets according to 2.20.2.7(2) may be dispensed with:

- The hatchway coamings are to be not less than 600 mm in height.
- For weather deck hatch covers located above a depth $H(x)$, $H(x)$ is to comply with the following criterion:

$$H(x) \geq T_{fb} + f_b + h \qquad \text{m}$$

where: T_{fb} — draught, in m, corresponding to the assigned summer load line;

f_b — minimum required freeboard, in m, determined in accordance with ICLL Regulation 28 as modified by further regulations as applicable;

h = 4.6 m for $\frac{x}{L_L} \leq 0.75$;

h = 6.9 m for $\frac{x}{L_L} > 0.75$.

- Labyrinths, gutter bars or equivalents are to be fitted proximate to the edges of each panel in way of the coamings. The clear profile of these openings is to be kept as small as possible.
- Where a hatch is covered by several hatch cover panels, the clear opening of the gap in between the panels is to be not wider than 50 mm.
- The labyrinths and gaps between hatch cover panels are to be considered as unprotected openings with respect to the requirements of intact and damage stability calculations.
- With regard to drainage of cargo holds and the necessary fire-fighting system, refer to the relevant requirements of Chapter 6, PART EIGHT of the Rules.
- Bilge alarms are to be provided in each hold fitted with non-weathertight covers.
- Furthermore, Chapter 3 of IMO MSC/Circ.1087 is to be complied with for the storage and segregation of containers carrying dangerous goods.

③ Cross-joint of multi-panel covers are to be provided with efficient drainage arrangements.

2.20.2.8 Hatch coamings are to comply with the following requirements:

(1) The net thickness of weather deck hatch coamings is not to be less than the larger of the following values:

- For Type-1 ships:

$$t = 0.0142s\sqrt{\frac{p_A}{0.95R_{eH}}} \quad \text{mm}$$

$$t = 6 + \frac{L_1}{100} \quad \text{mm}$$

- For Type-2 ships:

$$t = 0.016s\sqrt{\frac{p_{coam}}{0.95R_{eH}}} \quad \text{mm}$$

$$t_{\min} = 9.5 \quad \text{mm}$$

where: s — stiffener spacing, in mm;

P_A — horizontal weather design load, in kN/m^2, to be calculated according to 2.20.2.2(2) ① of this Section;

p_{coam} ——horizontal weather design load, in kN/m^2, to be calculated according to 2.20.2.2(2) ② of this Section;

$L_1 = L$, but need not be taken as greater than 300 m.

The continuous longitudinal hatch coamings within 0.4L amidships are also to comply with the relevant requirements of Section 2 of this Chapter.

(2) The stiffeners of hatch coaming are to meet the following requirements:

The stiffeners are to be continuous at the coaming stays.

For stiffeners with both ends constrained, the net section modulus Z and net shear area A_{shr}, , calculated on the basis of net thickness, are not to be less than:

- For Type-1 ships:

$$Z = \frac{p_A s l^2}{f_{bc} R_{eH}} \quad \text{cm}^3$$

$$A_{shr} = \frac{p_A s l^2}{R_{eH}} 10^{-2} \quad \text{cm}^2$$

where: f_{bc} =12 in general

= 8 for the end spans of stiffeners sniped at the coaming corners;

l — stiffener span, in m, to be taken as the spacing of coaming stays;

s — stiffener spacing, in mm;

P_A — horizontal weather design load, in kN/m^2, to be calculated according to 2.20.2.2(2) ① of this Section.

For sniped stiffeners of coaming at hatch corners, section modulus and shear area at the fixed support have to be increased by 35%. The gross thickness of the coaming plate at the sniped stiffener end is not to be less than:

$$t_{gr} = 19.6\sqrt{\frac{p_A s(l - 0.0005s)}{1000 R_{eH}}} \quad \text{mm}$$

- For Type-2 ships:

$$Z = 1.21\frac{p_{coam} s l^2}{f_{bc} c_p R_{eH}} \quad \text{cm}^3$$

where: f_{bc} —16 in general
12 for the end spans of stiffeners sniped at the coaming corners;
l —stiffener span, in m, to be taken as the spacing of coaming stays;
s — stiffener spacing, in mm;
P_A — horizontal weather design load, in kN/m^2, to be calculated according to 2.20.2.2(2)① of this Section;
p_{coam} — horizontal weather design load, in kN/m^2, to be calculated according to 2.20.2.2(2)② of this Section;
c_p — ratio of the plastic section modulus to the elastic section modulus of the stiffeners with an attached plate breadth, in mm, equal to 40t, where t is the plate net thickness
c_p — 1.16 in the absence of more precise evaluation

The horizontal stiffeners of continuous longitudinal hatch coamings within 0.4L amidships are also to comply with the relevant requirements of Section 2 of this Chapter.

(3) Coaming stays are to be designed for the loads transmitted through them and are to comply with the following requirements, in addition to the allowable stresses stipulated in 2.20.2.5 of this Section.

① Coaming stay section modulus and web thickness

At the connection with deck, the net section modulus Z, in cm^3, and the gross thickness t_w, in mm, of the coaming stays designed as beams with flange (examples 1 and 2 are shown in Figure 2.20.2.8(3)) are to be taken not less than:

$$Z = \frac{P s_c H_c^2}{1.9 R_{eH}} \quad \text{cm}^3$$

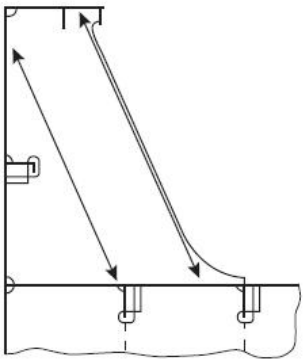
$$t_w = \frac{2 P s_c H_c}{h R_{eH}} \quad \text{mm}$$

where: H_C — stay height, in m;
s_c — stay spacing, in mm;
h — stay depth, in mm, at the connection with the deck;
p — pressure on coaming, in kN/m^2 , taken as p_A defined in 2.20.2.2(2)① in general and as p_{coam} defined in 2.20.2.2(2)② for Type-2 ships.

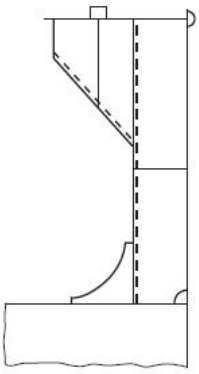
For other designs of coaming stays, such as those shown in Figure 2.20.2.8(3), examples 3 and 4, the stresses are to be determined through a grillage analysis or FEM. The calculated stresses are to comply with the permissible stresses according to 2.20.2.5 of this Section.

Coaming stays are to be supported by appropriate substructures. Face plates may only be included in the calculation of section modulus of coaming stays if an appropriate substructure is provided and welding provides an adequate joint.

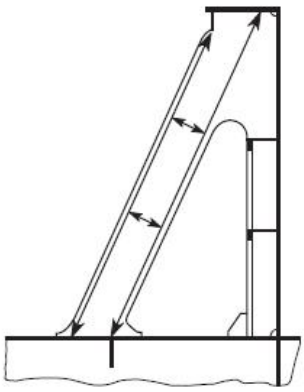
Webs are to be connected to the deck by fillet welds on both sides with a throat thickness of not less than $0.44t_w$. For Type-2 ships, toes of stay webs are to be connected to the deck plating with full or partial penetration double bevel welds extending over a distance not less than 15% of the stay width. For other ship types the size of welding for toes of webs at the lower end of coaming stays is to comply with the relevant requirements of Chapter 1 of this PART.



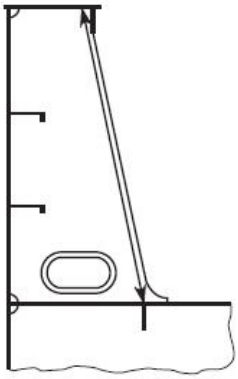
Example 1



Example 2



Example 3



Example 4

Figure 2.20.2.8(3) Examples of coaming stays

② For coaming stays, which transfer friction forces at hatch cover supports, fatigue strength is to be considered.

(4) The hatch coaming is also to comply with the following requirements:

① Hatch coamings which are part of the longitudinal hull structure are to be designed according to the relevant requirements of Section 2 of this Chapter.

② For structural members welded to coamings and for cutouts in the top of coamings, sufficient fatigue strength is to be verified.

③ Longitudinal hatch coamings with a length exceeding 0.1L are to be provided with tapered brackets or equivalent transitions and a corresponding substructure at both ends. At the end of the brackets, they are to be connected to the deck by full penetration welds of minimum 300 mm in length.

④ The local details are to be designed to transfer the loads on the hatch covers to the hatch coamings, and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions. Structures under deck are to be checked against the load transmitted by the stays. Unless otherwise stated, welding and material are to comply with the relevant requirements of CCS.

⑤ On ships carrying cargo on deck, such as timber, coal or coke, the stays are to be spaced not more than 1.5 m apart.

⑥ Coaming plates are to extend to the lower edge of the deck beams or hatch side girders are to be fitted that extend to the lower edge of the deck beams. Extended coaming plates and hatch side girders are to be flanged or fitted with face bars or half-round bars. See Figure 2.20.2.8(4).

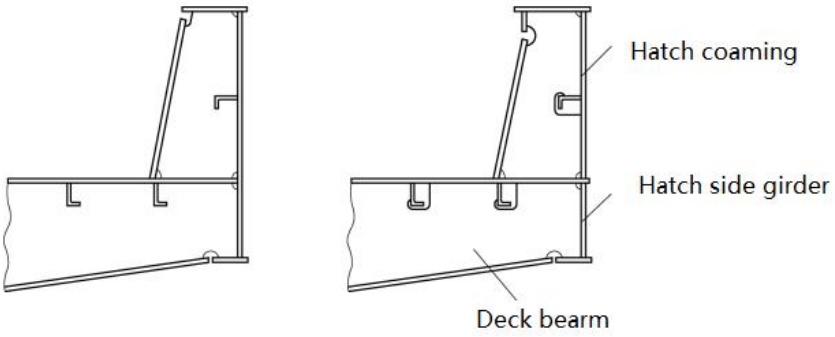


Figure 2.20.2.8(4) Example for the Extension of Coaming Plates

⑦ Drainage arrangement at the coaming is to comply with the following requirements:

If drain channels are provided inside the line of gasket by means of a gutter bar or vertical extension of the hatch side and end coaming, drain openings are to be provided at appropriate positions of the drain channels.

Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g. hatch covers, transitions to crane posts).

Drain openings are to be arranged at the ends of drain channels and are to be provided with non-return valves to prevent ingress of water from outside. It is unacceptable to connect fire hoses to the drain openings for this purpose.

If a continuous outer steel contact between cover and ship structure is arranged, drainage from the space between the steel contact and the gasket is also to be provided.

2.20.2.9 Closing arrangements of weathertight steel hatch covers

(1) Securing arrangements

① General requirements

Securing devices between cover and coaming and at cross-joints are to be installed to provide weathertightness. Sufficient packing line pressure is to be maintained. Securing

devices are to be appropriate to bridge displacements between cover and coaming due to hull deformations.

Securing devices are to be of reliable construction and effectively attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics. According to the requirements of 2.20.2.3(3)② of this Section, a sufficient number of securing devices is to be provided at each side of the hatch cover, including that consisting of several parts.

The materials of stoppers, securing devices and their welding are to comply with the relevant requirements of CCS Rules for Materials and Welding. Specifications of the materials are to be shown in the drawings of the hatch covers.

② Rod cleats

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

③ Hydraulic cleats

Where hydraulic cleating is adopted, a positive means is to be provided so that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

④ Cross-sectional area of the securing devices

The gross cross-sectional area of the securing devices is not to be less than:

$$A = 0.28qS_{SD}k_l \qquad \text{cm}^2$$

where: q —packing line pressure, in N/mm, minimum 5 N/mm;

S_{SD} — spacing between securing devices, in m, not to be taken less than 2 m;

$k_l = (\frac{235}{R_{eH}})^e$;

R_{eH} — the minimum yield stress of material, in N/mm^2, but not to be taken greater than $0.7R_m$;

R_m — tensile strength of material, in N/mm^2;

e =0.75 for $R_{eH} > 235$ N/mm^2;

e =1.00 for $R_{eH} \le 235$ N/mm^2.

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5m^2 in area.

Securing devices of special design in which significant bending or shear stresses occur may be designed as anti-lifting devices according to 2.20.2.9(1)⑤. The design load is taken as the packing line pressure q multiplied by the spacing S_{SD} between securing devices.

⑤ Anti-lifting devices

The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for the lifting forces resulting from loads according to 2.20.2.2(4) of this Section, refer to Figure 2.20.2.9(1). Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings the equivalent stress in the securing devices is not to exceed:

$$\sigma_V = \frac{150}{k_l} \qquad \text{N/mm}^2$$

where: k_l — as in 2.20.2.9(1)④.

Note: The partial load cases given in Table 2.20.2.2(4) may not cover all unsymmetrical loadings, critical for hatch cover lifting.

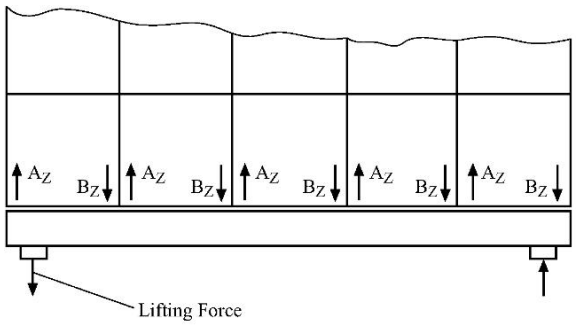


Figure 2.20.2.9(1) Lifting Forces at a Hatch Cover

The anti-lifting devices may be dispensed with according to the following requirements:
In the absence of hatch cover lifting under loads arising from the ship's rolling motion, securing devices for hatch covers may be omitted. In such cases, it is to be proven by means of grillage or finite element analysis that an equilibrium condition is achieved using compression only boundary elements for the vertical hatch cover supports. If securing devices are omitted, transverse cover guides are to be effective up to a height h_E, as shown in Figure 2.20.2.9(2), where h_E is not to be less than:

$$h_E = 1.75(2se + d^2)^{0.5} - 0.75d \quad \text{mm}$$

$$h_{E\min} = \text{height of the cover edge plate} + 150 \quad \text{mm}$$

where: e — largest distance from the inner edge of the transverse cover guide to the end of the cover edge plate, in mm;

s — total clearance within the transverse cover guide, with $10 \le s \le 40$, in mm;

d — distance between upper edge of transverse stopper and hatch cover support, in mm.

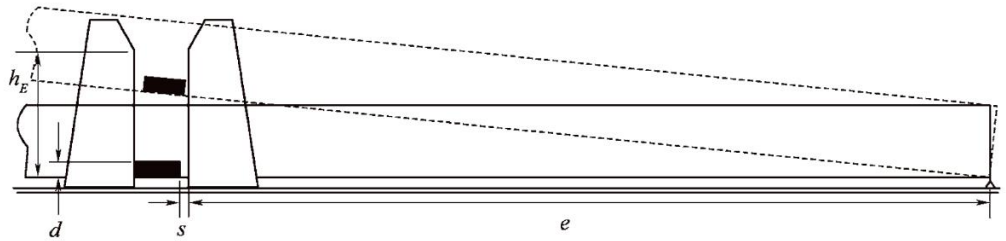


Figure 2.20.2.9(2) Height of Transverse Cover Guide

The transverse cover guides and their substructure are to be dimensioned in accordance with the transverse loads acting at a height h_E.

(2) Hatch cover supports, stoppers and supporting structures

① Horizontal mass forces

For the design of hatch cover supports, the horizontal mass force is to be taken as follows:

$$F_h = ma$$

where: F_h— horizontal mass force, in kN;

$a_X = 0.2g$ in longitudinal direction;

$a_Y = 0.5g$ in transverse direction;

m— sum of mass of cargo lashed on the hatch cover and mass of hatch cover.

The accelerations in longitudinal direction and in transverse direction need not be considered as acting simultaneously.

② Hatch cover supports

For the transmission of the support forces resulting from the load cases specified in 2.20.2.2 of this Section and of the horizontal mass forces specified in (2)①, supports are to be provided which are to be designed such that the nominal surface pressures in general do not exceed the values obtained from the following formula:

$$p_{n\max} = dp_n \qquad \text{N/mm}^2$$

where: d = 3.75-0.015L;

$d_{\max} = 3.0$;

$d_{\min} = 1.0$, in general;

$d_{\min} = 2.0$, for partial loading conditions, see 2.20.2.2(5);

P_n — Allowable nominal surface pressure, see Table 2.20.2.9(2).

Allowable Nominal Surface Pressure P_n Table 2.20.2.9(2)

Support material	P_n (N/mm^2) when loaded by	
	Vertical force	Horizontal force (on stoppers)
Hull structural steel	25	40
Hardened steel	35	50
Lower friction materials	50	—

For metallic supporting surfaces not subjected to relative displacements, the following nominal surface pressure applies:

$$p_{n\max} = 3p_n \qquad \text{N/mm}^2$$

Note: When the maker of vertical hatch cover support material can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions including relative motion for adequate number of cycles, permissible nominal surface pressure may be relaxed at the discretion of CCS. However, realistic long term distribution of spectra for vertical loads and relative horizontal motion is to be assumed and agreed with CCS.

Drawings of the supports are to be submitted for approval. In the drawings of supports, the permitted maximum pressure given by the material manufacturer is to be indicated.

Where large relative displacements of the supporting surfaces are to be expected, the use of material having low friction properties is recommended.

The substructures of the supports are to be of such a design that a uniform pressure distribution is achieved.

Irrespective of the arrangement of stoppers, the supports are to be able to transmit the following force P_h in the longitudinal and transverse direction:

$$P_h = \mu \cdot \frac{P_V}{\sqrt{d}}$$

where: P_V — vertical supporting force;

μ — frictional coefficient;

μ = 0.5 steel to steel.

For non-metallic, low-friction support materials on steel, the friction coefficient μ may be reduced but not to be less than 0.35 and it is to be submitted to CCS for approval.

Supports as well as the adjacent structures and substructures are to be designed such that the allowable stresses in 2.20.2.5 of this Section are not exceeded.

For substructures and adjacent structures of supports subjected to horizontal forces P_h, a fatigue strength is to be considered.

③ Hatch cover stoppers

Hatch covers are to be sufficiently secured against horizontal shifting. Stoppers are to be provided for hatch covers on which cargo is carried.

The greater of the loads resulting from 2.20.2.2(2) of this Section and 2.20.2.9(2)① is to be applied for the dimensioning of the stoppers and their substructures.

The allowable stress in stoppers and their substructures, in the cover, and of the coamings is to be determined according to 2.20.2.5 of this Section and in addition, the requirements in 2.20.2.9(2)② are to be taken into consideration.

Specifically for Type-2 ships, the following additional requirements are to be complied with:

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

With the exclusion of No.1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2.

This pressure may be reduced to 175 kN/m^2 when a forecastle is fitted in accordance with Section 13, Chapter 8 of this PART.

The equivalent stress in stoppers and their supporting structures, and calculated in the throat of the stopper welds is not to exceed the allowable value of $0.8R_{eH}$.

2.20.2.10 Corrosion addition and steel renewal

(1) Corrosion addition for hatch covers and hatch coamings

For scantlings of hatch cover components, the general corrosion additions t_S, as shown in Table 2.20.2.10, is required.

Corrosion Addition t_S for Hatch Covers and Hatch Coamings Table 2.20.2.10

Application	Structure	t_S[mm]
Weather deck hatches of container ships, car carriers, paper carriers and passenger vessels	Hatch covers	1.0
	Hatch coamings	1.5 for $t \le 10$
		$\frac{0.1t}{\sqrt{K}}+0.5$, but not greater than 3, for $t>10$
Weather deck cargo hatches of Type-2 ships	Hatch covers in general	2.0
	Top and bottom plating of double skin hatch covers	2.0
	Internal structure of double skin hatch covers	1.5
	Hatch coamings and coaming stays	1.5
Weather deck hatches of all other ships	Hatch covers in general	2.0
	Weather exposed plating and bottom plating of double skin hatch covers	1.5
	Internal structure of double skin hatch covers and closed box girders	1.0
	Hatch coamings not part of the longitudinal hull structure	1.5
	Hatch coamings part of the longitudinal hull structure	1.5 for $t \le 10$
		$\frac{0.1t}{\sqrt{K}}+0.5$, but not greater than 3, for $t>10$
	Coaming stays and stiffeners	1.5

Notes:

t: net thickness of hatch coaming required by the Rules.

K: material factor.

(2) Steel renewal

Steel renewal is required where the gauged thickness is less than t_{net} + 0.5 mm for

- single skin hatch covers,
- the plating of double skin hatch covers, and
- coaming structures the corrosion additions t_S of which are given in Table 2.20.2.10.

Coating is to be maintained in GOOD condition, as defined in 5.1.5.1(15), Chapter 5 of PART ONE of the Rules.

For internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when it is deemed necessary by CCS surveyor, on the basis of the plating corrosion or deformation. In these cases, steel renewal for the internal structures is to be required where the gauged thickness is less than t_{net}.

For corrosion addition t_S = 1.0 mm, the thickness for steel renewal is t_{net} and coating or annual gauging may be used for substitution of renewal when gauged thickness is between t_{net} and t_{net} + 0.5 mm.

For coaming structures, the corrosion additions t_S of which are not given in Table 2.20.2.10, steel renewal and coating or annual gauging are to be in accordance with the relevant requirements of CCS.

2.20.3 Steel pontoon covers

2.20.3.1 The design load of steel pontoon covers is to comply with the following requirements:

(1) The design load of vertical exposed hatch covers is to be calculated according to Table 2.20.2.2(1) of this Section.

(2) The permissible cargo load p on hatch covers is to be specified by the Owner or designer and included in the loading manual, complying with the following requirements:

① The permissible cargo load p for 'tween deck hatch covers is not to be less than:

$$p = 7.06h \qquad \text{kN/m}^2$$

where: h — the vertical distance, in m, measured from the hatch cover to the underside of hatch cover stiffeners on deck above.

This requirement does not apply to multi-purpose ships of which the 'tween deck hatch covers are used as 'tween deck, see Figure 2.20.3.1(2) of this Section.

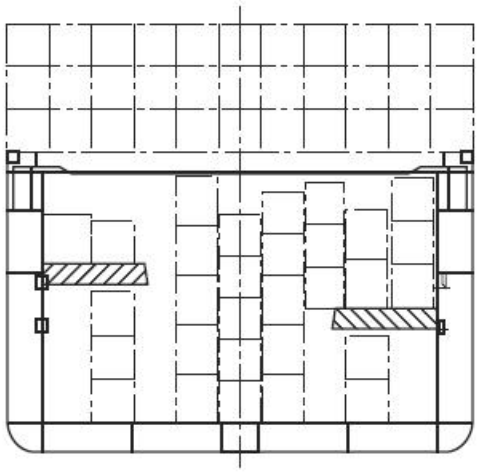


Figure 2.20.3.1(2)

② The permissible cargo load p for hatch covers in the accommodation spaces is not to be less than 12.7 kN/m^2.

2.20.3.2 The local scantlings of hatch covers are to comply with the following requirements:

(1) The thickness t of the top plating of steel hatch covers is not to be less than that obtained from the following formula:

$$t = 0.01s \quad \text{mm,} \quad \text{but in no case to be less than 6 mm.}$$

where: s— spacing of stiffeners, in mm.

(2) The scantlings of stiffeners and girders of steel pontoon covers are to comply with the following requirements:

① Where the uniformly distributed design load of vertical exposed hatch covers is applied, the section modulus W and the section moment of inertia I of stiffeners are not to be less than:

$$W = 7.82Kspl^2 \times 10^{-4} \quad \text{cm}^3$$

$$I = 1.44spl^3 \times 10^{-3} \quad \text{cm}^4$$

where: p— vertical weather design load, in kN/m^2;

s— spacing of stiffeners, in mm;

l— span of stiffener, in m;

K—material factor.

② Where the uniformly distributed cargo load is applied, the section modulus W and the section moment of inertia I of stiffeners are not to be less than:

$$W = 1.064Kspl^2 \times 10^{-3} \quad \text{cm}^3$$

$$I = 1.8spl^3 \times 10^{-3} \quad \text{cm}^4$$

where: p—permissible cargo load, in kN/m^2;

s—spacing of stiffeners, in mm;

l—span of stiffener, in m;

K—material factor.

③ Where the ends of stiffeners are effectively bracketed or continuous, the values of section modulus and moment of inertia may be reduced respectively by 33% and 80% than those obtained from ① or ②.

④ The scantlings of girders of steel pontoon covers are to be determined by direct calculations. Where steel pontoon covers are subject to uniformly distributed loading and girders are fitted in one direction only, however, the scantlings of girders may also be determined according to ① and ②.

2.20.3.3 The direct strength calculation of steel pontoon covers is to be in compliance with the requirements of 2.20.2.4 of this Section.

2.20.3.4 Yield strength and deformation criteria of steel hatch covers of steel pontoon covers

The yield strength and deflection of steel pontoon covers are to meet the requirements of Table 2.20.3.4.

Steel Pontoon Covers **Table 2.20.3.4**

Load	Allowable positive stress $[\sigma]$ (N/mm^2)	Allowable deflection (m)
Vertical weather design load	$0.70R_{eH}$	$0.0049\,l$
Loads other than vertical weather design load	$0.65R_{eH}$	$0.0044\,l$

2.20.3.5 The buckling strength of steel pontoon covers is to meet the requirements of Table 2.20.3.5(1).

Buckling Strength Criteria of Steel Pontoon Covers **Table 2.20.3.5(1)**

Structural member		Criteria
Top panels of hatch	Girders fitted in uni-axial direction	The normal stress of top panels in compression of girders is not to exceed 0.8 times the critical buckling stress σ_c, σ_c may be calculated according to 2.20.3.5(1)

Structural member		Criteria
covers	Girders fitted in bi-axial directions	Biaxial compressive stress of top panels, when calculated by means of finite plate element model, is to be in accordance with the relevant requirements in 2.20.2.6(1) of this Section
Girder webs		The shear stress of girder web panels is not to exceed 0.8 times the critical shear buckling stress τ_c, τ_c may be calculated according 2.20.3.5(3)
Stiffeners parallel to girders		The normal stress of attached plating of stiffeners in compression of girders parallel to stiffeners is not to exceed 0.8 times the critical buckling stress σ_c, σ_c may be calculated according to 2.20.3.5(2)

(1) Hatch cover plating critical stress

The compressive stress σ in the hatch cover plate panels, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{c1}, to be evaluated as defined below:

$$\sigma_{c1} = \sigma_{E1} \qquad \text{for } \sigma_{E1} \le \frac{R_{eH}}{2}$$

$$\sigma_{c1} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \qquad \text{for } \sigma_{E1} > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of the material, in N/mm^2;

σ_{E1} = $3.6E\left(\frac{t}{1000s}\right)^2$, in N/mm^2;

E — modulus of elasticity, in N/mm^2, = 2.06×10^5 for steel;

t — net thickness of plate panel, in mm;

s — spacing of secondary stiffeners, in m.

The mean compressive stress σ in each of the hatch cover plate panels, induced by the bending of primary supporting members perpendicular to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{c2}, to be evaluated as defined below:

$$\sigma_{c2} = \sigma_{E2} \qquad \text{for } \sigma_{E2} \le \frac{R_{eH}}{2}$$

$$\sigma_{c2} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \qquad \text{for } \sigma_{E2} > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of the material, in N/mm^2;

σ_{E2} = $0.9mE\left(\frac{t}{1000s_s}\right)^2$, in N/mm^2;

m = $c\left[1 + \left(\frac{s_s}{l_s}\right)^2\right]^2 \frac{2.1}{\psi + 1.1}$

E — modulus of elasticity, in N/mm^2, = 2.06×10^5 for steel;

t — net thickness of plate panel, in mm;

s_s — length of the shorter side of the plate panel, in m;

l_s — length of the longer side of the plate panel, in m;

ψ — ratio between smallest and largest compressive stress;

c = 1.3 when plating is stiffened by primary supporting members;

c = 1.21 when plating is stiffened by secondary stiffeners of angle or T type;

c = 1.1 when plating is stiffened by secondary stiffeners of bulb type;

c = 1.05 when plating is stiffened by flat bar.

The biaxial compressive stress in the hatch cover panels, when calculated by means of FEM shell element model, is to be in accordance with the requirements of 2.20.2.6, Chapter 2 of this PART.

(2) Hatch cover secondary stiffeners critical stress

The compressive stress σ in the top flange of secondary stiffeners, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{cs}, to be evaluated as defined below:

$$\sigma_{CS} = \sigma_{ES} \qquad \text{for} \quad \sigma_{ES} \le \frac{R_{eH}}{2}$$

$$\sigma_{cs} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{ES}}\right) \qquad \text{for} \quad \sigma_{ES} > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of the material, in N/mm^2;

σ_{ES} — ideal elastic buckling stress of the secondary stiffener, in N/mm^2, = minimum between σ_{E3} and σ_{E4};

σ_{E3} = $\dfrac{0.001EI_a}{Al^2}$, in N/mm^2;

E — modulus of elasticity, in N/mm^2, = 2.06×10^5 for steel;

I_a — moment of inertia of the secondary stiffener, in cm^4, including a top flange equal to the spacing of secondary stiffeners;

A — cross-sectional area of the secondary stiffener, in cm^2, including a top flange equal to the spacing of secondary stiffeners;

l — span of the secondary stiffener, in m;

σ_{E4} = $\dfrac{\pi^2 EI_w}{10^4 I_p l^2}\left(m^2 + \dfrac{K}{m^2}\right) + 0.385E\dfrac{I_t}{I_p}$, N/mm^2;

K = $\dfrac{Cl^4}{\pi^4 EI_w} \times 10^6$;

m — number of half waves, given by Table 2.20.3.5(2);

I_w — sectorial moment of inertia of the secondary stiffener about its connection with the plating, in cm^6:

$I_w = \dfrac{h_w^3 t_w^3}{36} \times 10^{-6}$, for flat bar secondary stiffeners;

$I_w = \dfrac{t_f b_f^3 h_w^2}{12} \times 10^{-6}$, for "Tee" secondary stiffeners;

$I_w = \dfrac{b_f^3 h_w^2}{12(b_f + h_w)^2}[t_f(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w] \times 10^{-6}$, for angles and bulb secondary stiffeners;

I_p — polar moment of inertia of the secondary stiffener about its connection with the plating, in cm^4:

$I_p = \dfrac{h_w^3 t_w}{3} \times 10^{-4}$, for flat bar secondary stiffeners;

$I_p = (\dfrac{h_w^3 t_w}{3} + h_w^2 b_f t_f) \times 10^{-4}$, for flanged secondary stiffeners;

I_t — St Venant's moment of inertia of the secondary stiffener without top flange, in cm^4:

$I_t = \dfrac{h_w t_w^3}{3} \times 10^{-4}$, for flat bar secondary stiffeners;

$$I_t = \frac{1}{3}[h_w t_w^3 + b_f t_f^3 (1 - 0.63\frac{t_f}{b_f})] \times 10^{-4}$$, for flanged secondary stiffeners;

h_w — web height of the secondary stiffener, in mm;

t_w — web net thickness of the secondary stiffener, in mm;

b_f — width of the secondary stiffener bottom flange, in mm;

t_f — net thickness of the secondary stiffener bottom flange, in mm;

s — spacing of secondary stiffeners, in m;

C — spring stiffness exerted by the hatch cover top plating, calculated by the following formula:

$$C = \frac{k_p E t_p^3}{3s(1 + \frac{1.33 k_p h_w t_p^3}{1000 s t_w^3})} \times 10^{-3};$$

$k_p = 1 - \eta_p$, to be taken not less than zero; for flanged secondary stiffeners, k_p need not be taken as less than 0.1;

$$\eta_p = \frac{\sigma}{\sigma_{E1}};$$

σ —normal stress of the attached plate of the wing plate of the primary supporting member;

σ_{E1} — as given in 2.20.3.5(1);

t_p — net thickness of the hatch cover plate panel, in mm.

Number of Half Waves (*m* value) **Table 2.20.3.5(2)**

K	$0 < K \leq 4$	$4 < K \leq 36$	$36 < K \leq 144$	$(m-1)^2 m < K \leq m^2(m+1)^2$
m	1	2	3	m

(3) Web panels of hatch cover primary supporting members critical stress

This check is to be carried out for the web panels of primary supporting members, formed by web stiffeners or by the crossing with other primary supporting members, the face plate (or the bottom cover plate) or the attached top cover plate.

The shear stress τ in the hatch cover primary supporting member web panels is not to exceed 0.8 times the critical buckling stress τ_c, to be evaluated as defined below:

$$\tau_c = \tau_E \quad \text{for } \tau_E \leq \frac{\tau_F}{2}$$

$$\tau_c = \tau_F (1 - \frac{\tau_F}{4\tau_E}) \quad \text{for } \tau_E > \frac{\tau_F}{2}$$

where: $\tau_F = \frac{R_{eH}}{\sqrt{3}}$ N/mm^2;

R_{eH} — yield stress of the material, in N/mm^2;

$$\tau_E = 0.9 k_t E \left[\frac{t_{pr,n}}{1000d} \right]^2 \quad \text{N/mm}^2;$$

E — modulus of elasticity, in N/mm^2, = 2.06×10^5 for steel;

$t_{pr,\,n}$ — net thickness of primary supporting member, in mm;

$$k_t = 5.35 + 4.0 \left(\frac{d}{a} \right)^2;$$

a — greater dimension of web panel of primary supporting member, in m;

d — smaller dimension of web panel of primary supporting member, in m.

For primary supporting members parallel to the direction of secondary stiffeners, the actual dimensions of the panels are to be considered.

For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_c. In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

2.20.3.6 Steel pontoon covers are to be provided with tarpaulins and securing devices in accordance with the following requirements:

(1) At least two layers of tarpaulin in good condition are to be provided for each hatchway in exposed freeboard and superstructure decks.

(2) Tarpaulins are to be free from jute, and the minimum weight in unit area of the material before treatment is to be:

0.65 kg/mm^2, if the material is tarred;

0.65 kg/mm^2, if the material is chemically dressed;

0.55 kg/mm^2, if the material is dressed with black oil.

(3) Cleats are to be welded to the hatch coamings or the horizontal stiffeners, and the cleats are to be so set as to fit the taper of the wedges. The width of cleats is not to be less than 65 mm, and the cleats are to be spaced not more than 600 mm from centre to centre. The first and last cleats along each side or end are to be arranged not more than 150 mm from the hatch covers.

(4) Wedges are to be of tough wood. They are to have a taper of not more than 1 in 6 and are not to be less than 13 mm in thickness at the point.

(5) For all hatchways situated in exposed freeboard and superstructure decks, steel bars or other equivalent means are to be provided in order to efficiently secure each section of hatch covers after the tarpaulins are battened down. Hatch covers of more than 1.5 m in length are to be secured by at least two such securing appliances.

(6) For all hatchways situated in other exposed positions, ring bolts or other fittings for lashings are to be provided.

2.20.3.7 The hatch coamings of steel pontoon covers are to comply with the following requirements:

(1) Construction of exposed hatch coamings

① The thickness t of hatch coamings is not to be less than that obtained from the following formula:

$$t = 0.05L + 6.5 \quad \text{mm}$$

where: L— length of ship, in m, need not be greater than 90 m.

② Coamings of 600 mm or more in height are to be stiffened on their upper edges or at about 250 mm below the upper edge by a horizontal bulb flat or equivalent strength member. The web depth of the horizontal bulb flat is not to be less than 180 mm, and an additional support is to be afforded by fitting vertical stays or brackets from the bulb flat to the deck at intervals of not more than 3 m. The web depth of the stiffeners or brackets is to be not less than that of the horizontal bulb flat and they are to be flanged or fitted with a face plate. Where the coamings are more than 900 mm in height, the spacing of the above-mentioned stays or brackets is to be suitably reduced. Where the coamings are equal to or more than 1,200 mm in height, an additional horizontal bulb flat or equivalent strength member is to be fitted in way of half height of the coaming. Where the coamings are subject to loaded containers, the hatch coamings and their supporting members are to be strengthened correspondingly.

③ Where no face plate is fitted, the upper edges of coamings are to be stiffened by half round bars or other rolled bars to ensure the rigidity of coamings and the smoothness of their upper edges.

④ Where the deck plating does not extend inside the coamings, the coamings at the corners of hatchways are to be rounded. For openings within 0.5L amidships, the radius of the rounded corner is to comply with the requirements of 2.4.4 of this Chapter.

If the deck plating extends inside the coamings, the coamings at the corners of hatchways may be square provided that the corners of deck openings are in compliance with the requirements of 2.4.4 of this Chapter and that the longitudinal coamings at hatch corners are extended in the form of a tapered bracket.

⑤ Extension brackets or rails arranged approximately in line with the cargo hatch side coamings and intended for the stowage of steel covers are not to be welded to a deckhouse or masthouse, unless upon calculation it shows that the hatch coamings may be used as longitudinal strength members of the hull.

⑥ Where the exposed hatch coamings act as deck girders, they are also to comply with the relevant requirements of 2.8.8 of this Chapter.

(2) Where the 'tween deck hatch coamings act as deck girders, they are also to comply with the relevant requirements of 2.8.8 of this Chapter.

2.20.4 Hatch covers with portable beams

2.20.4.1 The design load of hatch covers with portable beams is to comply with the following requirements:

(1) The vertical weather design load of exposed hatch covers is to comply with Table 2.20.2.2(1) of this Section.

(2) The permissible cargo load on hatch covers is to comply with the requirements of 2.20.3.1(2) of this Section.

2.20.4.2 Hatch covers with portable beams are to be in compliance with the following requirements:

(1) Hatch covers with portable beams, where the cover is made of steel, are to meet the requirements of 2.20.3.2(1) of this Section; where the cover is made of wood, the thickness t is not to be less than that obtained from the following formula:

$$t = 40S \quad \text{mm, but in no case to be less than 60 mm}$$

where: S— spacing of portable hatch beams, in m.

Where the design load exceeds 18.4 kN/m^2, the thickness of wood covers is to be increased in direct proportion to the load.

Both ends of wood hatch covers are to be protected by encircling galvanized steel bands, about 65 mm wide and 3 mm thick, efficiently secured.

(2) Where the vertical design load is applied, the exposed hatch covers with portable beams are to comply with the following requirements:

① The section modulus W and the section moment of inertia I of the portable beams are not to be less than:

$$W = 0.782\,KSpl^2 \quad \text{cm}^3$$
$$I = 1.44\,Spl^3 \quad \text{cm}^4$$

where:

p — vertical weather design load, in kN/m^2, to be calculated according to 2.20.4.1 of this Section;

S — spacing of portable beams, in m;

l — span of portable beam, in m;

K — material factor.

② The ends of web plates are to be doubled, or inserts fitted for at least 180 mm along length of web.

③ The portable beams are to be stiffened at their upper and lower edges by continuous face plates. The width of the upper face plate is to be sufficient to provide a bearing surface of not less than 65 mm for hatch covers, and a vertical flat bar with a height of 50 mm is to be arranged on the upper face plate.

④ Carriers or sockets are to provide means for the efficient fitting and securing of portable hatch beams. The width of bearing surface is at least to be 75 mm.

⑤ The section modulus W and the section moment of inertia I of stiffeners of steel covers are not to be less than:

$$W = 0.664Kspl^2 \quad \text{cm}^3$$
$$I = 1.13spl^3 \quad \text{cm}^4$$

where:

p — vertical weather design load, in kN/m^2, to be calculated according to 2.20.4.1 of this Section;

l — span of stiffener, in m;

s — spacing of stiffeners, in m;

K — material factor.

(3) Where the uniformly distributed cargo load is applied, the hatch covers with portable beams are to comply with the following requirements:

① The section modulus W and the section moment of inertia I of portable beams are not to be less than:

$$W = 1.064KSpl^2 \quad \text{cm}^3$$
$$I = 1.8Spl^3 \quad \text{cm}^4$$

where:

p — permissible cargo load, in kN/m^2;

S — spacing of portable beams, in m;

l — span of portable beam, in m;

K — material factor.

② Portable beams are also to comply with the requirements of 2.20.4.2(2)② to ④.

③ The section modulus W and the section moment of inertia I of portable beams are not to be less than:

$$W=1.064Kspl^2 \quad \text{cm}^3$$

$$I=1.8spl^3 \quad \text{cm}^4$$

where:

p — permissible cargo load, in kN/m^2;

l — span of portable beam, in m;

s — spacing of portable beams, in m;

K — material factor.

(4) The scantling of stiffeners and girders with a variable cross-section for hatch covers with portable beams are to comply with the requirements of 2.20.3.2(3) of this Section.

2.20.4.3 The direct strength calculation of hatch covers with portable beams is to comply with the requirements of 2.20.2.4 of this Section.

2.20.4.4 The yield strength and deformation of hatch covers with portable beams is to comply with the requirements of 2.20.3.4 of this Section.

2.20.4.5 The buckling strength of hatch covers with portable beams is to comply with the requirements of 2.20.3.5 of this Section.

2.20.4.6 The closing appliances of hatch covers with portable beams are to comply with the requirements of 2.20.3.6 of this Section.

2.20.4.7 The hatch coamings of hatch covers with portable beams are to comply with the requirements of 2.20.3.7 of this Section.

2.20.5 Miscellaneous openings

2.20.5.1 Miscellaneous openings are to comply with the requirements of 1.12.7 of Chapter 1 of this PART.

2.20.5.2 Small hatchways on exposed decks are also to comply with the following requirements:

(1) The height of coamings of small hatchways is to comply with the requirements of 2.20.1.8 of this Section. The thickness of the coamings is not to be less than the minimum thickness as required in this Chapter for the deck inside the line of openings for that position, or 11 mm, whichever is the lesser;

(2) Small hatchways are to be provided with steel weathertight hatch covers and reliable securing devices. The means of securing are to be such that weathertightness can be maintained in any condition. The thickness of the hatch covers is not to be less than the minimum thickness required by this Chapter for the deck inside the line of openings for that position, or 8 mm, whichever is the lesser;

(3) Strength and securing of small hatches on the exposed fore deck are also to comply with the relevant requirements of Section 7, Chapter 1 of this PART.

Section 21 VEHICLE DECKS

2.21.1 General requirements

2.21.1.1 Where wheeled vehicles are to be stowed on the deck or used for cargo handling, the scantlings of the deck or hatch covers are to comply with the relevant requirements in this PART and in addition, are to be checked for strength in accordance with the requirements of this Section.

2.21.1.2 Where wheeled vehicles are to be stowed on the inner bottom or used for cargo handling, the strength of inner bottom plating in way may also be checked by reference to the requirements of this Section.

2.21.2 Deck plating

2.21.2.1 The thickness of deck plating is to comply with the following requirements:

(1) The thickness t of deck plating is not to be less than that obtained from the following formula:

$$t = CJ\sqrt{PK} + 1.5 \quad \text{mm}$$

where: P — load, in t, on the tyre print. Two closely spaced wheels may be regarded as a combined wheel print and the sum of loads on both tyre prints is to be taken;

K — material factor;

C, J — coefficients, to be calculated as follows:

For $0.5 \leq \frac{u}{v} < 1$:

$$J = 0.73(0.85 - \frac{u}{v}) + \frac{4.58}{\frac{v}{s} + 0.62}$$

$$C = 1 - (0.099\frac{v}{s} + 0.013)(2.5 - \frac{l}{s})$$

For $1 \leq \frac{u}{v} < 2$:

$$J = 0.51(0.79 - \frac{u}{v}) + \frac{4.58}{\frac{v}{s} + 0.62}$$

$$C = 1 - (0.156\frac{v}{s} + 0.009)(2.5 - \frac{l}{s})$$

For $2 \leq \frac{u}{v} < 3$:

$$J = 0.4(0.66 - \frac{u}{v}) + \frac{4.30}{\frac{v}{s} + 0.57}$$

$$C = 1 - (0.196\frac{v}{s} + 0.013)(2.5 - \frac{l}{s})$$

where: $\frac{u}{v}$ — aspect ratio of tyre print, see Figure 2.21.2.1(1). For 2 tyre prints on one plate panel, see Figure 2.21.2.1(2), $u' = 2u$; where $\frac{u'}{v} \geq 3$, calculating by $u_1 = v_1 = \sqrt{u'v}$;

l — span of frames, in m;

s — spacing of frames, in m;

when $l/s > 2.5$, to be taken as 2.5.

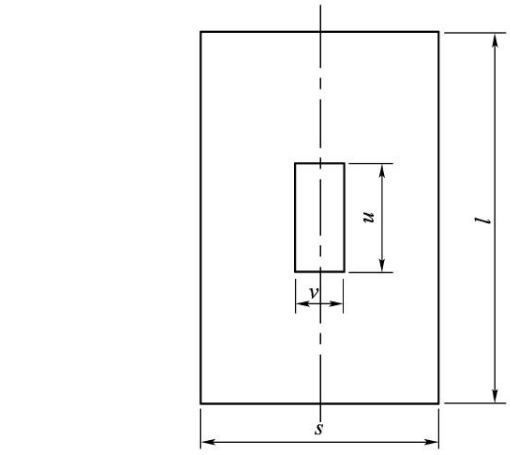


Figure 2.21.2.1(1)

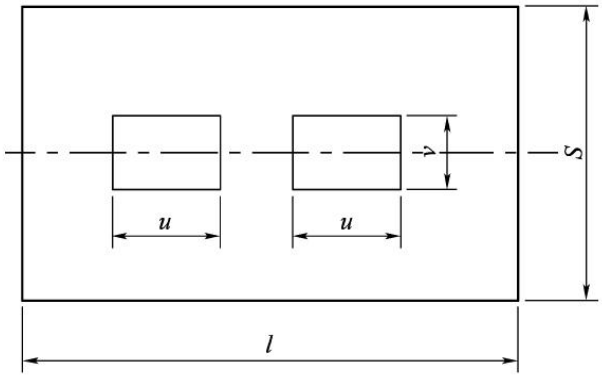


Figure 2.21.2.1(2)

(2) Where forklift trucks are to be used for cargo handling on decks and no data for tyre print and deadweight, etc., are available, the thickness of deck plating may be obtained in accordance with the following formula:

$$\frac{s}{t} \leq \frac{111}{P+1} + 27$$

where: t — thickness of deck plating, in mm;

s — spacing of deck longitudinals or beams, in mm;

P — cargo weight lifted by the forklift truck, in t.

(3) Where wheeled vehicles are to be stowed or used on insulated decks, attention is to be paid to the effect on the insulation coating due to deck deformation when the permissible loading of decks is determined based on the thickness of deck plating.

2.21.2.2 The section modulus of deck beams and longitudinals are to comply with the following requirements:

(1) Where forklift trucks are to be used for cargo handling on cargo deck, the section modulus W of deck beams or longitudinals is not to be less than that obtained from the following formula:

$$W = (0.375J_1Pl + 1.25J_2hsl^2)K \quad \text{cm}^3$$

where: P — total weight of forklift truck, in t;

h — design head on the deck, in m, see 2.8.1.1 of this Chapter;

s — spacing of frames, in m;

l — span of frames, in m;

K — material factor;

J_1, J_2 — coefficients, to be taken according to Table 2.21.2.2.

Coefficients J_1 and J_2 **Table 2.21.2.2**

J	0.1	0.2	0.3	0.4	0.5 and over
J_1	15.4	14.6	13.35	11.8	10.1
J_2	1.89	1.85	1.73	1.55	1.30

Note: J = wheel spacing/span of frame, where wheel spacing is to be taken as the spacing between the two outermost wheels on the same axle.

(2) Where decks are permanently intended for the carriage of vehicles, the section modulus W of deck beams or longitudinals is not to be less than that obtained from the following formula:

$$W = (0.536J_1Pl + 1.25J_2shl^2)K \quad \text{cm}^3$$

where: P — load on one axle, in t, i.e. total weight of the vehicle divided by the number of axles. Where the distribution of weight is not uniform, P is to be taken as the maximum axle load;

h — design head on deck, in m, in accordance with 2.8.1.1 of this Chapter, but h need not be more than 2.5 m;

s — spacing of frames, in m;

l — span of frames, in m;

K — material factor;

J_1, J_2 — coefficients, to be taken according to Table 2.21.2.2.

(3) In addition to the above-mentioned requirements, the strength of deck beams or lonitudinals is to be checked according to the following requirements: the allowable bending stress is not to exceed $104/K$, in N/mm² if it is assumed that both ends of beams or longitudinals are fixed rigidly and that the beam is only subjected to the concentrated load of wheels.

2.21.2.3 The section modulus of deck transverses or girders is to comply with the following requirements:

(1) Where the deck transverses or girders are subject to uniformly distributed loading, the section modulus W is not to be less than that obtained from the following formula:

$$W = 4.75bhl^2K \quad \text{cm}^3$$

where: b — spacing of transverses or girders, in m;

l — span of transverse or girder, in m;

h — design head on deck, in m, in accordance with 2.8.1.1 of this Chapter;

K — material factor.

(2) Where the deck girders or transverses are subject to concentrated loads, with or without the addition of uniformly distributed load, the section modulus is to be determined by calculations. During the calculation, 100% end fixity is to be assumed, and the permissible bending stress is to be taken as $118/K$, in N/mm².

2.21.3 Hatch covers

2.21.3.1 Where wheeled vehicles are to be stowed or used for cargo handling on hatch covers, the thickness of hatch cover plating is to comply with the provisions in 2.21.2.1 of this Section.

2.21.3.2 Where wheeled vehicles are to be stowed or used for cargo handling on hatch covers, the section modulus W of hatch cover stiffeners is not to be less than that obtained from the following formula:

$$W = (J_3Pl + 1.67J_4shl^2)K \quad \text{cm}^3$$

where: P — load on one axle, in t, see 2.21.2.2 of this Section;

h — design head on the hatch cover, in m; $h = 0.14\,p$, where p is the vertical weather design load on the hatch cover given in 2.20.2.2(1) of this Chapter;

s — spacing of stiffeners, in m;

l — span of stiffener, in m;

K — material factor;

J_3, J_4 — coefficients, to be taken according to Table 2.21.3.2.

Coefficients J_3 and J_4 **Table 2.21.3.2**

J	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
J_3	11.96	10.69	9.58	8.46	7.46	6.51	5.55	4.23	2.38
J_4	2.32	1.89	1.55	1.28	1.07	0.91	0.73	0.36	0.11

Note: J = wheel spacing/span of stiffeners, where wheel spacing is to be taken as the spacing between the two outermost wheels on the same axle.

Section 22 STRENGTHENED FOR HEAVY CARGOES

2.22.1 General requirements

2.22.1.1 Ships complying with the requirements of this Section will be assigned the class notation: Strengthened for Heavy Cargoes.

2.22.1.2 Ships of loading rate γ not greater than 0.833m^3/t (see 1.1.2.15 of Chapter 1) are to comply with the requirements of this Section, except when loaded by steel coils on a wooden support.

2.22.1.3 Special considerations are to be given to the strengthening requirements where the inner bottom plating of the cargo hold is loaded by bulky cargo or bearing concentrated load.

2.22.2 Requirements for hull structures

2.22.2.1 The strength deck and bottom in way of cargo holds are to be framed longitudinally, and the ship is to be provided with a double bottom within the region of cargo spaces.

2.22.3 Strengthening of bottom framing

2.22.3.1 The plate floors are generally to be spaced not more than 2.5 m apart, and the thickness of the floors is not to be less than that required in 2.6.11.2 of this Chapter.

2.22.3.2 The bottom girders are generally to be spaced not more than 3.6 m apart, and the thickness of side girders is not to be less than that required in 2.6.10.2 of this Chapter.

2.22.3.3 The thickness of watertight or oiltight floors is to comply with the requirements of 2.6.11.2 of this Chapter.

2.22.3.4 The thickness t of inner bottom plating is not to be less than that obtained from the following formulae:

$$t = (0.04L + 5s + 1.1)\sqrt{K} + 5 \qquad \text{mm}$$

$$t = 4.65s\sqrt{\frac{HK}{\gamma}} \qquad \text{mm}$$

where: L — length of ship, in m, L need not be taken greater than 400 m;

s — spacing of inner bottom longitudinals, in m;

γ — stowage rate, in m³/t, but not to be greater than 0.833;

H — vertical distance, in m, measured from the inner bottom plating to deck at side amidships;

K — material factor.

2.22.3.5 The section modulus W of inner bottom longitudinals is not to be less than 85% of that of bottom longitudinals as required in 2.6.12.2 of this Chapter, nor to be less than that obtained from the following formula:

$$W = \frac{8.5}{\gamma} Hsl^2 K \quad \text{cm}^3$$

where: γ, H and s — same as defined in 2.22.3.4 of this Section;

l — span of inner bottom longitudinal, in m;

K— material factor.

2.22.3.6 Where vertical stays are fitted in way of the mid-span of inner bottom longitudinals and the inner bottom longitudinals are subject to uniformly distributed loading, the scantlings of bottom longitudinals and stays may be determined by direct calculations.

2.22.3.7 The construction of the duct keel is to comply with the requirements of 2.6.3 of this Chapter. But the section modulus W of the inner bottom stiffening members is not to be less than the values derived from 2.22.3.5 of this Section, and in this case s is the spacing of the stiffening members, in m, and l is the span of stiffening members, in m.

Section 23 STRENGTHENING FOR GRABS

2.23.1 General requirements

2.23.1.1 This Section applies to ships intended to carry dry cargo in bulk, and include such types as bulk carriers, ore carriers and combination carriers.

2.23.2 Class notation

2.23.2.1 The class notation Grab*(X) is assigned to ships with holds designed for loading/unloading by grabs having a maximum specific weight up to X tons, in compliance with the requirements of this Section.

2.23.3 Structural strengthening

2.23.3.1 The thickness t_{GR}, in mm, of the inner bottom plating is not to be less than that obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 50)\sqrt{sK} + 5.0 \quad \text{mm}$$

where: M_{GR} — mass of unladen grab, in tons;
s — spacing, in m, of ordinary stiffeners, measured at mid-span;
K — material factor.

2.23.3.2 The thickness t_{GR}, in mm, of hopper tank sloping plate, transverse lower stool, transverse bulkhead plating and inner hull up to a height of 1.5 m above the lowest point of the inner bottom, excluding bilge wells, is to be not less than the value obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 42)\sqrt{sK} + 3.5 \quad \text{mm}$$

where: M_{GR} — mass of unladen grab, in tons;
s — spacing, in m, of ordinary stiffeners, measured at mid-span;
K — material factor.

Section 24 ANALYSIS OF TEMPERATURE FIELD AND THERMAL STRESS OF CARGO TANK STRUCTURE

2.24.1 General requirements

2.24.1.1 This Section applies to ships carrying liquefied gases in bulk, ships carrying dangerous liquid chemicals having a temperature higher than 80℃ at atmospheric pressure in bulk, oil tankers and asphalt carriers, and contains specific requirements for cargo tank thermal stress calculation as required in Chapter 10, PART EIGHT of the Rules, Chapter A4 of CCS Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk, Chapter A4, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, and other relevant rules of CCS.

2.24.1.2 Unless approved by CCS, the following two loading modes are not to be used:

(1) cargoes of different temperatures and natures are carried simultaneously in adjacent tanks or in the cargo tank area;

(2) liquid cargo and ballast water of high (low) temperature are carried simultaneously in cargo tanks and adjacent ballast tanks.

2.24.1.3 In this Section, the thermal stress calculation for cargo tanks include two steps which are to be performed in sequence. At step 1, the distribution of temperature field of cargo tanks and associated structures is to be obtained through heat transferring analysis with the given temperatures of hot/cold sources of liquid cargo and the given ambient temperatures. Step 2 is to use the distribution of temperature field so obtained as input condition for thermal analysis, so as to obtain the thermal-expansion-induced thermal stress of any structure in the temperature field due to temperature difference.

2.24.1.4 The heat transferring calculation in this Section is based on an assumed steady state heat transferring in three-dimensional space, no change of material parameters and boundary

conditions is made in conjunction with any temperature change in the analysis of linear heat transferring, and only the effects of transferring through structures and insulation are considered.

2.24.1.5 The thermal calculation in this Section is based on the assumption of a "sequentially coupled heat-structure (sequentially coupled problem)", i.e., the effects of changes in the temperature field on the machinery field are considered without taking account of the effects of the latter on the former. Moreover, the high temperature creeping effects of structures are not considered.

2.24.1.6 In calculation, it is assumed that heat is transferred between hull structural members by conduction, and that heat exchange between air and hull structural members exposed to it is natural convection only.

2.24.1.7 In heat transferring calculation and thermal stress analysis, recognized finite element thermal analysis programs and finite element structural analysis programs are to be used.

2.24.1.8 Where methods or assumptions other than those specified in the Rules are to be used in calculation, they are to be approved by CCS.

2.24.2 Plans and documents

2.24.2.1 In addition to calculations as generally required by relevant CCS documents for direct finite element structural calculation, the following heat transferring calculation and thermal stress analysis documents together with associated drawings and documents are to be submitted:

(1) Arrangement of insulation layers and details of their connection;

(2) Thermal parameters of insulation layers (coefficient of thermal conductivity, etc.);

(3) Heat balance calculation and analysis report, including the following:

a. maximum design temperature of liquid cargo to be carried (the temperature indicated in class notation);

b. design target values of external surface temperature of steel plating of inner side, inner bottom and deck, if any;

c. lowest/highest ambient temperature (atmosphere and seawater) for intended operating route;

d. distribution of temperature field under consideration.

(4) Thermal stress calculation report: thermal stress calculation based on the distribution of temperature field as obtained according to (3) and performed according to this Section, including check of resultant stresses for combinations of thermal stress with corresponding sea conditions and loading conditions.

2.24.3 Model for analysis

2.24.3.1 Scope of model: For integral tanks, it is to be in accordance with the requirements of Appendix 1, Chapter 5 of this PART. If necessary (temperature gradient is large), modeling of the fore end area of the foremost cargo tank and that of the aft end area of the aftermost cargo tank are to be considered. For independent tanks, at least the entire tank structure is to be taken. For the effects of temperature on the supporting structure of cargo tanks and on the hull, see the relevant requirements of Appendix 1, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For heat transferring analysis, the model is to cover all contributing heat insulation materials and structures, except that stainless liner may be neglected; for thermal stress analysis, the model is merely a structural one.

2.24.3.2 Structural elements: The principled requirements for modeling in respect to types of elements and meshing, etc., are as given in Appendix 1, Chapter 5 of this PART.

2.24.3.3 Insulation elements: For rock wool thermal insulation, the elements are generally of solid-element type, thickness is taken as that of the insulation layer (excluding stainless liner), and other principles for modeling, e.g. element type selection and meshing, are similar to those for structures. However, simplification is allowed, as appropriate, in way of complex intersection of certain structures (insulation), e.g. connection of a longitudinal or transverse corrugated bulkhead with upper stool.

2.24.3.4 Boundary conditions for heat transferring analysis:

(1) The thermal transferring analysis for the determination of steel grades required for structural materials used at low temperatures is to be in accordance with the following requirements:

a. For ships carrying dangerous chemicals in bulk, to which CCS Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk apply and for which thermal stress calculation is to be performed, the boundary conditions regarding external atmospheric temperature and seawater temperature are to be taken in accordance with Chapter A4 of CCS Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk. For ships carrying liquefied gases in bulk, to which CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk apply and for which thermal stress calculation is to be performed, the boundary conditions regarding external atmospheric temperature and seawater temperature are to be taken in accordance with Chapter A4, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

b. For ships not covered by a. above, the boundary conditions regarding external atmospheric temperature and seawater temperature are as follows:
portions of hull below draught line – the defined surface temperature is the lowest temperature in water and if icing is possible for the intended operating route, this temperature is to be taken as 0°C;
portions of hull above draught line – the defined surface temperature is the possibly lowest atmospheric temperature for the intended operating route, e.g. -20°C.

(2) In respect to the determination of maximum thermal stress, the temperature load condition applied as input for the thermal analysis is to be the maximum difference between the liquid cargo temperature and the ambient temperature for the intended operating route.

(3) For the side of cargo tank insulation or bare structural shell which is in direct contact with liquid cargo, the defined surface temperature is the highest stable temperature of liquid cargo being carried.

(4) For the space within double bottom and double side skin, the ambient temperature may be directly taken a little higher than the external temperature, and the assumed convective heat transfer between air and steel plating as mentioned above (heat transferring by air is assumed to be little) is defined in respect to external surfaces of inner side shell and inner bottom (the surfaces not exposed to liquid cargo). Alternatively, this space may be taken as a three-dimensional finite element model of air elements and incorporated into the finite element heat transferring model. The heat transferring calculation is performed according to the assumption of 2.24.1.6, without taking account of the heat transferring by air. Where there are special requirements for the highest temperature criterion regarding periphery of cargo tanks, the surface temperature is to be defined as so required.

(5) The external surface temperature of the independent tank structure is to be defined according to the above requirements, as applicable.

(6) The gas temperature in cargo tanks in the half-loaded condition may be assumed as the liquid cargo temperature, and the boundary conditions for heat convection of gas are to be used to simulate the effects of gas on structure.

2.24.3.5 In thermal analysis, the structural boundary conditions for the integral tank model are to be in accordance with the requirements of Appendix 1, Chapter 5 of this PART. For independent tanks, the model structural boundary conditions are to be taken as those for the loading conditions corresponding to temperature loads. In addition, restraint of linear displacement δ_x in the direction of ship's length is to be released at a certain end (e.g. end B) of section model for the structural boundary condition of above model.

2.24.4 Thermal calculation and loading conditions

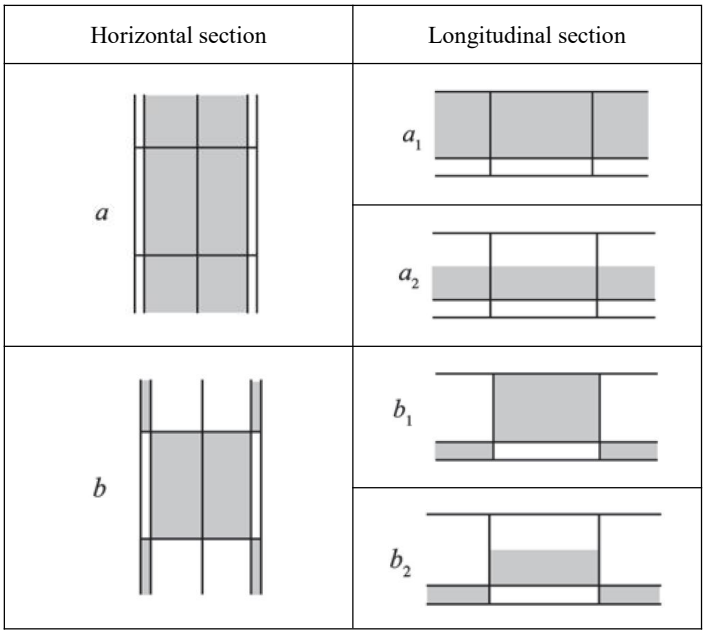
2.24.4.1 The distribution values of the three-dimensional temperature field obtained from heat transferring analysis are to be used as temperature loads in structural strength calculation. For tankers as stipulated in the Rules, where independent tanks are fitted, temperature loads in the full load condition are to be calculated; where integral tanks are fitted, the load conditions are to be as shown in Figure 2.24.4.1, and the following are to be complied with:

(a) — only sagging mode is considered;

(b), (c) — sagging and hogging modes are considered respectively.

And for (a), (b) and (c), both full and half load conditions in the above modes are to be considered. The half load condition means the loading height of liquid cargo is half the height of tank.

Where any loading condition specified in the loading manual or occurring in service is worse than the above conditions under consideration, the temperature load calculated to such loading condition is to be included. For cargo tanks of other ship types, temperature loads in relevant loading conditions are to be calculated in accordance with the requirements of the applicable rules.



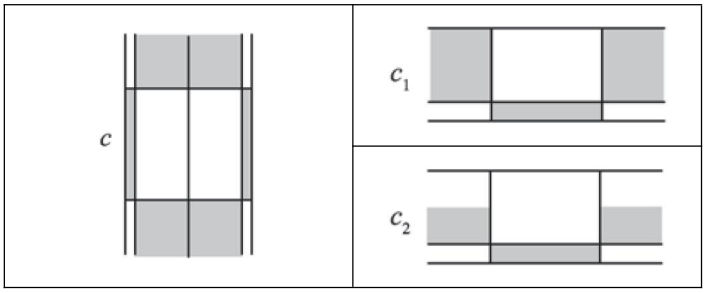


Figure 2.24.4.1

2.24.4.2 The temperature loads as calculated above are to be applied to the model of each corresponding loading condition. The calculation and application of routine loading conditions are to follow the applicable requirements in Appendix 1, Chapter 5 of this PART, Appendix 1 and Appendix 2 of PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and other relevant documents or routine practice.

2.24.4.3 Where only longitudinal tension and compression stresses less than $42/K$ N/mm^2 (K being material factor) are applied in regard to thermal stresses induced by temperature loads, the longitudinal bending moment of hull girder may not to be applied to both ends of the model under consideration, subject to agreement of CCS.

2.24.4.4 The heat conduction coefficient and linear expansion coefficient of steel as well as the convective heat exchange coefficient of air are to be provided by designer. For asphalt carriers during preliminary design, reference may be made as follows:

Heat conduction coefficient of carbon steel: 60.6 W/(m·K) – for heat transferring calculation (thermal analysis);

Linear expansion coefficient of carbon steel: 11×10^{-6}(1/K) – for heat stress calculation (structural analysis);

Convective heat exchange coefficient of air: 11.6 W/(m^2·K) – for heat transferring calculation (thermal analysis). Where the length of the finite element model is measured in mm, the value taken is to be multiplied by 10^{-6}.

The heat conduction coefficient for insulation material is to be taken according to the actual design.

2.24.5 Strength criteria

2.24.5.1 For an integral tank model, the criteria are as given in Appendix 1, Chapter 5 of this PART; for hull portion of an independent tank model, the criteria are as given in Appendix 1 and Appendix 2 of PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk; for construction materials of independent tanks of petroleum asphalt carriers, the criteria are as given in Section 2 of Chapter 10, PART EIGHT of the Rules.

2.24.5.2 Where wave loads are obtained by direct calculation on the basis of dynamic loading, the permissible stress taken according to 2.24.5.1 may be multiplied by 1.1 and the minimum buckling safety factor may be multiplied by 0.9.

2.24.5.3 For a finite element model, for which the longitudinal hull girder bending moment is not taken into account, the permissible stress is to be adjusted as follows on the basis of Appendix 1, Chapter 5 of this PART, without any change to other requirements:

For all plating $[\sigma_e] = 175/K$

For longitudinal plating $[\sigma_l] = 110/K$

For longitudinal girders $[\tau] = 83/K$

For transverse members (including floors, transverse bulkheads) $[\tau] = 93/K$

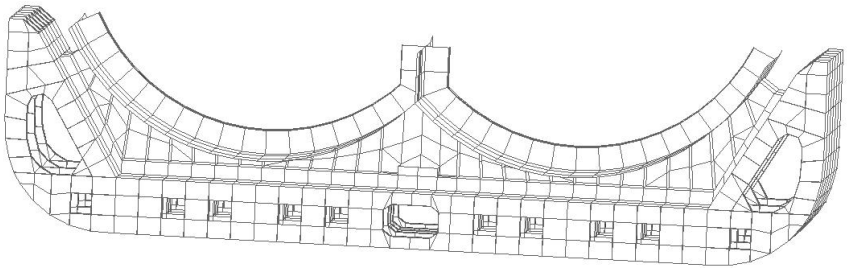
where: K — material factor.

2.24.6 Inner liner or membrane

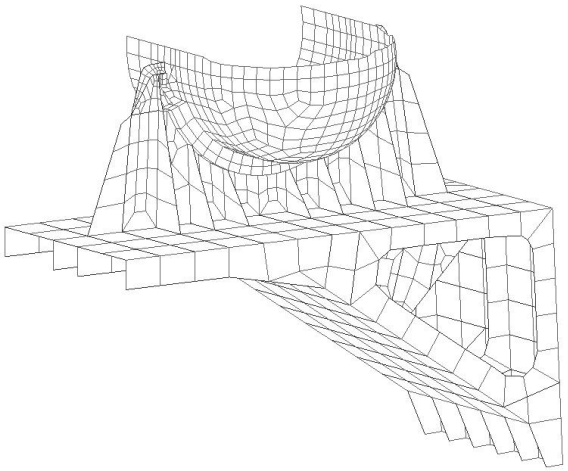
2.24.6.1 For an integral tank model, consideration is to be given to using suitable elastic joints and slightly movable riveting means to eliminate or reduce its inner stressing and deformation due to temperature-induced expansion or contraction of the inner liner or membrane, ensuring that the thermal stress of the inner liner or membrane will not exceed the permissible value and that the deformation will not cause any damage to the function of insulation layers.

2.24.7 Analysis of temperature field for supporting structures of independent tank

2.24.7.1 The finite element model for analysis of temperature field includes supporting structure and its connected hull structure as well as indpendnent tank structure.



(1) Finite element model for analysis of temperature filed of supporting strucutre of independent tank



(2) Finite element model for analysis of temperature field of supporting structure of deck tank

Figure 2.24.7.1 Finite Element Model of Supporting Strucutre of Independent Tank

2.24.7.2 The types of elements and meshing for structural finite element model are to meet the relevant requirements of Section 5, Chapter 1 of this PART of the Rules.

2.24.7.3 Geometry element, generally hexahegdron element is to be used for laminiated wood structure.

2.24.7.4 The longitudinal range of model is to include spacing of each web frame before or after supporting structure, the transverse range is to be taken as the width of ship (for deck tank, to be taken as the overall width of supporting structure), the vertical range is to be taken as the distance from the bottom of ship to the top of supporting structure (for deck tank, to be taken as the distance from deck structure to the top of supporting structure).

2.24.7.5 Boundary conditions for heat transferring analysis of hull structure connected with supporing structure are to be in accordance with the 2.24.3.4 of this Section, those for independent tank connected with supporting structure are to be taken as the temperature of liquid cargo, and those for supporting structure exposed in air are to be taken as the conditions for convective heat transfer, see Figure 2.24.7.5.

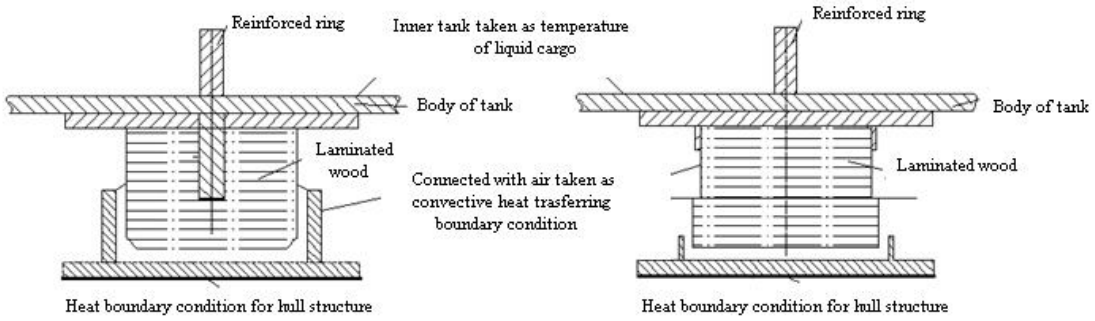


Figure 2.24.7.5 Diagram of Boundary Conditions for Analysis of Temperature Field of Supporting Structures

2.24.7.6 For material properties and air convection coefficient of model, see the relevant requirements of 2.24.4.4 of this Section.

2.24.7.7 The analysis of temperature field is to at least include the ambient temperature conditions specified in Chapter 4, PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

Section 25 STRUCTURAL STRENGTHENING LOADED BY STEEL COILS ON A WOODEN SUPPORT

2.25.1 General requirements

2.25.1.1 The thickness of inner bottom plating, bilge hopper sloping plate and inner hull plating up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating as well as section modulus and shear area of stiffeners for ships intended to carry steel coils are to comply with the requirements of this Section.

2.25.1.2 The provision is determined based on the assumption of Figure 2.25.1.2 as the standard means of securing steel coils on the dunnage.

2.25.1.3 All steel coils are presumed to be of the same characters.

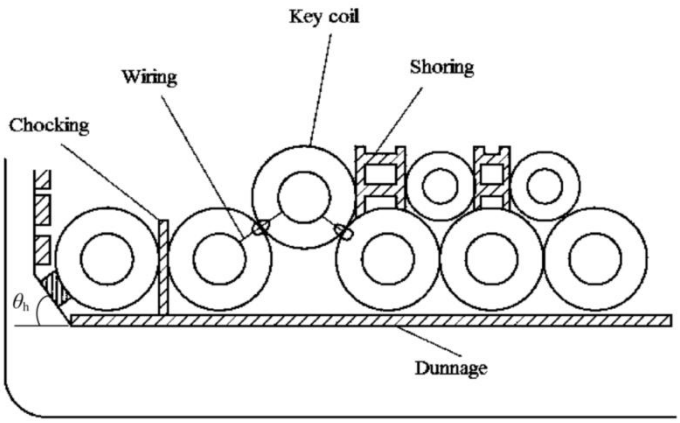


Figure 2.25.1.2 Inner Bottom Loaded by Steel Coils

2.25.2 Accelerations

2.25.2.1 In order to calculate the accelerations, the following coordinates are to be used for the transverse and vertical positions of calculated point:

$$y_{G-SC} = \begin{cases} B_h/4 & \text{for port} \\ -B_h/4 & \text{for starboard} \end{cases}$$

$$z_{G-SC} = h_{DB} + \left\{1 + (n_1 - 1)\frac{\sqrt{3}}{2}\right\}\frac{d_{SC}}{2}$$

where: B_h — breadth in m, at the mid of the hold, of the cargo hold at the level of connection of bilge hopper plate with side shell or inner hull;

d_{sc} — diameter of steel coils, in m;

h_{DB} — depth of double bottom, in m.

Vertical acceleration a_v, in m/s^2, are to be calculated by the formulae defined in 1.5.2 of Section 5, Chapter 1 of this PART and tangential acceleration a_R due to roll, in m/s^2, is to be calculated by the following formula:

$$a_R = \varphi_m \left(\frac{2\pi}{T_R}\right)^2 \sqrt{y_{G-SC}{}^2 + R^2}$$

where: φ_m, maximum angle of roll, T_R, roll period — see the formulae defined in 1.5.2 of Section 5, Chapter 1 of this PART**;**

$$R = z_{G-SC} - \min\left(\frac{D}{4} + \frac{d}{2}, \frac{D}{2}\right)$$

where: d — draught, in m.

2.25.3 Inner bottom plating

2.25.3.1 The thickness of plating of longitudinally framed inner bottom is not to be less than the value obtained, in mm, from the following formula:

$$t = K_1\sqrt{\frac{(g + 0.5a_v)F_{SC}}{\lambda_p R_{eH}}} + t_c \quad \text{mm}$$

where: K_1— coefficient taken equal to:

$$K_1 = \sqrt{\frac{1.7slK_2 - 0.73s^2K_2^2 - \left(l - l'\right)^2}{2l'\left(2s + 2lK_2\right)}}$$

t_c — corrosion addition, in mm, generally taken 2.5 mm, to be taken 5 mm where the cargo holds are designed for loading/unloading by grabs;

a_v — vertical acceleration, in m/s^2, calculated according to the formula defined in 1.5.2, Section 5, Chapter 1 of this PART;

g — acceleration due to gravity, g = 9.81 m/s^2;

F_{SC}— equivalent mass of steel coils, in kg, taken equal to:

$$F_{SC} = K_S \frac{W_{SC} n_1 n_2}{n_3}$$

λ_p— permissible bending stress coefficient of plating, generally taken 0.8, to be taken 0.9 as the calculated structural member is not contributing to the hull girder longitudinal strength;

l — length of long edge of elementary plate panel taken along the side length, in m;

s — length of short edge of elementary plate panel taken along the side length in way of middle of span l, in m;

K_s— coefficient, taken equal to:

K_s =1.4 when steel coils are lined up in one tier with a key coil;

K_s =1.0 in other cases;

W_{SC}— mass of one steel coil, in kg;

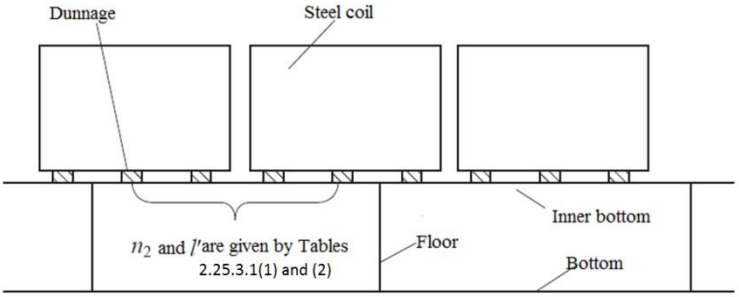
R_{eH} — minimum yield stress of material, in N/mm^2;

n_1— number of tiers of steel coils;

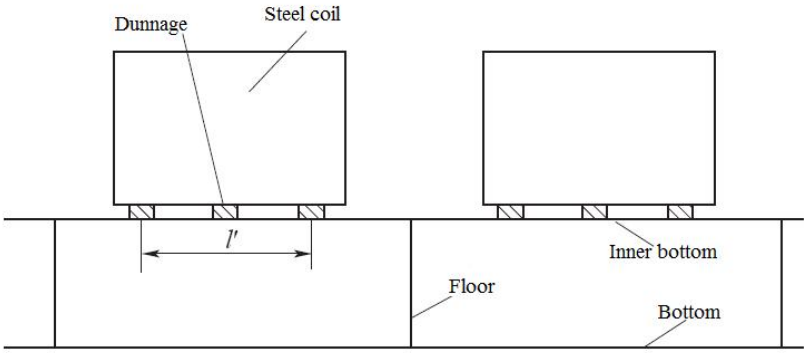
n_2— number of load points per elementary plate panel of inner bottom (see Figure 2.25.3.1). For steel coil loading related to floor plates of inner bottom (see Figure 2.25.3.1(2)), $n_2 = n_3$; for steel coil loading irrelevant to floor plates of inner bottom (see Figure 2.25.3.1(1)), n_2 is to be consistent with Table 2.25.3.1(1). For cases not included in Table 2.25.3.1(1), n_2 is to be determined in accordance with the following formula:

$$\frac{n_2 - 1}{n_3} + INT\left(\frac{n_2 - 1}{n_3}\right) \cdot 0.2 < \frac{l}{l_s} \le \frac{n_2}{n_3} + INT\left(\frac{n_2}{n_3}\right) \cdot 0.2$$

where: $INT(\ )$ is the integral function, taking the integral parts of values.



(1)



(2)

Figure 2.25.3.1 Loading Condition of Steel Coils

n_3 — number of dunnages supporting one steel coil;

l_s — length of a steel coil, in m;

K_2 — coefficient taken equal to:

$$K_2 = -\frac{s}{l} + \sqrt{\left(\frac{s}{l}\right)^2 + 1.37\left(\frac{l}{s}\right)^2\left(1-\frac{l'}{l}\right)^2 + 2.33}$$

l' — distance, in m, between outermost load points per elementary plate panel in ship's length (see Figure 2.25.3.1). For steel coil loading related to floor plates of inner bottom (see Figure 2.25.3.1(2)), l' is to be the distance between the dunnages of the external ends supporting the steel coils; for steel coil loading irrelevant to floor plates of inner bottom (see Figure 2.25.3.1(1)), l' is to be consistent with Table 2.25.3.1(2). For cases not included in Table 2.25.3.1(2), l' is to be determined in accordance with the following formula:

$$l' = \left[\frac{n_2 - 1}{n_3} + 0.2 \cdot INT\left(\frac{n_2 - 1}{n_3}\right)\right] l_s$$

where: $INT(\ )$ is the integral function, taking the integral parts of values.

Number *n*2 of Load Points per Elementary Plate Panel **Table 2.25.3.1(1)**

n_2	$n_3=2$	$n_3=3$	$n_3=4$	$n_3=5$
1	$0<\frac{l}{l_s}\le 0.5$	$0<\frac{l}{l_s}\le 0.33$	$0<\frac{l}{l_s}\le 0.25$	$0<\frac{l}{l_s}\le 0.2$
2	$0.5<\frac{l}{l_s}\le 1.2$	$0.33<\frac{l}{l_s}\le 0.67$	$0.25<\frac{l}{l_s}\le 0.5$	$0.2<\frac{l}{l_s}\le 0.4$
3	$1.2<\frac{l}{l_s}\le 1.7$	$0.67<\frac{l}{l_s}\le 1.2$	$0.5<\frac{l}{l_s}\le 0.75$	$0.4<\frac{l}{l_s}\le 0.6$
4	$1.7<\frac{l}{l_s}\le 2.4$	$1.2<\frac{l}{l_s}\le 1.53$	$0.75<\frac{l}{l_s}\le 1.2$	$0.6<\frac{l}{l_s}\le 0.8$
5	$2.4<\frac{l}{l_s}\le 2.9$	$1.53<\frac{l}{l_s}\le 1.87$	$1.2<\frac{l}{l_s}\le 1.45$	$0.8<\frac{l}{l_s}\le 1.2$
6	$2.9<\frac{l}{l_s}\le 3.6$	$1.87<\frac{l}{l_s}\le 2.4$	$1.45<\frac{l}{l_s}\le 1.7$	$1.2<\frac{l}{l_s}\le 1.4$
7	$3.6<\frac{l}{l_s}\le 4.1$	$2.4<\frac{l}{l_s}\le 2.73$	$1.7<\frac{l}{l_s}\le 1.95$	$1.4<\frac{l}{l_s}\le 1.6$
8	$4.1<\frac{l}{l_s}\le 4.8$	$2.73<\frac{l}{l_s}\le 3.07$	$1.95<\frac{l}{l_s}\le 2.4$	$1.6<\frac{l}{l_s}\le 1.8$
9	$4.8<\frac{l}{l_s}\le 5.3$	$3.07<\frac{l}{l_s}\le 3.6$	$2.4<\frac{l}{l_s}\le 2.65$	$1.8<\frac{l}{l_s}\le 2.0$
10	$5.3<\frac{l}{l_s}\le 6.0$	$3.6<\frac{l}{l_s}\le 3.93$	$2.65<\frac{l}{l_s}\le 2.9$	$2.0<\frac{l}{l_s}\le 2.4$

Distance between Load Points in Ship Length Direction per Elementary Plate Panel of Inner Bottom

Table 2.25.3.1(2)

n_2	n_3			
	2	3	4	5
1	Actual breadth of dunnage			
2	$0.5l_s$	$0.33l_s$	$0.25l_s$	$0.2l_s$
3	$1.2l_s$	$0.67l_s$	$0.50l_s$	$0.4l_s$
4	$1.7l_s$	$1.20l_s$	$0.75l_s$	$0.6l_s$
5	$2.4l_s$	$1.53l_s$	$1.20l_s$	$0.8l_s$
6	$2.9l_s$	$1.87l_s$	$1.45l_s$	$1.2l_s$
7	$3.6l_s$	$2.40l_s$	$1.70l_s$	$1.4l_s$
8	$4.1l_s$	$2.73l_s$	$1.95l_s$	$1.6l_s$
9	$4.8l_s$	$3.07l_s$	$2.40l_s$	$1.8l_s$
10	$5.3l_s$	$3.60l_s$	$2.65l_s$	$2.0l_s$

2.25.4 Bilge hopper sloping plate and inner hull plate

2.25.4.1 The thickness of plating of longitudinally framed bilge hopper sloping plate and inner hull is not to be less than the value obtained, in mm, from the following formula:

$$t = K_1\sqrt{\frac{a_{hopper}F'_{SC}}{\lambda_p R_{eH}}} + t_c \quad \text{mm}$$

where: K_1— coefficient, defined in 2.25.3;

t_c ——corrosion addition, in mm, generally taken 2.5 mm, to be taken 3.5 mm for bilge hopper sloping plate and inner hull plate within 1.5 m height from the lowest point of inner bottom where the cargo holds are designed for loading/unloading by grabs;

R_{eH} — minimum yield stress of material, in N/mm^2;

a_{hopper}— factor taken equal to:

$$a_{hopper} = -a_R \sin\left(\tan^{-1}\left|\frac{y_{G-SC}}{R}\right| - \theta_h\right) + g\cos\left(\theta_h - \varphi_m\right)$$

θ_h — angle, in degree, between inner bottom plate and bilge hopper sloping plate or inner hull plate, see Figure 2.25.1.2;

φ_m — in degree, see formula specified in 1.5.2 of Section 5, Chapter 1 of this PART;

a_R— tangential acceleration defined in 2.25.2;

g — acceleration due to gravity, g = 9.81 m/s^2;

y_{G-SC}— centre of gravity in transverse direction, in m, defined in 2.25.2;

R— factor, defined in 2.25.2;

F'_{SC}—equivalent mass of steel coils, in kg, taken equal to:

$$F'_{SC} = C_k \cdot \frac{W_{SC} n_2}{n_3}$$

λ_p—permissible bending stress coefficient of plating, defined in 2.25.3;

C_k— coefficient, taken equal to:

C_k =3.2, when steel coils are lined up two or more tier, or when steel coils are lined up one tier and key coil is located second or third from bilge hopper sloping plate or inner hull plate;

C_k =2.0, in other cases.

2.25.5 Stiffeners of inner bottom

2.25.5.1 The section modulus W and the shear area A of single span stiffeners located on inner bottom plating are not to be less than the values obtained from the following formulae:

$$W = 1.1K_3\frac{\left(g + 0.5a_v\right)F_{SC}}{8\lambda_s R_{eH}} \quad \text{cm}^3$$

$$A = \frac{5\left(g + 0.5a_v\right)F_{SC}}{0.9\tau_{eH}\sin\phi} \times 10^{-3} \quad \text{cm}^2$$

where: K_3— coefficient, defined in Table 2.25.5.1, to be taken as $2l_e/3$ for $n_2 > 10$;

l_e — effective span of stiffeners, in m, see 1.2.3, Section 2, Chapter 1 of this PART;

a_v— vertical acceleration, in m/s^2, calucated according to the formula defined in 1.5.2, Section 5, Chapter 1 of this PART;

g — acceleration due to gravity, g = 9.81 m/s^2;

F_{SC}—equivalent mass of steel coils, in kg, defined in 2.25.3;

R_{eH} — minimum yield stress of material, in N/mm^2;

λ_s ——permissible bending stress coefficient of stiffeners, taken 0.9;

τ_{eH} — shear yield stress of material, in N/mm^2, taken equal to:

$$\tau_{eH} = \frac{R_{eH}}{\sqrt{3}}$$

ϕ — angle between stiffener web and shell plating, in degree, to be taken at the middle of span of stiffener.

Coefficient K_3 **Table 2.25.5.1**

n_2	1	2	3	4	6	7	8	9	10
K_3	l_e	$l_e - \frac{l'^2}{l_e}$	$l_e - \frac{2l'^2}{3l_e}$	$l_e - \frac{5l'^2}{9l_e}$	$l_e - \frac{7l'^2}{15l_e}$	$l_e - \frac{4l'^2}{9l_e}$	$l_e - \frac{3l'^2}{7l_e}$	$l_e - \frac{5l'^2}{12l_e}$	$l_e - \frac{11l'^2}{27l_e}$

2.25.6 Stiffeners located on bilge hopper sloping plate or inner hull plate

2.25.6.1 The section modulus W and the net shear area A of single span stiffeners located on bilge hopper sloping plate and inner hull plate are not to be less than the values obtained from the following formulae:

$$W = 1.1K_3 \frac{a_{hopper} F'_{SC}}{8\lambda_s R_{eH}} \quad \text{cm}^3$$

$$A = \frac{5a_{hopper} F'_{SC}}{0.9\tau_{eH} \sin\phi} \times 10^{-3} \quad \text{cm}^2$$

where: K_3— coefficient, defined in Table 2.25.5.1, to be taken as 2l/3 for n_2 > 10;

l_e — effective span of stiffeners, in m, see 1.2.3, Section 2, Chapter 1 of this PART;

R_{eH} — minimum yield stress of material, in N/mm^2;

a_{hopper} — coefficient, defined in 2.25.4.1;

τ_{eH} — shear yield stress of material, in N/mm^2, see 2.25.5.1;

λ_s ——permissible bending stress coefficient of stiffeners, see 2.25.5.1;

F'_{SC}—equivalent mass of steel coils, in kg, defined in 2.25.4;

ϕ — angle, in degree, defined in 2.25.5.

Appendix 1 LOADING INSTRUMENTS

1 General Requirements

1.1 Application

1.1.1 This Appendix applies to loading instruments consisting of the onboard computer system as required by 2.2.8 of this Chapter.

1.1.2 This Appendix applies to onboard computers which are, as required by 1.9.1.3 of Chapter 1 of this PART, capable of providing intact stability information, and to onboard computers having stability software, as stated in 1.9.1.4 of that Chapter.

1.1.3 The loading instruments covered by this Appendix are passive systems with manual data entry and active systems in the off-line operation mode only, excluding any active system with sensors reading and entering the contents of tanks, etc., and any integrated system which controls or initiates actions based on the sensor-supplied inputs.

The definitions of passive, active and integrated systems are given in paragraph 2 of Appendix 2.

1.2 Class notations

1.2.1 The class notation for a loading instrument consists of any combination of Loading Computer and the letters S, I, G and D, with each of these four letters indicating that the loading instrument is capable of calculating and checking one of the following items:

S: Hull strength in various loading conditions.

I: Intact stability.

G: Stability for the carriage of grain in bulk.

D: Damage stability.

For example, the class notation of Loading Computer S, I, D shows that the ship is provided with a loading instrument capable of calculating and checking the hull strength, intact stability and damage stability in various loading conditions.

1.3 Inspections of loading instruments

1.3.1 Inspections of loading instruments include hardware inspection, software approval, actual installation inspection and inspection after construction. Steps of implementation for inspections of loading instruments are shown in Figure 1.3.1.

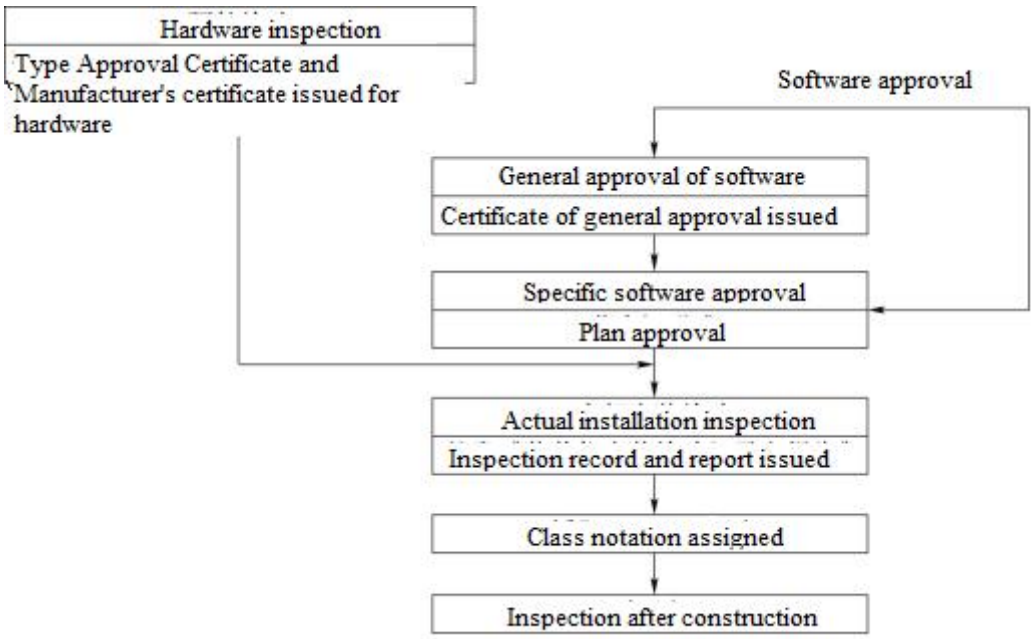


Figure 1.3.1 Steps of Implementation for Surveys of Loading Instruments

1.3.2 Software approval may be carried out by either one of the following two methods:

(1) On completion of general approval of software, software approval is carried out for a specific ship;

(2) Software approval is carried out directly to a specific ship.

1.3.3 Provision of loading instruments on board the ship may be made by either one of the following two methods:

(1) a single loading instrument to be provided on board the ship;

(2) two same loading instruments to be provided on board the ship, one for main use and the other as standby.

2 Hardware Inspections

2.1 General requirements

2.1.1 Loading instrument hardware inspections are to be carried out in accordance with the requirements for inspections of products in Chapter 3 of PART ONE of the Rules and this Section and, in general, consist of examination of plans and documents, type tests.

2.1.2 Hardware of loading instruments consists, in general, of computers and peripheral apparatus, where the printer is supplied as a separate unit from the computer, the type test of such a printer is not necessary.

2.1.3 Where two available loading instruments are installed onboard a ship, type approval certificate may be exempted, however, installation test is to be carried out.

2.2 Plans and documents

2.2.1 Where an application for hardware inspections is made, the following plans and documents should be submitted to CCS for approval:

(1) Technical specifications of hardware and peripheral apparatus;

(2) Fixing and installation of loading instruments;
(3) Type test program.

2.3 Type tests

2.3.1 Type tests are to be carried out by a verification and test organization authorized by CCS and, in general, with the presence of the CCS Surveyor.

2.3.2 Type test items

(1) Visual inspection;
(2) Performance;
(3) Electric power supply variations;
(4) Dry heat;
(5) Damp heat;
(6) Vibration;
(7) Inclination and rolling;
(8) Protection by enclosure;
(9) Low temperatures;
(10) Electromagnetic compatibility.

2.3.3 Where the loading instruments, of which hardware is installed in an air-conditioned room, are used only for the purpose of calculation, and no input of external signals or output of control signals is made, the items of type tests may be suitably reduced.

2.3.4 Where one main computer together with a standby one are provided onboard the ship, the hardware may not be subject to the type tests.

2.3.5 For the methods used in type tests, reference may be made to CCS Guidelines for Type Approval Test of Electric and Electronic Products or the relevant requirements of standards acceptable to CCS.

3 Functional Requirements for Software

3.1 General requirements

3.1.1 The functions of loading instruments are to cover at least calculating and indicating still water bending moment and shear force at the specified hull positions in any loading condition or light ship condition quickly and easily. Where applicable, the maximum permissible value of a still water torsional moment resulted from the non-uniform loading of cargoes is to be indicated.

3.1.2 Single point loading instruments (i.e. with only one check point on board the ship) are not acceptable to CCS.

3.1.3 Loading instruments are not to be substituted for the approved or confirmed final loading manual or stability information (hereinafter referred to as the final loading manual), and the results of the calculations are only applicable to the ship for which it has been approved.

3.1.4 For a specific ship, the requirements for overall strength are mandatory.Where the installed loading instruments have the function of stability calculations and are assigned an appropriate class notation, however, the stability calculation software is to be capable of calculations for all stability requirements (including intact stability, grain-carrying stability and damage stability),

either as mandatory or non-mandatory ones, applicable to the ship and is to contain relevant stability information, subject to the approval by CCS.

3.1.5 It is recommended that software be provided with an online help function, i.e. the software system may provide online help for input, output, calculation and printing.

3.1.6 The software is to be such that a common user can not alter the inputted data of the actual ship such as the geometrical characteristics, light ship weight, centre of gravity, capacity table, curve of allowable values.

3.1.7 The software is to be such that any user can not alter the inputted application programs.

3.1.8 The software is to, as far as possible, reduce significant or illogical input errors and alert the user to any input value exceeding the actual maximum capacity of a compartment or any negative value of the capacity.

3.1.9 The software is to be capable of clearly judging whether a loading condition complies with the relevant requirements, i.e. calculating for a certain loading condition. Where the calculation results exceed the permissible values, the user is to be alerted by distinct means such as prominent display, special markings or visible and audible alarms, screen display or printout.

3.1.10 The software is to be provided with passwords so that the computer will refuse to work and alert the user where any illegal password is input.

3.1.11 The software is to be at least capable of calculating the displacement and centre of gravity in any loading conditions and completing calculation and criteria of overall strength (and stability, if applicable) of the ship, displaying and printing out date and time of performing calculation and saving calculation results. All input data and calculation results displayed on the screen and printed out, including the fore and after draughts, are to be in definite and uniform measurement units and easily comparable with the approved final loading manual to avoid possible confusion and misunderstanding, with the identification marking and version number of the software being clearly indicated on each printed page.

3.1.12 The software interface is to be fully user-friendly and to alert the user to any operational error. Data loss or dead stop of the computer caused by the user's error is to be minimized.

3.2 Overall strength

3.2.1 The functional requirements for software in respect to overall strength are given in 2.2.8 of this Chapter.

3.3 Intact stability

3.3.1 The software is to use direct calculation to check intact stability and the following requirements are to be met:

(1) The software is to be capable of calculating and displaying the height of the centre of gravity and initial metacentric height of the ship and correcting free surface effects and comparing such values with the permissible values, where applicable. If any permissible value is exceeded, an alarm is to be automatically initiated.

(2) The software is to be at least capable of calculating and displaying *GZ* curves and correcting free surface effects.

(3) The software is to be capable of calculating the intact stability in any loading conditions and achieving the criteria for intact stability according to the relevant requirements. The method for achieving the criteria is to be in conformity with the final loading manual and any other method

used for this purpose is to be indicated in submissions and subject to agreement of CCS plan approval unit. The software is to be capable of automatically initiating an alarm in case of any permissible criterion being exceeded.

3.3.2 If damage stability is checked by the software according to the provisions of 3.5.2 of this Section, intact stability can be checked based on the same method.

3.4 Stability for carriage of grain in bulk

3.4.1 The software is to be in compliance with the relevant requirements in 3.3 of this Appendix.

3.4.2 The software is to be capable of inputting the permissible inclining moment curves.

3.4.3 The software is to be capable of calculating the stability for the carriage of grain in bulk and achieving the criteria for the stability according to the relevant requirements. The method for achieving the criteria is to be in conformity with the final loading manual. The software is at least to be able to calculate the inclining moment of actual shift of grain and the permissible inclining moment to which comparison is made. The software is to be capable of automatically initiating an alarm in case of any permissible value being exceeded.

3.5 Damage stability

3.5.1 If the software uses direct calculation to check damage stability, the following requirements are to be met:

(1) The software is to indicate whether the calculation is performed by means of loss of buoyancy or increase of weight, and the former is recommended.

(2) The software is to be capable of making corrections of free surface effects for *GZ* curves.

(3) The software is to be capable of allowing for corrections for liquid loss of damaged tanks.

(4) The software is to define the damaged compartment(s) and associated damage conditions in advance for selection by the crew in calculation, and be capable of calculating and displaying the *GZ* curves after damage.

(5) The software is to be capable of calculating the equilibrium position and stability in any damage condition, covering fore, after and mean draughts, trimming values, heeling angles, distance from equilibrium waterline to flooding openings, residual initial metacentric height, residual stability etc., and achieving the criteria for damage stability according to the relevant requirements. The method for achieving the criteria is to be in conformity with the final loading manual. The software is to be capable of automatically initiating an alarm in case of any permissible criterion being exceeded.

3.5.2 If damage stability is checked by the software on the basis of approved limit curves (the curve of permissible vertical position of the centre of gravity or the curve of permissible initial metacentric heights) or loading conditions, the following requirements are to be met:

(1) The software is to be capable of calculating and displaying displacement, the position of the centre of gravity, buoyancy and initial metacentric height of the ship in any loading condition and correcting free surface effects as required and comparing such values with the approved data.

(2) The software is to be capable of automatically initiating an alarm in case of any permissible criterion being exceeded (if limit curves are used) or any acceptable and safe tolerance being exceeded (compared with loading condition).

3.6 Additional requirements for bulk carriers, ore carriers and combination carriers

3.6.1 In addition to the above requirements, the loading instruments on board bulk carriers, ore carriers and combination carriers are to comply with the requirements of Section 7, Chapter 8 of this PART.

4 Software Approval

4.1 General requirements

4.1.1 Software approval consists of general approval and specific approval, covering:

(1) verification that the data used are consistent with the current condition of the ship;

(2) verification and approval of the test conditions;

(3) verification that the software is appropriate for the required type of ship and corresponding calculations.

4.2 Requirements for general approval of software

4.2.1 The general approval of software of loading instruments means approval of design and calculation programs of the software, i.e. approval of the design methods, calculation functions and principles and relevant documents for programing and usage of the said software through actual tests on representative ships selected according to the submitted scope of application.

4.2.2 The general approval of software of loading instruments may specifically include the following:

(1) Design methods, calculation functions and principles of the software are to be in conformity with the classification/statutory requirements and comply with the relevant requirements in section 3 of this Appendix.

(2) For ships of different types selected for tests, the calculation results for the typical loading conditions selected according 4.6 of this Appendix are, by comparison with those of the loading manual approved by CCS or CCS plan approval software, to comply with the accuracy requirements in 4.7 of this Appendix.

(3) User’s operation manual of loading instruments is to comply with the relevant requirements in 4.8 of this Appendix.

4.2.3 CCS will issue a Certificate of General Approval of Software of Loading Instruments to the software upon general approval by CCS.

4.2.4 The application and restrictions, e.g. applicable ship types and functional restrictions, are to be noted on the Certificate of General Approval of Software of Loading Instruments.

4.2.5 A Certificate of General Approval of Software of Loading Instruments remains valid for a period not exceeding 5 years. When the certificate expires and if the applicant confirms that no change has been made to the version of the said software, CCS will renew the Certificate of General Approval of Software of Loading Instruments. However, the plan approval unit responsible for the software approval is to carry out nonscheduled assessments of the software as necessary, e.g. in response to complaints from users.

4.2.6 Where the applicant has made any change to the software without re-approval by CCS, the Certificate of General Approval of Software of Loading Instruments issued by CCS is no longer valid.

4.2.7 Where the version of the loading instrument software, of which general approval is granted by CCS, is upgraded or changed, resubmission for approval is required. Submission of plans and documents which are the same as those for the approved version is unnecessary, but the applicant should indicate this in the application.

4.3 Steps of implementation for general approval of software

4.3.1 The general approval of software of loading instruments is to be carried out in accordance with the relevant CCS requirements for plan approval.

4.3.2 The applicant is to fill in an application for software approval of loading instruments. For the relevant contents of the application, refer to the relevant requirements of section 3 of this Appendix.

4.3.3 The test ships are to be so selected that all ship types and their functions as required in the application are covered. And the following are to be complied with:

(1) for the strength calculation software, the applicant is to select the calculation results for at least one test ship, which may be either the sample ship provided by CCS or the one determined by the applicant. Where the latter is selected, the prior agreement of the plan approval unit is necessary;

(2) for the stability calculation software, test ships are to be selected in accordance with 6.1 of Appendix 2 of this Chapter.

4.3.4 The applicant is to submit the following plans and documents to CCS plan approval unit. After examination and approval, one set of their copies is to be returned to the applicant, one set sent to the Headquarters of CCS and one set filed by the plan approval unit (where application for specific approval of the software is made for the test ship at the same time, an additional copy of the user's operation manual and that of the calculation and test report are required for CCS survey unit):

(1) Specification of the software system (for information), covering design method, calculation functions and principles, data structure as well as flowchart of the software, and explaining functional items as determined in the application and computational accuracy of the software such as methods used for numerical integration, interpolation, etc.

(2) User's operation manual of loading instruments (for information).

(3) Data of test ship(s) inputted in the software (for information), such as main dimensions, lightweight distribution and centre of gravity, Bonjean curves, hydrostatic data, tank capacity, permissible still water shear forces, permissible still water bending moments and, where applicable, correction factors of bulkhead shear forces and permissible still water torsional moments. Where the software has computation functions for intact stability, stability for the carriage of grain in bulk, damage stability, etc., corresponding data are also to be submitted for approval.

(4) Test report (for approval) of loading calculations for conditions to be selected according to the requirements in 4.6 of this Appendix with the agreement of the plan approval unit, covering the input data and all output results.

(5) General arrangement, lines, final loading manual of the test ship(s) and other additional plans or data required by CCS for information or use in check calculations.

(6) A set of installation discs, including the executing software and internal testing data.

4.3.5 On satisfactory completion of examination of the above-mentioned plans and documents, the Certificate of Software Approval of Loading Instruments may be issued.

4.4 Requirements for specific approval of software

4.4.1 The specific approval of software means, for the purpose of a specific ship, the approval of loading instrument's software installed on board, i.e. the approval of the design method, calculation functions and principles, input data, user's operation manual, full-scale test report and other documents.

4.4.2 The specific approval of software may specifically include the following:

(1) Design methods, calculation functions and principles of the software are to be in conformity with the classification requirements and comply with the relevant requirements in section 3 of this Appendix.

(2) All input data of the software are to be consistent with those of the actual ship, i.e. being taken from the finished documents approved or confirmed by CCS, and in particular the lightweight and centre of gravity are to be taken from the inclining test report. Where the software is capable of stability calculation, the input data are to comply with paragraph 6.2 of Appendix 2.

(3) The computation points along the ship's length and their number are to comply with CCS rules.

(4) The permissible still water bending moments, permissible still water shear forces, and where applicable, permissible still water torsional moments and correction factors of bulkhead shear forces at the computation points along the ship's length are to be consistent with those in the final loading manual.

(5) The calculation results for the typical loading conditions selected according to 4.6 of this Appendix are, by comparison with those of the final loading manual or CCS plan approval software, to comply with the accuracy requirements in 4.7 of this Appendix.

(6) User's operation manual of the loading instrument is to comply with the requirements in 4.8 of this Appendix.

4.4.3 For software with a Certificate of General Approval of Software of Loading Instruments and in respect to the applicable ship types and functions stated in the Certificate, where application is made for specific approval of the software, submission of design methods, calculation functions and principles of the software is unnecessary.

4.4.4 For software without a Certificate of General Approval of Software of Loading Instruments, the applicant may directly apply to CCS for specific approval of loading instrument software.

4.5 Steps of implementation for specific approval of software

4.5.1 The specific approval of software is to be carried out in accordance with the relevant CCS requirements.

4.5.2 For the relevant contents of the application, refer to the relevant requirements of section 3 of this Appendix.

4.5.3 The applicant is to submit the following plans and documents to CCS:

(1) For software without general approval by CCS, the applicable contents for the specific ship as required in (1), (2), (3), (4), (5) and (6) of 4.3.4 of this Appendix are to be submitted.

(2) For software with general approval by CCS, the applicable contents for the specific ship as required in (2), (3), (4), (5) and (6) of 4.3.4 of this Appendix and a copy of the Certificate of General Approval of Software of Loading Instruments are to be submitted.

4.6 Test conditions

4.6.1 Test conditions are to be selected from the final loading manual.

4.6.2 Test conditions are at least to contain loading conditions for the following:

(1) for minimum displacement, such as lightship condition or arrival condition with light ballast;

(2) for maximum still water bending moment, such as ballast or partially loaded conditions;

(3) for maximum displacement, such as fully loaded conditions;

(4) any condition resulting in extremely large still water shear force, such as ore loaded in alternate holds, etc.;

(5) where the software is capable of the stability calculation for carriage of grain in bulk, the test conditions are to include the one of a fully loaded hold with even filling at its ends, the one of a fully loaded hold with uneven filing at its ends and the one of a partly loaded hold;

(6) where the software is capable of both intact stability calculation and damage stability calculation, the necessary typical conditions are to comply with paragraph 6.2 of Appendix 2.

4.6.3 The test conditions are to contain the arrival and departure conditions and cover all loaded holds and all functions of the software as far as possible.

4.6.4 The approved test conditions are to be stored as input data in such a way that no user can alter them. A copy of the approved test conditions is to be available on board.

4.7 Permissible values and error control

4.7.1 All selected permissible values and the calculation points along the ship's length are to be taken from the finished documents approved by CCS.

4.7.2 The curves of still water shear forces and still water bending moments are to be consistent with the corresponding curve tendency in the final loading manual. The peak value of still water bending moment is normally to occur at the position where the still water shear force is zero.

4.7.3 The maximum values of still water shear force, still water bending moment and still water torsional moment and their calculated values at the calculation points along the ship's length are, as compared with the calculation results of the final loading manual, to have their errors controlled within the ranges given in Table 4.7.3.

Error Control **Table 4.7.3**

	Error (in comparison to approved value, %)
Still water shear force	$\leq \pm 5\%$
Still water bending moment	$\leq \pm 5\%$
Still water torsional moment	$\leq \pm 5\%$

4.7.4 The errors of the software in stability calculation are to comply with paragraph 5 of Appendix 2.

4.7.5 During examination, where the errors of the calculated values for individual calculation points of the loading instrument are significant as compared with the values of the final loading manual and no adequate evidence is available for wrong calculation of the loading instrument, check is to be made by using CCS plan approval software and the calculation results by this software are to be accepted as standard ones. Where any principled error is found in the final loading manual, the unit which has approved the manual is to be informed of this matter together with the recommendation that the existing loading manual be revised.

4.8 Operation manual

4.8.1 At least one copy of operation manual of loading instrument of the ship is to be kept on board.

4.8.2 The operation manual of loading instrument is to be written in a language used by the users on board, and the language is to be the same as that used for screen display, printout and the approved final loading manual kept on board. Where the language is not English, an English translation is to be available.

4.8.3 The operation manual is to be written in a clear and unambiguous manner. The use of flowcharts is recommended for illustrating operational processes.

4.8.4 The operation manual is to contain the following:

(1) particulars and version number of the software;

(2) a copy of the Certificate of General Approval of Software of Loading Instruments (where applicable);

(3) specification of hardware needed to run the software and guidance for software installation;

(4) software running steps shown in menus and dialogues, description of error messages and warnings likely to be encountered and unambiguous instructions for subsequent actions to be taken by the user in each case;

(5) lightweight and coordinates of centre of gravity;

(6) full deadweight description of each test condition for loading calculation;

(7) diagrams of the permissible still water shear forces and still water bending moments and where applicable, the permissible cargo torque;

(8) where applicable, shear force correction factors;

(9) operation procedure shown by calculation cases;

(10) input and output data, calculation results shown by screen display, with necessary explanatory text;

(11) explanation for function keys.

5 Actual Installation Inspections

5.1 General requirements

5.1.1 The Owner or the entrusting party is to submit application to CCS survey unit situated at the port of call of the ship.

5.1.2 The crew may master the operation and calculation of the loading instrument on board through learning or training. The installation inspection is to be carried out by the crew.

5.1.3 Actual installation inspection is to be carried out soon after the loading instrument has been installed on board the ship for verification of satisfactory operation and calculation and for check of strength and stability. Where by that time the final loading manual has not been approved, the installation inspection may be postponed until the manual is approved.

5.2 Inspections and tests

5.2.1 Where the loading instruments are provided as a main computer and a standby one on board a ship, installation inspections are to be carried out respectively and both computers are to be found satisfactory.

5.2.2 The installation inspections are to be carried out in the presence of CCS Surveyor. The

following items are to be included in the installation inspections:

(1) checking the certificate of hardware;

(2) checking that the user's operation manual and test report of loading calculation are kept on board the ship;

(3) examining the environment and position for installing the system: confirming that the position and method for installing the system are as required in the specification;

(4) system stability testing: the computer system is to be capable of working normally after a continuous running period of one hour;

(5) self-checking capability tests of hardware and peripheral apparatus: self-check tests to be carried out according to the specification for hardware and peripheral apparatus with self-check capability;

(6) transient power failure test: re-starting the system after a period of 30 s of transient power failure, and confirming that:

① it is still capable of working normally; and

② its programs and data are not lost;

(7) software security tests: where an illegal password is inputted (or in case of human maloperation), the system should refuse to work;

(8) software safety tests: a common user is not to be capable of changing the application program and the input ship's data such as geometrical characteristics, tank capacity table, curve of permissible values;

(9) system performance tests: the calculation results from the system operated by the crew of the ship based upon the loading conditions as stated in the approved test report of loading calculations are to be the same as those in the approved test report. Where the software is capable of stability calculation, tests are also to comply with paragraph 8 of Appendix 2.

5.2.3 The test report of loading calculations printed out by the loading instrument during installation inspection is to be confirmed and signed by the attending Surveyor. After satisfactory installation inspection, the sttending Surveyor will issue a report and CCS will assign an appropriate class notation to the loading instrument.

5.3 Inspections of existing loading instruments on board ships

5.3.1 For ships provided with loading instruments approved by other member Societies of IACS, the operation manual, test report of loading calculations approved and related certificates of loading instrument hardware and software issued by these Societies may be reviewed, and installation inspections are to be carried out in accordance with 5.2.2 of this Appendix.

5.3.2 For ships provided with loading instruments not complying with the relevant requirements of CCS or approved by a party which is not member of IACS, installation inspections are to be carried out once again.

5.3.3 For ships assigned with class notation "Loading Computer", the survey after construction is to be carried out in accordance with relevant requirements of 6.3.5 of Chapter 6, PART ONE of the Rules.

Appendix 2 IACS UR L5 COMPUTER SOFTWARE FOR ONBOARD STABILITY CALCULATIONS

(Rev.4, June 2020)

Application

This Unified Requirement is applicable to software which calculates the stability of actual loading conditions and which is installed on ships and on units subject to compliance with the 1966 Load Line Convention or the 1988 Protocol to the Load Line Convention, as amended, the IMO MODU Code and/or the 2008 IS Code.

The use of onboard computers for stability calculations is not a requirement of class.

Stability software installed onboard shall cover all mandatory class and statutory intact and damage stability requirements applicable to the ship. This UR, requires approval of software installed on onboard computers which is capable of performing stability calculations.

Active and passive systems are defined in paragraph 2. This UR covers passive systems and the off-line operation mode of active systems only.

The requirements in this UR apply to stability software on ships contracted for construction① on or after 1 July 2005②③④.

1 General

- The scope of a stability calculation software shall be in accordance with the stability information as approved by the Administration and shall at least include all information and perform all calculations or checks as necessary to ensure compliance with the applicable stability requirements.
- Approved stability software is not a substitute for the approved stability information, and is used as a supplement to the approved stability information to facilitate stability calculations.
- The input/output information shall be easily comparable with approved stability information so as to avoid confusion and possible misinterpretation by the operator relative to the approved stability information.
- An operation manual is to be provided for the onboard computer stability software.
- The language in which the stability information is displayed and printed out as well as the operation manual written shall be the same as used in the ship's approved stability information. The Society may require a translation into a language considered appropriate.
- The onboard computer software for stability calculations is to be ship specific and the results

---

① The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contracted for construction", refer to IACS Procedural Requirement (PR) No.29.

② Changes introduced in Rev.2 of this UR are to be uniformly applied by IACS Societies on ships contracted for construction on or after 1 January 2007.

③ Changes introduced in Rev.3 of this UR are to be uniformly applied by IACS Societies on ships contracted for construction on or after 1 July 2018.

④ Changes introduced in Rev.4 of this UR are to be uniformly applied by IACS Societies on ships contracted for construction on or after 1 July 2021.

of the calculations are to be only applicable to the ship for which it has been approved.

− In case of modifications implying changes in the main data or internal arrangement of the ship, the specific approval of any original stability calculation software is no longer valid. The software is to be modified accordingly and reapproved.

2 Calculation Systems

A passive system requires manual data entry;
an active system replaces the manual entry with sensors reading and entering the contents of tanks, etc.; and
a third system, an integrated system, controls or initiates actions based on the sensor-supplied inputs and is not within the scope of this UR.

3 Types of Stability Software

Four types of calculations performed by stability software are acceptable depending upon a vessel's stability requirements:

Type 1

Software calculating intact stability only (for vessels not required to meet a damage stability criterion).

Type 2

Software calculating intact stability and checking damage stability on basis of a limit curve (e.g. for vessels applicable to SOLAS Part B-1 damage stability calculations, etc.) or checking all the stability requirements (intact and damage stability) on the basis of a limit curve.

Type 3

Software calculating intact stability and damage stability by direct application of preprogrammed damage cases based on the relevant Conventions or Codes for each loading condition (for some tankers, etc.).

Type 4

Software calculating damage stability associated with an actual loading condition and actual flooding case, using direct application of user defined damage, for the purpose of providing operational information for safe return to port (SRtP).

Damage stability of both Type 3 and Type 4 stability software shall be based on a hull form model, that is, directly calculated from a full three-dimensional geometric model.

4 Functional Requirements

4.1 General requirements for any type of stability software

4.1.1 The calculation program shall present relevant parameters of each loading condition in order to assist the Master in his judgement on whether the ship is loaded within the approval limits. The following parameters shall be presented for a given loading condition:

− deadweight data;
− lightship data;
− trim;
− draft at the draft marks and perpendiculars;
− summary of loading condition displacement, VCG, LCG and, if applicable, TCG;
− downflooding angle and corresponding downflooding opening (not applicable for Type 2

software which uses limit curve for checking all the stability requirements. However, if intact stability criteria are given in addition to the limit curve, downflooding angle and the corresponding downflooding opening shall be indicated);

− compliance with stability criteria: Listing of all calculated stability criteria, the limit values, the obtained values and the conclusions (criteria fulfilled or not fulfilled) (not applicable for Type 2 software which uses limit curve for checking all the stability requirements. However, if intact stability criteria are given in addition to the limit curve, the limit values, the obtained values and the conclusion shall be indicated).

4.1.2 A clear warning shall be given on screen and in hard copy printout if any of the loading limitations are not complied with.

Loading limitations shall include, but may not be limited to:

− Trim, draught, liquid densities, tank filling levels, initial heel;

− Use of limit KG/GM curves in conjunction with above for Type 2;

− Restrictions to the stowage height for timber where timber load lines are assigned.

4.1.3 Type 3 software is to include pre-defined relevant damage cases for both sides of the ship according to the applicable rules for automatic check of a given loading condition.

4.1.4 The date and time of a saved calculation shall be part of the screen display and hard copy printout.

4.1.5 Each hard copy printout shall contain identification of the calculation program including version number.

4.1.6 Units of measurement are to be clearly identified and used consistently within a loading calculation.

4.1.7 For Type 3 and Type 4 software, the system shall be pre-loaded with a detailed computer model of the complete hull, including appendages, all compartments, tanks and the relevant parts of the superstructure considered in the damage stability calculation, wind profile, down-flooding and up-flooding openings, cross-flooding arrangements, internal compartment connections and escape routes, as applicable and according to the type of stability software.

4.1.8 For Type 1 and Type 2 software, in case a full three dimensional model is used for stability calculations, the requirements of the computer model are to be as per paragraph 4.1.7 above to the extent as applicable and according to the type of stability software.

4.2 Further requirements for Type 4 stability software

4.2.1 The normal (Type 1, 2 and 3) and SRtP (Type 4) software need not be “totally separated”. Where the normal and SRtP software are not totally separated:

− the function of switching between normal software and Type 4 software shall be provided.

− the actual intact loading condition is to be the same for both functions (normal operation and SRtP); and

− the SRtP module needs only to be activated in case of an incident.

Approval of Type 4 (SRtP) software is for stability only.

4.2.2 In passenger ships which are subject to SRtP and have an onboard stability computer and shore-based support, such software need not be identical.

4.2.3 Each internal space shall be assigned its permeability as shown below, unless a more accurate permeability has been reflected in the approved stability information.

Space	Permeability

	Default	Full	Partially filled	Empty
Container Spaces	0.95	0.70	0.80	0.95
Dry Cargo spaces	0.95	0.70	0.80	0.95
Ro-Ro spaces	0.95	0.90	0.90	0.95
Cargo liquids	0.95	0.70	0.80	0.95
Intended for consumable liquids	0.95	0.95	0.95	0.95
Stores	0.95	0.60	(0.60)	0.95
Occupied by machinery	0.85			
Void spaces	0.95			
Occupied by accommodation	0.95			

4.2.4 The system shall be capable of accounting for applied moments such as wind, lifeboat launching, cargo shifts and passenger relocation.

4.2.5 The system shall account for the effect of wind by using the method in SOLAS regulation II-1/7-2.4.1.2 as the default, but allow for manual input of the wind speed/pressure if the on-scene pressure is significantly different (P = 120 N/m^2 equates to Beaufort 6; approximately 13.8 m/s or 27 knots).

4.2.6 The system shall be capable of assessing the impact of open main watertight doors on stability (e.g. for each damage case provided for verification, additional damage stability calculation shall be done and presented, taking into account any watertight door located within the damaged compartment(s)).

4.2.7 The system shall utilize the latest approved lightship weight and centre of gravity information.

4.2.8 The output of the software is to be such that it provides the master with sufficient clear unambiguous information to enable quick and accurate assessment of the stability of the vessel for any actual damage, the impact of flooding on the means of escape and the controls of devices necessary for managing and/or controlling the stability of the ship.

When the actual loading condition is input in the SRtP software, the following output (intact stability) shall be available:

− deadweight data;
− lightship data;
− trim;
− heel;
− draft at the draft marks and perpendiculars;
− summary of loading condition displacement, VCG, LCG and, if applicable, TCG;
− downflooding angle and corresponding downflooding opening;
− free surfaces;
− GM value;
− GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg;
− compliance with relevant intact stability criteria (i.e. 2008 IS Code): listing of all calculated intact stability criteria, the limiting values, the obtained values and the evaluation (criteria fulfilled or not fulfilled);
− GM/KG limiting curve according to SOLAS, Ch II-1, Regulation 5-1.

When the actual loading condition is associated to the actual damage case(s) due to the casualty, the following output (damage stability) shall be available:

− trim;
− heel;
− draft at the draft marks and perpendiculars;
− progressive flooding angle and corresponding progressive flooding openings;
− GM value;
− GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg;
− compliance with stability criteria: listing of all calculated stability criteria, the limit values, the obtained values and the conclusions (criteria fulfilled or not fulfilled);
− the survivability criteria for Type 4 software (SRtP) are left to the discretion of the Administration;
− relevant flooding points (unprotected or weathertight) with the distance from the damage waterline to each point;
− list of all flooded compartments with the permeability considered;
− amount of water in each flooded compartment;
− escape route immersion angles;
− a profile view, deck views and cross-sections of the ship indicating the flooded waterplane and the damaged compartments.

4.2.9 For ro-ro passenger ships there shall be algorithms in the software for estimating the effect of water accumulation on deck (WOD) (e.g. 1. In addition to the predefined significant wave height taken from the approved stability document, there shall be possibility for the crew to input manually the significant wave height of the ship navigation area in the system, 2. In addition to the predefined significant wave height taken from the approved stability document, calculations with two additional significant wave heights shall be submitted for checking the correctness of the algorithms in the software for estimating the effect of WOD). *

* This paragraph applies to Ro-Ro Passenger ships subject to the Stockholm Agreement (IMO Circular Letter No. 1891)

5 Acceptable Tolerances

Depending on the type and scope of programs, the acceptable tolerances are to be determined differently, according to 5.1 or 5.2. Deviation from these tolerances shall not be accepted unless the Society considers that there is a satisfactory explanation for the difference and that there will be no adverse effect on the safety of the ship.

Examples of pre-programmed input data include the following:

Hydrostatic data: Displacement, LCB, LCF, VCB, KM_t and MCT versus draught.

Stability data: KN or MS values at appropriate heel/trim angles versus displacement, stability limits.

Compartment data: Volume, LCG, VCG, TCG and FSM/Grain heeling moments vs level of the compartment's contents.

Examples of output data include the following:

Hydrostatic data: Displacement, LCB, LCF, VCB, KM_t and MCT versus draught as well as actual draughts, trim.

Stability data: FSC (free surface correction), GZ-values, KG, GM, KG/GM limits, allowable grain heeling moments, derived stability criteria, e.g. areas under the GZ curve, weather criteria.

Compartment data: Calculated Volume, LCG, VCG, TCG and FSM/Grain heeling moments vs level of the compartment's contents.

The computational accuracy of the calculation program results shall be within the acceptable tolerances, specified in 5.1 or 5.2, of the results using an independent program or the approved stability information with identical input.

5.1 Programs which use only pre-programmed data from the approved stability information as the basis for stability calculations, shall have zero tolerances for the printouts of input data.

Output data tolerances are to be close to zero, however, small differences associated with calculation rounding or abridged input data are acceptable.

Additionally differences associated with the use of hydrostatic and stability data for trims that differ from those in the approved stability information are acceptable, subject to review by the individual Society.

5.2 Programs which use hull form models as their basis for stability calculations, shall have tolerances for the printouts of basic calculated data established against either data from the approved stability information or data obtained using the approval authority's model. Acceptable tolerances shall be in accordance with Table 1.

Table 1

Hull Form Dependent	
Displacement	+/- 2%
Longitudinal center of buoyancy, from *AP*	+/- 1%/50 cm
Vertical center of bouyancy	+/- 1%/5 cm
Transverse center of bouyancy	+/- 0.5% of *B*/ 5 cm
Longitudinal center of flotation, from *AP*	+/- 1%/50 cm
Moment to trim 1 cm	+/- 2%
Transverse metacentric height	+/- 1%/5 cm
Longitudinal metacentric height	+/- 1%/50 cm
Cross curves of stability	+/- 5 cm
Compartment dependent	
Volume or deadweight	+/- 2%
Longitudinal center of gravity, from *AP*	+/- 1%/50 cm
Vertical centre of gravity	+/- 1%/5 cm
Transverse center of gravity	+/- 0.5% of *B*/5 cm
Free surface moment	+/- 2%
Shifting moment	+/- 5%
Level of contents	+/- 2%
Trim and stability	
Draughts (forward, aft, mean)	+/- 1%/5 cm
GM_t (both solid and corrected for free surfaces)	+/- 1%/5 cm
GZ values	+/- 5% /5 cm
Downflooding angle	+/- 2°
Equilibrium angles	+/- 1°
Distance from *WL* to unprotected and weathertight openings, or other relevant point, if applicable	+/- 5%/5 cm
Areas under righting arm curve	+/- 5% / 0.0012 m · rad

Notes:

1. Deviation in % = [(base value − applicant's value)/base value] × 100

where the "base value" may be from the approved stability information or the society's computer model.

2. When applying the tolerances in Table 1 having two values, the allowable tolerance is the greater of the two values.

3. Where differences in calculation methodology exist between the programs used in the comparison, this may be a basis for accepting deviations greater than that specified in Table 1 provided a software examination is carried out in sufficient detail to clearly document that such differences are technically justifiable.

4. Deviation from these tolerances shall not be accepted unless the Society considers that there is a satisfactory explanation for the difference and that it is clearly evident from the Society's stability calculations that the deviation does not impact compliance with the required stability criteria for the ship under consideration.

6 Approval Procedure

Conditions of approval of the onboard software for stability calculations

The onboard software used for stability calculations is subject to approval, which is to include:

- verification of type approval, if any;
- verification that the data used are consistent with the current condition of the ship (refer to paragraph 6.2);
- verification and approval of the test conditions;
- verification that the software is appropriate for the type of ship and stability calculations required;
- verification of functional requirements under paragraph 4.1.2.

The satisfactory operation of the software with the onboard computer(s) for stability calculations is to be verified by testing upon installation (refer to paragraph 8). A copy of the approved test conditions and the operation manual for the computer/software are to be available on board.

6.1 General Approval (optional)

Upon application to the Society for general approval of the calculation program, the Society may provide the applicant with test data consisting of two or more design data sets, each of which is to include a ship's hull form data, compartmentation data, lightship characteristics and deadweight data, in sufficient detail to accurately define the ship and its loading condition. Acceptable hull form and compartmentation data may be in the form of surface coordinates for modeling the hull form and compartment boundaries, e.g: a table of offsets, or in the form of pre-calculated tabular data, e.g: hydrostatic tables, capacity tables, etc., depending upon the form of data used by the software being submitted for approval. Alternatively, the general approval may be given based on at least two test ships agreed upon between the Society and the applicant.

In general, the software is to be tested for two types of ships for which approval is requested, with at least one design data set for each of the two types. Where approval is requested for only one type of ship, a minimum of two data sets for different hull forms of that type of ship are required to be tested. For calculation software which is based on the input of hull form data, design data sets shall be provided for three types of ships for which the software is to be approved, or a minimum of three data sets for different hull forms if approval is requested for only one type of ship. Representative ship types which require different design data sets due to their hull forms, typical arrangements, and nature of cargo include: tanker, bulk carrier, container ship, and other dry cargo and passenger ships. The test data sets shall be used by the applicant to run the calculation program for the test ships. The results obtained (together with the hydrostatic data and cross-curve data developed by the program, if appropriate) shall be submitted to the Society for the assessment of the program's computational accuracy. The Society shall perform parallel calculations using the same data sets and a comparison of these results will be made against the applicant's submitted program's results.

6.2 Specific Approval

- The Society shall verify the accuracy of the computational results and actual ship data used by the calculation program for the particular ship on which the program will be installed.
- Upon application to the Society for data verification, the Society and the applicant shall agree on a minimum of four loading conditions, taken from the ship's approved stability information, which are to be used as the test conditions. For ships carrying liquids in bulk, at least one of the conditions shall include partially filled tanks. For ships carrying grain in bulk, one of the grain loading conditions shall include a partially filled grain compartment. Within the test conditions each compartment shall be loaded at least once. The test conditions normally are to cover the range of load draughts from the deepest envisaged loaded condition to the light

ballast condition and shall include at least one departure and one arrival condition.

For Type 4 stability software for SRtP, the Society shall examine at least three damage cases, each of them associated with at least three loading conditions taken from the ship's approved stability information. Output of the software is to be compared with results of corresponding load / damage case in the approved damage stability booklet or an alternative independent software source.

- The Society is to verify that the following data, submitted by the applicant, is consistent with arrangements and most recently approved lightship characteristics of the ship according to current plans and documentation on file with the Society, subject to possible further verification on board:
  - Identification of the calculation program including version number;
  - Main dimensions, hydrostatic particulars and, if applicable, the ship profile;
  - The position of the forward and after perpendiculars, and if appropriate, the calculation method to derive the forward and after draughts at the actual position of the ship's draught marks;
  - Ship lightweight and centre of gravity derived from the most recently approved inclining experiment or light weight check;
  - Lines plan, offset tables or other suitable presentation of hull form data if necessary for the Society to model the ship;
  - Compartment definitions, including frame spacing, and centres of volume, together with capacity tables (sounding/ullage tables), free surface corrections, if appropriate;
  - Cargo and consumables distribution for each loading condition.

Verification by the Society does not absolve the applicant and shipowner of responsibility for ensuring that the information programmed into the onboard computer software is consistent with the current condition of the ship.

7 Operation Manual

A simple and straightforward operation manual is to be provided, containing descriptions and instructions, as appropriate, for at least the following:

- installation;
- function keys;
- menu displays;
- input and output data;
- required minimum hardware to operate the software;
- use of the test loading conditions;
- computer-guided dialogue steps;
- list of warnings.

8 Installation Testing

To ensure correct working of the computer after the final or updated software has been installed, it is the responsibility of the ship's Master to have test calculations carried out according to the following pattern in the presence of a Society surveyor:

From the approved test conditions at least one load case (other than light ship) shall be calculated.

Note: Actual loading condition results are not suitable for checking the correct working of the computer.

Normally, the test conditions are permanently stored in the computer.

Steps to be performed:

- Retrieve the test load case and start a calculation run; compare the stability results with those in the documentation.
- Change several items of deadweight (tank weights and the cargo weight) sufficiently to change the draught or displacement by at least 10%. The results are to be reviewed to ensure that they differ in a logical way from those of the approved test condition.
- Revise the above modified load condition to restore the initial test condition and compare the results. Confirm that the relevant input and output data of the approved test condition have been replicated.
- Alternatively, one or more test conditions shall be selected and the test calculation performed by entering all deadweight data for each selected test condition into the program as if it were a proposed loading. The results shall be verified as identical to the results in the approved copy of the test conditions.

9 Periodical Testing

It is the responsibility of the ship's Master to check the accuracy of the onboard computer for stability calculations at each Annual Survey by applying at least one approved test condition. If a Society surveyor is not present for the computer check, a copy of the test condition results obtained by the computer check is to be retained on board as documentation of satisfactory testing for the surveyor's verification.

At each Special Survey this checking for all approved test loading conditions is to be done in presence of the surveyor.

The testing procedure shall be carried out in accordance with paragraph 8.

10 Other Requirements

Protection against unintentional or unauthorised modification of programs and data shall be provided.

The program shall monitor operation and activate an alarm when the program is incorrectly or abnormally used.

The program and any data stored in the system shall be protected from corruption by loss of power.

Error messages with regard to limitations such as filling a compartment beyond capacity, or exceeding the assigned load line, etc., shall be included.

Appendix 3 Guidelines for UR S11.2.1.3 for ballast loading conditions of cargo vessels involving partially filled ballast tanks

1 General guidance note regarding the use of UR S11.2.1.3

1.1 This document is intended for guidance and interpretation of UR S11.2.1.3 “Partially filled ballast tanks in ballast loading conditions”.

1.2 Case A and B are generally applicable for ballast loading conditions for any cargo vessel which might have one Ballast Water (BW) Tank (or one pair of BW Tanks) partially filled.

1.3 Case C is showing the conditions necessary for checking longitudinal strength for a conventional ore carrier with two pairs of large wing water ballast tanks partly filled during the ballast voyage.

1.4 Where applicable, similar considerations are to be given to other cargo vessels covered by UR S11 where ballast loading conditions involving partially filled ballast tanks may cause concerns for the longitudinal strength of the vessels.

1.5 This Appendix does not apply to CSR Bulk Carriers and Oil Tankers or to container ships to which UR S11A is applicable.

1.6 In the Figures, the conditions only intended for strength verification (not operational) are marked with a star (*), full tanks are marked with “Full”, empty tanks are marked with “Empty”, and consumables are marked with “cons.” .

2 Case A and B

2.1 Case A

Fig. 1 shows Case A, with a cargo vessel where partial filling of BW Tank no. 6 (P/S) is permitted and may take place at any time during the ballast voyage. Intermediate condition(s) should be specified as shown in the Figure, however filling/partial filling of BW Tank no. 6 (P/S) may be done at any step to keep acceptable trim and propeller immersion during the ballast voyage.

To obtain full operational flexibility regarding the filling level of BW Tank no. 6 (P/S), loading conditions A2 (full at departure)* and A8 (empty at arrival)* shall be added for strength verification. Additional conditions (full and empty BW Tank no. 6 (P/S)) related to the intermediate conditions A3-A6 are not necessary as A2* and A8* will be the most critical one.

2.2 Case B

Fig. 2 shows Case B, with a cargo vessel where partial filling of BW Tank no. 6 (P/S) to a given level (f6-int%) will be done after a specified % consumables is reached, see conditions B2 and B3. Before this % consumables (shown as 50% in this Figure) is reached, BW Tank no. 6 (P/S) shall be kept empty. When reaching a given level of consumables (shown as 20% in Figure 2), BW Tank no. 6 (P/S) shall be kept full, see conditions B5 and B6. Two additional intermediate conditions (B4* and B7*) shall be added for longitudinal strength verification.

In order to categorize a vessel according to Case B, clear operational guidance for partial filling of ballast tanks, in association with the consumption level as shown in Figure 2, is to be given in the loading manual. If such operational guidance is not given, Case A is to be applied.

Case A has no limitation of consumables, whereas Case B has limitation of consumables.

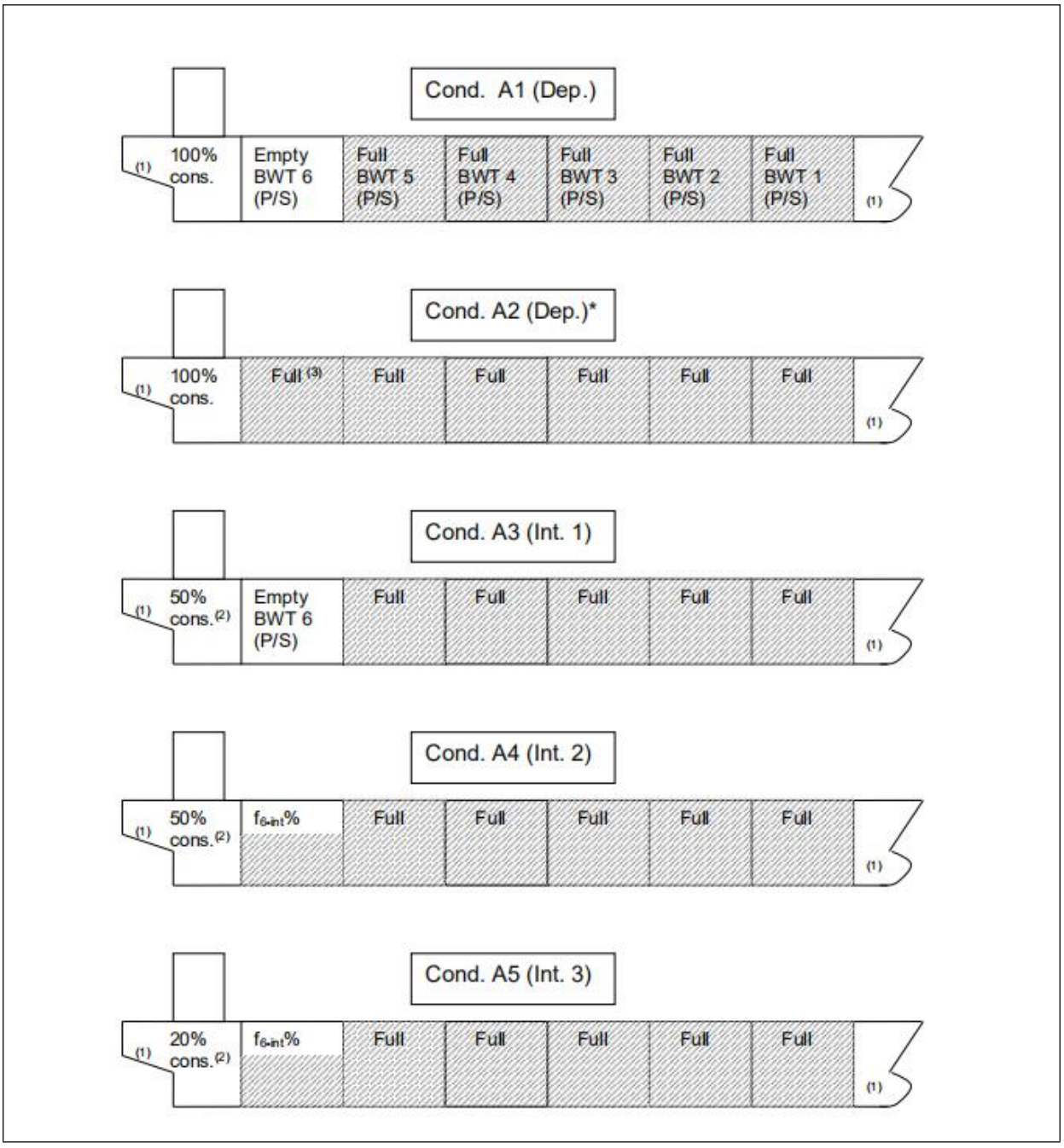
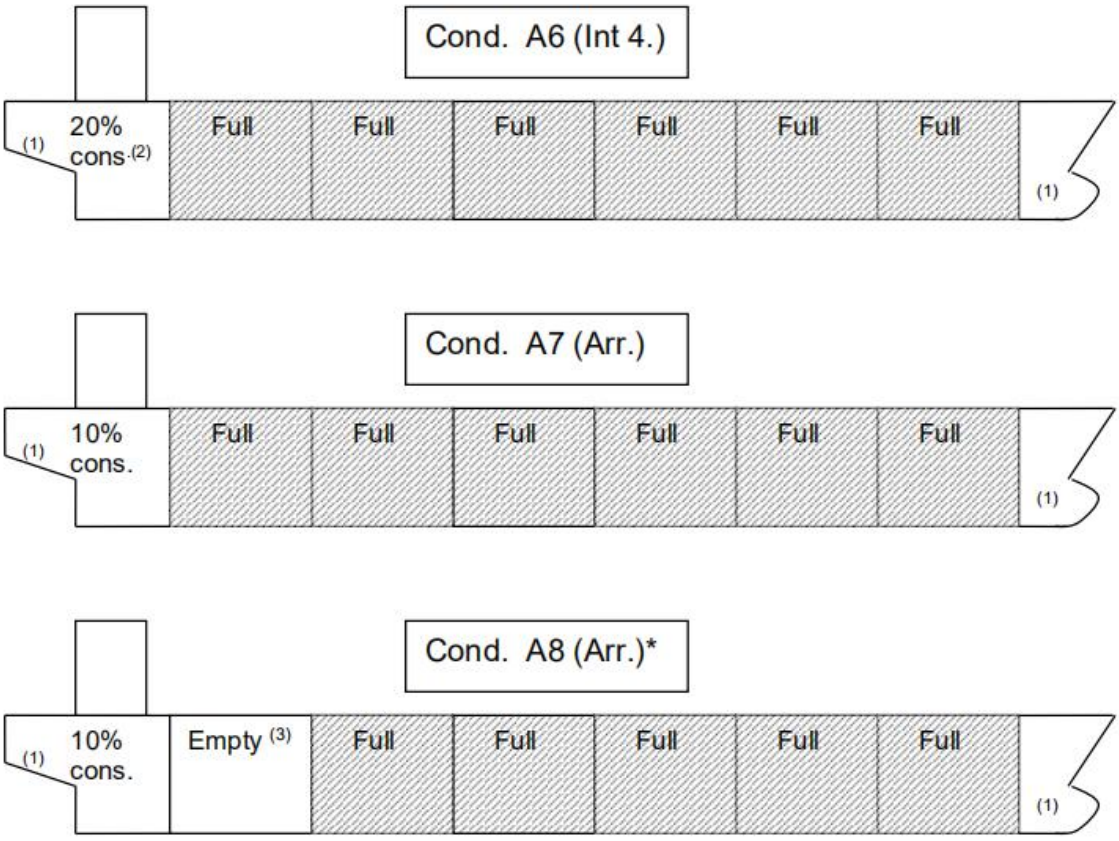


Figure 1 Case A, Partial filling of ballast tank no. 6 (P/S) is permitted at any stage during voyage. The intermediate conditions are specified, however other partial filling of BW Tank no. 6 (P/S) may be applied to keep acceptable trim and propeller immersion during the ballast voyage. Conditions only intended for strength verification (not operational) are marked: *



Notes

(1) For peak tanks intended to be partially filled, all combinations of full or partially filled at intended level for those tanks are to be investigated.

(2) The intermediate condition(s) to be specified incl. % consumables.

(3) For bulk carriers carrying ore and with large wing water ballast tanks full/empty may be replaced with maximum/minimum filling levels according to trim limitations given in S11.2.1.3.

Figure 1 (Continued)

Case A, Partial filling of ballast tank no. 6 (P/S) is permitted at any stage during voyage. The intermediate condition is specified, however other partial filling of BW Tank no. 6 (P/S) may be applied to keep acceptable trim and propeller immersion during the ballast voyage. Conditions only intended for strength verification (not operational) are marked: *

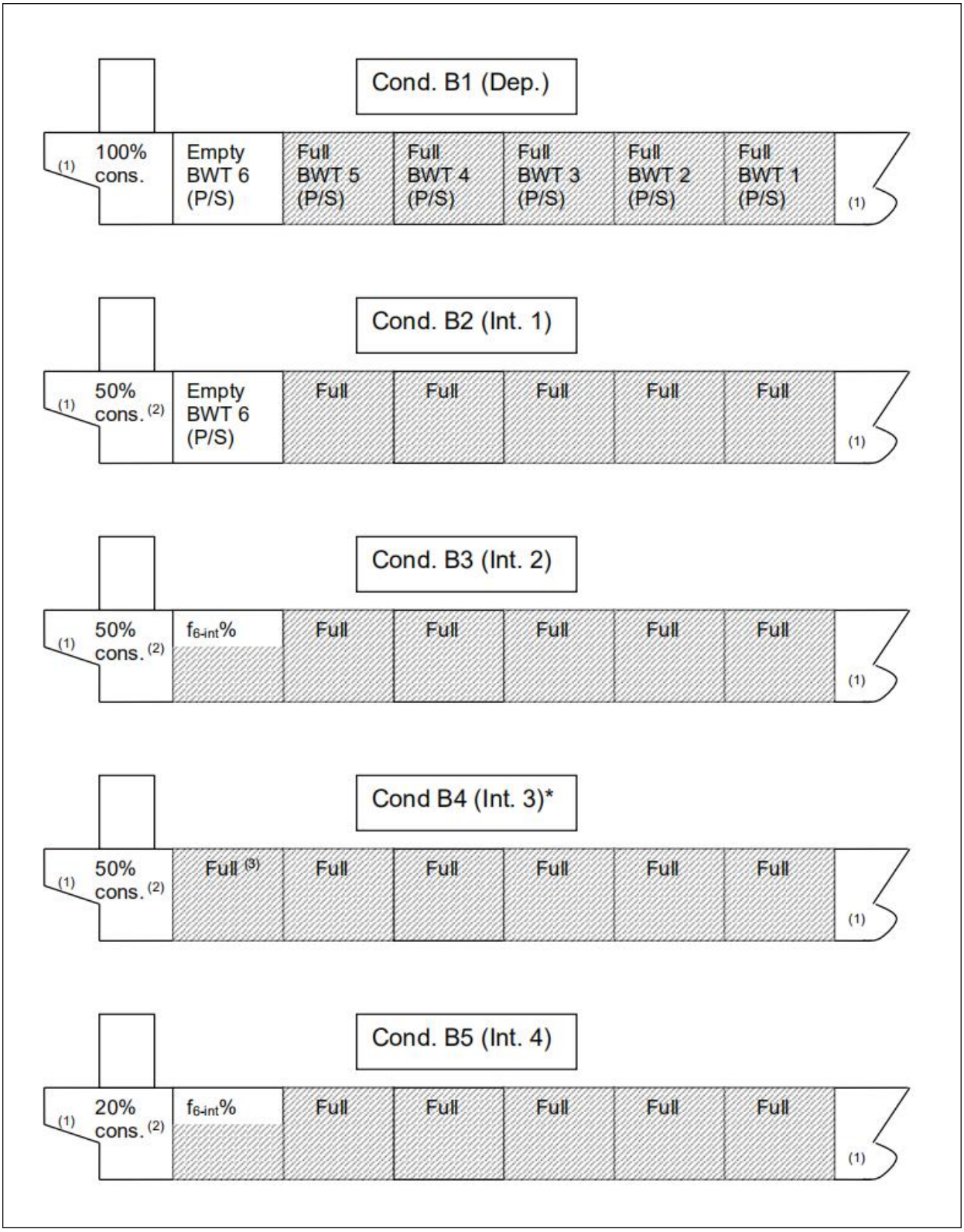
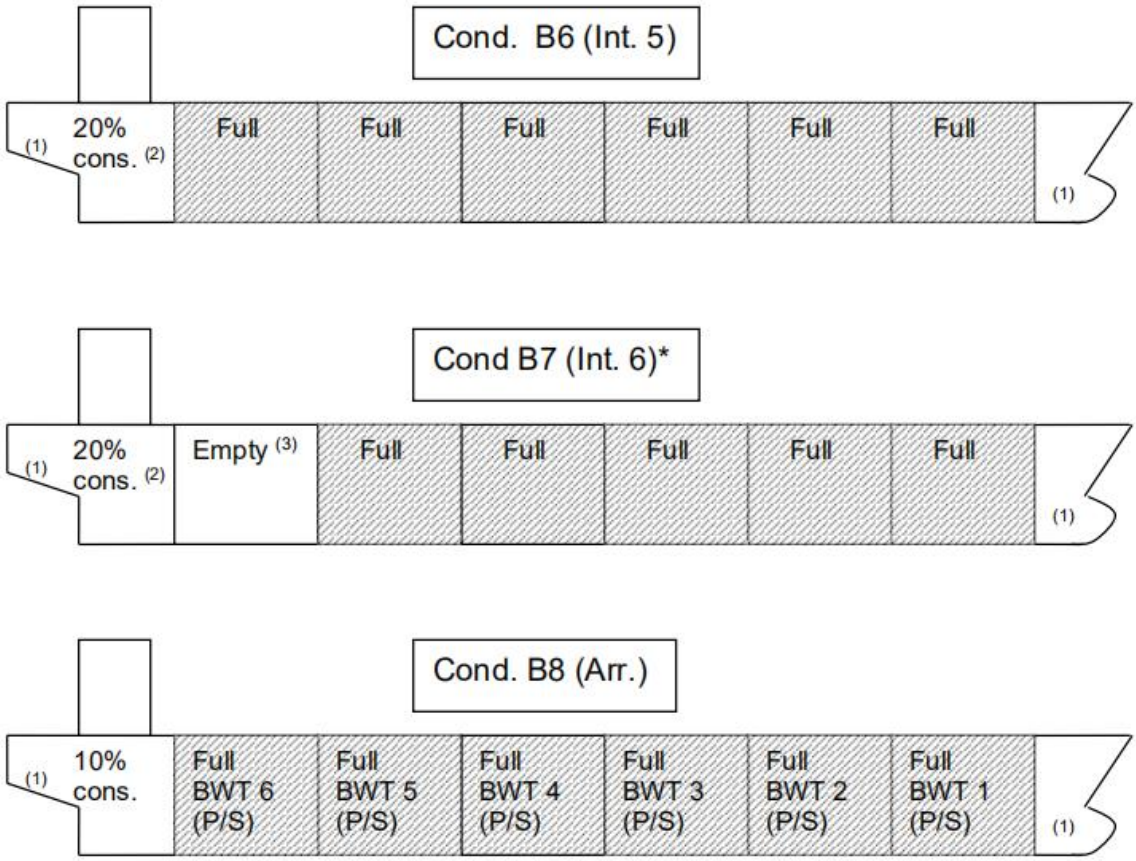


Figure 2 Case B, Partial filling of BW Tank no. 6 (P/S) only allowed during intermediate conditions, in this example between 50-20% consumables. Conditions only intended for strength verification (not operational) are marked: *



Notes

(1) For peak tanks intended to be partially filled, all combinations of full or partially filled at intended level for those tanks are to be investigated.

(2) The intermediate condition(s) to be specified incl. % consumables.

(3) For bulk carriers carrying ore and with large wing water ballast tanks full/empty may be replaced with maximum/minimum filling levels according to trim limitations given in S11.2.1.3.

Figure 2 (Continued)

Case B, Partial filling of BW Tank no. 6 (P/S) only allowed during intermediate conditions, in this example between 50-20% consumables. Conditions only intended for strength verification (not operational) are marked: *

3 Case C – Conventional (with usual arrangement of WBT) ore carrier with two pairs of partially filled ballast water tanks

Fig. 3(a) show the operational loading conditions, departure condition (C1), four intermediate conditions (C2-C5) and arrival condition (C6), for a conventional (with usual arrangement of WBT) ore carrier with partial filling of both BW tank no.1 (P/S) and 7 (P/S) during voyage.

Filling level in partially filled BW tanks nos.1 (P/S) and 7 (P/S) for the operational conditions during ballast voyage is given in Table 1.

Table 1

Loading condition	Consumables	Filling level, WBT 1(P/S)	Filling level, WBT 7(P/S)
C1–Departure	100%	f_{1dep}%	f_{7dep}%
C2–Intermediate 1	50%(1)	f_{1dep}%	f_{7dep}%
C3–Intermediate 2	50%(1)	f_{1int}%	f_{7int}%
C4–Intermediate 3	20%(1)	f_{1int}%	f_{7int}%
C5–Intermediate 4	20%(1)	f_{1arr}%	f_{7arr}%
C6–Arrival	10%	f_{1arr}%	f_{7arr}%

Note: (1) % consumables to be specified, indicated to 50% and 20 %.

Fig. 3(b) and Fig. 3(c) show the additional twelve loading conditions (C1-1 ~ C1-12) which shall be added for longitudinal strength verification of the departure condition (C1).

Fig. 3(d) and Fig. 3(i) show the additional 32 loading conditions (C2-1 ~ C2-12, C3-1 ~ C3-4, C4-1 ~ C4-12 and C5-1 ~ C5-4) which shall be added for longitudinal strength verification of the intermediate conditions (C2 ~ C5).

Fig. 3(j) and Fig. 3(k) show the additional twelve loading conditions (C6-1 ~ C6-12) which shall be added for longitudinal strength verification of the arrival condition (C6).

For the additional loading conditions, the maximum and the minimum filling level of BW tank are according to trim and propeller immersion limitations given in S11.2.1.3:

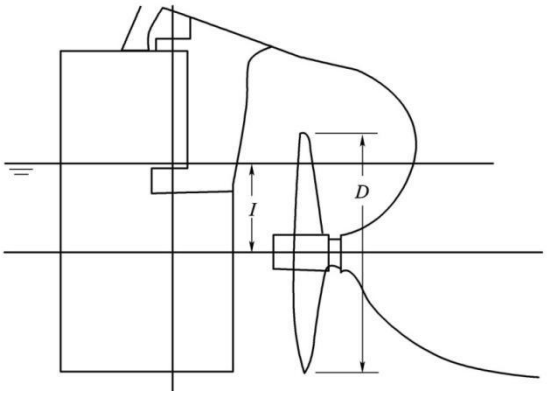
However, for conventional ore carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of these tanks lead to the ship's trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of these one or maximum two pairs of ballast tanks such that the ship's condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks are to be considered between empty and full. The trim conditions mentioned above are:

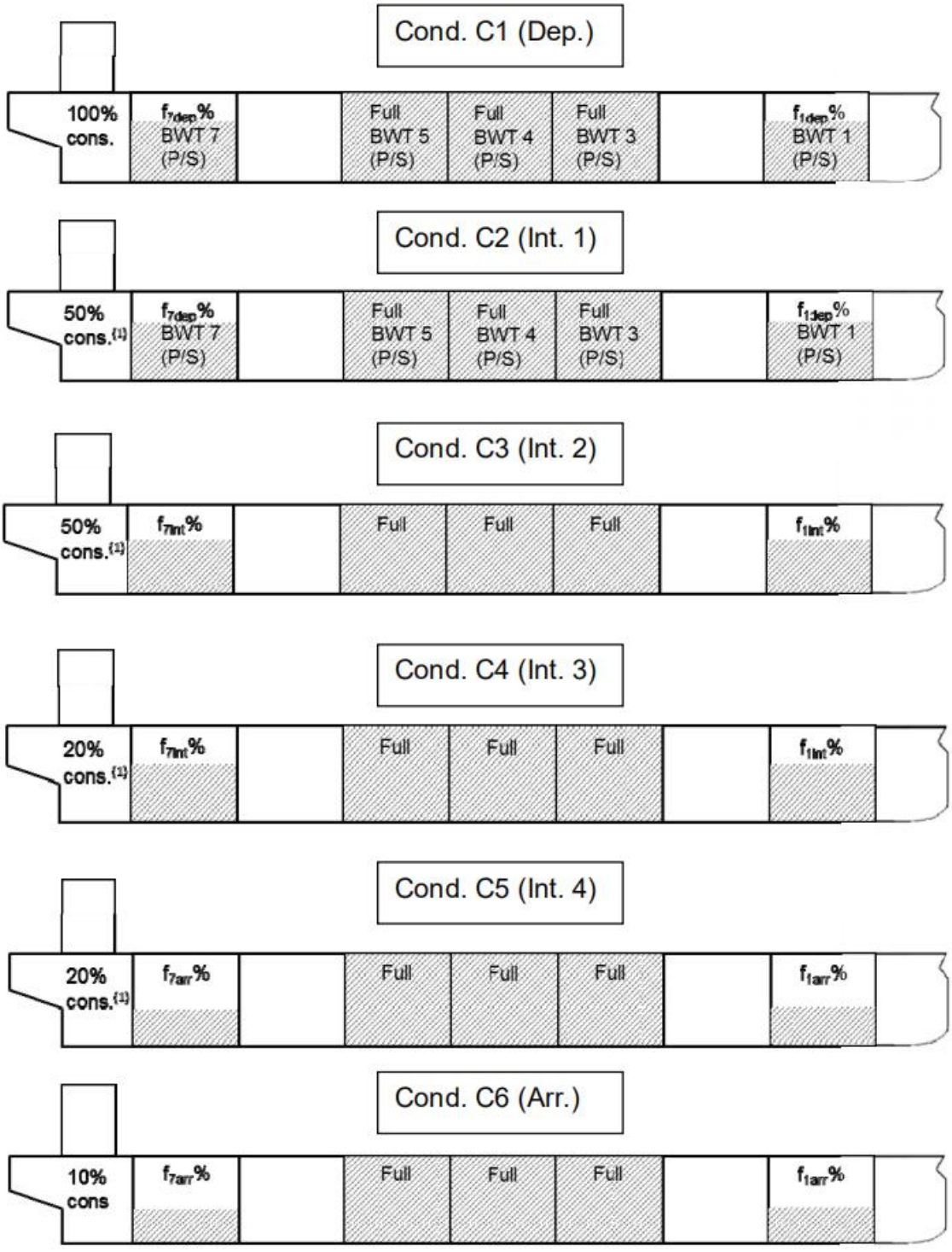
- trim by stern of 3% of the ship's length, or
- trim by bow of 1.5% of ship's length, or
- any trim that cannot maintain propeller immersion (I/D) not less than 25%, where;

I = the distance from propeller centerline to the waterline

D = propeller diameter

(see the following figure)


I
D



Notes

(1) The intermediate condition(s) to be specified incl. % consumables.

(2) Figures 3(b)-3(k): Maximum and minimum filling level of BW tank according to trim and propeller immersion limitations given in S11.2.1.3.

Figure 3(a) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during ballast voyage, operational conditions C1-C6.

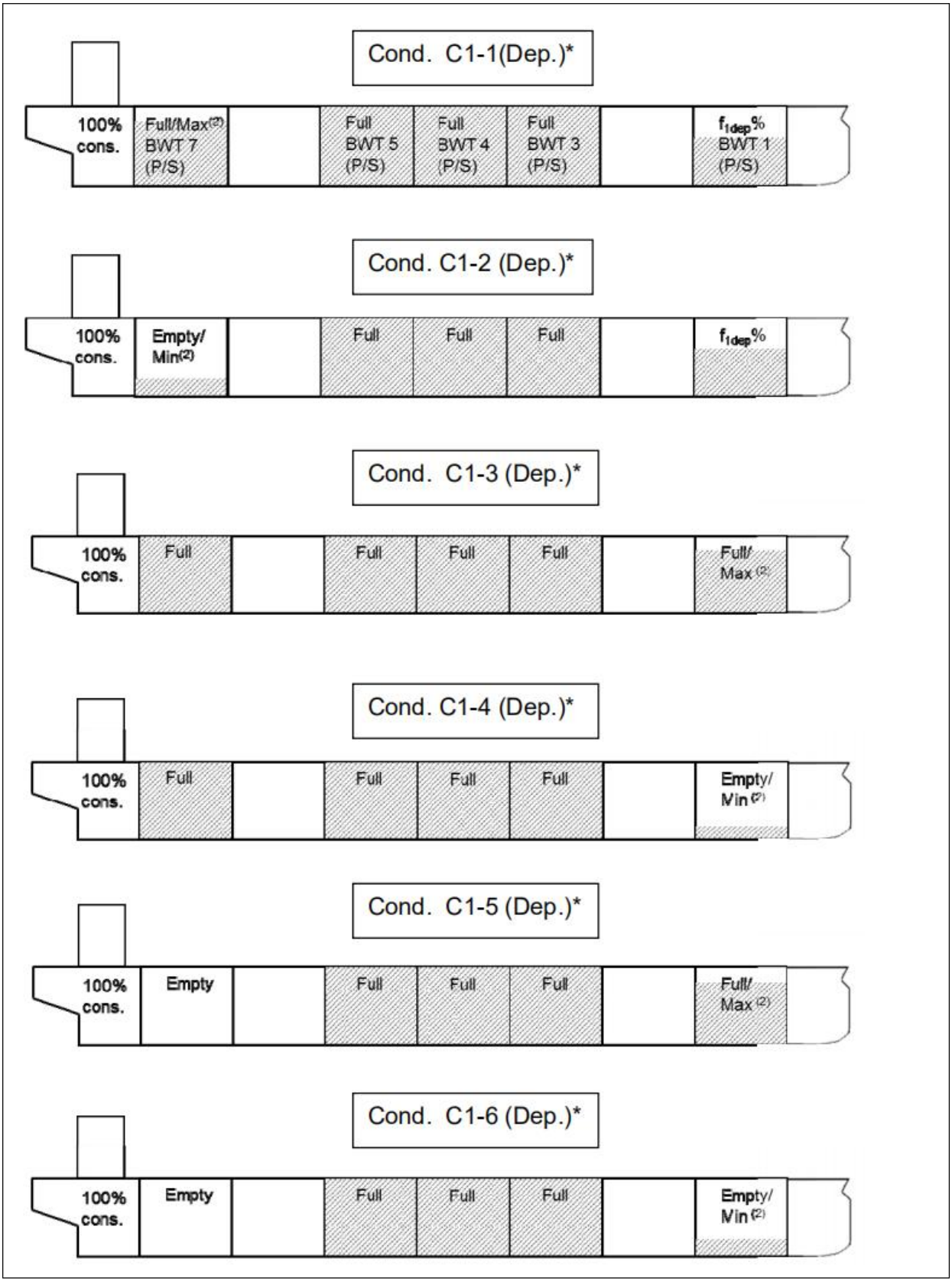


Figure 3(b) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Departure conditions C1-1~C1-6, only intended for strength verification (not operational) are marked: *

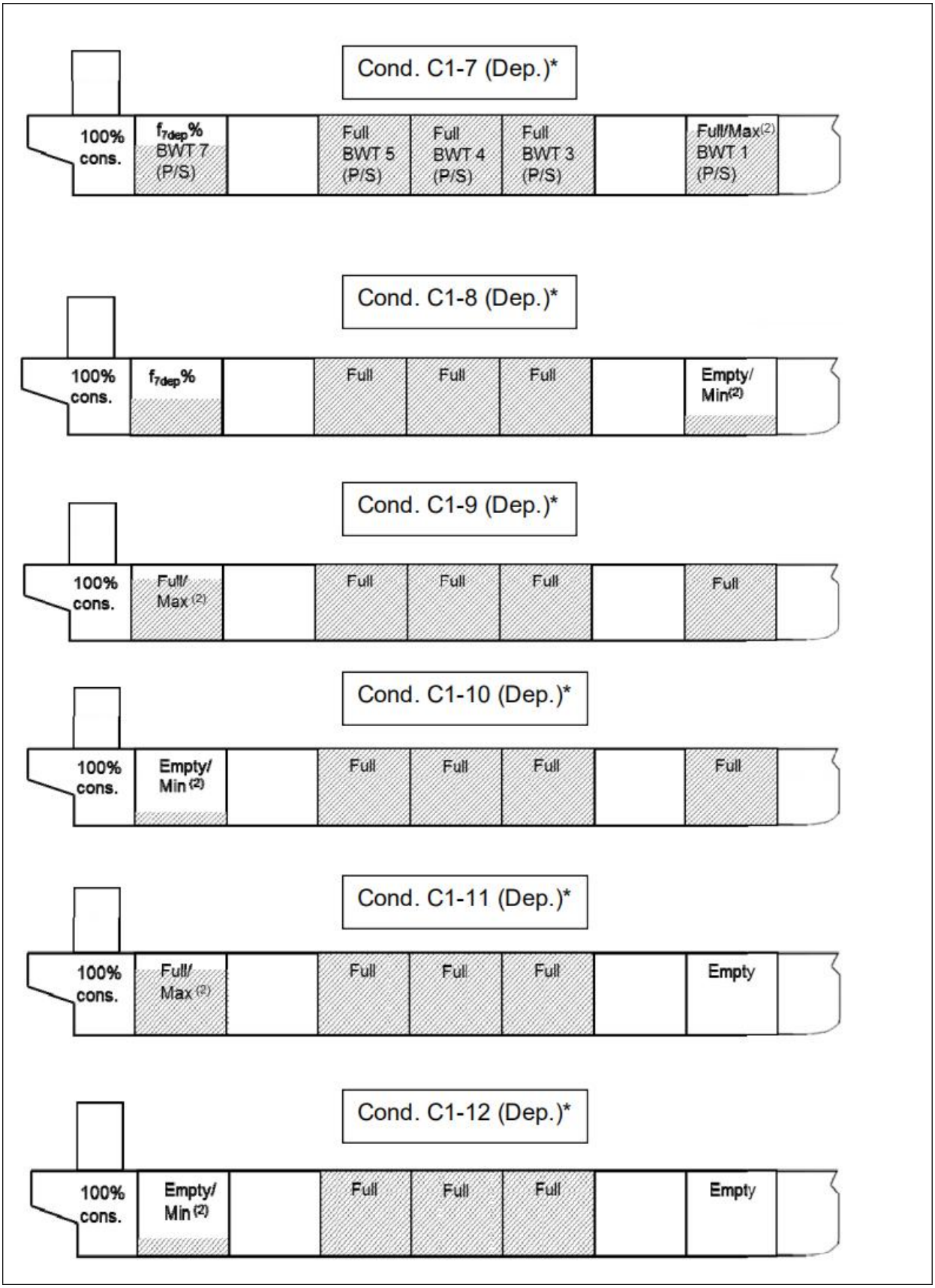


Figure 3(c) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Departure conditions CD1-7~C1-12, only intended for strength verification (not operational) are marked: *

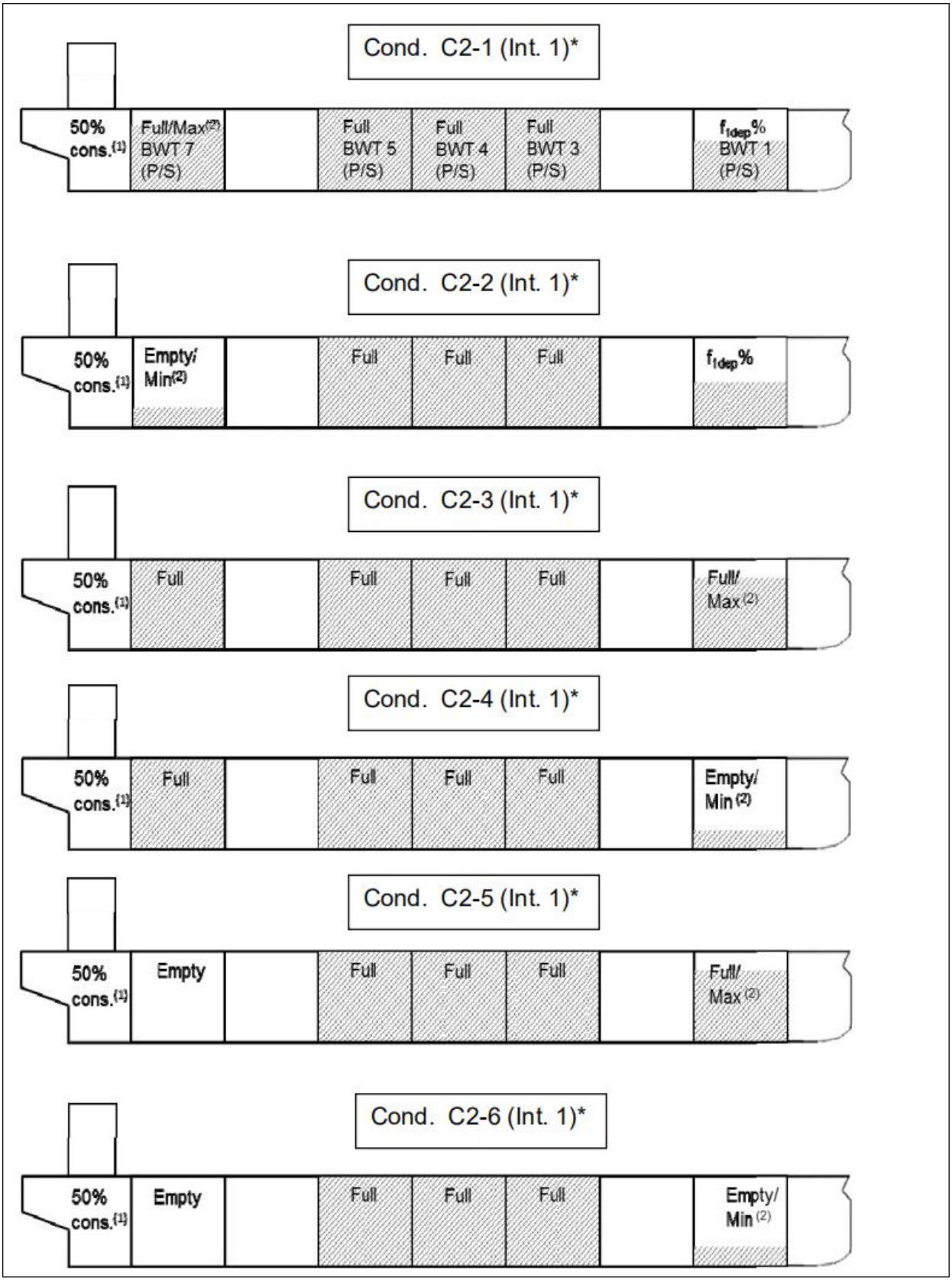


Figure 3(d) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C2-1~C2-6, only intended for strength verification (not operational) are marked: *

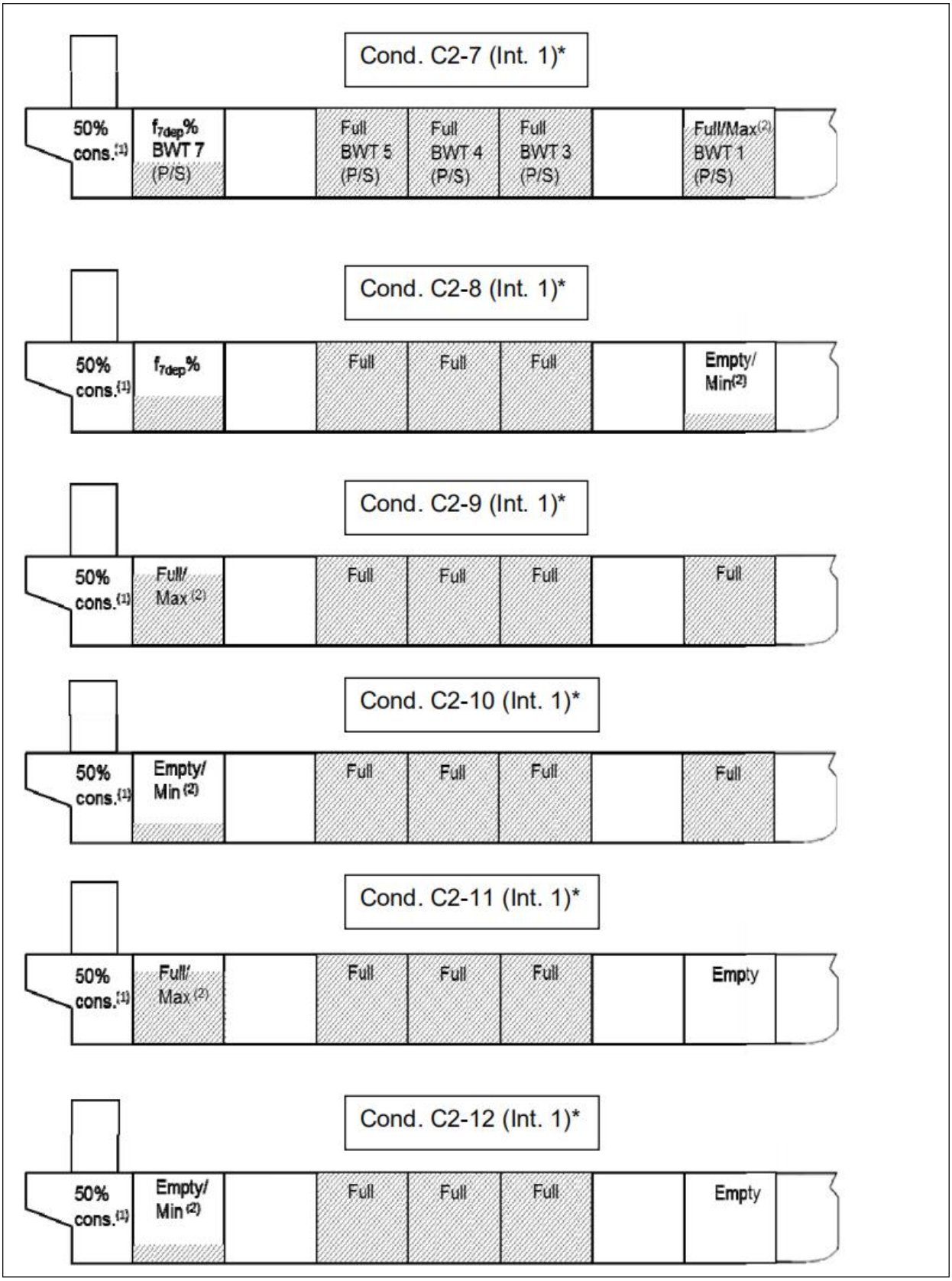


Figure 3(e) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C2-7~C2-12, only intended for strength verification (not operational) are marked: *

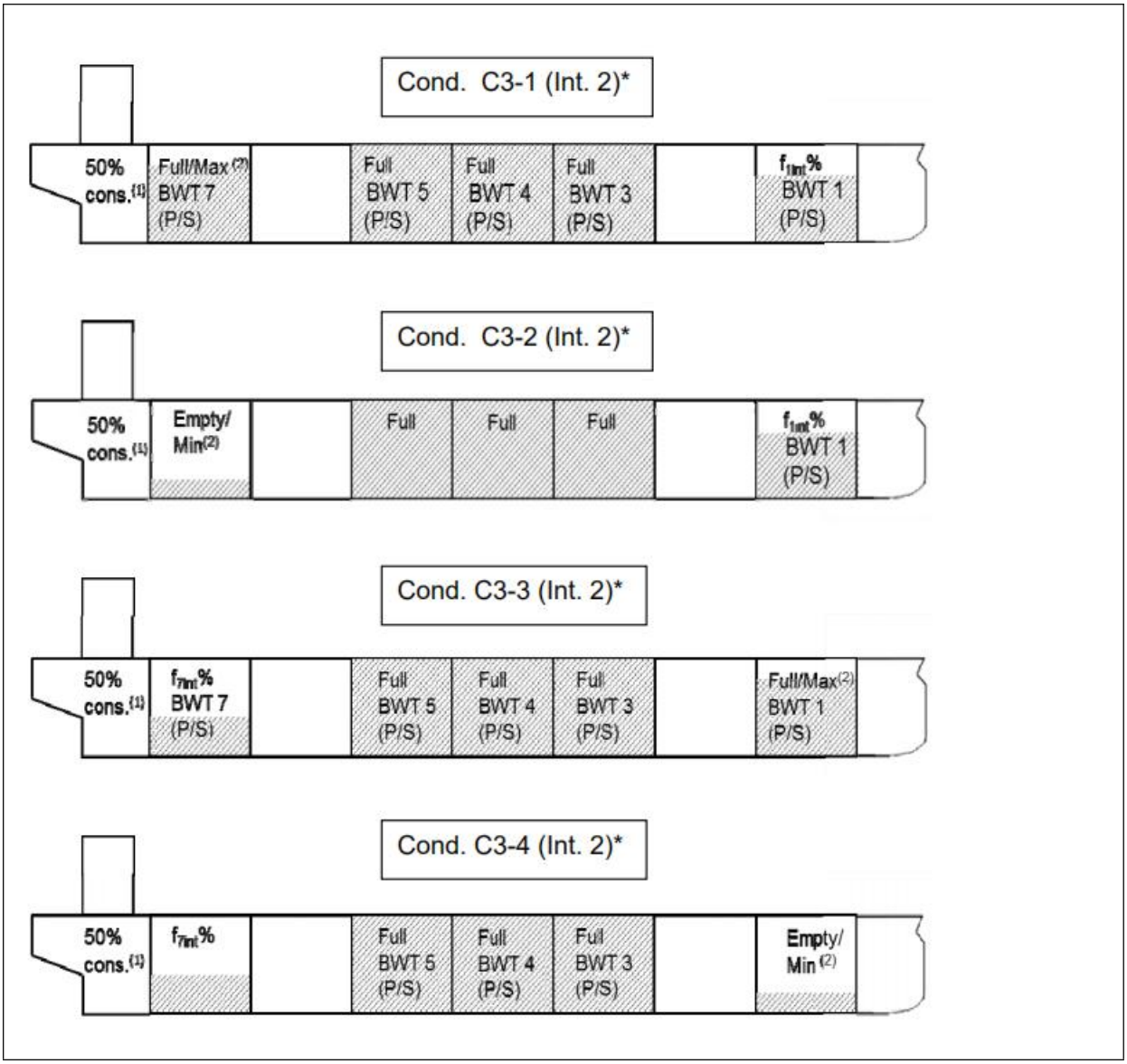


Figure 3(f) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C3-1~C3-4, only intended for strength verification (not operational) are marked: *

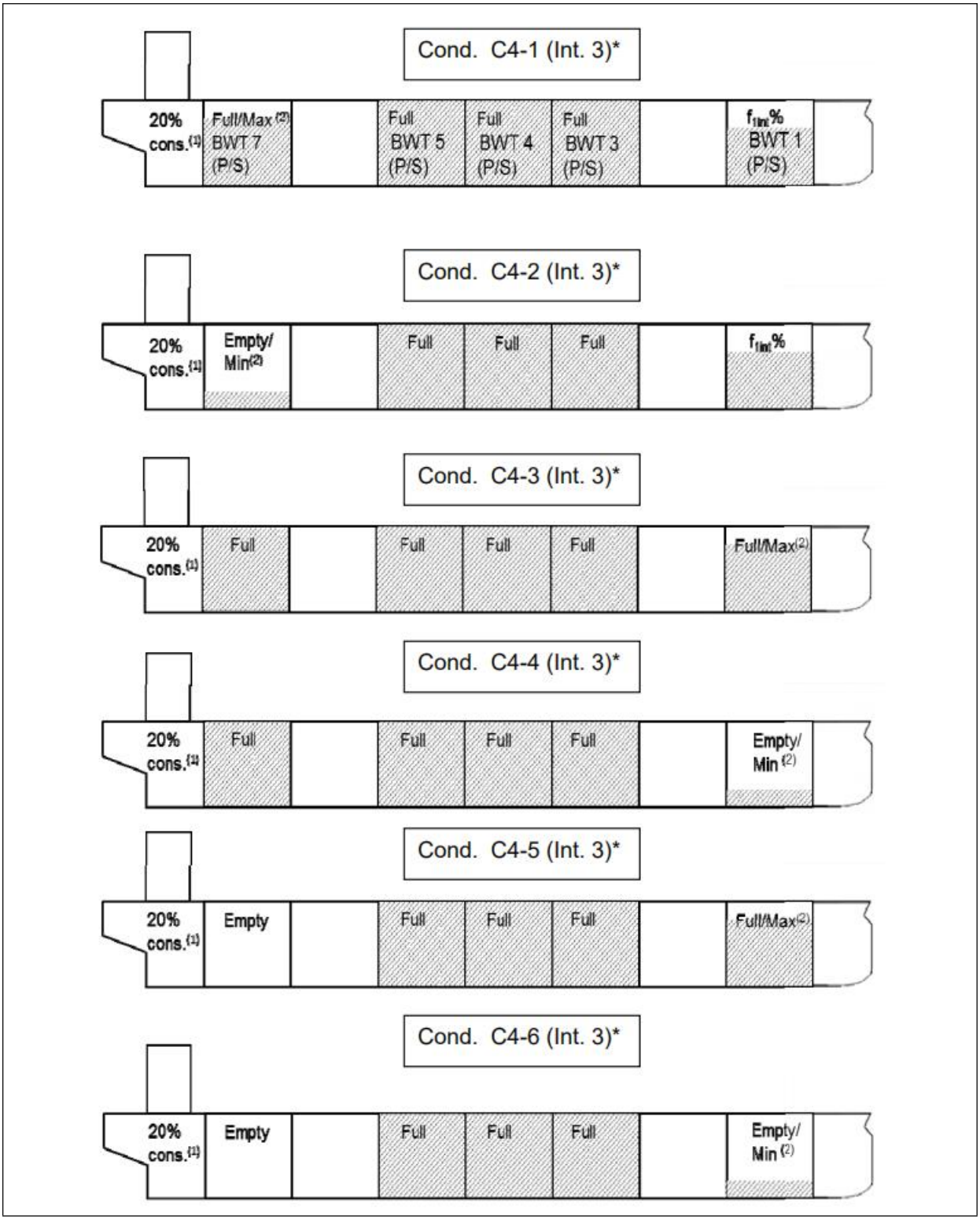


Figure 3(g) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C4-1~C4-6, only intended for strength verification (not operational) are marked: *

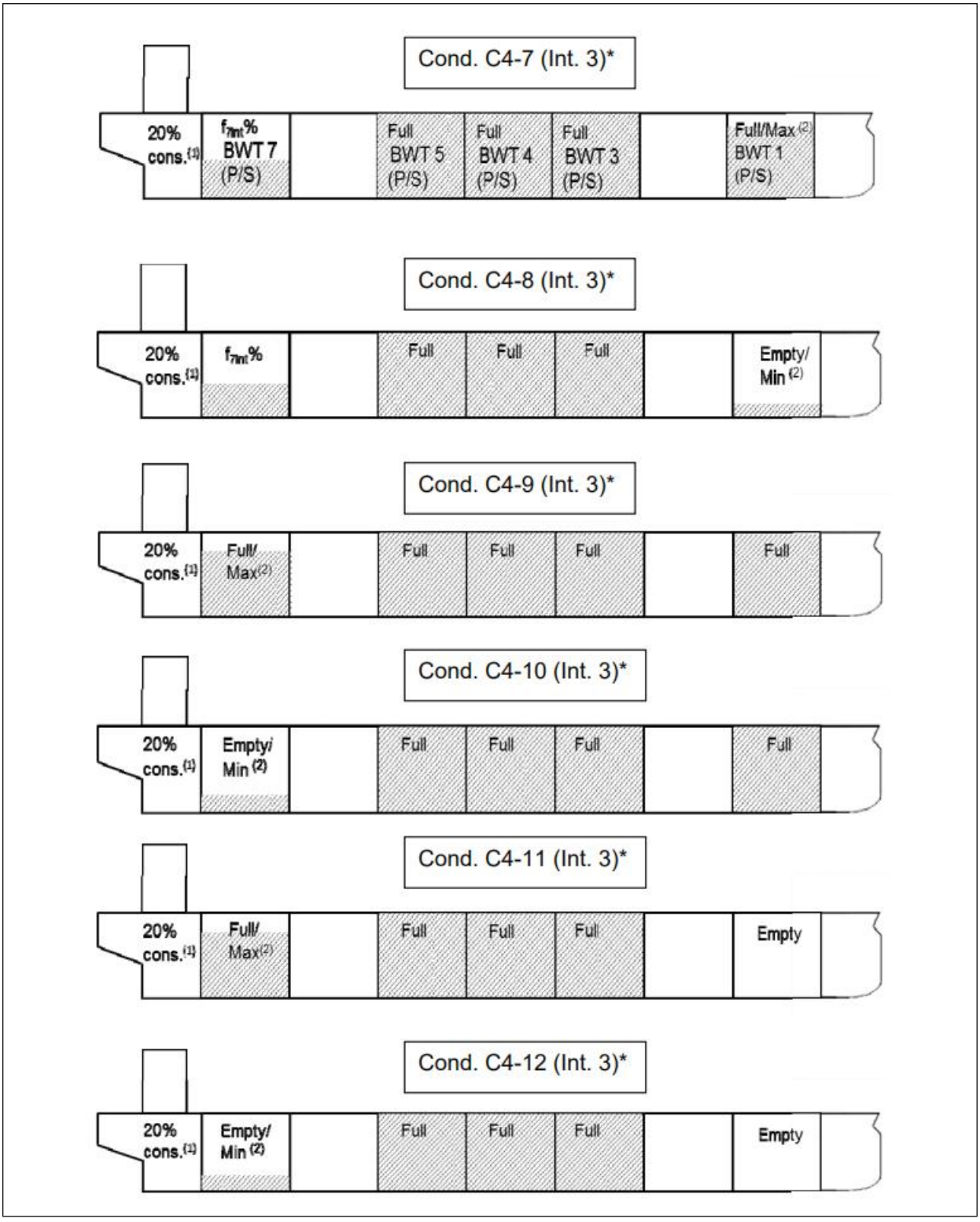


Figure 3(h) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C4-7~C4-12, only intended for strength verification (not operational) are marked: *

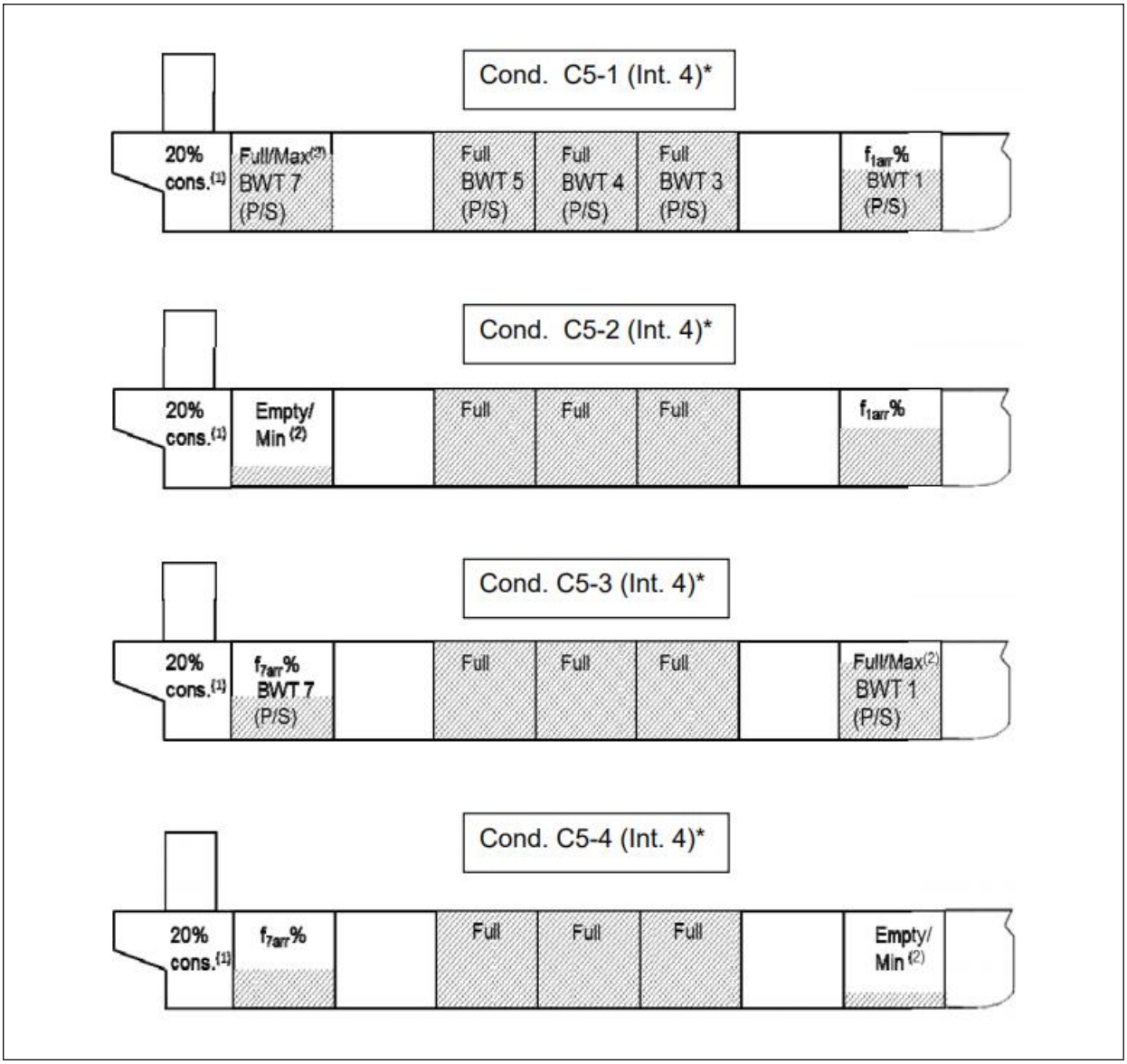


Figure 3(i) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C5-1~C5-4, only intended for strength verification (not operational) are marked: *

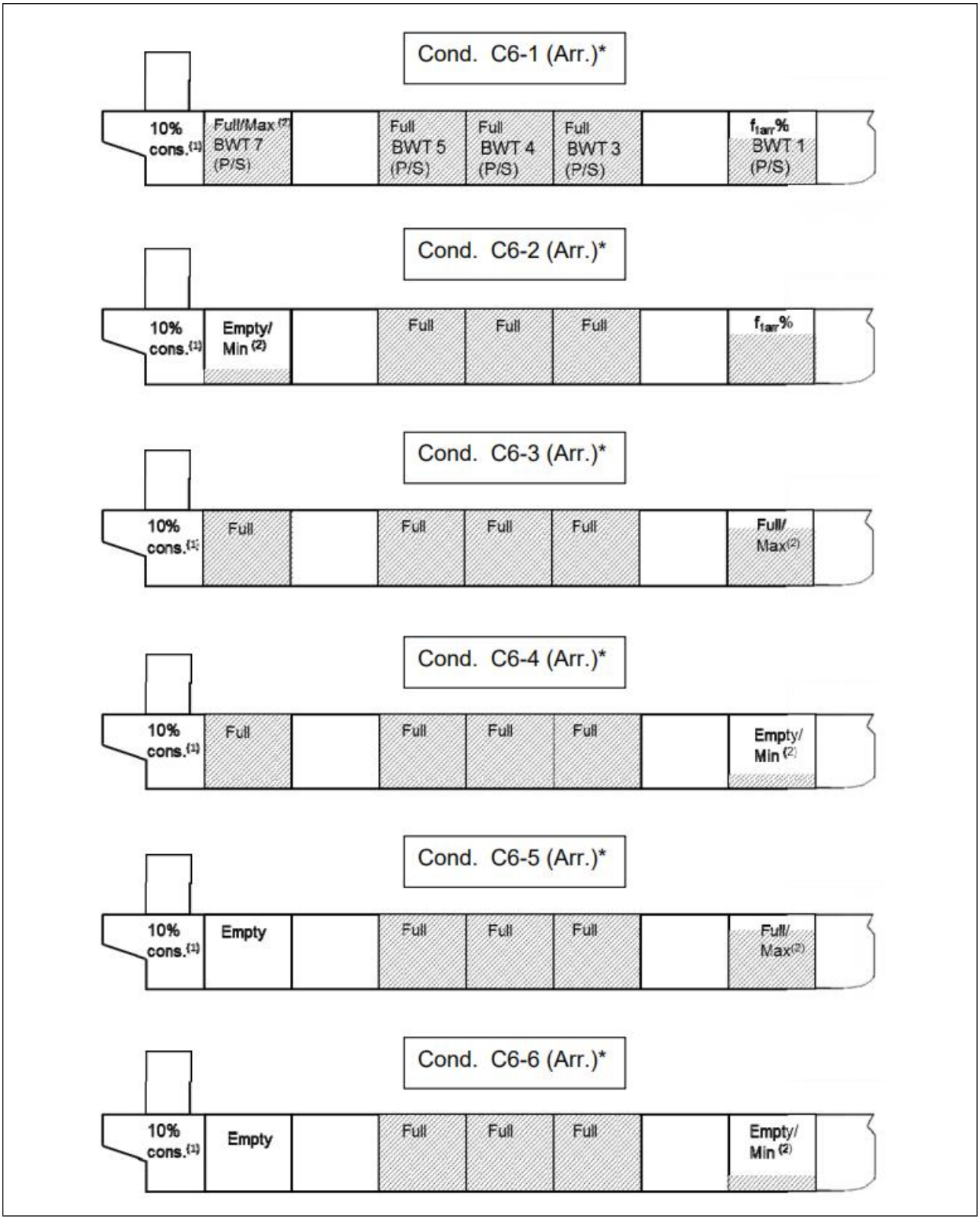


Figure 3(j) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Arrival conditions C6-1~C6-6, only intended for strength verification (not operational) are marked: *

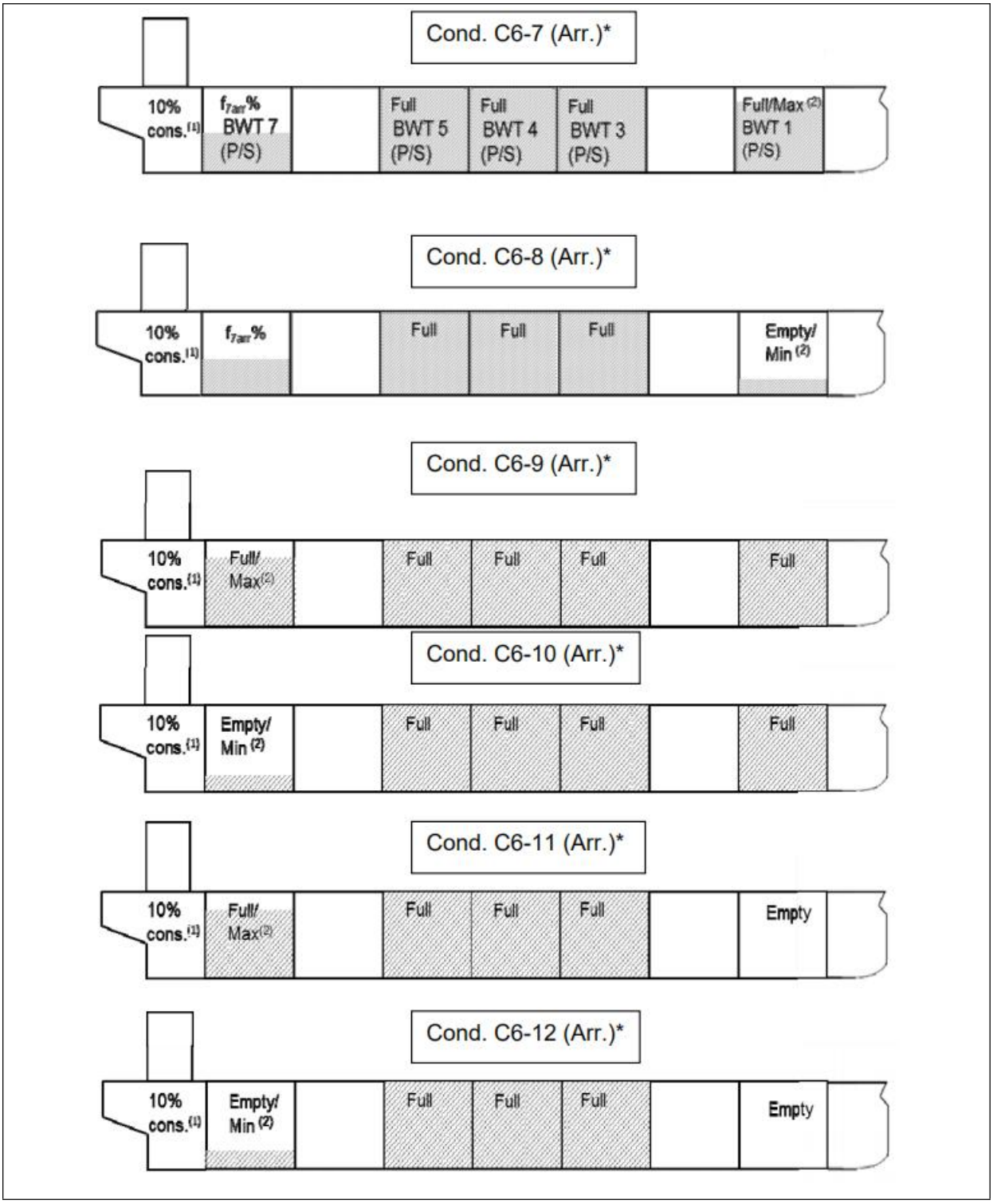


Figure 3(k) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 5 (P/S) during voyage. Arrival conditions C6-7~C6-12, only intended for strength verification (not operational) are marked: *

Appendix 4 SLAMMING STRENGTH ASSESSMENT OF BOW BOTTOM STRUCTURES

1 General

1.1 General provisions

1.1.1 This Appendix applies to strength assessment of bow bottom structures against slamming for mono-hull ships.

1.1.2 The strength assessment against bottom slamming in this Appendix is based on Ochi-Mottor theory to predict the extreme value of slamming pressures and anti-plastic failure method to evaluate the slamming strength of shell plating, longitudinals and bottom grillage.

1.1.3 The longitudinal extent for the strength assessment of bow bottom slamming is to be consistent with that specified in 2.15.3 of Chapter 2 of this PART.

1.1.4 Where direct calculation is adopted, the relative motion results required by the procedure to calculate the slamming pressures are to be given by solving three-dimensional linear sea-keeping program.

2 Slamming Pressure

2.1 Calculation of slamming pressures

2.1.1 The slamming pressures P_B, in kPa, at each section is to be obtained from the following formula:

$$P_B = eP_S$$

where: e — correction coefficient, see 2.15.3.5 of this Chapter;

P_S — extreme value of slamming pressures, calculated in way of each transverse section when e =1 and the maximum value is taken, in kPa, to be obtained by the following formula:

$$P_S = \frac{1}{2}\rho k_1 C_{ps}\left\{V_0^2 - 2E_v \ln\left[1-(1-\alpha)^{1/n}\right]\right\}$$

where: ρ — density of seawater, in t/m^3, taken as 1.025;

k_1 — slamming coefficient, obtained according to Table 2.1.1, the intermediate value may be obtained from interpolation:

Slamming Coefficient k_1 **Table 2.1.1**

b_1 / d_1	1.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0

For containerships, passenger ships and vehicle carriers	4.0	9.5	20.0	26.0	29.5	32.0	33.0	34.2	35.3	36.2
For other types of ships	4.0	9.5	20.0	26.0	28.5	29.6	30.0	29.6	28.8	28.0

d_1 — d/10, in m, where d is the draught;

b_1 — half breadth of the waterline for the transverse section concerned under draught d_1, in m;

C_{ps} — coefficient, taken as 0.44;

V_0 — critical slamming speed, in m/s, obtained from the following formulae:

$$V_0=\begin{cases}0.0925\sqrt{L}, & \text{for container ship, passenger ship and vehicle carrier}\\ 0.07\sqrt{L}, & \text{for other ship}\end{cases}$$

E_v — variance of vertical relative velocities for the hull and wave surface of transverse section concerned, determined according to 2.1.2 of this Appendix;

α — assurance rate, taken as 0.01;

n — number of impacts, replaced by the mean number of impacts N within t_n, obtained from the following formula:

$$N=3600\frac{t_n}{2\pi}\sqrt{\frac{E_v}{E_r}}\exp\left\{-\left(\frac{T_f^2}{E_r}+\frac{V_0^2}{E_v}\right)\right\}$$

where: t_n — the calculated navigation time, in h, obtained according to Table 2.2.4;

E_r — variance of vertical relative motions for the hull and wave surface of transverse section concerned, determined according to 2.1.2 of this Appendix;

T_f — draught of transverse section concerned in assessment condition, in m.

2.1.2 Variance of vertical relative motions for the hull and wave surface of transverse section concerned E_r and variance of vertical relative velocities for the hull and wave surface of transverse section concerned E_v are obtained from the following formula:

$$E_r = 0.25(C_{pc}M_r)^2 / f_r$$

$$E_v = 0.25(\omega_e C_{pc}M_r)^2 / f_v$$

where: C_{pc} — correction factor of vertical relative motion probability, taken as 1.2;

ω_e — encounter frequency, in rad/s, obtained from the following formula:

$$\omega_e = \omega(1+\frac{0.4\omega V_c}{g})$$

ω — effective wave frequency based on 80% length of the ship, in rad/s, obtained from the following formula:

$$\omega = \sqrt{\frac{2\pi g}{0.8L}}$$

V_c — considered ship speed, in m/s, obtained from the following formula:

$$V_c = 0.5144V$$

where: V — defined in 1.1.2.27 of Chapter 1;

M_r — vertical relative motions for the hull and wave surface of the considered section, in m, obtained from the following formula:

$$M_r = H_{\min}\left[1 + \frac{4.5}{(C_b + 0.2)}\left(\frac{x_a}{L} - x_m\right)^2\right]$$

$H_{\min}$ — minimum wave height for calculation, in m, obtained from the following formula:

$$H_{\min} = \frac{0.0545}{k_m} L\left(C_b + 0.2\right)^{0.3} \exp(-0.0044L)$$

x_a — longitudinal position from the considered section to the after perpendicular, in m;

x_m — coefficient, obtained from the following formula, to be taken not less than 0.2;

$$x_m = 0.45 - \frac{0.309V}{\sqrt{gL}}$$

k_m — coefficient, obtained from the following formula:

$$k_m = 1 + \frac{4.5\left(0.5 - x_m\right)^2}{(C_b + 0.2)}$$

f_r 、 f_v — coefficient along the length of ship, obtained from the following formula, the intermediate value may be obtained by linear interpolation:

$$f_r、f_v = \begin{cases} \text{obtained according to Table 2.1.2(1),} & \text{for } L \leq 200\ m \\ \text{take values for 200m and 300m and interp olation according to the length of ship ,} & \text{for } 200m < L < 300m \\ \text{obtained according to Table 2.1.2(2),} & \text{for } L \geq 300\ m \end{cases}$$

Coefficient f_r , f_v Table 2.1.2 (1)

x_a / L	0.80	0.85	0.90	0.95
f_r	7.30	5.03	3.86	3.21

f_v	4.08	3.39	3.01	2.70

Coefficient f_r , f_v Table 2.1.2 (2)

x_a / L	0.80	0.85	0.90	0.95
f_r	3.15	2.52	2.21	2.08
f_v	1.00	1.00	1.00	1.00

2.2 Relative motion direct calculation

2.2.1 In calculation of the extreme value of slamming pressures, variance of vertical relative motions for the hull and wave surface of transverse section concerned E_r and vertical relative velocities E_v may be determined by direct calculation according to the requirements of this Section, namely the zero moment of motion response given respectively by spectrum analysis. In this case, the E_r and E_v of each section concerned are given by direct calculation, the slamming pressure P_B is replaced by the actual calculated value of extreme value of slamming pressures P_S.

2.2.2 For the direct strength assessment against bow bottom slamming, the loading condition with a minimum draught forward in navigation is to be identified from the Loading Manual.

2.2.3 Two-parameter P-M spectrum is adopted to model the wave power spectrum density function, which is given by the following formula:

$$S(\omega) = \frac{124H_S^2}{T_Z^4}\omega^{-5}\exp(-\frac{496}{T_Z^4}\omega^{-4})f_0(\theta)$$

where: H_s — significant wave height, in m;

T_z — mean zero-crossing period, in s;

ω — angular frequency of wave components, in rad/s;

$f_0(\theta)$ — wave spreading function, obtained from the following formula:

$$f_0(\theta) = \begin{cases} \frac{2}{\pi}\cos^2(\theta-\theta_m), & |\theta-\theta_m| < 90 \\ 0, & \text{Other values} \end{cases}$$

where: θ — extension wave direction, in degree;

θ_m — main wave direction, in degree.

2.2.4 The extreme value of slamming pressures is to be determined by short-term prediction approach and the significant wave height *Hs* is obtained from the following formulae:

$$H_S = \begin{cases} 8-0.6\left(\frac{300-L}{100}\right)^{1.5} & \text{m}, L < 300\text{m} \\ 8+0.6\left(\frac{L-300}{100}\right)^{1.5} & \text{m}, L \geq 300\text{m} \end{cases}$$

The average zero up-crossing wave period T_z and calculated navigation time t_n are to be selected in accordance with Table 2.2.4 and the intermediate values are to be obtained by interpolation.

Selection of sea wave conditions **Table 2.2.4**

Significant wave height H_S (m)	6.0	7.0	8.0	9.0
Average zero up-crossing wave period T_Z (s)	8.703	9.400	9.990	10.503
Calculated navigation time t_n (h)	41	35	35	35

2.2.5 The speed is to be taken as 0.75V.

2.2.6 The head sea and head oblique sea are to be considered, and interval between wave heading angles is not to be greater than 30 degrees.

2.2.7 The range of wave frequencies is to include 0.2 rad/s to 1.8 rad/s in increments taken as 0.05 rad/s.

2.2.8 Linear rolling damping may be determined by test or empirical formula, if not applicable, 5% of the critical rolling damping value may be taken.

2.2.9 Where direct calculation is adopted for relative motion, the slamming coefficient k_1 in 2.1.1 of this Appendix is obtained from the following formula:

$$k_1 = \exp(1.377 + 2.419a_1 - 0.873a_3 + 9.624a_5)$$

where: a_1, a_2, a_3 —the coefficient of three-parameter conformal mapping for the transverse section under draught d_1 to unit circle as follows:

$$Z_0 = U(\zeta + a_1\zeta^{-1} + a_3\zeta^{-3} + a_5\zeta^{-5})$$

Z_0 — section coordinate;

ζ — circle coordinate;

U — scale ratio, $U = \dfrac{d_1}{1 - a_1 + a_3 - a_5}$.

3 Strength Assessment

3.1 Slamming strength of shell plating

3.1.1 The pressure P_{cp} related to the ultimate capacity of shell plating is to be obtained from the following formula:

$$P_{cp} = \frac{12R_{eH}t_1^2}{a^2\left[3 - \dfrac{2}{\beta^2}\left(\sqrt{1+3\beta^2} - 1\right)\right]} \quad \text{MPa}$$

where: R_{eH} — yield stress of material, in N/mm^2;

t_1 — net thickness of plate panel, in mm;

a — length of the shorter side of the plate panel, in mm;

b — length of the longer side of the plate panel, in mm;

β — ratio between the sides, $\beta = b/a$.

3.1.2 When the relationship of the ultimate capacity P_{cp} and the extreme value of slamming pressures P_B is satisfied as below, the shell plating is considered to be with sufficient capacity against slamming:

$$1000\frac{P_{cp}}{P_B} \geqslant 0.75$$

where: P_B —slamming pressures, in kPa, see 2.1 of this Appendix.

3.2 Slamming strength of shell longitudinals

3.2.1 The pressure P_{cl} related to the ultimate capacity of shell longitudinals is to be obtained from the following formula:

$$P_{cl} = \frac{16R_{eH}W_T}{al^2} \quad \text{MPa}$$

where: R_{eH} — yield stress of material, in N/mm^2;

a — spacing of longitudinals, in mm;

l — span of longitudinals, in mm;

W_T — section modulus of longitudinals, including plate flange, in mm^3.

3.2.2 When the relationship of the ultimate capacity pressure P_{cl} and the extreme value of slamming pressures P_B is satisfied as below, the shell longitudinals are considered to be with sufficient capacity against slamming:

$$1000\frac{P_{cl}}{P_B} \geqslant 0.75$$

where: P_B —slamming pressures, in kPa, see 2.1 of this Appendix.

3.3 Slamming strength of bottom grillage

3.3.1 Structural FE model

(1) The longitudinal extent of the model is to include the calculation range as specified in 1.3 of this Appendix and at least extend to one web frame distance forward and aft. The transverse extent is to be selected as possible as to reduce the effect of boundary constraints on the response of bottom grillage. For example, the scope between the knuckle to the mid-line of the inner bottom may be selected for oil tankers and similar selection is applicable for other ships.

(2) Selection and meshing of elements are to comply with the requirements of Section 5, Chapter 1 of this PART.

(3) Strength evaluation is to be carried out for all primary members within the extent of strengthening of bottom forward.

(4) When the stress distribution or stiffness of members is affected by the openings on primary members, the methods may be adopted in accordance with the requirements of Section 5, Chapter 1 of this PART.

3.3.2 Boundary constraints

Floors and girders at the boundary of model are to be rigidly fixed.

3.3.3 Loads

According to the principle of slamming, the slamming pressure acts on the floor at the centre girder, the affected area is a square. The length of a side of this square S_1 is obtained from the following formula:

$$S_1 = \sqrt{1.1C_bLB \times 10^{-3}} \quad \text{m}$$

The extreme value of slamming pressure at each station of bow bottom will not occur at the same time, therefore the extreme value acting at each station is to be calculated respectively and the

maximum pressure of the bottom grillage is obtained. The distribution of slamming pressures on the floor is to be determined according to the following three situations:

(1) $S_1<S$:

The slamming pressure only acts on one floor, see Figure 3.3.3(1), the force Q acting on the floor in per unit length is to be calculated by the following formula:

$$Q = C_D P_B S_1 \quad \text{kN/m}$$

where: S — spacing of floors, in m;

P_B —slamming pressures, in kPa, see 2.1 of this Appendix;

C_D —dynamic slamming coefficient, to be taken as 0.8.

(2) $S<S_1<2S$:

The slamming pressure acts on two floors, see Figure 3.3.3(2), the force Q acting on the floor in per unit length is to be calculated by the following formula:

$$Q = 0.5 C_D P_B S_1 \quad \text{kN/m}$$

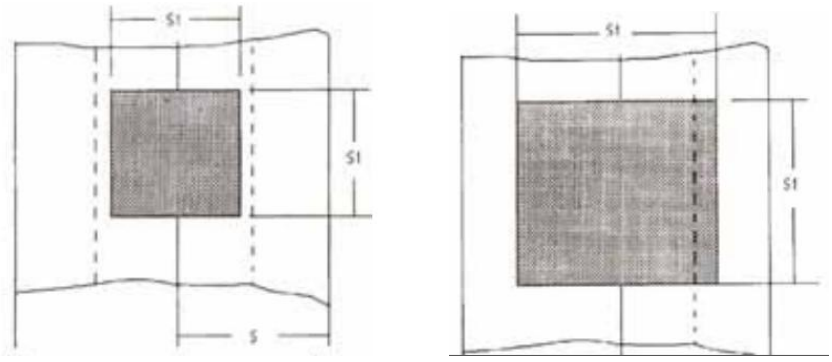
(3) $S_1>2S$:

The slamming pressure acts on three floors, the force Q_c acting on the intermediate floor in per unit length is to be calculated by the following formula:

$$Q_C = C_D P_B S \quad \text{kN/m}$$

The force Q_s acting on the side floor in per unit length is to be calculated by the following formula:

$$Q_S = 0.5 C_D P_B (S_1 - S) \quad \text{kN/m}$$



(1) (2)

Figure 3.3.3

3.3.4 Acceptance criteria

Permissible stress of direct calculation of slamming strength for bow bottom grillage is to be determined in accordance with Table 3.3.4.

Permissible Stress **Table 3.3.4**

Member	Positive stress of inner bottom plating σ (N/mm^2)	Positive stress of outer bottom plating σ (N/mm^2)	Shear stress τ (N/mm^2)	Equivalent stress σ_e (N/mm^2)
Girder	122/K	112/K	108/K	180/K
Floor	132/K	132/K	98/K	196/K

Note: K— material factor.

Appendix 5 BUCKLING STRENGTH ASSESSMENT OF SHIP STRUCTURAL ELEMENTS

SECTION 1 APPLICATION AND DEFINITIONS

Abbreviation

EPP —— Elementary plate panel, as defined in [1.2.3.1];

PSM —— Primary supporting member;

SP —— Stiffened panel, as defined in [1.2.3.3];

UP —— Unstiffened panel, as defined in[1.2.3.3].

1.1 Application

1.1.1 General Requirements

1.1.1.1 Relevant unified requirements concerning strength of ships

This Appendix establishes a general buckling assessment procedure as illustrated in Figure 1.1.1.1, and is to be applied in conjunction with Section 20 of Chapter 2 for hatch cover structures. The Section 20 of Chapter 2 is referred to as Relevant UR-S hereafter in this Appendix.

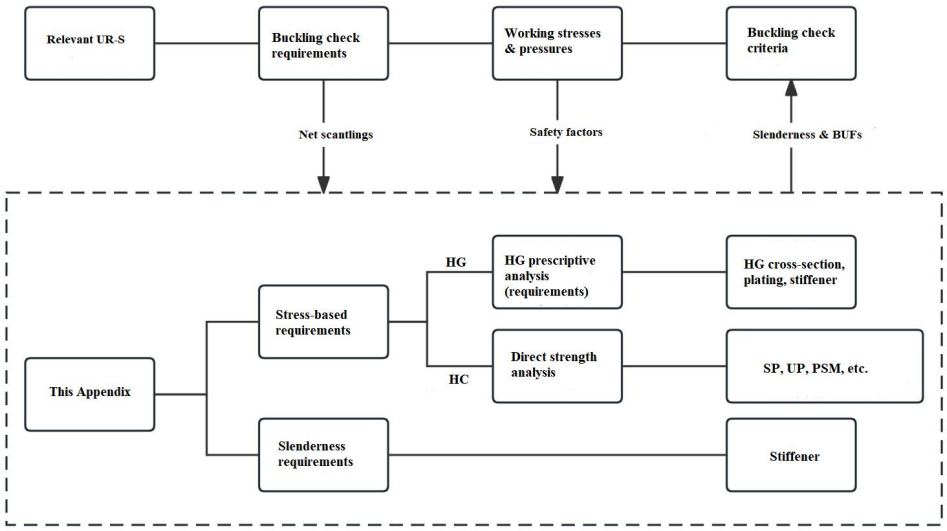


Figure 1.1.1.1 Overview of applying this UR in conjunction with Relevant UR-S

1.1.2 Application of this Appendix

1.1.2.1 Sections of this Appendix and application description

The buckling checks are to be performed according to:

(1) Section 1 for general definitions regarding buckling capacity, allowable buckling utilisation factors and buckling check criteria.

(2) Section 2 for the slenderness requirements of longitudinal and transverse stiffeners①.

(3) Section 3 for the prescriptive buckling requirements of plates, longitudinal and transverse stiffeners, primary supporting members and other structures subject to hull girder stresses②.

---

① The requirements in Section 2 of this Appendix are only applicable to stiffeners in the hatch cover structure.

② The requirements in Section 3 of this Appendix are not mandatory.

(4) Section 4 for direct strength analysis (usually by finite element method) buckling requirements of hatch cover structural members including plates, stiffeners and primary supporting members.
(5) Section 5 for the determination of buckling capacities of plate panels, stiffeners, primary supporting members and column structures.

1.1.2.2 Buckling assessment with this Appendix

For the buckling assessment of a ship hull girder, a hatch cover or other structural components, the slenderness requirements as defined in Section 2 and the buckling requirements as defined in Section 3 or Section 4 are to be checked as per the requirements of the applicable Relevant UR-S.

1.1.2.3 Alternative methods

This Appendix contains the general methods for the determination of buckling capacities of plate panels, stiffeners, primary supporting members, and columns. For special cases not covered in this Appendix, such as a whole plate structure with stiffeners in two directions (i.e., a stiffened panel with both primary and secondary stiffeners), other more advanced methods, such as finite element analysis methods, can be used with the consent of CCS.

1.2 Terminology and Assumptions

1.2.1 Buckling

1.2.1.1 Buckling strength

Buckling strength or capacity refers to the strength of a structure under in-plane compressions and/or shear and lateral load. Buckling strength with consideration of the buckling behaviour in [1.2.1.2] gives a lower bound estimate of ultimate capacity, or the maximum load a structural member can carry without suffering major permanent set.

For each structural member, its buckling strength is to be taken as corresponding to the most unfavourable or critical buckling mode.

1.2.1.2 Buckling behaviour

Buckling strength assessment takes into account both elastic buckling and post-buckling behaviours. Post-buckling can consider the internal redistribution of loads depending on the load situation, slenderness and type of structure. Such as for the buckling assessment of plates, generally its positive elastic post-buckling effect can be utilized.

As such, for slender structures, the calculated buckling strength is typically higher than the ideal elastic buckling stress (minimum eigenvalue). Accepting elastic buckling of slender plate panels implies that large elastic deflections and reduced in-plane stiffness may occur at higher buckling utilisation levels.

1.2.2 Net Scantling Approach

1.2.2.1 General requirements

Unless otherwise specified, all the scantling requirements, including slenderness requirements, in this Appendix are based on net scantlings obtained by removing full corrosion addition t_c from the gross offered thicknesses.

1.2.2.2 Corrosion addition

Corrosion addition t_c referred to in this Appendix is defined in the Relevant UR-S.

1.2.2.3 Stress calculation models

The structural models used for the calculation of stresses to be applied for buckling assessment, which are usually based on net scantlings, are defined in the Relevant UR-S.

1.2.3 Structural Idealisation

1.2.3.1 Elementary plate panel (EPP)

An elementary plate panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary supporting members. The plate panel length, *a*, and breadth, *b*, of the EPP are defined respectively as the longest and shortest plate edges, as shown in Figure 1.2.3.1.

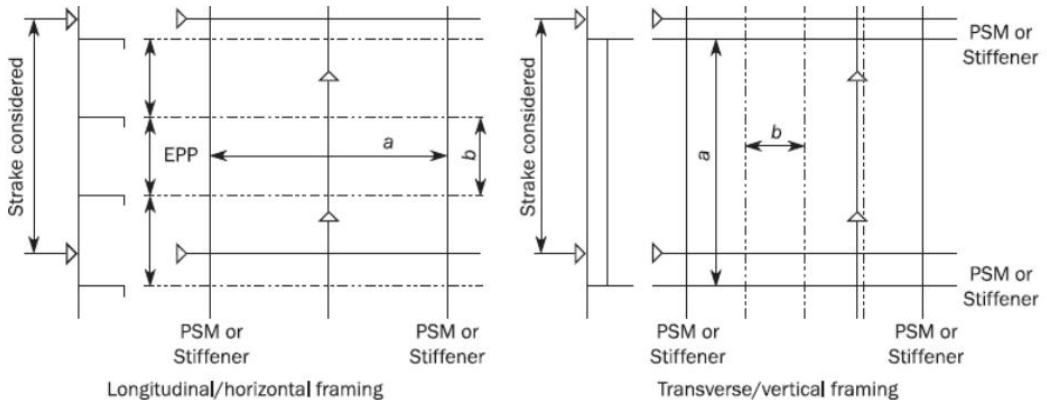


Figure 1.2.3.1 Elementary plate panel (EPP) definition

1.2.3.2 Standard types of stiffeners

Definitions of the cross-sectional dimensions of typical stiffener types are shown in Figure 1.2.3.2(1), which are flat bars, bulb flats, angles, L2 and T bars. If applicable, other types of stiffeners can be idealized to one of the typical types in Figure 1.2.3.2(1) for buckling check. For the U-type stiffener which is usually fitted in some hatch covers, the definition of its cross-sectional dimensions is shown in Figure 1.2.3.2(2).

Unless otherwise specified, the full span or full length *l*, in mm, of a stiffener is to be used for buckling check, which equals to the spacing between primary supporting members.

Symbolic dimensions of the cross-sections are as below:

b_1 —— Width of the attached plate enclosed by the U-type stiffener, in mm, as shown in Figure 1.2.3.2(2);

b_2 —— Width of the attached plate between adjacent U-type stiffeners, in mm, as shown in Figure 1.2.3.2(2);

b_f —— Width of the flange or face plate of the stiffener, in mm, as shown in Figure 1.2.3.2(1) and Figure 1.2.3.2(2);

$b_{f\text{-}out}$ —— Maximum distance, in mm, from mid thickness of the web to the flange edge, in mm, as shown in Figure 1.2.3.2(1);

d_f —— Breadth of the extended part of the flange for L2profiles, in mm, as shown in Figure 1.2.3.2(1);

e_f —— Distance from attached plating to centre of flange, in mm, as shown in Figure 1.2.3.2(1). For its detailed definition, refer to Section 5, Symbols;

h_w —— Depth of stiffener web, in mm, as shown in Figure 1.2.3.2(1) and Figure 1.2.3.2(2);

t_f —— Net flange thickness, in mm;

t_p —— Net thickness of plate, in mm;

t_w —— Net web thickness, in mm.

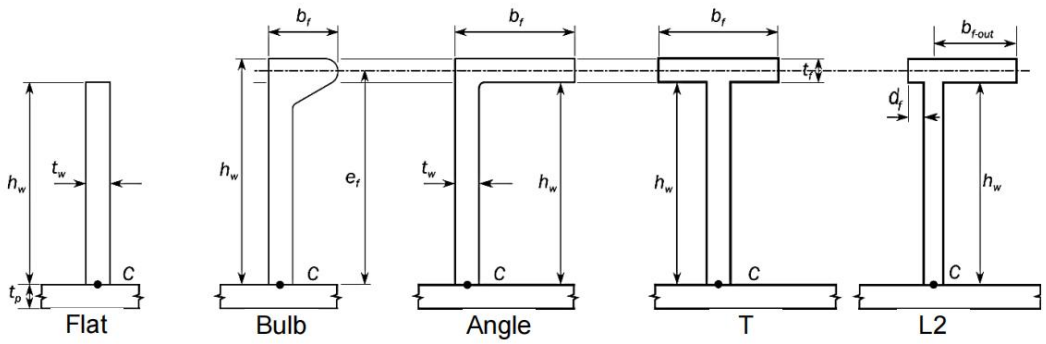


Figure 1.2.3.2(1) Dimensions of typical stiffener cross sections

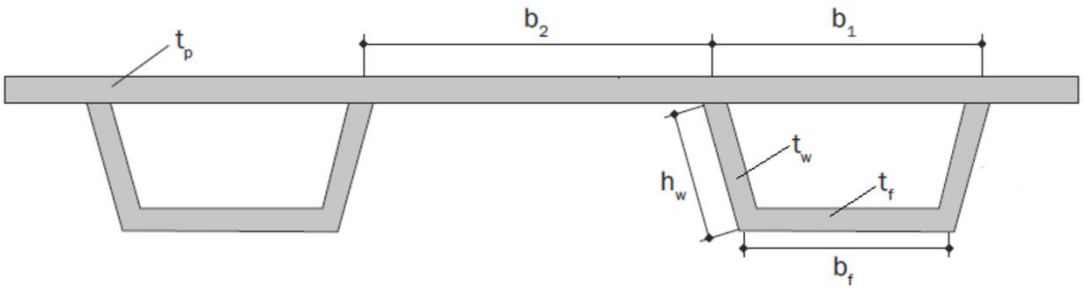


Figure 1.2.3.2(2) Dimensions of a U-type stiffener cross section

1.2.3.3 Stiffened panel (SP) and unstiffened panel (UP)

For a panel with relatively strong interactive effect between the stiffener and its attached plate, each stiffener with its attached plate as a whole is to be modelled as a stiffened panel (SP), so as to be able to consider both of its local and global buckling modes.

However, for an EPP, if its buckling strength can be checked without considering its interactive effect with stiffeners fitted along its edges, it is to be modelled as an unstiffened panel (UP).

1.2.4 Sign Convention

1.2.4.1 Stresses

In this Appendix, compressive and shear stresses are to be taken as positive, tension stresses are to be taken as negative.

1.3 Assessment Methods and Acceptance Criteria

1.3.1 Assessment Methods

1.3.1.1 Method A and Method B

The buckling assessment is to be carried out according to one of the following two methods taking into account different boundary condition types:

(1) Method A: All the edges of the EPP are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates.

(2) Method B: The edges of the EPP are not forced to remain straight due to low in-plane stiffness at the edges and/or no surrounding structure/neighbouring plates.

1.3.1.2 SP-A、SP-B、UP-A and UP-B models

For the buckling assessment of the stiffened panel (SP) and unstiffened panel (UP) structural models defined in [1.2.3.3], with application of either Method A or Method B for the plate buckling assessment, the following four buckling assessment models are established:

(1) SP-A: a stiffened panel with application of Method A.

(2) SP-B: a stiffened panel with application of Method B.

(3) UP-A: an unstiffened panel with application of Method A.

(4) UP-B: an unstiffened panel with application of Method B.

1.3.2 Buckling Utilisation Factor

1.3.2.1 The utilisation factor, η, is defined as the ratio between the applied loads and the corresponding buckling capacity.

1.3.2.2 For combined loads, the utilisation factor, η_{act}, is to be defined as the ratio of the applied equivalent stress and the corresponding buckling capacity, as shown in Figure 1.3.2.2, and is to be taken as:

$$\eta_{act} = \frac{W_{act}}{W_U} = \frac{1}{\gamma_c}$$

where:

W_{act} —— Equivalent applied stress. The actual applied stresses are given in Section 3 and Section 4 respectively for buckling assessment by prescriptive and direct strength analysis;

W_U —— Equivalent buckling capacity. For plates and stiffeners, their respective buckling or ultimate capacities are given in Section 5;

γ_c —— Stress multiplier factor at failure.

For each typical failure mode, the corresponding buckling capacity of the panel is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until collapse occurs, i.e., when the increased or decreased stresses are on a buckling strength interaction curve or surface.

Figure 1.3.2.2 illustrates the buckling capacity and the buckling utilisation factor of a structural member subject to σ_x and σ_y stresses.

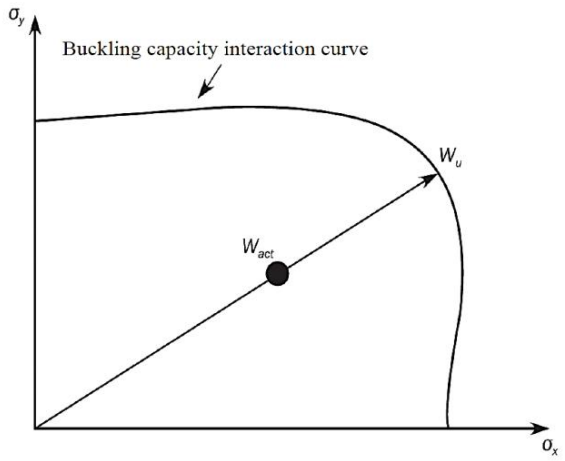


Figure 1.3.2.2 Illustration of buckling capacity and buckling utilisation factor

1.3.3 Allowable Buckling Utilisation Factor

1.3.3.1 The allowable buckling utilisation factor η_{all} is to be taken according to the Relevant UR-S.

1.3.4 Buckling Acceptance Criteria

1.3.4.1 A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where:

η_{act} —— Buckling utilisation factor based on the applied stress, defined in [1.3.2.2];

η_{all} —— Allowable buckling utilisation factor, as defined in [1.3.3.1].

SECTION 2 SLENDERNESS REQUIREMENTS

Symbols

For symbols not defined in this section, refer to Section 1, [1.2.3.2].

R_{eH} —— Specified minimum yield stress of the structural member being considered, in N/mm^2.

2.1 General Requirements

2.1.1 Introduction

2.1.1.1 The stiffener elements except for U-type stiffeners are to comply with the applicable slenderness and proportion requirements given in this Section.

2.2 Stiffeners

2.2.1 Proportions of Stiffeners

2.2.1.1 Net thickness of all stiffener types

The net thickness of stiffeners is to satisfy the following criteria:

(1) Stiffener web plate:

$$t_w \geq \frac{h_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

(2) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where:

C_w, C_f —— Slenderness coefficients given in Table 2.2.1.1.

Slenderness Coefficient **Table 2.2.1.1**

Type of Stiffener	C_w	C_f
Angle and L2 bars	75	12
T-bars	75	12
Bulb flats	45	-
Flat bars	22	-

If requirement (2) is not fulfilled, the effective free flange outstand, in mm, used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-max} = C_f t_f \sqrt{\frac{235}{R_{eH}}}$$

For built-up profile where the relevant yielding strength for the web of built-up profile without the edge stiffener is acceptable, as an alternative the web can be assessed according to the web requirements of Angle and L2 bars in Table 2.2.1.1, and the edge stiffener can be assessed as a flat bar stiffener according to [2.2.1.1]. The requirement to flange in [2.2.1.2] shall still apply.

2.2.1.2 Net dimensions of angle and T-bars

The total flange breadth, b_f, in mm, for angle and T-bars is to satisfy the following criterion:

$$b_f \geq 0.2h_w$$

2.3 Primary Supporting Members

2.3.1 Proportions and Stiffness

2.3.1.1 Proportions of web plate and flange

The scantlings of webs and flanges of primary supporting members are to comply with the relevant requirements of [4.1], Section 2, Chapter 8, PART NINE of the Rules.

SECTION 3 BUCKLING REQUIREMENTS FOR HULL GIRDER PRESCRIPTIVE ANALYSIS

Symbols

η_{all} : Allowable buckling utilisation factor, as defined in Section 1, [1.3.3.1].

LCP：Load calculation point, as defined in [3.1.2.1].

3.1 General Requirements

3.1.1 Introduction

3.1.1.1 This Section applies to plate panels including plane and curved plate panels, stiffeners and corrugation of longitudinal corrugated bulkheads subject to hull girder compression and shear stresses.

3.1.1.2 The ship longitudinal extent where the buckling check is performed for structural elements subject to hull girder stresses is to be in accordance with the Relevant UR-S.

3.1.1.3 Design load sets: The buckling check is to be performed for all design load sets corresponding to the design loading conditions defined in the Relevant UR-S with the most unfavourable pressure combinations.

For each design load set, for all static and dynamic load cases, the lateral pressure is to be determined at the load calculation point defined in [3.1.2.1], and is to be applied together with the hull girder stress combinations defined in the Relevant UR-S.

3.1.2 Definitions

3.1.2.1 Load calculation point

The load calculation points (LCP) for both elementary plate panels (EPP) and stiffeners are defined as follows:

(1) LCP for hull girder stresses of EPP

The hull girder stresses for EPP are to be calculated at the load calculation points defined in Table 3.1.2.1.

Load calculation points (LCP) coordinates for plate buckling assessment

Table 3.1.2.1

LCP coordinates	Hull girder bending stress		Hull girder shear stress
	Non horizontal plating	Horizontal plating	
x coordinate	Mid-length of the EPP		
y coordinate	Both upper and lower ends of the EPP (points A1 and A2 in Figure 3.1.2.1(1))	Outboard and inboard ends of the EPP (points A1 and A2 in Figure 3.1.2.1(1))	Mid-point of EPP (point B in Figure 3.1.2.1(1))
z coordinate	Corresponding to *x* and *y* values		

(2) LCP for hull girder stresses of longitudinal stiffeners

The hull girder stresses for longitudinal stiffeners are to be calculated at the following load calculation point:

① at the mid length of the considered stiffener;

② at the intersection point between the stiffener and its attached plate.

(3) LCP for pressure of horizontal stiffeners

The load calculation point for the pressure is located at:

① middle of the full length, *l*, of the considered stiffener;

② the intersection point between the stiffener and its attached plate.

(4) LCP for pressure of non-horizontal stiffeners

The lateral pressure, *P* is to be calculated as the maximum between the value obtained at middle of the full length, *l*, and the value obtained from the following formulae:

$P = \frac{p_U + p_L}{2}$, when the upper end of the vertical stiffener is below the lowest zero pressure level;

$P = \frac{l_1}{l}\frac{p_L}{2}$, when the upper end of the vertical stiffener is at or above the lowest zero pressure level.

where: l_1 —— Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level;

p_U, p_L ——Lateral pressure at the upper and lower end of the vertical stiffener span, *l*, respectively.

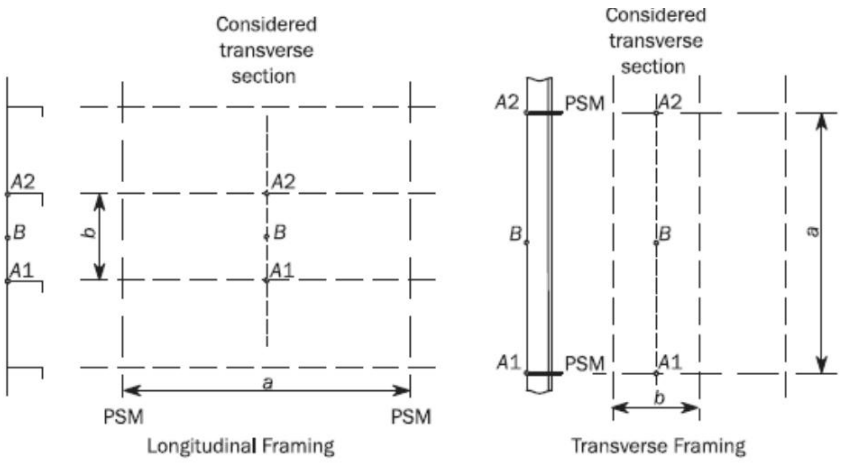


Figure 3.1.2.1(1) LCP for plate buckling assessment (PSM means the primary supporting members)

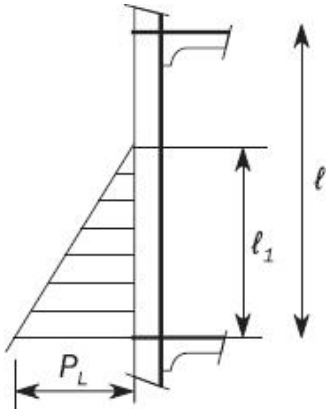


Figure 3.1.2.1(2) Definition of pressure for vertical stiffeners

3.1.3 Equivalent plate panels

3.1.3.1 Longitudinal stiffening with varying plate thickness

In longitudinal stiffening arrangement, when the plate thickness varies over the width b, of a plate panel (EPP), the buckling check is to be performed for an equivalent plate panel width,combined with the smaller plate thickness, t_1. The width of this equivalent plate panel, b_{eq}, in mm, is defined by the following formula:

$$b_{eq} = l_1 + l_2(\frac{t_1}{t_2})^{1.5}$$

where: l_1——Width of the part of the plate panel with the smaller plate thickness, t_1, in mm, as defined in Figure 3.1.3.1;

l_2—— Width of the part of the plate panel with the greater plate thickness, t_2, in mm, as defined in Figure 3.1.3.1.

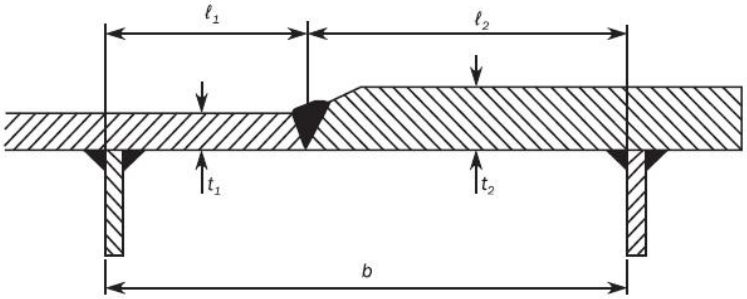


Figure 3.1.3.1 Plate thickness change over the width

3.1.3.2 Transverse stiffening with varying plate thickness

In transverse stiffening arrangement, when an EPP is made with different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the EPP, the stresses and pressures being estimated for the EPP at the LCP.

3.1.3.3 Plate panel with different materials

When the plate panel is made of different materials, the minimum yield strength is to be used for the buckling assessment.

3.2 Buckling Criteria

3.2.1 Overall Stiffened Panel

3.2.1.1 The buckling strength of overall stiffened panels is to satisfy the following criterion:

$$\eta_{overall} \leq \eta_{all}$$

where: $\eta_{overall}$ ——Maximum overall buckling utilisation factor as defined in Section 5, [5.2.1].

3.2.2 Plates

3.2.2.1 The buckling strength of elementary plate panels is to satisfy the following criterion:

$$\eta_{plate} \leq \eta_{all}$$

where: η_{plate} ——Maximum plate buckling utilisation factor as defined in Section 5, [5.2.2] where SP-A model is to be used.

For the determination of η_{plate} of the vertically stiffened side shell plating of single side skin bulk carrier between hopper and topside tanks, the cases 12 and 16 of Section 5, Table 3 corresponding to the shorter edge of the plate panel clamped are to be considered together with a mean σ_y stress and $\varphi_y = 1$.

3.2.3 Stiffeners

3.2.3.1 The buckling strength of stiffeners or of side frames of single side skin bulk carriers is to satisfy the following criterion:

$$\eta_{stiffener} \leq \eta_{all}$$

where：$\eta_{stiffener}$ ——Maximum stiffener buckling utilisation factor as defined in Section 5, [5.2.3].

Note 1: This buckling check can only be fulfilled when the overall stiffened panel buckling check, as defined in [3.2.1], is satisfied.

Note 2: The buckling check of the stiffeners is only applicable to the stiffeners fitted along the long edge of the buckling panel.

3.2.4 Vertically Corrugated Longitudinal Bulkheads

3.2.4.1 The shear buckling strength of vertically corrugated longitudinal bulkheads is to satisfy the following criterion:

$$\eta_{shear} \leq \eta_{all}$$

where: η_{shear} —— Maximum shear buckling utilisation factor, defined as

$$\eta_{shear} = \frac{\tau_{bhd}}{\tau_c} \ ;$$

τ_{bhd} ——Shear stress, in N/mm^2, in the bulkhead taken as the hull girder shear stress defined in the Relevant UR-S;

τ_c —— Shear critical stress, in N/mm^2, as defined in Section 5, [2.2.3].

3.2.5 Horizontally Corrugated Longitudinal Bulkheads

3.2.5.1 Each corrugation unit within the extension of half flange, web and half flange (i.e. single corrugation as shown in grey in Figure 3.2.5.1) is to satisfy the following criterion:

$$\eta_{column} \leq \eta_{all}$$

where: η_{column}—— Overall column buckling utilisation factor, as defined in Section 5, [5.3.1].

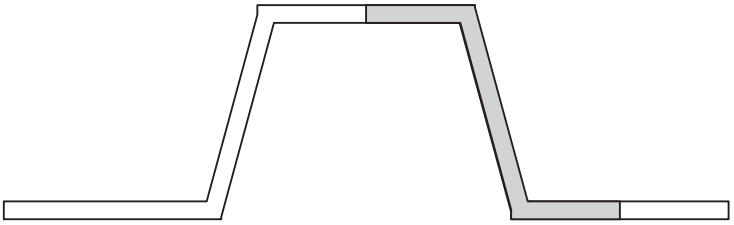


Figure 3.2.5.1 Single corrugation

SECTION 4 BUCKLING REQUIREMENTS FOR DIRECT STRENGTH ANALYSIS OF HATCH COVERS

Symbols

R_{eH_P}——Yield stress of the plate panel, as defined in [4.2.1.3];

R_{eH_S}——Yield stress of the stiffener, as defined in [4.2.1.3];

α—— Aspect ratio of the plate panel as defined in the Symbol list of Section 5;

η_{all} ——Allowable buckling utilisation factor, as defined in Section 1, [1.3.3.1].

4.1 General Requirements

4.1.1 Introduction

4.1.1.1 The requirements of this Section apply to the buckling assessment of hatch cover structural members based on direct strength analysis (usually by finite element method) and subjected to normal stress, shear stress and lateral pressure.

4.1.1.2 All structural elements in the direct strength analysis carried out according to the Relevant UR-S are to be assessed individually. The buckling checks are to be performed for the following structural elements:

- Stiffened and unstiffened panels.
- Web plate in way of openings.

4.2 Stiffened and Unstiffened Panels

4.2.1 General Requirements

4.2.1.1 The plate panel of a hatch cover structure is to be modelled as stiffened panel or unstiffened panel, with either Method A or Method B as defined in Section 1, [1.3.1.1] to be used for the calculation of the plate buckling capacity, which in combination is also equivalent to use the buckling assessment models defined in Section 1, [1.3.1.2].

4.2.1.2 Average thickness of plate panel

For FE analysis, where the plate thickness along a plate panel is not constant, the panel used for the buckling assessment is to be modelled with a weighted average thickness taken as:

$$t_{avr} = \frac{\sum_1^n A_i t_i}{\sum_1^n A_i}$$

where: A_i——Area of the *i*-th plate element;

t_i ——Net thickness of the *i*-th plate element;

n ——Number of finite elements defining the buckling plate panel.

4.2.1.3 Yield stress of the plate panel and stiffener

The panel yield stress R_{eH_P} is taken as the minimum value of the specified yield stresses of the elements within the plate panel.

The stiffener yield stress R_{eH_S} is taken as the minimum value of the specified yield stress of the elements within the stiffener.

4.2.2 Stiffened Panels

4.2.2.1 For a stiffened panel (SP), each stiffener with attached plate is to be idealized as a stiffened panel model of the extent defined in the Relevant UR-S.

4.2.2.2 If the stiffener properties or stiffener spacing varies within the stiffened panel, the calculations are to be performed separately for all configurations of the panels, i.e. for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel.

4.2.2.3 The buckling check of the stiffeners of stiffened panels is only applicable to the stiffeners fitted along the longer side edges of the buckling panel.

4.2.3 Unstiffened Panels

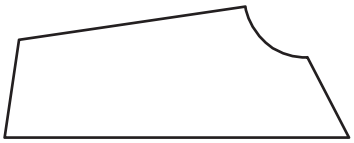
4.2.3.1 Irregular plate panel

In way of web frames, horizontal girders and brackets, the geometry of the panel (i.e. plate bounded by web stiffeners/face plate) may not have a rectangular shape. In this case, an equivalent rectangular panel is to be defined according to [4.2.3.2] for irregular geometry and [4.2.3.3] for triangular geometry and to comply with buckling assessment.

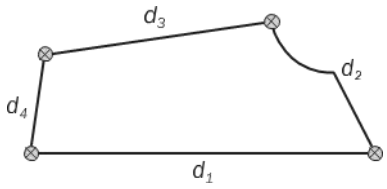
4.2.3.2 Equivalent EPP of an unstiffened panel with irregular geometry

Unstiffened panels with irregular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

(1) The four corners closest to a right angle, 90 deg, in the bounding polygon for the plate are identified.

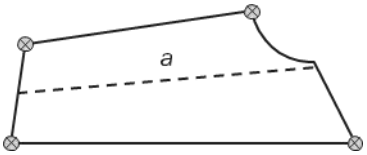


(2) The distances along the plate bounding polygon between the corners are calculated, i.e. the sum of all the straight-line segments between the end points.



(3) The pair of opposite edges with the smallest total length is identified, i.e. minimum of $d_1 + d_3$ and $d_2 + d_4$.

(4) A line joins the middle points of the chosen opposite edges (i.e. a mid-point is defined as the point at half the distance from one end). This line defines the longitudinal direction for the capacity model. The length of the line defines the length of the capacity model, a, measured from one end point.



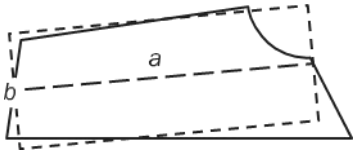
(5) The length of shorter side, *b,* in mm, is to be taken as:

$$b = \frac{A}{a}$$

where:

A —— Area of the plate in mm^2;

a —— Length defined in (4), in mm.

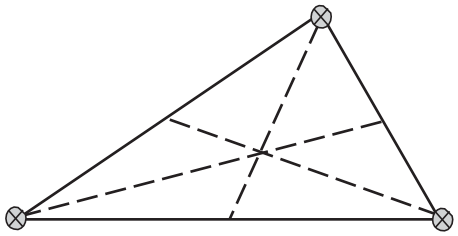


(6) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.

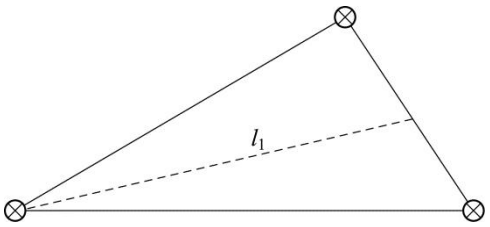
4.2.3.3 Modeling of an unstiffened plate panel with triangular geometry

Unstiffened panels with triangular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

(1) Medians are constructed as shown below:



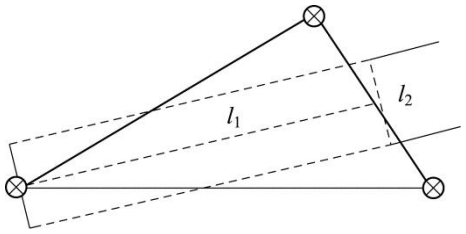
(2) The longest median is identified. This median the length of which is l_1, in mm, defines the longitudinal direction for the capacity model.



(3) The width of the model, l_2, in mm, is to be taken as:

$$l_2 = \frac{A}{l_1}$$

where: *A* —— Area of the plate, in mm^2.



(4) The lengths of shorter side, *b,* and of the longer side, *a*, in mm, of the equivalent rectangular plate panel are to be taken as:

$$b = \frac{l_2}{C_{tri}}$$

$$a = l_1 C_{tri}$$

where: $C_{tri} = 0.4\frac{l_2}{l_1} + 0.6$

(5) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel and are to be used for the buckling assessment of the equivalent rectangular panel.

4.2.4 Reference Stress

4.2.4.1 The stress distribution is to be taken from the direct strength analysis according to the Relevant UR-S and applied to the buckling model.

4.2.4.2 For FE analysis, the reference stresses are to be calculated using the stress-based reference stresses as defined in Section 6.

4.2.5 Lateral Pressure

4.2.5.1 The lateral pressure applied to the direct strength analysis is also to be applied to the buckling assessment.

4.2.5.2 Where the lateral pressure is not constant over a buckling panel defined by a number of finite plate elements, an average lateral pressure, in N/mm^2, is calculated using the following formula:

$$P_{avr} = \frac{\sum_1^n A_i P_i}{\sum_1^n A_i}$$

where:

A_i—— Area of the *i*-th plate element, in mm^2;

P_i—— Lateral pressure of the *i*-th plate element, in N/mm^2;

n—— Number of the finite elements in the buckling panel.

4.2.6 Buckling Criteria

4.2.6.1 UP-A

The compressive buckling strength of UP-A is to satisfy the following criterion:

$$\eta_{UP-A} \leq \eta_{all}$$

where: η_{UP-A} —— Maximum buckling utilisation factor of plate, calculated according to Method A as defined in Section 5, [5.2.2].

4.2.6.2 UP-B

The compressive buckling strength of UP-B is to satisfy the following criterion:

$$\eta_{UP-B} \leq \eta_{all}$$

where: η_{UP-B} —— Maximum buckling utilisation factor of plate, calculated according to Method B as defined in Section 5, [5.2.2].

4.2.6.3 SP-A

The compressive buckling strength of SP-A is to satisfy the following criterion:

$$\eta_{SP-A} \leq \eta_{all}$$

where: $\eta_{SP\text{-}A}$—— Buckling utilisation factor of the stiffened panel, taken as the maximum of the buckling utilisation factors calculated as below:

- The overall stiffened panel buckling utilisaiton factor $\eta_{overall}$ as defined in Section 5, [5.2.1];
- The plate buckling utilisation factor η_{plate} calculated according to Method A as defined in Section 5 [5.2.2];
- The stiffener buckling utilisation factor $\eta_{stiffener}$ as defined in Section 5, [5.2.3] considering separately the properties (thickness, dimensions), the pressures defined in [4.2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note 1: The stiffener buckling strength check can only be fulfilled when the overall stiffened panel capacity check, as defined in Section 5, [5.2.1], is satisfied.

4.2.6.4 SP-B

The compressive buckling strength of SP-B is to satisfy the following criterion:

$$\eta_{SP-B} \leq \eta_{all}$$

where: $\eta_{SP\text{-}B}$—— Buckling utilisation factor of the stiffened panel, taken as the maximum of the buckling utilisation factors calculated as below:

- The overall stiffened panel buckling utilisation factor $\eta_{overall}$ as defined in Section 5, [5.2.1];
- The plate buckling utilisation η_{plate} calculated according to Method B as defined in Section 5, [5.2.2];
- The stiffener buckling utilisation factor $\eta_{stiffener}$ as defined in Section 5, [5.2.3] considering separately the properties (thickness, dimensions), the pressures defined in [4.2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note 1: The stiffener buckling strength check can only be fulfilled when the overall stiffened panel capacity check, as defined in Section 5, [5.2.1], is satisfied.

4.2.6.5 Web plate in way of openings

The web plate of primary supporting members with openings is to satisfy the following criterion:

$$\eta_{opening} \leq \eta_{all}$$

where: $\eta_{opening}$—— Maximum web plate utilisation factor in way of openings, calculated with the definition in Section 1, [1.3.2.2] and the stress multiplier factor at failure γ_c which can be calculated following the requirements in Section 5, [5.2.4].

SECTION 5 BUCKLING CAPACITY

Symbols

A_p —— Net sectional area of the stiffener attached plating, in mm^2, taken as:

$A_p = st_p$;

A_s —— Net sectional area of the stiffener without attached plating, in mm^2;

a —— Length of the longer side of the plate panel, in mm;

b —— Length of the shorter side of the plate panel, in mm;

b_{eff} —— Effective width of the attached plating of a stiffener, in mm, as defined in [5.2.3.5];

b_{eff1} —— Effective width of the attached plating of a stiffener, in mm, without the shear lag effective taken as:

(1) For $\sigma_x > 0$,

① For prescriptive assessment:

$$b_{eff1} = \frac{C_{x1}b_1 + C_{x2}b_2}{2}$$

② For FE analysis:

$$b_{eff1} = C_x b$$

(2) For $\sigma_x \leq 0$,

$$b_{eff1} = b;$$

b_f —— Breadth of the stiffener flange, in mm;

b_1, b_2 —— Width of plate panel on each side of the considered stiffener, in mm. For stiffened panels fitted with U-type stiffeners, b_1 and b_2 are as defined in Section 1, Figure 1.2.3.2(2);

C_{x1}, C_{x2} —— Reduction factor defined in Table 5.2.2.3 calculated for the EPP1 and EPP2 on each side of the considered stiffener according to case 1;

d —— Length of the side parallel to the cylindrical axis of the cylinder corresponding to the curved plate panel as shown in Table 5.2.2.6, in mm;

e_f —— Distance from attached plating to center of flange, in mm, as shown in Section 1, Figure 1.2.3.2(1), to be taken as:

$e_f = h_w$ for flat bar profile

$e_f = h_w - 0.5t_f$ for bulb profile

$e_f = h_w + 0.5t_f$ for angle, L2 and T profiles.

F_{long} —— Coefficient defined in [5.2.2.4];

F_{tran} —— Coefficient defined in [5.2.2.5];

h_w —— Depth of stiffener web, in mm, as shown in Section 1, Figure 1.2.3.2(1);

l —— Span, in mm, of stiffener equal to spacing between primary supporting members of span of side frame equal to the distance between the hopper tank and top wing tank in way of the side shell;

R —— Radius of curved plate panel, in mm;

R_{eH_P} —— Specified minimum yield stress of the plate, in N/mm^2;

R_{eH_S} —— Specified minimum yield stress of the stiffener, N/mm^2;

S —— Partial safety factor, unless otherwise specified in the Relevant UR-S, to be taken as 1.0;

t_p —— Net thickness of plate panel, in mm;

t_w —— Net stiffener web thickness, in mm;

t_f —— Net flange thickness, in mm;

x-axis —— Local axis of a rectangular buckling panel parallel to its long edge;

y-axis —— Local axis of a rectangular buckling panel perpendicular to its long edge;

α —— Aspect ratio of the plate panel, defined in Table 5.2.2.3, to be taken as: $\alpha = \frac{a}{b}$;

β —— Coefficient taken as: $\beta = \frac{1-\psi}{\alpha}$;

ω —— Coefficient taken as: $\omega = min\,(3, \alpha)$;

σ_x —— Normal stress applied on the edge along *x*-axis of the buckling panel, in N/mm^2;

σ_y —— Normal stress applied on the edge along *y*-axis of the buckling panel, in N/mm^2;

σ_1 —— Maximum normal stress along a panel edge, in N/mm^2;

σ_2 —— Minimum normal stress along a panel edge, in N/mm^2;

σ_E —— Elastic buckling reference stress, in N/mm^2, to be taken as:

(1) For the application of the limit state of plane plate panels according to [5.2.2.1]:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{b}\right)^2$$

(2) For the application of the limit state of curved plate panels according to [5.2.2.6]:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{d}\right)^2;$$

τ —— Applied shear stress, in N/mm^2;

τ_c —— Buckling strength in shear, in N/mm^2;

ψ —— Edge stress ratio to be taken as: $\psi = \frac{\sigma_2}{\sigma_1}$;

γ —— Stress multiplier factor acting on loads. When the factor is such that the loads reach the interaction formulae, $\gamma = \gamma_c$;

γ_c —— Stress multiplier factor at failure;

γ_{GEB} —— Stress multiplier factor of global elastic buckling capacity.

5.1 General Requirements

5.1.1 Introduction

5.1.1.1 This Section contains the methods for determination of the buckling capacities of plate panels, stiffeners, primary supporting members and columns.

5.1.1.2 For the application of this Section, the stresses σ_x, σ_y and τ applied on the structural members are defined in:

(1) Section 3 for hull girder prescriptive buckling requirements.

(2) Section 4 for direct strength analysis buckling requirements of hatch covers.

5.1.1.3 Buckling capacity

The buckling capacity is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until the interaction formulae defined in [5.2.1.1], [5.2.2.1] and [5.2.3.4] of this Section are equal to 1.0, respectively.

5.1.1.4 Buckling utilisation factor

The buckling utilisation factor of the structural member is equal to the highest utilisation factor obtained for the different buckling modes.

5.1.1.5 Lateral pressure

The lateral pressure is to be applied and considered as constant for the calculation of buckling capacities as defined in [5.1.1.3].

5.2 Buckling Capacity of Plate Panels

5.2.1 Overall Stiffened Panels

5.2.1.1 The elastic stiffened panel limit state is based on the following interaction formula, which sets a precondition for the buckling check of stiffeners in accordance with [5.2.3.4]:

$$\frac{\gamma_c}{\gamma_{GEB}} = 1$$

with the corresponding buckling utilisation factor defined as:

$$\eta_{overall} = \frac{1}{\gamma_c}$$

where: the stress multiplier factor of global elastic buckling capacity, γ_{GEB}, are to be calculated based on the following formulae:

$\gamma_{GEB} = \gamma_{GEB,bi+\tau}$ for $\tau \neq 0$ and ($\sigma_x > 0$ or $\sigma_y > 0$) ;

$\gamma_{GEB} = \gamma_{GEB,bi}$ for $\tau = 0$ and ($\sigma_x > 0$ or $\sigma_y > 0$) ;

$\gamma_{GEB} = \gamma_{GEB,\tau}$ for $\tau \neq 0$ and ($\sigma_x \leq 0$ or $\sigma_y \leq 0$) .

where: $\gamma_{GEB,bi+\tau}$, $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are stress multiplier factors of the global elastic buckling capacity for different load combinations as defined in [5.2.1.2], [5.2.1.3] and [5.2.1.4], respectively. For the calculation of $\gamma_{GEB,bi+\tau}$, $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$, neither σ_x nor σ_y are to be taken less than 0.

σ_x, σ_y —— Applied normal stress to the plate panel, in N/mm^2, to be taken as defined in [5.2.2.7];

τ —— Applied shear stress, in N/mm^2, to be taken as defined in [5.2.2.7].

5.2.1.2 The stress multiplier factor $\gamma_{GEB,bi}$ for the stiffened panel subjected to biaxial loads is taken as:

$$\gamma_{GEB,bi} = \frac{\pi^2}{L_{B1}^2 L_{B2}^2} \frac{\left[D_{11}L_{B2}^4 + 2(D_{12} + D_{33})n^2 L_{B1}^2 L_{B2}^2 + n^4 D_{22} L_{B1}^4\right]}{L_{B2}^2 N_x + n^2 L_{B1}^2 N_y}$$

where:

N_x—— Load per unit length applied on the edge along *x*-axis of the stiffened panel, in N/mm, taken as

$N_x = \sigma_{x,av}(A_p + A_s)/s$

For stiffened panels fitted with U-type stiffeners, stiffener spacing *s* is taken as:

$s = b_1 + b_2$

Where b_1 and b_2 are as defined in Figure 5.3.1.4;

N_y—— Load per unit length applied on the edge along *y*-axis of the stiffened panel, in 方 N/mm, taken as:

$N_y = c\sigma_y t_p$;

L_{B1}—— Stiffener span, in mm, distance between primary supporting members, i.e.

$L_{B1} = l$;

L_{B2}—— Width of stiffened panel between stiffened panels, in mm, taken as 6 times of the stiffer spacing, i.e. $L_{B2} = 6s$;

n—— Number of half waves along the direction perpendicular to the stiffener axis. The factor $\gamma_{GEB,bi}$ is to be taken as the smallest value larger than 0.

c—— Factor taking into account the normal stress distribution in the panel boundaries acting perpendicular to the stiffener's axis:

$c = 0.5(1 + \Psi)$ for $0 \leq \Psi \leq 1$;

$c = \frac{1}{2(1-\Psi)}$ for $\Psi < 0$;

Ψ—— Edge stress ratio for case 2 according to Table 5.3.1.3;

$\sigma_{x,av}$—— Average stress, in MPa, for both plate and stiffener after Poisson correction, taken as:

$\sigma_{x,av} = \sigma_x - \nu c\sigma_y A_s/(A_p + A_s) \geq 0$ for $\sigma_x > 0$ and $\sigma_y > 0$

$\sigma_{x,av} = \sigma_x$ for $\sigma_x \leq 0$ or $\sigma_y \leq 0$;

$D_{11}, D_{12}, D_{22}, D_{33}$ —— Bending stiffness coefficients, in N·mm, of the stiffened panel, defined in general as:

$$\left.\begin{aligned} D_{11} &= \frac{EI_{eff}10^4}{s} \\ D_{12} &= \frac{Et_p^3\nu}{12(1-\nu^2)} \\ D_{22} &= \frac{Et_p^3}{12(1-\nu^2)} \\ D_{33} &= \frac{Et_p^3}{12(1+\nu)} \end{aligned}\right\}$$

For stiffened panels fitted with U-type stiffeners, D_{12} and D_{22} are defined as:

$$D_{22} = \frac{Et_p^3}{12(1-\nu^2)}\left[1.2 + 4.8 \times Min\left(1.0,\ \frac{b_1^2}{h_w(b_1+b_2)}\right) \times Min\left(1.0, \left(\frac{t_w}{t_p}\right)^3\right)\right]$$

$$D_{12} = \nu D_{22}$$

h_w—— Breadth of U-type stiffener web as defined in Figure 5.3.1.4;

I_{eff}——Moment of inertia, in cm^4, of the stiffener including the effective width of the attached plating, same as I defined in [5.2.3.4].

5.2.1.3 The stress multiplier factor $\gamma_{GEB,\tau}$, for the stiffened panel subjected to pure shear load is taken as:

$$\gamma_{GEB,\tau} = \frac{\sqrt[4]{D_{11}^3 D_{22}}}{(L_{B1}/2)^2 N_{xy}}\left[8.125 + 5.64\sqrt{\frac{(D_{12}+D_{33})^2}{D_{11}D_{22}}} - 0.6\frac{(D_{12}+D_{33})^2}{D_{11}D_{22}}\right] \quad \text{for } D_{11}D_{22} \geq (D_{12}+D_{33})^2$$

$$\gamma_{GEB,\tau} = \frac{\sqrt{2D_{11}(D_{12}+D_{33})}}{(L_{B1}/2)^2 N_{xy}}\left[8.3 + 1.525\frac{D_{11}D_{22}}{(D_{12}+D_{33})^2} - 0.493\frac{D_{11}^2 D_{22}^2}{(D_{12}+D_{33})^4}\right] \text{ for } D_{11}D_{22} < (D_{12}+D_{33})^2$$

where: $N_{xy} = \tau t_p$

5.2.1.4 The stress multiplier factor$\gamma_{GEB,bi+\tau}$, for the stiffened panel subjected to combined loads is taken as:

$$\gamma_{GEB,bi+\tau} = \frac{1}{2}{\gamma_{GEB,\tau}}^2\left[-\frac{1}{\gamma_{GEB,bi}} + \sqrt{\frac{1}{{\gamma_{GEB,bi}}^2} + 4\frac{1}{{\gamma_{GEB,\tau}}^2}}\right]$$

where: $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are as defined in [5.2.1.2] and [5.2.1.3], respectively.

5.2.2 Plates

5.2.2.1 Plate limit state

The plate limit state is based on the following interaction formulae:

$$\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}}\right)^{e_0} - B\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}}\right)^{\frac{e_0}{2}}\left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}}\right)^{\frac{e_0}{2}} + \left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}}\right)^{e_0} + \left(\frac{\gamma_{c1}|\tau|S}{\tau_c}\right)^{e_0} = 1$$

$$\left(\frac{\gamma_{c2}\sigma_x S}{\sigma_{cx}}\right)^{\frac{2}{\beta_p^{0.25}}} + \left(\frac{\gamma_{c2}|\tau|S}{\tau_c}\right)^{\frac{2}{\beta_p^{0.25}}} = 1 \text{ for } \sigma_x \geq 0$$

$$\left(\frac{\gamma_{c3}\sigma_y S}{\sigma_{cy}}\right)^{\frac{2}{\beta_p^{0.25}}} + \left(\frac{\gamma_{c3}|\tau|S}{\tau_c}\right)^{\frac{2}{\beta_p^{0.25}}} = 1 \text{ for } \sigma_y \geq 0$$

$$\frac{\gamma_{c4}|\tau|S}{\tau_c} = 1$$

with:

$$\gamma_c = Min\,(\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4})$$

and the corresponding buckling utilisation factor defined as:

$$\eta_{plate} = \frac{1}{\gamma_c}$$

where:

σ_x, σ_y ____ Applied normal stress to the plate panel, in N/mm^2, to be taken as defined in [5.2.2.7];

τ ____ Applied shear stress to the plate panel, in N/mm^2;

σ_{cx}____ Ultimate buckling stress, in N/mm^2, in direction parallel to the longer edge of the buckling panel as defined in [5.2.2.3];

σ_{cy}____ Ultimate buckling stress, in N/mm^2, in direction parallel to the shorter edge of the buckling panel as defined in [5.2.2.3];

τ_c____ Ultimate buckling shear stress, in N/mm^2, as defined in [5.2.2.3];

$\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4}$ Stress multiplier factors at failure for each of the above different limit states. γ_{c2} and γ_{c3} are only to be considered when $\sigma_x \geq 0$ and $\sigma_y \geq 0$ respectively.

B ____ Coefficient given in Table 5.2.2.1;

e_0____ Coefficient given in Table 5.2.2.1;

β_p____ Plate slenderness parameter taken as:

$\beta_p = \frac{b}{t_p}\sqrt{\frac{R_{eH_P}}{E}}$.

Definition of coefficients of B and e_0 Table 5.2.2.1

Applied stress	$\boldsymbol{B}$	$\boldsymbol{e_0}$
$\sigma_x \geq 0$ and $\sigma_y \geq 0$	$0.7 - 0.3\,\beta_p/\alpha^2$	$2/\beta_p^{0.25}$
$\sigma_x < 0$ or $\sigma_y < 0$	1.0	2.0

5.2.2.2 Reference degree of slenderness

The reference degree of slenderness is to be taken as:

$$\lambda = \sqrt{\frac{R_{eH_P}}{K\sigma_E}}$$

where: K——Buckling factor, as defined in Table 5.2.2.3 and Table 5.2.2.6.

5.2.2.3 Ultimate buckling stresses

The ultimate buckling stresses of plate panels, in N/mm^2, are to be taken as:

$$\sigma_{cx} = C_x R_{eH_P}$$

$$\sigma_{cy} = C_y R_{eH_P}$$

The ultimate buckling stress of plate panels subject to shear, in N/mm^2, is to be taken as:

$$\tau_c = C_\tau \frac{R_{eH_P}}{\sqrt{3}}$$

where: C_x, C_y, C_τ ——Reduction factors, as defined in Table 5.2.2.3.

For the 1st Equation of [5.2.2.1], when $\sigma_x < 0$ or $\sigma_y < 0$, the reduction factors are to be taken as :

$$C_x = C_y = C_\tau = 1$$

For other cases:

(1) For SP-A and UP-A, c_1 is calculated according to Table 5.2.2.3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

(2) For SP-B and UP-B, c_1 is calculated according to Table 5.2.2.3 by using

$$c_1 = 1$$

(3) For vertically stiffened single side skin of bulk carrier, c_1 is calculated according to Table 5.2.2.3 by using

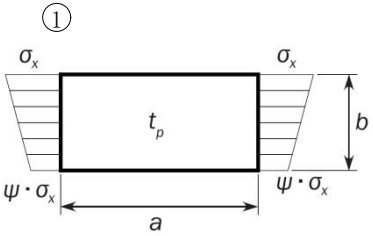
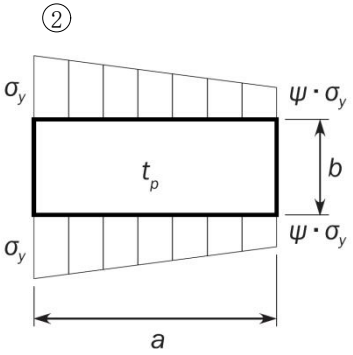
$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

(4) For corrugation of corrugated bulkheads, c_1 is calculated according to Table 5.2.2.3 by using

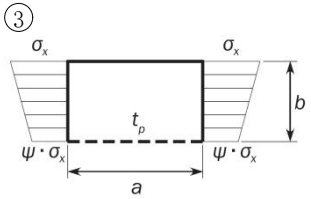
$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

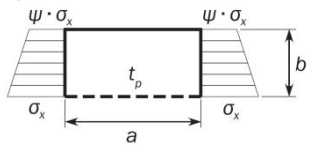
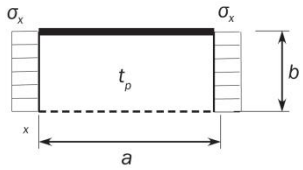
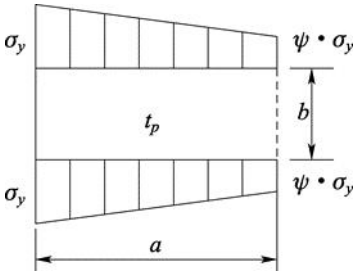
The boundary conditions for plates are to be considered as simply supported, see cases in ①, ② and ⑮ of Table 5.2.2.3. If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of Table 5.2.2.3 with the consent of CCS.

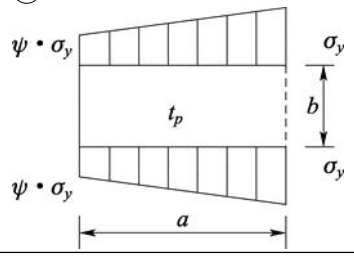
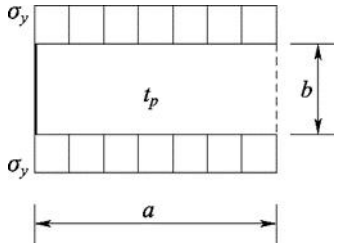
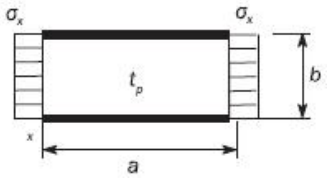
Buckling factor and reduction factor plane plate panels Table 5.2.2.3

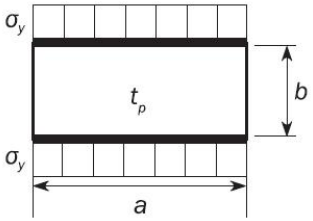
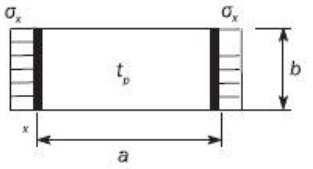
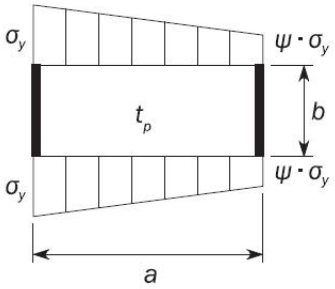
Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
① 	$1 \geq \psi \geq 0$	$K_x = F_{long}\dfrac{8.4}{\psi + 1.1}$		When $\sigma_x \leq 0$, $C_x = 1$; When $\sigma_x > 0$, $C_x = 1$ for $\lambda \leq \lambda_c$; $C_x = c\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ where: $c = (1.25 - 0.12\psi) \leq 1.25$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$
	$0 > \psi > -1$	$K_x = F_{long}[7.63 - \psi(6.26 - 10\psi)]$		
	$\psi \leq -1$	$K_x = F_{long}\left[5.975(1-\psi)^2\right]$		
② 	$1 \geq \psi \geq 0$	$K_y = F_{tran}\dfrac{2\left(1+\frac{1}{\alpha^2}\right)^2}{1+\psi+\frac{(1-\psi)}{100}\left(\frac{2.4}{\alpha^2}+6.9 f_1\right)}$		When $\sigma_y \leq 0$, $C_y = 1$; When $\sigma_y > 0$: $C_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2(H-R)}{\lambda^2}\right)$ where: $c = (1.25 - 0.12\psi) \leq 1.25$ $R = \lambda\left(1 - \dfrac{\lambda}{c}\right)$ for $\lambda < \lambda c$ $R = 0.22$ for $\lambda \geq \lambda c$
		$\alpha \leq 6$	$f_1 = (1-\psi)(\alpha - 1)$	
		$\alpha > 6$	$f_1 = 0.6(1 - \dfrac{6\psi}{\alpha})(\alpha + \dfrac{14}{\alpha})$ but not greater than $14.5 - \dfrac{0.35}{\alpha^2}$	

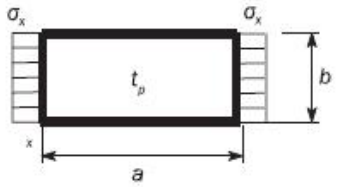
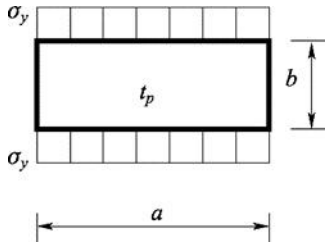
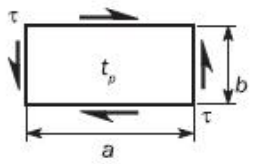
<table>
<tr>
<td></td>
<td>$1-\frac{4\alpha}{3} \le \psi < 0$</td>
<td colspan="2">$K_y = \frac{200F_{tran}\left(1+\beta^2\right)^2}{(1-f_3)(100+2.4\beta^2+6.9f_1+23f_2)}$</td>
<td rowspan="5">$\lambda_c = 0.5c(1+\sqrt{1-0.88/c})$
$F = \left(1-\left(\frac{K}{0.91}-1\right)\Big/\lambda_p^2\right)c_1 \ge 0$
$\lambda_p^2 = \lambda^2 - 0.5$ for $1 \le \lambda_p^2 \le 3$
c_1 as defined in 5.1.1.3.
$H = \lambda - \frac{2\lambda}{c(T+\sqrt{T^2-4})} \ge R$
$T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$</td>
</tr>
<tr>
<td></td>
<td>$\alpha > 6(1-\psi)$</td>
<td>$f_1 = 0.6(\frac{1}{\beta}+14\beta)$
but not greater than
$14.5-0.35\beta^2$
$f_2 = f_3 = 0$</td>
</tr>
<tr>
<td></td>
<td>$3(1-\psi) \le \alpha \le 6(1-\psi)$</td>
<td>$f_1 = \frac{1}{\beta}-1$
$f_2 = f_3 = 0$</td>
</tr>
<tr>
<td></td>
<td>$1.5(1-\psi) \le \alpha < 3(1-\psi)$</td>
<td>$f_1 = \frac{1}{\beta}-(2-\omega\beta)^4-9(\omega\beta-1)(\frac{2}{3}-\beta)$
$f_2 = f_3 = 0$</td>
</tr>
<tr>
<td></td>
<td>$1-\psi \le \alpha < 1.5(1-\psi)$</td>
<td>For $\alpha > 1.5$,
$f_1 = 2\left(\frac{1}{\beta}-16\left(1-\frac{\omega}{3}\right)^4\right)(\frac{1}{\beta}-1)$
$f_2 = 3\beta-2$; $f_3 = 0$
For $\alpha \le 1.5$,
$f_1 = 2\left(\frac{1.5}{1-\psi}-1\right)\left(\frac{1}{\beta}-1\right)$</td>
</tr>
</table>

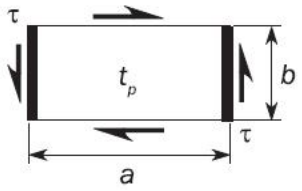
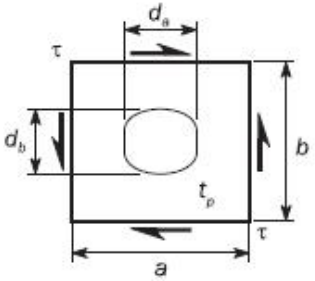
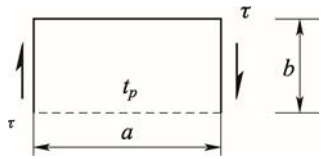
			$f_2 = \frac{\psi(1-16f_4^2)}{1-\alpha}$; $f_3 = 0$ $f_4 = \left[1.5 - Min(1.5;\alpha)\right]^2$	
		$0.75(1-\psi) \le \alpha < (1-\psi)$	$f_1 = 0$ $f_2 = 1 + 2.31(\beta - 1) - 48\left(\frac{4}{3} - \beta\right) f_4^2$ $f_3 = 3f_4(\beta - 1)\left(\frac{f_4}{1.81} - \frac{\alpha - 1}{1.31}\right)$ $f_4 = \left[1.5 - \text{Min}(1.5;\alpha)\right]^2$	
	$\psi < 1 - \frac{4\alpha}{3}$	$K_y = 5.972 F_{tran} \frac{\beta^2}{1 - f_3}$ where, $f_3 = f_5\left(\frac{f_5}{1.81} + \frac{1+3\psi}{5.24}\right)$ $f_5 = \frac{9}{16}\left[1 + Max(-1;\psi)\right]^2$		
③  	$1 \ge \psi \ge 0$	$K_x = \frac{4(0.425 + 1/\alpha^2)}{3\psi + 1}$		For UP-A: $C_x = 1$ for $\lambda \le 0.75$ $C_x = \frac{0.75}{\lambda}$ for $\lambda > 0.75$ For UP-B:
	$0 > \psi > -1$	$K_x = 4(0.425 + 1/\alpha^2)(1+\psi)$ $-5\psi(1 - 3.42\psi)$		

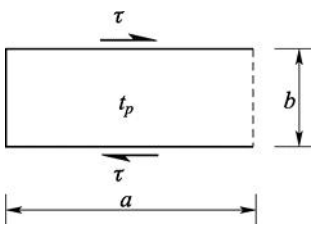
<table>
<tr>
<td>④
  </td>
<td>$1 \geq \psi \geq -1$</td>
<td colspan="2">$K_x = \left(0.425 + \frac{1}{\alpha^2}\right)\frac{3-\psi}{2}$</td>
<td rowspan="3">$C_x = 1$ for $\lambda \leq 0.7$
$C_x = \frac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$</td>
</tr>
<tr>
<td rowspan="2">⑤
  </td>
<td rowspan="2">-</td>
<td>$\alpha \geq 1.64$</td>
<td>$K_x = 1.28$</td>
</tr>
<tr>
<td>$\alpha < 1.64$</td>
<td>$K_x = \frac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$</td>
</tr>
<tr>
<td rowspan="2">⑥
  </td>
<td>$1 \geq \psi \geq 0$</td>
<td colspan="2">$K_y = \frac{4(0.425+\alpha^2)}{(3\psi+1)\alpha^2}$</td>
<td rowspan="2">For UP-A:
$C_y = 1$ for $\lambda \leq 0.75$
$C_y = \frac{0.75}{\lambda}$ for $\lambda > 0.75$
For UP-B:
$C_y = 1$ for $\lambda \leq 0.7$
$C_y = \frac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$</td>
</tr>
<tr>
<td>$0 > \psi \geq -1$</td>
<td colspan="2">$K_y = 4\left(0.425+\alpha^2\right)(1+\psi)\frac{1}{\alpha^2} - 5\psi(1-3.42\psi)\frac{1}{\alpha^2}$</td>
</tr>
</table>

⑦ 	$1 \geq \psi \geq -1$	$K_y = \left(0.425 + \alpha^2\right)\frac{3-\psi}{2\alpha^2}$	
⑧ 	--	$K_y = 1 + \frac{0.56}{\alpha^2} + \frac{0.13}{\alpha^4}$	
⑨ 	—	$K_x = 6.97$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
⑩	—	$K_y = 4 + \frac{2.07}{\alpha^2} + \frac{0.67}{\alpha^4}$	$C_y = 1$ for $\lambda \leq 0.83$ $C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$

				
⑪ 	—	$\alpha \geq 4$	$K_x = 4$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 4 + 2.74\left[\frac{4-\alpha}{3}\right]^4$	
⑫ 	-	K_y = K_y determined as per case ②		For $\alpha < 2$, $C_y = C_{y2}$; For $\alpha \geq 2$, $C_y = \left(1.06 + \frac{1}{10\alpha}\right) C_{y2}$; where, C_{y2}: C_y determined as per case ②

⑬ 	—	$\alpha \geq 4$	$K_x = 6.97$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 6.97 + 3.1\left[\frac{4-\alpha}{3}\right]^4$	
⑭ 	—	$K_y = \frac{6.97}{\alpha^2} + \frac{3.1}{\alpha^4}\left(\frac{4-1/\alpha}{3}\right)^4$		$C_y = 1$ for $\lambda \leq 0.83$ $C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
⑮ 	—	$K_\tau = \sqrt{3}\left[5.34 + \frac{4}{\alpha^2}\right]$		$C_\tau = 1$ for $\lambda \leq 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
⑯	—	$K_\tau = \sqrt{3}\left[5.34 + \mathrm{Max}\left[\frac{4}{\alpha^2}; \frac{7.15}{\alpha^{2.5}}\right]\right]$		

			
⑰ 	—	$K_\tau = K_{\tau case15} r$ $K_{\tau case15}$: K_τ according to case ⑮ r = opening reduction factor taken as $r = \left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$ with $\frac{d_a}{a} \le 0.7$ *and* $\frac{d_b}{b} \le 0.7$	
⑱ 	—	$K_\tau = \sqrt{3}\left(0.6 + \frac{4}{\alpha^2}\right)$	$C_\tau = 1$ for $\lambda \le 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
⑲	—	$K_\tau = 8$	

			
Edge boundary conditions：- - - - - - - - - - - - Plate edge free; ——————Plate edge simply supported; ▬▬▬ Plate edge clamped.			
Note (1): Cases listed are general cases. Each stress component (σ_x, σ_y) is to be understood in local coordinates.			

5.2.2.4 Correction factor F_{long}

The correction factor F_{long} depending on the edge stiffener types on the longer side of the buckling panel is defined in Table 5.2.2.4. An average value of F_{long} is to be used for plate panels having different edge stiffeners. For stiffener types other than those mentioned in Table 5.2.2.4, the value of c is to be agreed by CCS. In such a case, value of c higher than those mentioned in Table 5.2.2.4 can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate by CCS.

Correction factor F_{long} Table 5.2.2.4

<table>
<tr><th colspan="3">Structural element types</th><th>F_{long}</th><th>c</th></tr>
<tr><td colspan="3">Unstiffened Panel</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="6">Stiffened Panel</td><td colspan="2">Stiffener not fixed at both ends</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="4">Stiffener fixed at both ends</td><td>Flat bar(1)</td><td rowspan="4">$F_{long} = c + 1 \ for \ \frac{t_w}{t_p} > 1$
$F_{long} = c\left(\frac{t_w}{t_p}\right)^3 + 1 \ for \ \frac{t_w}{t_p} \le 1$</td><td>0.10</td></tr>
<tr><td>Bulb profile</td><td>0.30</td></tr>
<tr><td>Angle profile</td><td>0.40</td></tr>
<tr><td>T profile</td><td>0.30</td></tr>
<tr><td>Girder of high rigidity (e.g. bottom transverse)</td><td>1.4</td><td>N/A</td></tr>
<tr><td>U-type profile fitted on hatch cover(2)</td><td>(1) Plate on which the U-type profile is fitted, including EPP b_1 and EPP b_2:
● For $b_2 < b_1$: F_{long}=1;
● For $b_2 \ge b_1$:
$F_{long} = \left(1.55 - 0.55\frac{b_1}{b_2}\right)\left[1 + c\left(\frac{t_w}{t_p}\right)^3\right]$
(2)Other plates of the U-type profile:
F_{long}=1</td><td>0.2</td></tr>
<tr><td colspan="5">Notes:
(1) t_w is the net web thickness, in mm, without the correction defined in [5.4.3.5] of this Section.
(2) b_1, b_2 and t_w are defined in Section 1, Figure 1.2.3.2(2).</td></tr>
</table>

5.2.2.5 Correction factorF_{tran}

The correction factor F_{tran} is to be taken as:

(1) For transversely frame EPP of single side skin bulk carrier, between the hopper and top wing tank:

① $F_{tran} = 1.25$ when the two adjacent frames are supported by one tripping bracket fitted in way of the adjacent plate panels;

② $F_{tran} = 1.33$ when the two adjacent frames are supported by two tripping brackets each fitted in way of the adjacent plate panels.

③ $F_{tran} = 1.15$ elsewhere.

(2) For the attached plate of a U-type stiffener fitted on a hatch cover:

$$F_{tran} = \text{Max}\left(3 - 0.08(F_{tran0} - 6)^2, 1.0\right) \le 2.25$$

where:

$$F_{tran0} = \text{Min}\left(\frac{b_2}{b_1} + \frac{6b_2^2}{\pi^2 h_w (b_1 + b_2)}\left(\frac{t_w}{t_p}\right)^3, 6\right) \text{ for EPP } b_2;$$

$$F_{tran0} = \text{Min}\left(\frac{b_1}{b_2} + \frac{6b_1^2}{\pi^2 h_w (b_2 + b_1)}\left(\frac{t_w}{t_p}\right)^3, 6\right) \text{ for EPP } b_1.$$

with b_1, b_2 and h_w as defined in Figure 1.2.3.2(2) of this Section.

Coefficient F defined in Case 2 of Table 5.2.2.3 is to be replaced by the following formula:

$$F = \left[1 - \left(\frac{K_y}{0.91F_{tran}} - 1\right)/\lambda_p^2\right]c_1 \geq 0$$

(3) For other cases, the correction factor F_{tran} is to be taken as 1.0.

5.2.2.6 Curved plate panels

This requirement for curved plate limit state is applicable when $R/t_p \leq 2500$. Otherwise, the requirement for plate limit state given in [5.2.2.1] of this Section is applicable.

The curved plate limit state is based on the following interaction formula:

$$\left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}}\right)^{1.25} - 0.5 \cdot \left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}}\right)\left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}}\right) + \left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}}\right)^{1.25} + \left(\frac{\gamma_c \tau \sqrt{3} S}{C_\tau R_{eH_P}}\right)^2 = 1.0$$

With the corresponding buckling utilisation factor defined as:

$$\eta_{curved_plate} = \frac{1}{\gamma_c}$$

where:

σ_{ax}—— Applied axial stress to the cylinder corresponding to the curved plate panel, in N/mm^2. In case of tensile axial stresses, $\sigma_{ax} = 0$;

σ_{tg}—— Applied tangential stress to the cylinder corresponding to the curved plate panel, in N/mm^2. In case of tensile tangential stresses, $\sigma_{tg} = 0$;

C_{ax}, C_{tg}, C_τ —— Buckling reduction factor of the curved plate panel, as defined in Table 5.2.2.6.

The stress multiplier factor, γ_c, of the curved plate panel need not be taken less than the stress multiplier factor, γ_c, for the expanded plane panel according to [5.2.2.1] of this Section.

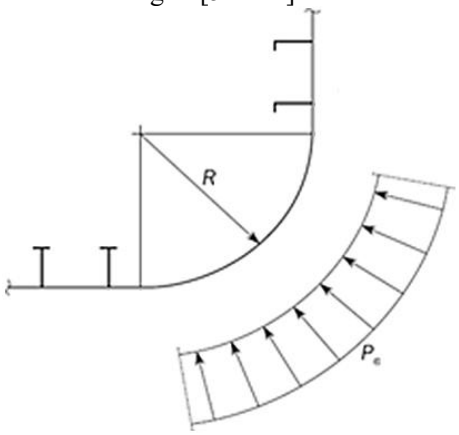
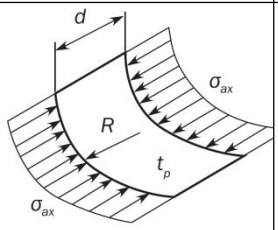
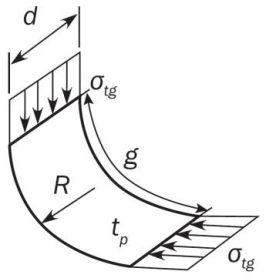
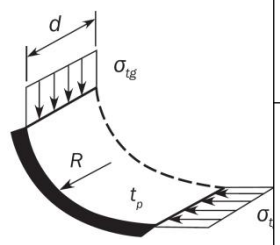
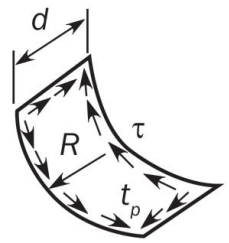


Figure 5.2.2.6 Transverse stiffened bilge plating

Buckling factor and reduction factor for curved plate panel with $R/t_p \leq 2500$ Table 5.2.2.6

Case	Aspect ratio	Buckling factor *K*	Reduction factor *C*
1	$\frac{d}{R} \leq 0.5\sqrt{\frac{R}{t_p}}$	$K = 1 + \frac{2}{3}\frac{d^2}{Rt_p}$	For general application $C_{ax} = 1$ for $\lambda \leq 0.25$

Case	Aspect ratio	Buckling factor K	Reduction factor C
	$\frac{d}{R} > 0.5\sqrt{\frac{R}{t_p}}$	$K = 0.267\frac{d^2}{Rt_p}\left[3 - \frac{d}{R}\sqrt{\frac{t_p}{R}}\right]$ $\geq 0.4\frac{d^2}{Rt_p}$	$C_{ax} = 1.233 - 0.933\lambda$ for $0.25 < \lambda \leq 1$ $C_{ax} = 0.3/\lambda^2$ for $1 < \lambda \leq 1.5$ $C_{ax} = 0.2/\lambda^2$ for $\lambda > 1.5$ For curved single fields, e.g. bilge strake, which are bounded by plane panels as shown in Figure 5.2.2.6: $C_{ax} = \frac{0.65}{\lambda^2} \leq 1.0$
2 	$\frac{d}{R} > 1.63\sqrt{\frac{R}{t_p}}$	$K = \frac{d}{\sqrt{Rt_p}} + 3\frac{(Rt_p)^{0.175}}{d^{0.35}}$	For general application: $C_{tg} = 1$ for $\lambda \leq 0.4$ $C_{tg} = 1.274 - 0.686\lambda$ for $0.4 < \lambda \leq 1.2$ $C_{tg} = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$ For curved single fields, e.g. bilge strake, which are bounded by plane panels as shown in Figure 5.2.2.6: $C_{tg} = \frac{0.8}{\lambda^2} \leq 1.0$
	$\frac{d}{R} > 1.63\sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 2.25\left(\frac{R^2}{dt_p}\right)^2$	
3 	$\frac{d}{R} \leq \sqrt{\frac{R}{t_p}}$	$K = \frac{0.6d}{\sqrt{Rt_p}} + \frac{\sqrt{Rt_p}}{d} - 0.3\frac{Rt_p}{d^2}$	As in load case 2
	$\frac{d}{R} \leq \sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 0.291\left(\frac{R^2}{dt_p}\right)^2$	
4 	$\frac{d}{R} \leq 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\sqrt{28.3 + \frac{0.67d^3}{R^{1.5}t_p^{1.5}}}$	$C_\tau = 1$ for $\lambda \leq 0.4$; $C_\tau = 1.274 - 0.686\lambda$, for $0.4 < \lambda \leq 1.2$; $C_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
	$\frac{d}{R} \leq 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\frac{0.28d^2}{R\sqrt{Rt_p}}$	
Explanations for boundary conditions - - - - - - - - - - - - Plate edge free; ———— Plate edge simply supported; ▬▬▬ Plate edge clamped.			

5.2.2.7 Applied normal and shear stresses to plate panels

The normal stress, σ_x and σ_y, in N/mm^2, to be applied for the overall stiffened panel capacity and the plate panel capacity calculations as given in [5.2.1.1] and [5.2.2.1] respectively, are to be taken as follows:

(1) For FE analysis, the reference stresses as defined in Section 4, [4.2.4];

(2) For prescriptive assessment of the overall stiffened panel capacity and the plate panel capacity, the axial or transverse compressive stresses calculated according to the Relevant UR-S, at load calculation points of the considered stiffener or the considered elementary plate panel, as defined in (1) and (2) of Section 3, [3.1.2.1] respectively. However, in case of transverse stiffening arrangement, the transverse compressive stress used for the assessment of the overall stiffened panel capacity is to be taken as the

compressive stress calculated at load calculation points of the stiffener attached plating, as defined in (1) of Section 3, [3.1.2.1].

(3) For grillage analysis where the stresses are obtained based on beam theory, the stresses taken as:

$$\sigma_x = \frac{\sigma_{xb} + \nu\sigma_{yb}}{1 - \nu^2}$$

$$\sigma_y = \frac{\sigma_{yb} + \nu\sigma_{xb}}{1 - \nu^2}$$

where:

σ_{xb}, σ_{yb} —— Stress, in N/mm^2, from grillage beam analysis respectively along x and y axis of the plate attached to the PSN web.

The shear stress, τ, in N/mm^2, to be applied for the overall stiffened panel capacity and the plate panel capacity calculations as given in [5.2.1.1] and [5.2.2.1] respectively, are to be taken as follows:

① For FE analysis, the reference shear stresses as defined in Section 4, [4.2.4];

② For prescriptive assessment of the plate panel buckling capacity, the shear stresses calculated according to the Relevant UR-S, at load calculation points of the considered elementary plate panel, as defined in (1) of Section 3, [3.1.2.1];

③ For prescriptive assessment of the overall elastic stiffened panel buckling capacity, the shear stresses calculated according to the Relevant UR-S, at the following load calculation point:

(a) At the middle of the full span, *l*, of the considered stiffener;

(b) At the intersection point between the stiffener and its attached plating.

(4) For grillage beam analysis, $\tau = 0$ in the plate attached to the PSM web.

5.2.3 Stiffeners

5.2.3.1 Buckling modes

The following buckling modes are to be checked:

(1) Stiffener induced failure (*SI*);

(2) Associated plate induced failure (*PI*).

5.2.3.2 Web thickness of flat bar

For accounting the decrease of the stiffness due to local lateral deformation, the effective web thickness of flat bat stiffener, in mm, is to be used in [5.2.1] and [5.2.3.4] for the calculation of the net sectional area, A_s, the net section modulus, Z, and the moment of inertia, I, of the stiffener and is taken as:

$$t_{w_red} = t_w \left(1 - \frac{2\pi^2}{3}\left(\frac{h_w}{s}\right)^2 \left(1 - \frac{b_{eff1}}{s}\right)\right)$$

5.2.3.3 Idealisation of bulb profile

Bulb profiles are to be considered as equivalent angle profiles. The net dimensions of the equivalent built-up section are to be obtained from the following formulae:

$$h_w = h_w^{'} - \frac{h_w^{'}}{9.2} + 2$$

$$b_f = \alpha\left(t_w^{'} + \frac{h_w^{'}}{6.7} - 2\right)$$

$$t_f = \frac{h_w^{'}}{9.2} - 2$$

$$t_w = t_w^{'}$$

where: $h_w^{'}, t_w^{'}$——Net height and thickness of a bulb section, in mm, as shown in Figure 5.2.3.3;

α ——Coefficient equal to:

$$\alpha = 1.1 + \frac{\left(120 - h_w^{'}\right)^2}{3000} \quad \text{for } h_w^{'} \le 120$$

$$\alpha = 1.0 \quad \text{for } h_w^{'} > 120.$$

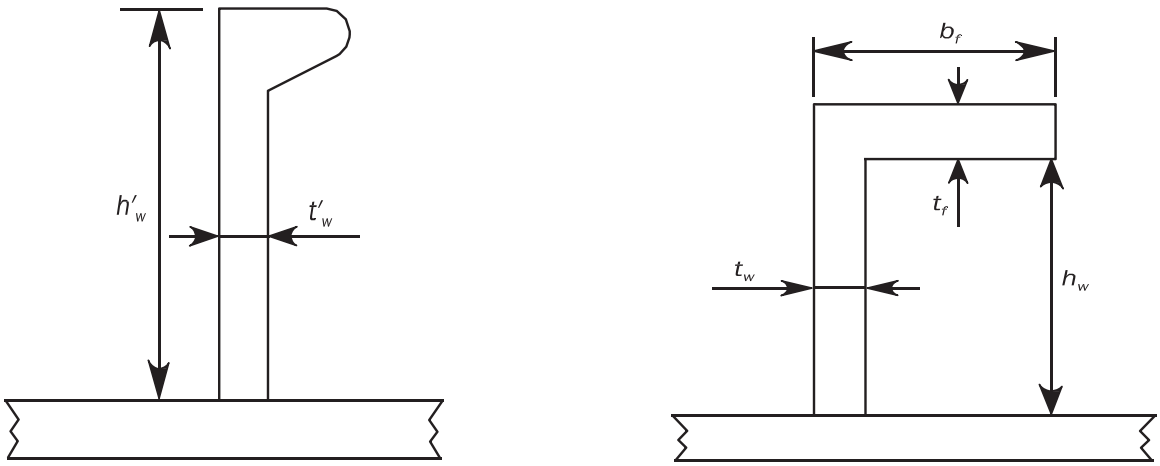


Figure 5.2.3.3 Idealisation of bulb stiffener

5.2.3.4 Ultimate buckling capacity

When $\sigma_a + \sigma_b + \sigma_w > 0$ while initially setting γ = 1, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c \sigma_a + \sigma_b + \sigma_w}{R_{eH}} S = 1$$

with the corresponding buckling utilisation factor defined as:

$$\eta_{stiffener} = \frac{1}{\gamma_c}$$

where:

σ_a —— Effective axial stress, in N/mm^2, at mid span of the stiffener, acting on the stiffener with its attached plating

$$\sigma_a = \sigma_x \frac{st_p + A_s}{b_{eff1} t_p + A_s} \quad .$$

σ_x —— Nominal axial stress, in N/mm^2, acting on the stiffener with its attached plating:

(1) For FE analysis, σ_x is the FE corrected stress as defined in [5.2.3.6] in the attached plating in the direction of the stiffener axis;

(2) For prescriptive assessment, σ_x is the axial stress, in N/mm^2, calculated according to Section 3, [3.2.2.1] at load calculation point of the stiffener, as defined in Section 3, [3.1.2.1];

(3) For grillage beam analysis, σ_x is the stress acting along the *x*-axis of the attached buckling panel.

R_{eH} —— Specified minimum yield stress of the material, in N/mm^2:

(1) $R_{eH} = R_{eH_S}$ for stiffener induced failure *(SI)*;

(2) $R_{eH} = R_{eH_P}$ for plate induced failure *(PI)*.

σ_b —— Bending stress in the stiffeners, in N/mm^2:

$\sigma_b = \frac{M_0 + M_1 + M_2}{1000Z}$.

Z —— Net section modulus of stiffener, including effective width of attached plating according to [5.2.3.5], to be taken as:

(1) The section modulus calculated at the top of stiffener flange for stiffener induced failure *(SI)*;

(2) The section modulus calculated at the bottom of attached plating for plate induced failure *(PI)*.

M_2 —— Bending moment, in N·mm, due to eccentricity of sniped stiffeners, to be taken as:

(1) $M_2 = 0$ for continuous stiffeners;

(2) $M_2 = C_{snip} w_{na} \gamma \sigma_x (A_p + A_s)$ for stiffeners sniped at one or both ends.

C_{snip} —— Coefficient to account for the end effect of the stiffener sniped at one or both ends, to be taken as:

(1) $C_{snip} = -1.2$ for stiffener induced failure *(SI)*;

(2) $C_{snip} = 1.2$ for plate induced failure (*PI*).

σ_w —— Stress due to torsion, in N/mm^2, as defined in [5.4.4.4].

M_1 —— Bending moment, in N·mm, due to the lateral load, *P,* taken as follows:

(1) $M_1 = C_i \frac{|P|sl^2}{24\times10^3}$ for continuous stiffener;

(2) $M_1 = C_i \frac{|P|sl^2}{8\times10^3}$ for sniped stiffener at both ends;

(3) $M_1 = C_i \frac{|P|sl^2}{14.2\times10^3}$ for stiffener sniped at one end and continuous at the other end.

P —— Lateral load, in kN/m^2:

(1) For FE analysis， P is the average pressure as defined in Section 4, [4.2.5.2] in the attached plating;

(2) For prescriptive assessment, P is the static pressure calculated at load calculation point of the stiffener, as defined in Section 3, [3.1.2.1].

C_i —— Pressure coefficient:

(1) $C_i = C_{SI}$ for stiffener induced failure (*SI);*

(2) $C_i = C_{PI}$ for plate induced failure (*PI).*

C_{PI} —— Plate induced failure pressure coefficient:

(1) $C_{PI} = 1$ if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{PI} = -1$ if the lateral pressure is applied on the same side as the stiffener.

C_{SI} —— Stiffener induced failure pressure coefficient:

(1) $C_{SI} = -1$ if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{SI} = 1$ if the lateral pressure is applied on the same side as the stiffener.

M_0 —— Bending moment, in Nmm, due to the lateral deformation *w* of stiffener:

$$M_0 = F_E C_{sl} \frac{\gamma}{\gamma_{GEB}-\gamma} w_0 \text{ with precondition } \gamma_{GEB} - \gamma > 0.$$

γ_{GEB} —— Stress multiplier factor of global elastic buckling capacity as defined in [5.2.1].

F_E —— Ideal elastic buckling force of the stiffener, in N:

$$F_E = \left(\frac{\pi}{l}\right)^2 EI \times 10^4.$$

I —— Moment of inertia, in cm^4, of the stiffener including effective width of attached plating. *I* is to comply with the following requirement:

$$I \geq \frac{st_p^3}{12\times10^4}.$$

t_p (1) —— Net thickness of plate, in mm, to be taken as:

(2) For prescriptive requirements: the mean thickness of the two attached plating panels;

(3) For FE analysis, the thickness of the considered EPP on one side of the stiffener.

C_{sl} —— Deformation reduction factor to account for global slenderness, to be taken as:

(1) $C_{sl} = 1 - \frac{1}{12}\lambda_G^4$ for $\lambda_G \leq 1.56$;

(2) $C_{sl} = 3/\lambda_G^4$ for $\lambda_G > 1.56$.

λ_G —— The reference degree of global slenderness of the stiffened panel, to be taken as:

$$\lambda_G = \sqrt{\frac{\gamma_{ReH}}{\gamma_{GEB}}}$$

where: $\gamma_{ReH} = \frac{\text{Min}\,(R_{eH_P},\ R_{eH_S})}{\sqrt{\sigma_{x,av}^2+\sigma_y^2-\sigma_{x,av}\sigma_y+3\tau^2}}$.

$\sigma_{x,av}$ —— Average stress for both plate and stiffener as defined in [5.2.1.2].

σ_y —— Applied transverse stress to the plate panel as defined in [5.2.1.1].

τ —— Applied shear stress to the plate panel as defined in [5.2.1.1].

w_0 —— Assumed imperfection, in mm, to be taken as:

$$w_0 = l/1000;$$

σ_w —— Stress due to torsional deformation, in N/mm^2, to be taken as:

(1) For stiffener induce failure (*SI)*

① For $\sigma_a > 0$:

$$\sigma_w = Ey_w e_f \Phi_0 \left(\frac{m_{tor}\pi}{l_{tor}}\right)^2 \left(\frac{1}{1-\frac{\gamma\sigma_a}{\sigma_{ET}}} - 1\right) \text{ with precondition } \sigma_{ET} - \gamma\sigma_a > 0$$

② For $\sigma_a \leq 0$:

$$\sigma_w = 0$$

(2) For plate induced failure (*PI)*

$$\sigma_w = 0$$

y_w —— Distance, in mm, from centroid of stiffener cross section to the free edge of stiffener flange, to be taken as:

(1) $y_w = \frac{t_w}{2}$ for flat bar;

(2) $y_w = b_f - \frac{h_w t_w^2 + t_f b_f^2}{2A_s}$ for angle and bulb profiles;

(3) $y_w = b_{f-out} + 0.5t_w - \frac{h_w t_w^2 + t_f(b_f^2 - 2b_f d_f)}{2A_s}$ for L2 profile;

(4) $y_w = \frac{b_f}{2}$ for T profile.

Φ_0 —— Coefficient taken as:

$$\Phi_0 = \frac{l_{tor}}{m_{tor} h_w} \times 10^{-4}.$$

σ_{ET} —— Reference stress for torsional buckling, in N/mm^2, to be taken as:

$$\sigma_{ET} = \frac{E}{I_p}\left[\left(\frac{m_{tor}\pi}{l_{tor}}\right)^2 I_\omega \times 10^2 + \frac{1}{2(1+\nu)} I_T + \left(\frac{l_{tor}}{m_{tor}\pi}\right)^2 \varepsilon \times 10^{-4}\right].$$

I_p —— Net polar moment of inertia of the stiffener defined in Table 5.4.4.4, in cm^4, about point *C* as shown in Section 1 Figure 1.2.3.2, as defined in Table 5.2.3.4.

I_T —— Net St. Venant's moment of inertia of the stiffener, in cm^4, as defined in Table 5.2.3.4.

I_ω —— Net sectional moment of inertia of the stiffener, in cm^6, about point *C* as shown in Section 1, Figure 1.2.3.2(1), as shown in Table 5.2.3.4.

l_{tor} —— Stiffener span, in mm, distance equal to spacing between primary supporting members, i.e. $l_{tor} = l$. When the stiffener is supported by tripping brackets, l_{tor} is to be taken as the maximum spacing between the adjacent primary supporting members and fitted tripping brackets.

m_{tor} —— Number of half waves, taken as a positive integer so as to give smallest reference stress for torsional buckling.

ε —— Degree of fixation, to be taken as:

$\varepsilon = \left(\frac{3b}{t_p^3} + \frac{2h_w}{t_w^3}\right)^{-1}$ for bulb, angle, L2 and T profiles;

$\varepsilon = \left(\frac{t_p^3}{3b}\right)$ for flat bars.

A_w —— Net web area, in mm^2;

A_f —— Net flange area, in mm^2.

Moment of inertia Table 5.2.3.4

Cross section characteristics	**Flat bars**	**Bulb, angle, L2 and T profiles**
I_p	$\frac{h_w^3 t_w}{3 \times 10^4}$	$\left(\frac{A_w(e_f - 0.5t_f)^2}{3} + A_f e_f^2\right) \times 10^{-4}$
I_T	$\frac{h_w t_w^3}{3 \times 10^4}\left(1 - 0.63\frac{t_w}{h_w}\right)$	

		$\frac{(e_f - 0.5t_f)t_w^3}{3 \times 10^4}\left(1 - 0.63\frac{t_w}{e_f - 0.5t_f}\right) + \frac{b_f t_f^3}{3 \times 10^4}\left(1 - 0.63\frac{t_f}{b_f}\right)$
I_ω	$\frac{h_w^3 t_w^3}{36 \times 10^6}$	For bulb, angle and L2 profiles: $\frac{A_f^3 + A_w^3}{36 \times 10^6} + \frac{e_f^2}{10^6}\left(\frac{A_f b_f^2 + A_w t_w^2}{3} - \frac{(A_f b_f + A_w t_w)^2}{4(A_f + A_w)}\right)$ For T profile: $\frac{b_f^3 t_f e_f^3}{12 \times 10^6}$
Notes: (1) t_w is the net web thickness, in mm. t_{w_red} as defined in [5.2.3.2] is not to be used in this Table; (2) d_f is to be taken as 0 for bulb and angle profiles.		

5.2.3.5 Effective width of attached plating

The effective width of attached plating of stiffeners, b_{eff} in mm, is to be taken as:

(1) For $\sigma_x > 0$:

① For FE analysis,

$$b_{eff} = Min\,(C_x b, \chi_s s)$$

② For prescriptive assessment,

$$b_{eff} = Min\left(\frac{C_{x1} b_1 + C_{x2} b_2}{2}, \chi_s s\right)$$

(2) For $\sigma_x \leq 0$:

$$b_{eff} = \chi_s s$$

where: χ_s —— Effective width coefficient to be taken as:

① $\chi_s = \frac{1.12}{1 + \frac{1.75}{\left(\frac{\ell_{eff}}{s}\right)^{1.6}}} \leq 1.0$ for $\frac{\ell_{eff}}{s} \geq 1$

② $\chi_s = 0.407\frac{\ell_{eff}}{s}$ for $\frac{\ell_{eff}}{s} < 1.$

ℓ_{eff}____ Effective length of the stiffener, in mm, taken as:

(1) $\ell_{eff} = \frac{l}{\sqrt{3}}$ for stiffener fixed at both ends;

(2) $\ell_{eff} = 0.75l$ for stiffener simply supported at one end and fixed a the other.

(3) $\ell_{eff} = l$ for stiffener simply supported at both ends.

5.2.3.6 FE corrected stresses for stiffener capacity

When the reference stresses σ_x and σ_y obtained by FE analysis according to Section 4, [4.2.4] are both compressive, σ_x is to be corrected according to the following formulae:

(1) If $\sigma_x < \nu\sigma_y$

$$\sigma_{xcor} = 0$$

(2) If $\sigma_x \geq \nu\sigma_y$

$$\sigma_{xcor} = \sigma_x - \nu\sigma_y$$

5.2.4 Primary Supporting Members

5.2.4.1 Web plate in way of openings

The web plate of primary supporting members with openings is to be assessed for buckling based on the combined axial compressive and shear stresses.

The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in Table 5.2.4.1.

The interaction formulae of [5.2.2.1] are to be used with:

$$\sigma_x = \sigma_{av}$$

$$\sigma_y = 0$$

$$\tau = \tau_{av}$$

where: σ_{av} —— Weighted average compressive stress, in N/mm^2, in the area of web plate being considered, i.e. *P1, P2* and *P3* as shown in Table 5.2.4.1.

For the application of Table 5.2.4.1, the weighted average shear stress is to be taken as:

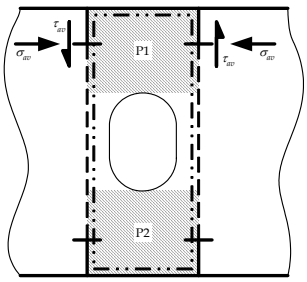
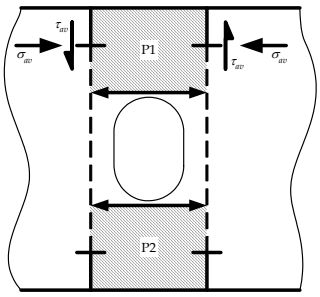
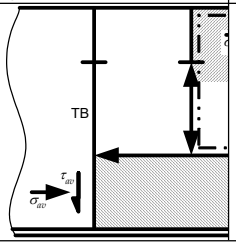
(1) Opening modelled in primary supporting members:

τ_{av} —— Weighted average compressive stress, in N/mm^2, in the area of web plate being considered, i.e. *P1, P2* and *P3* as shown in Table 5.2.4.1.

(2) Opening not modelled in primary supporting members:

τ_{av} —— Weighted average shear stress, in N/mm^2, given in Table 5.2.4.1.

Buckling reduction factors of web plate in way of openings Table 5.2.4.1

Configuration (1)		C_x, C_y	C_τ	
			Opening modelled in PSM	**Opening not modelled in PSM**
(a) Without edge reinforcements (2)		Separate reduction factors are to be applied to areas *P1* and *P2* using case ③ or case ⑥ in Table 5.2.2.3, with edge stress ratio: ψ＝1.0	Separate reduction factors are to be applied to areas *P1* and *P2* using case ⑱ or case ⑲ in Table 5.2.2.3.	When case ⑰ of Table 5.2.2.3 is applicable: A common reduction factor is to be applied to areas *P1* and *P2* using case ⑰ with: $\tau_{av} = \tau_{av}(web)$; When case ⑰ of Table 5.2.2.3 is not applicable: Separate reduction factors are to be applied to areas *P1* and *P2* using case ⑱ or case ⑲ with: $\tau_{av} = \tau_{av}(web)h/(h - h_0)$
(b) With edge reinforcement		Separate reduction factors are to be applied for areas *P1* and *P2* using C_x for case ① or C_y for case ② in Table 5.2.2.3 with stress ratio: ψ＝1.0.	Separate reduction factors are to be applied for areas *P1* and *P2* using case ⑮ in Table 5.2.2.3.	Separate reduction factors are to be applied to areas *P1* and *P2* using case ⑮ in Table 5.2.2.3 with: $\tau_{av} = \tau_{av}(web)h/(h - h_0)$
(c) Example of hole in web			Panels *P1* and *P2* are to be evaluated in accordance with (a). Panel *P3* is to be evaluated in accordance with (b).	

where:

h —— Height, in m, of the web of the primary supporting member in way of the opening;

h_0 —— Height, in m, of the opening measured in the depth of the web;

$\tau_{av}(web)$ —— Weighted average shear stress, in N/mm^2, over the web height of the primary supporting

Configuration (1)	C_x, C_y	C_τ	
		Opening modelled in PSM	Opening not modelled in PSM
member. Note (1) Web panels to be considered for buckling in way of openings are shown shaded and numbered *P1*, *P2*, etc. Note (2) For a PSM web panel with opening and without edge reinforcements as shown in configuration (a), the applicable buckling assessment method depends on its specific boundary conditions. If one of the long edges along the face plate or along the attached plating is not subject to "inline support", i.e. the edge is free to pull in, Method B should be applied. In other cases, typically such as when the short plate edge is attached to the plate flanges, Method A is applicable.			

5.2.4.2 Reduction factors of web plate in way of openings

The reduction factors, C_x or C_y in combnaiton with C_τ of the plate panel(s) of the web adjacent to the opening is to be taken as shown in Table 5.2.4.1.

5.2.4.3 The equivalent plate panel of web plate of primary supporting members crossed by perpendicular stiffeners is to be idealised as shown in Figure 5.2.4.3.

The correction of panel breadth is applicable also for other slot configurations provided that the web or collar plate is attached to at least one side of the passing stiffener.

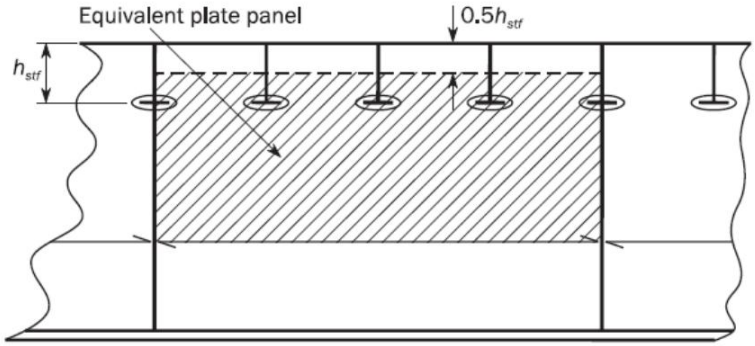


Figure 5.2.4.3 PMS web plate idealisation

5.2.5 Stiffened Panels with U-type Stiffeners

5.2.5.1 Local plate buckling

For stiffened panels with U-type stiffeners, local plate buckling is to be checked for each of the plate panels EPP b_1, b_2, b_f and h_w (see Section 1, Figure 1.2.3.2(2)) separately as follows:

(1) The attached plate panels EPP b_1, b_2 are to be assessed using SP-A model, where in the calculation of buckling factors K_x as defined in Case ① of Table 5.2.2.3, the correction factor F_{long} for U-type stiffeners as defined in Table 5.2.2.4 is to be used; and in the calculation of K_y as defined in Case ② of Table, the F_{tran} for U-type stiffeners as defined in [5.2.2.5] is to be used.

(2) The face plate and web plate panels EPP b_f and h_w are to be assessed using UP-B model with $F_{long} = 1$ and $F_{tran} = 1$.

5.2.5.2 Overall stiffened panel buckling and stiffener buckling

For a stiffened panel with U-type stiffeners, the overall buckling capacity and ultimate capacity of the stiffeners are to be checked with warping stress σ_w = 0, and with bending moment of inertia including effective width of attached plating being calculated based on the following assumptions:

(1) The two web panels of a U-type stiffener are to be taken as perpendicular to the attached plate with thickness equal to t_w and height equal to the distance between the attached plate and the face plate of the stiffener.

(2) Effective width of the attached plating b_{eff}, taken as the sum of the b_{eff} calculated for EPP, b_1 and b_2 respectively according to SP-A model.

(3) Effective width of the attached plating of a stiffener without shear lag effect, b_{eff1}, taken as the sum of the b_{eff1} calculated for the EPP, b_1 and b_2 respectively.

5.3 Buckling capacity of column structures

5.3.1 Column Buckling of Corrugations

5.3.1.1 Buckling utilisation factor

The column buckling utilisation factor, η, for axially compressed corrugations is to be taken as:

$$\eta_{column} = \frac{\sigma_{av}}{\sigma_{cr}}$$

where: σ_{av} —— Average axial compressive stress in the member, in N/mm^2;

σ_{cr} —— Minimum critical buckling stress, in N/mm^2, taken as:

① $\sigma_{cr} = \sigma_E$ for $\sigma_E \leq 0.5R_{eH_S}$

② $\sigma_{cr} = \left(1 - \frac{R_{eH_S}}{4\sigma_E}\right) R_{eH_S}$ for $\sigma_E > 0.5R_{eH_S}$;

σ_E —— Elastic column compressive buckling stress, in N/mm^2, according to [5.3.1.2];

R_{eH_S} —— Specified minimum yield stress of the considered member, in N/mm^2. For built-up members, the lowest specified minimum yield stress is to be used.

5.3.1.2 Elastic column buckling stress

The elastic compressive column buckling stress, σ_E, in N/mm^2 of members subject to axial compression is to be taken as:

$$\sigma_E = \pi^2 E f_{end} \frac{I}{A l_{pill}^2} \times 10^{-4}$$

where: I —— Net moment of inertia about the weakest axis of the cross section, in cm^4;

A —— Net cross-sectional area of the member, in cm^2;

l_{pill} —— Unsupported length of the member, in m;

f_{end} —— End constraint factor, corresponding to simply supported ends is to be applied except for fixed end support to be used in way of stool with width exceeding 2 times the depth of the corrugation, taken as:

- $f_{end} = 1.0$ where both ends are simply supported;
- $f_{end} = 2.0$ where one end is simply supported and the other end is fixed;
- $f_{end} = 4.0$ where both ends are fixed.

SECTION 6 STRESS BASED REFERENCE STRESSES

Symbols

a —— Length, in mm, of the longer side of the plate panel as defined in Section 5;

b —— Length, in mm, of the shorter side of the plate panel as defined in Section 5;

A_i —— Area, in mm^2, of the i-th plate element of the buckling panel;

n —— Number of plate elements in the buckling panel;

σ_{xi} —— Actual stress, in N/mm^2, at the centroid of the *i*-th plate element in *x* direction, applied along the shorter edge of the buckling panel;

σ_{yi} —— Actual stress, in N/mm^2, at the centroid of the *i*-th plate element in *y* direction, applied along the longer edge of the buckling panel;

ψ —— Edge stress ratio as defined in Section 5;

τ_i —— Actual membrane shear stress, in N/mm^2, at the centroid of the *i*-th plate element of the buckling panel.

6.1 Stress Based Method

6.1.1 Introduction

6.1.1.1 This Section provides a method to determine stress distribution along edges of the considered buckling panel by second-order polynomial curve, by linear distribution using least square method and by weighted average approach. The reference stress is the stress components at centre of plate element transferred into the local system of the considered buckling panel.

6.1.1.2 Definition

A regular panel is a plate panel of rectangular shape. An irregular panel is plate panel which is not regular, as detailed in Section 4, [4.2.3.1].

6.1.2 Stress Application

6.1.2.1 Regular panel

The reference stresses are to be taken as defined in [6.2.1] for a regular panel when the following conditions are satisfied:

- At least, one plate element centre is located in each third part of the long edge *a* of a regular panel; and
- This element center is located at a distance in the panel local *x* direction not less than *a*/4 to at least one of the element centers in the adjacent third part of the panel.

Otherwise, the reference stresses are to be taken as defined in [6.2.2] for an irregular panel.

6.1.2.2 Irregular panel and curved panel

The reference stresses of an irregular panel or of a curved panel are to be taken as defined in [6.2.2].

6.2 Reference Stresses

6.2.1 Regular Panel

6.2.1.1 Longitudinal stress

The longitudinal stress σ_x applied on the shorter edge of the buckling panel is to be calculated as follows:

For plate buckling assessment, the distribution of $\sigma_x(x)$ is assumed as second order polynomial curve as:

$$\sigma_x = Cx^2 + Dx + E$$

The best fitting curve $\sigma_x(x)$ is to be obtained by minimising the square error Π considering the area of each element as a weighting factor:

$$\Pi = \sum_{i=1}^{n} A_i\left[\sigma_{xi} - (Cx_i^2 + Dx_i + E)\right]^2$$

The unknown coefficients *C*, *D* and *E* is yield zero first derivatives, $\partial\Pi$ with respect to *C, D* and *E,* respectively.

$$\begin{cases} \dfrac{\partial\Pi}{\partial C} = 2\displaystyle\sum_{i=1}^{n} A_i x_i^2\left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \\ \dfrac{\partial\Pi}{\partial D} = 2\displaystyle\sum_{i=1}^{n} A_i x_i\left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \\ \dfrac{\partial\Pi}{\partial E} = 2\displaystyle\sum_{i=1}^{n} A_i\left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \end{cases}$$

The unknown coefficients *C, D* and *E* can be obtained by solving the 3 above equations.

$$\sigma_{x1} = \frac{1}{b}\int_0^b \sigma_x(x)dx = \frac{b^2}{3}C + \frac{b}{2}D + E$$

$$\sigma_{x2} = \frac{1}{b}\int_{a-b}^{a} \sigma_x(x)dx = \left(a^2 - ab + \frac{b^2}{3}\right)C + \left(a - \frac{b}{2}\right)D + E$$

If $-\frac{D}{2C} < \frac{b}{2}$ or $-\frac{D}{2C} > a - \frac{b}{2}$, , σ_{x3} is to be ignored. Otherwise, σ_{x3} is taken as:

$$\sigma_{x3} = \frac{1}{b}\int_{x_{min}}^{x_{max}} \sigma_x(x)dx = \frac{b^2}{12}C - \frac{D^2}{4C} + E$$

where: $x_{min} = -\frac{b}{2} - \frac{D}{2C}$

$$x_{max} = \frac{b}{2} - \frac{D}{2C}$$

The longitudinal stress is to be taken as:

$$\sigma_x = Max\left(\sigma_{x1}, \sigma_{x2}, \sigma_{x3}\right) \ ;$$

The edge stress ratio is to be taken as:

$$\psi_x = 1$$

For overall stiffened panel buckling and stiffener buckling assessments, the longitudinal stress σ_x applied on the shorter edge of the attached plate is to be taken as:

$$\sigma_x = \frac{\sum_{i=1}^{n} A_i\sigma_{xi}}{\sum_{i=1}^{n} A_i}$$

The edge stress ratio ψ_x for the stress σ_x is equal to 1.0.

6.2.1.2 Transverse stress

The transverse stress σ_y applied along the longer edges of the buckling panel is to be calculated by extrapolation of the transverse stresses of all elements up to the shorter edges of the considered buckling panel.

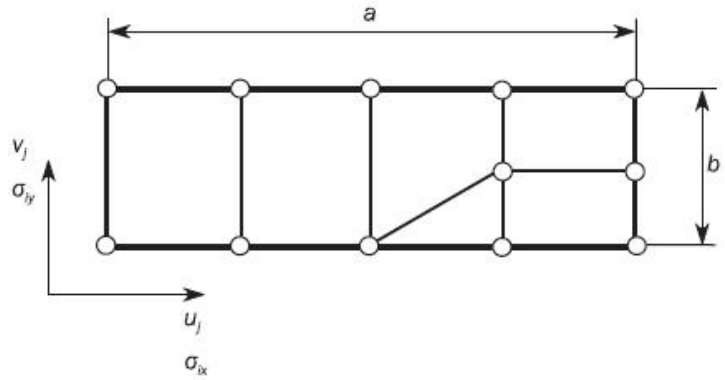


Figure 6.2.1.2 Buckling panel

The distribution of $\sigma_y(x)$ is assumed as straight line. Therefore:

$$\sigma_y(x) = A + Bx$$

The best fitting curve $\sigma_y(x)$ is to be obtained by the least square method minimising the square error Π considering area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^{n} A_i\left[\sigma_{yi} - (A + Bx_i)\right]^2$$

The unknown coefficients A and B are to yield zero first partial derivatives, $\partial\Pi$ with respect to A and B, respectively.

$$\frac{\partial\Pi}{\partial A} = 2\sum_{i=1}^{n} A_i\left[\sigma_{yi} - (A + Bx_i)\right] = 0$$

$$\frac{\partial\Pi}{\partial B} = 2\sum_{i=1}^{n} A_i x_i\left[\sigma_{yi} - (A + Bx_i)\right] = 0$$

The unknown coefficients A and B are obtained by solving the 2 above equations and are given as follow:

$$A = \frac{\left(\sum_{i=1}^{n} A_i\sigma_{yi}\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i x_i\sigma_{yi}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2}$$

$$B = \frac{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i\sigma_{yi}\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i\sigma_{yi}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2}$$

The transverse stress is to be taken as:

$$\sigma_y = max\,(A, A + Ba)$$

The edge stress ratio is to be taken as:

$$\psi_y = \frac{min\,(A, A + Ba)}{max\,(A, A + Ba)} \text{ for } \sigma_y > 0$$

$$\psi_y = 1 \text{ for } \sigma_y \leq 0.$$

6.2.1.3 Shear stress

The shear stress τ is to be calculated using a weighted average approach, and is to be taken as:

$$\tau = \frac{\sum_{i=1}^{n} A_i\tau_i}{\sum_{i=1}^{n} A_i}$$

6.2.2 Irregular Panel and Curved Panel

6.2.2.1 Reference stresses

The longitudinal, transverse and shear stresses are to be calculated using a weighted average approach. They are to be taken as:

$$\sigma_x = \frac{\sum_{i=1}^{n} A_i \sigma_{xi}}{\sum_{i=1}^{n} A_i}$$

$$\sigma_y = \frac{\sum_{i=1}^{n} A_i \sigma_{yi}}{\sum_{i=1}^{n} A_i}$$

$$\tau = \frac{\sum_{i=1}^{n} A_i \tau_i}{\sum_{i=1}^{n} A_i}$$

The edge stress ratios are to be taken as:

$$\psi_x = 1;$$

$$\psi_y = 1.$$

CHAPTER 3 EQUIPMENT AND OUTFITS

Section 1 RUDDERS

3.1.1 General requirements

3.1.1.1 Basic assumptions

(1) This Section applies to ordinary profile rudders, and to some enhanced profile rudders with special arrangements for increasing the rudder force. Rudders not conforming to the profile types included in this Section will be subject to special consideration.

(2) This section applies to rudders made of steel. Rudders made of material different from steel will be subject to special consideration.

3.1.1.2 Design considerations

(1) Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

(2) Suitable arrangements are to be provided to prevent the rudder from lifting.

(3) In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the waterline at scantling draught (without trim), two separate watertight seals/stuffing boxes are to be provided.

3.1.1.3 Materials

(1) Welded parts of rudders are to be made of materials complying with relevant requirements for hull structural steel in CCS Rules for Materials and Welding.

(2) Material factor k for normal and high tensile steel plating may be taken into account when specified in each individual rule requirement. The material factor k is to be taken as defined in Section 3, Chapter 1 of this PART, unless otherwise specified.

(3) Steel grade of plating materials for rudders and rudder horns are to be in accordance with Section 3, Chapter 1 of this PART.

(4) Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled, forged or cast carbon manganese steel in accordance with CCS Rules for Materials and Welding.

(5) For rudder stocks, pintles, keys and bolts the minimum yield stress is not to be less than 200 N/mm^2. The requirements of this Section are based on a material's yield stress of 235 N/mm^2. If material is used having a yield stress differing from 235 N/mm^2 the material factor K is to be determined as follows:

$$K=\left(\frac{235}{R_{eH}}\right)^{e}$$

where: e = 0.75 for $R_{eH} > 235$ N/mm^2;

e = 1.00 for $R_{eH} \leq 235$ N/mm^2;

R_{eH} —specified minimum yield stress (N/mm^2) of material used, and is not to be taken greater than $0.7R_m$ or 450 N/mm^2, whichever is the smaller value;

R_m — tensile strength (N/mm^2) of material used.

3.1.1.4 Welding and design details

(1) Slot-welding is to be limited as far as possible. Slot welding is not to be used in areas with large in-plane stresses transversely to the slots or in way of cut-out areas of semi-spade rudders.

When slot welding is applied, the length of slots is to be minimum 75 mm with breadth of 2t, where t is the rudder plate thickness, in mm. The distance between ends of slots is not to be more than 125 mm. The fillet leg length is to comply with calculation requirements in 1.4.4, Chapter 1 of this PART, and welding is to be based on a weld factor of 0.44. The slots are to be fillet welded around the edges and filled with a suitable compound, e.g. epoxy putty. Slots are not to be filled with weld.

Continuous slot welds are to be used in lieu of slot welds. When continuous slot welding is applied, the root gap is to be between 6-10 mm. The bevel angle is to be at least 15°.

(2) In way of the rudder horn recess of semi-spade rudders, the radii in the rudder plating except in way of solid part in cast steel are not to be less than 5 times the plate thickness, but in no case less than 100 mm. Welding in side plate is to be avoided in or at the end of the radii. Edges of side plate and weld adjacent to radii are to be ground smooth.

(3) Welds in the rudder side plating subjected to significant stresses from rudder bending and welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) are to be made as

full penetration welds. In way of highly stressed areas e.g. cut-out of semi-spade rudder and upper part of spade rudder, cast or welding on ribs is to be arranged. Two sided full penetration welding is normally to be arranged. Where back welding is impossible welding is to be performed against ceramic backing bars or equivalent. Steel backing bars may be used and are to be continuously welded on one side to the bevelled edge, see Figure 3.1.1.4(3). The bevel angle is to be at least 15° for one sided welding.

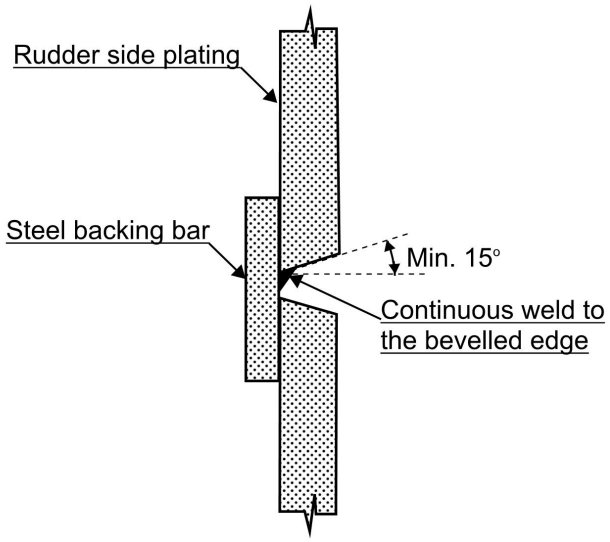


Figure 3.1.1.4(3) Use of steel backing bar in way of full penetration welding of rudder side plating

(4) Requirements for welding and design details of rudder trunks are described in 3.1.9.2 of this Section.
(5) Requirements for welding and design details when the rudder stock is connected to the rudder by horizontal flange coupling are described in 3.1.6.1(4) of this Section.
(6) Requirements for welding and design details of rudder horns are described in 3.1.9.1(3).

3.1.1.5 Equivalence

(1) CCS may accept alternatives to requirements given in this Section, provided they are deemed to be equivalent.
(2) Direct analyses adopted to justify an alternative design are to take into consideration all relevant modes of failure, on a case by case basis. These failure modes may include, amongst others: yielding, fatigue, buckling and fracture. Possible damages caused by cavitation are also to be considered.
(3) Where deemed necessary by CCS, lab tests, or full scale tests may be requested to validate the alternative design approach.

3.1.2 Rudder force and rudder torque

3.1.2.1 Rudder blades without cut-outs

(1) The rudder force C_R upon which the rudder scantlings are to be based is to be determined from the following formula:

$$C_R = 132 K_1 K_2 K_3 A V^2 \quad \text{N}$$

where: C_R — rudder force, in N;
A — area of rudder blade, in m^2;
V — maximum service speed (knots). When the speed is less than 10 knots, V is to be replaced by the following:
$V_{min} = (V + 20) / 3$
For the astern condition the maximum astern speed V_{astern} (the greatest speed which the ship is designed to maintain in service at sea at the deepest sea-going draught) is to be used, however, in no case less than:
$V_{astern} = 0.5\ V$;
K_1 — factor depending on the aspect ratio λ of the rudder area;
$K_1 = (\lambda + 2)/3$, with λ not to be taken greater than 2;
$\lambda = b^2/A_t$;
b — mean height of the rudder area, in m. Mean breadth and mean height of rudder are calculated according to the coordinate system in Figure 3.1.2.1;
A_t — sum of rudder blade area A and area of rudder post or rudder horn, if any, within the height b, in m^2;

K_2 — coefficient depending on the type of the rudder and the rudder profile according to Table 3.1.2.1; data may be provided by tests with approval of CCS;

K_3 = 0.8 for rudders outside the propeller jet;
= 1.15 for rudders behind a fixed propeller nozzle;
= 1.0 otherwise.

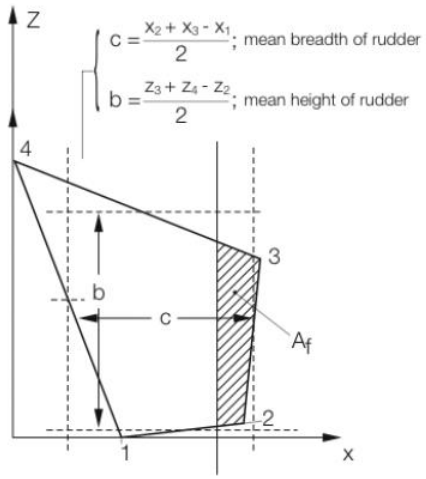
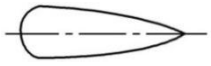
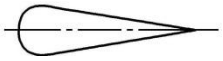
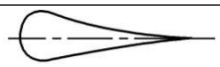
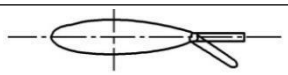


Figure 3.1.2.1

Factor K_2 **Table 3.1.2.1**

Profile Type		K_2	
		Ahead condition	Astern condition
NACA-00 series Göttingen		1.1	0.80
Flat side		1.1	0.90
Hollow		1.35	0.90
High lift rudders		1.7	1.30
Fish tail		1.4	0.8
Single plate		1.0	1.0
Mixed profiles （e.g. HSVA）		1.21	0.9

(2) The rudder torque is to be calculated for both the ahead and astern condition as follows:

$$Q_R = C_R r \quad \text{Nm}$$

where: $r = c\,(\alpha\text{-}k)$, in m;

c — mean breadth of rudder area, in m, see Figure 3.1.2.1;

α — coefficient, taken as 0.33 for ahead condition and 0.66 for astern condition; special consideration may be given for high lift rudders, and taken as 0.40 for ahead condition and 0.66 for astern condition if no test data may be provided;

$k = \frac{A_f}{A}$;

A_f — portion of the rudder blade area situated ahead of the centre line of the rudder stock, in m^2;

$r_{min} = 0.1c$, in m, for ahead condition.

3.1.2.2 Rudder blades with cut-outs (semi-spade rudders)

The total rudder force C_R is to be calculated according to 3.1.2.1(1) of this Section. The pressure distribution over the rudder area, upon which the determination of rudder torque and rudder blade strength is to be based, is to be derived as follows:

The rudder area may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2, so that $A = A_1 + A_2$ (see Figure 3.1.2.2).

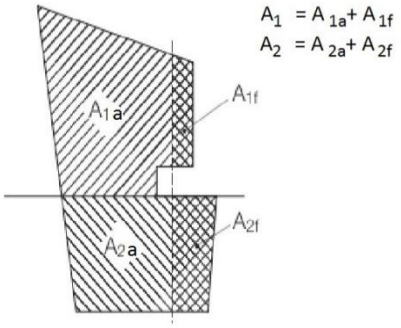


Figure 3.1.2.2 Areas A_1 and A_2

The levers r_1 and r_2 are to be determined as follows:

$$r_1 = c_1 (\alpha - k_1), \text{ m};$$

$$r_2 = c_2 (\alpha - k_2), \text{ m};$$

where: c_1, c_2 — mean breadth of partial areas A_1, A_2 determined, where applicable, in accordance with Figure 3.1.2.1;

$$k_1 = \frac{A_{1f}}{A_1};$$

$$k_2 = \frac{A_{2f}}{A_2};$$

A_{1a} —portion of A_1 situated aft of the centre line of the rudder stock, in m^2;

A_{1f} — portion of A_1 situated ahead of the centre line of the rudder stock, in m^2;

A_{2a} —portion of A_2 situated aft of the centre line of the rudder stock, in m^2;

A_{2f} — portion of A_2 situated ahead of the centre line of the rudder stock, in m^2;

α = 0.33 for ahead condition;

α = 0.66 for astern condition;

For parts of a rudder behind a fixed structure such as the rudder horn:

α = 0.25 for ahead condition;

α = 0.55 for astern condition;

The resulting force of each part may be taken as:

$$C_{R1} = C_R \frac{A_1}{A} \quad \text{N}$$

$$C_{R2} = C_R \frac{A_2}{A} \quad \text{N}$$

The resulting torque of each part may be taken as:

$$Q_{R1} = C_{R1} r_1 \quad \text{N·m}$$

$$Q_{R2} = C_{R2} r_2 \quad \text{N·m}$$

The total rudder torque is to be calculated for both the ahead and astern condition as follows:

$$Q_R = Q_{R1} + Q_{R2} \quad \text{N·m}$$

For ahead condition Q_R is not to be taken less than:

$$Q_{Rmin} = 0.1\, C_R \frac{A_1 c_1 + A_2 c_2}{A} \quad \text{N·m}$$

3.1.3 Rudder strength calculation

3.1.3.1 The rudder force and resulting rudder torque as given in 3.1.2 of this Section causes bending moments and shear forces in the rudder body, bending moments and torques in the rudder stock, supporting forces in pintle bearings and rudder stock bearings and bending moments, shear forces and torques in rudder horns and heel pieces. The rudder body is to be stiffened by horizontal and vertical webs enabling it to act as a bending girder.

3.1.3.2 The bending moments, shear forces and torques as well as the reaction forces are to be determined by a direct calculation or by an approximate simplified method considered appropriate by CCS. For rudders

supported by sole pieces or rudder horns these structures are to be included in the calculation model in order to account for the elastic support of the rudder body. Guidelines for calculation of bending moment and shear force distribution are given in Appendix 1 to this Chapter.

3.1.4 Rudder stock scantlings

3.1.4.1 The rudder stock diameter required for the transmission of the rudder torque is to be dimensioned such that the torsional stress τ_t is not exceeding the following value:

$$\tau_t = 68 / K \quad \text{N/mm}^2$$

The rudder stock diameter for the transmission of the rudder torque d_t is therefore not to be less than:

$$d_t = 4.2\sqrt[3]{Q_R K} \quad \text{mm}$$

where: Q_R — total rudder torque [N·m] as calculated in 3.1.2.1(2) and 3.1.2.2 of this Section;

K — material factor for the rudder stock as given in 3.1.1.3(5) of this Section.

3.1.4.2 Rudder stock scantlings due to combined loads

If the rudder stock is subjected to combined torque and bending, the equivalent stress in the rudder stock is not to exceed $118 / K$ N/mm^2.

K — material factor for the rudder stock as given in 3.1.1.3(5).

The equivalent stress σ_c is to be determined by the formula:

$$\sigma_c = \sqrt{\sigma_b^2 + 3\tau_t^2} \quad \text{N/mm}^2$$

where: bending stress: $\sigma_b = \dfrac{10.2M}{d_c^3} \times 10^3$ N/mm^2;

torsional stress: $\tau_t = \dfrac{5.1Q_R}{d_c^3} \times 10^3$ N/mm^2.

The rudder stock diameter d_c is therefore not to be less than:

$$d_c = d_t \sqrt[6]{1 + \frac{4}{3}\left(\frac{M}{Q_R}\right)^2} \quad \text{mm} \qquad \text{mm}$$

where: M — bending moment, in N·m, at the station of the rudder stock considered.

For a spade rudder with trunk extending inside the rudder, the rudder stock scantlings are to be checked against the two cases defined in 2.2, Appendix 1 of this Chapter.

3.1.4.3 Before significant reductions in rudder stock diameter due to the application of steels with specified minimum yield stresses exceeding 235 N/mm^2 are granted, CCS may require the evaluation of the rudder stock deformations. Large deformations of the rudder stock are to be avoided in order to avoid excessive edge pressures in way of bearings.

3.1.5 Rudder blade

3.1.5.1 Permissible stresses

The section modulus and the web area of a horizontal section of the rudder blade are to be such that the following stresses will not be exceeded:

(1) In general, except in way of rudder recess sections where (2) applies

① bending stress σ_b $110/k$ N/mm^2

② shear stress τ $50/k$ N/mm^2

③ equivalent stress $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$ $120/k$ N/mm^2

K — material factor for the rudder plating as given in 3.1.1.3(2).

(2) In way of the recess for the rudder horn pintle on semi-spade rudders

① bending stress σ_b 75 N/mm^2

② shear stressτ 50 N/mm^2

③ equivalent stress $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$ 100 N/mm^2

Note: The stresses in (2) apply equally to high tensile and ordinary steels.

3.1.5.2 Rudder plating

The thickness t of the rudder side, top and bottom plating is not to be less than:

$$t = 5.5 s \beta \sqrt{K} \sqrt{d + C_R 10^{-4} / A} + 2.5 \quad \text{mm}$$

where: d — scantling draught, in m;

C_R — rudder force, in N, according to 3.1.2.1 of this Section;

A — rudder area, in m^2;

$\beta=\sqrt{1.1-0.5(\frac{s}{b})^2}$ max. 1.00 if $\frac{b}{s} \geq 2.5$;

s — smallest unsupported width of plating, in m;

b — greatest unsupported width of plating, in m;

K — material factor for the rudder plating as given in 3.1.1.3(2).

The thickness of the nose plate of rudder blades is not to be less than 1.2 times that of rudder side plating, but need not be greater than 22 mm. The thickness of web plates is not to be less than the greater of 70% of the rudder side plating thickness and 8 mm.

The rudder plating in way of the solid part is to be of increased thickness per 3.1.5.3(4).

3.1.5.3 Connections of rudder blade structure with solid parts

(1) Solid parts in forged or cast steel, which house the rudder stock or the pintle, are to be provided with protrusions.

These protrusions are not required when the web plate thickness is less than:

-10 mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders;

-20 mm for other web plates.

(2) The solid parts are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

(3) Minimum section modulus of the connection with the rudder stock housing.

The section modulus of the cross-section of the structure of the rudder blade W_s, in cm^3, formed by vertical web plates and rudder plating, which is connected with the solid part where the rudder stock is housed is to be not less than:

$$W_s = c_s d_c^{\,3} \left(\frac{H_E - H_x}{H_E} \right)^2 \frac{K}{K_s} 10^{-4} \text{ cm}^3$$

where: c_s — coefficient, to be taken equal to:

= 1.0 if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate;

= 1.5 if there is an opening in the considered cross-section of the rudder;

d_c — diameter of rudder stock in way of lower bearing, in mm, calculated according to 3.1.4 of this Section;

H_E — vertical distance between the lower edge of the rudder blade and the upper edge of the solid part, in m;

H_X — vertical distance between the considered cross-section and the upper edge of the solid part, in m;

K — material factor for the rudder blade plating as given in 3.1.1.3(2);

K_s — material factor for the rudder stock as given in 3.1.1.3(5).

The actual section modulus of the cross-section of the structure of the rudder blade is to be calculated with respect to the symmetrical axis of the rudder. The breadth of the rudder plating, in m, to be considered for the calculation of section modulus is to be not greater than:

$$b = s_v + 2H_X / 3 \quad \text{m}$$

where: s_v — spacing between the two vertical webs, in m (see Figure 3.1.5.3).

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted.

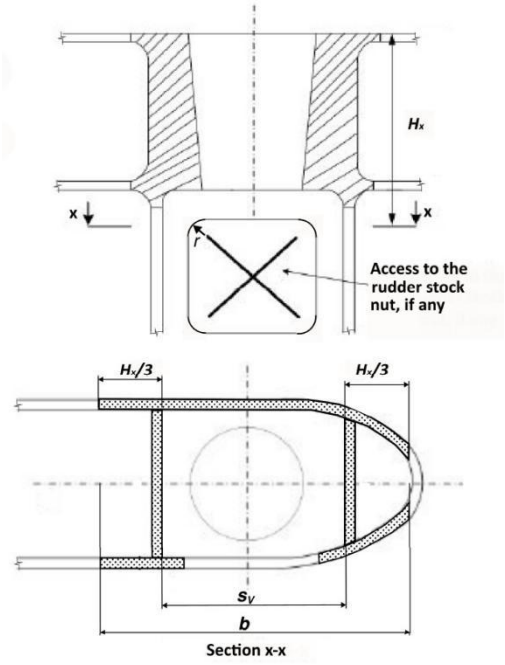


Figure 3.1.5.3 Cross-section of the connection between rudder blade structure and rudder stock housing, example with opening in only one side shown

(4) The thickness of the horizontal web plates connected to the solid parts, in mm, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the following values:

$$t_H = 1.2t \quad \text{mm}$$

$$t_H = 0.045 d_s^{\,2} / S_H \quad \text{mm}$$

where: t— defined in 3.1.5.2 of this Section;

d_S — diameter, in mm, to be taken equal to:

= d_c, as per 3.1.4.2 of this Section, for the solid part housing the rudder stock;

=d_p, as per 3.1.7.1 of this Section, for the solid part housing the pintle;

S_H — spacing between the two horizontal web plates, in mm.

The increased thickness of the horizontal webs is to extend fore and aft of the solid part at least to the next vertical web.

(5) The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from Table 3.1.5.3.

Thickness of side plating and vertical web plates Table 3.1.5.3

Type of rudder	Thickness of vertical web plates, in mm		Thickness of rudder plating, in mm	
	Rudder blade without opening	Rudder blade with opening	Rudder blade without opening	Area with opening
Rudder supported by sole piece	1.2 t	1.6 t	1.2 t	1.4 t
Semi-spade and spade rudders	1.4 t	2.0 t	1.3 t	1.6 t

where: t = thickness of the rudder plating, in mm, as defined in 3.1.5.2 of this Section.

The vertical web plates and rudder plating the thickness of which has been increased are to extend below the solid piece at least to the next horizontal web.

3.1.5.4 Single plate rudders

(1) Mainpiece diameter

The mainpiece diameter is calculated according to 3.1.4.1 and 3.1.4.2 of this Section respectively. For spade rudders the lower third may taper down to 0.75 times stock diameter.

(2) Blade thickness

The blade thickness t is not to be less than:

$$t_b = 1.5 s V \sqrt{K} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffening arms, in m not to exceed 1 m;

V — speed in knots, see 3.1.2.1(1) of this Section;

K — material factor for the rudder plating as given in 3.1.1.3(2) of this Section.

(3) Arms

The thickness of the arms t_a is not to be less than the blade thickness:

$$t_a = t_b \quad \text{mm}$$

The section modulus W is not to be less than:

$$W = 0.5\, s\, C_1^2\, V^2\, K \quad \text{cm}^3$$

where: C_1 — horizontal distance from the aft edge of the rudder to the centreline of the rudder stock, in m;

K — material factor as given in 3.1.1.3(2) or 3.1.1.3 (5) of this Section respectively.

3.1.6 Rudder stock couplings

3.1.6.1 Horizontal flange couplings

(1) The diameter of the coupling bolts d_b is not to be less than:

$$d_b = 0.62\sqrt{d_s^3 K_b / n e_m K_s} \quad \text{mm}$$

where: d_s — stock diameter, taken equal to the greater of the diameters d_t or d_c according to 3.1.4.1 and 3.1.4.2, in mm;

n — total number of bolts, which is not to be less than 6;

e_m — mean distance, in mm, of the bolt axes from the centre of the bolt system;

K_s — material factor for the stock as given in 3.1.1.3(5) of this Section;

K_b — material factor for the bolts as given in 3.1.1.3(5) of this Section.

(2) The thickness of the coupling flanges t_f, in mm, is not to be less than the greater of the following formulae:

$$t_f = d_b\sqrt{K_f / K_b} \quad \text{mm}$$

$$t_f = 0.9 d_b \quad \text{mm}$$

where: K_f — material factor for flange as given in 3.1.1.3(5) of this Section;

K_b — material factor for the bolts as given in 3.1.1.3(5) of this Section;

d_b — bolt diameter, in mm, calculated for a number of bolts not exceeding 8.

(3) The width of material between the perimeter of the bolt holes and the perimeter of the flange is not to be less than 0.67 d_b.

(4) The welded joint between the rudder stock and the flange is to be made in accordance with Figure 3.1.6.1 or equivalent.

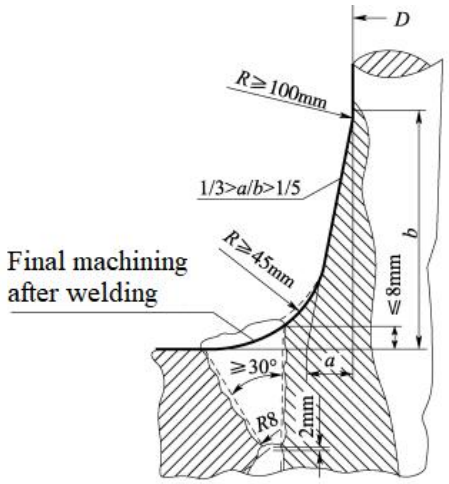


Figure 3.1.6.1 Welded joint between rudder stock and coupling flange

(5) Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

3.1.6.2 Vertical flange couplings of rudder stock and rudder blades

(1) The diameter of the coupling bolts d_b, in mm, is not to be less than:

$$d_b = 0.81 d_s / \sqrt{n} \times \sqrt{K_b / K_s} \quad \text{mm}$$

where: d_s — stock diameter [in mm] in way of coupling flange;

n — total number of bolts, which is not to be less than 8;

K_b — material factor for bolts as given in 3.1.1.3(5) of this Section;

K_s — material factor for stock as given in 3.1.1.3(5) of this Section.

(2) The first moment of area of the bolts about the centre of the coupling, m, is to be not less than:

$$m = 0.00043\ d_s^3 \qquad \text{cm}^3$$

(3) The thickness of the coupling flanges is to be not less than the bolt diameter, and the width of the flange material between the perimeter of the bolt holes and the perimeter of the flange is to be not less than 0.67 d_b.

(4) Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

3.1.6.3 Cone couplings with key

(1) Tapering and coupling length

Cone couplings without hydraulic arrangements for mounting and dismounting the coupling are to have a taper c on diameter of 1:8 − 1:12.

Where $c = (d_0 - d_u) / l_c$, see Figure 3.1.6.3(a) and Figure 3.1.6.3(c).

The diameters d_0 and d_u are shown in Figure 3.1.6.3(a) and the cone length, l_c, is defined in Figure 3.1.6.3(c).

The cone coupling is to be secured by a slugging nut. The nut is to be secured, e.g. by a securing plate as shown in Figure 3.1.6.3(a).

The cone shapes are to fit exactly. The coupling length l is to be, in general, not less than $1.5d_0$.

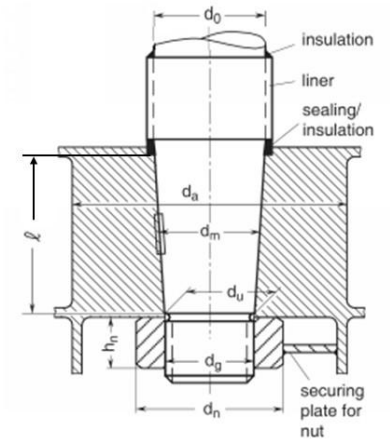


Figure 3.1.6.3(a) Cone coupling with key

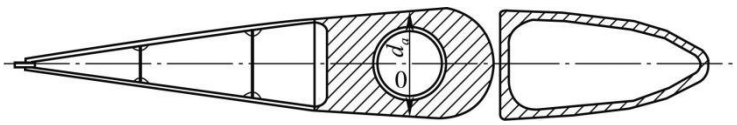


Figure 3.1.6.3(b) Gudgeon outer diameter d_a

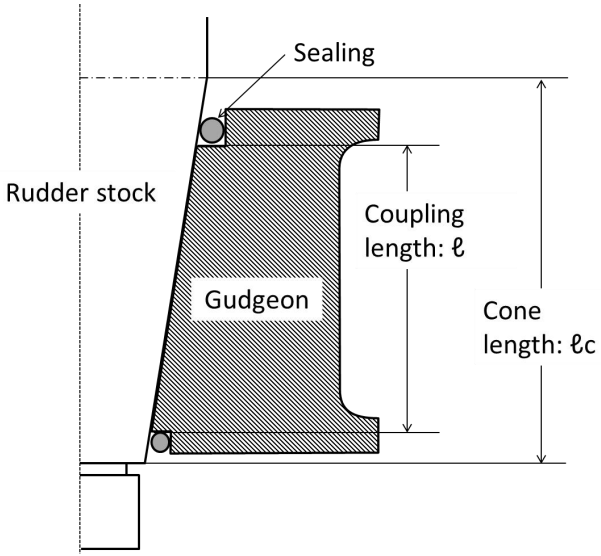


Figure 3.1.6.3(c) Cone length and coupling length

(2) Dimensions of key

For couplings between stock and rudder a key is to be provided, the shear area a_s of which, in cm^2, is not to be less than:

$$a_s = \frac{17.55 Q_F}{d_k R_{eH1}} \quad \text{cm}^2$$

where:

Q_F — design yield moment of rudder stock, in N·m;

$Q_F = 0.02664 d_t^3 / K$ N·m

Where the actual diameter d_{ta} is greater than the calculated diameter d_t, the diameter d_{ta} is to be used. However, d_{ta} applied to the above formula need not be taken greater than 1.145 d_t.

d_t — stock diameter, in mm, according to 3.1.4.1 of this Section;

K — material factor for stock as given in 3.1.1.3(5) of this Section;

d_k — mean diameter of the conical part of the rudder stock, in mm, at the key;

R_{eH1} —specified minimum yield stress of the key material, in N/mm^2.

The effective surface area a_k, in cm^2, of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5 Q_F}{d_k R_{eH2}}$$

where: R_{eH2} —specified minimum yield stress of the key, stock or coupling material, in N/mm^2.

(3) The dimensions of the slugging nut are to be as follows (see Figure 3.1.6.3(a)):

external thread diameter: $d_g \geq 0.65\, d_o$,

height: $h_n \geq 0.6\, d_g$,

outer diameter: $d_n \geq 1.2\, d_u$ or $1.5\, d_g$, whichever is the greater.

(4) It is to be proved that 50% of the design yield moment is solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to 3.1.6.4(2) and 3.1.6.4(3) for a torsional moment $Q'_F = 0.5 Q_F$.

(5) Notwithstanding the requirements of 3.1.6.3(2) and 3.1.6.3(4), where a key is fitted to the coupling between stock and rudder and it is considered that the entire rudder torque is transmitted by the key at the couplings, the scantlings of the key as well as the push-up force and push-up length are to be calculated according to the torque transmitted (not to be greater than the design yielding torque of the rudder stock.

3.1.6.4 Cone couplings with special arrangements for mounting and dismounting the couplings

(1) Where the stock diameter exceeds 200 mm, the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone is to be more slender, c ≈1:12 to ≈1:20.

In case of hydraulic pressure connections the nut is to be effectively secured against the rudder stock or the pintle.

For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the push-up pressure and the push-up length are to be determined according to 3.1.6.4(2) and 3.1.6.4(3) respectively.

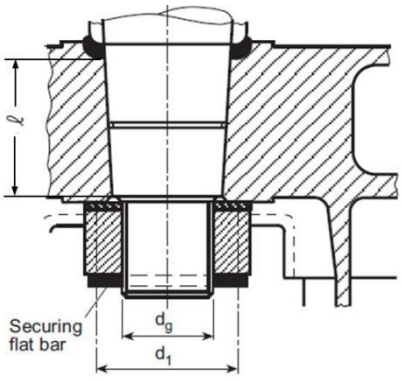


Figure 3.1.6.4 Cone couplings without key

(2) Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2 Q_F \times 10^3}{d_m^{\,2} l \pi \mu_0} \quad \text{N/mm}^2$$

$$p_{req2} = \frac{6M_c \times 10^3}{l^2 d_m} \quad \text{N/mm}^2$$

where: Q_F — design yield moment of rudder stock, as defined in 3.1.6.3(2) of this Section, in N·m;

d_m — mean cone diameter, in mm, see Figure 3.1.6.3(a);

l — coupling length, in mm;

μ_0 — frictional coefficient, equal to 0.15;

M_c — bending moment in rudder stock at the top of the cone coupling (e.g. in case of spade rudders), in N·m.

For spade rudder with trunk extending inside the rudder, the coupling is to be checked against the two cases defined in 2.2, Appendix 1 of this Chapter.

It has to be proved by the designer that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure, in N/mm², is to be determined by the following formula:

$$p_{perm} = \frac{0.95R_{eH}(1-\alpha^2)}{\sqrt{3+\alpha^4}} - p_b \quad \text{N/mm}^2 \quad \text{N/mm}^2$$

where: $p_b = \dfrac{3.5M_c \times 10^3}{d_m l^2}$ N/mm²;

R_{eH} — specified minimum yield stress of the material of the gudgeon, in N/mm²;

$\alpha = \dfrac{d_m}{d_a}$;

d_m — diameter, in mm, see Figure 3.1.6.3(a);

d_a — outer diameter of the gudgeon to be not less than 1.25 d_0, in mm, see Figure 3.1.6.3 (a) and 3.1.6.3(b). (The least diameter is to be considered).

(3) Push-up length

The push-up length Δl, in mm, is to comply with the following formula:

$$\Delta l_1 \le \Delta l \le \Delta l_2$$

where: $\Delta l_1 = \dfrac{p_{req} d_m}{E\left(\dfrac{1-\alpha^2}{2}\right)c} + \dfrac{0.8R_{tm}}{c}$ mm

$$\Delta l_2 = \frac{p_{perm} d_m}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8R_{tm}}{c} \quad \text{mm}$$

R_{tm} — mean roughness, in mm, taken equal to 0.01;

c — taper on diameter according to 3.1.6.4(1) of this Section, in mm;

Note: In case of hydraulic pressure connections the required push-up force P_e, in N, for the cone may be determined by the following formula:

$$P_e = p_{req} d_m \pi l \left(\frac{c}{2} + 0.02\right)$$

The value 0.02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed. Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval by CCS.

3.1.7 Pintles

3.1.7.1 Scantlings

The pintle diameter d_p, in mm, is not to be less than:

$$d_p = 0.35\sqrt{BK_p} \quad \text{mm}$$

where: B — relevant bearing force, in N;

k_p — material factor for pintle as given in 3.1.1.3(5) of this Section.

3.1.7.2 Couplings

(1) Tapering

Pintles are to have a conical attachment to the gudgeons with a taper on diameter not greater than:
1:8 to 1:12 for keyed and other manually assembled pintles applying locking by slugging nut,
1:12 to 1:20 on diameter for pintles mounted with oil injection and hydraulic nut.
(2) Push-up pressure for pintle
The required push-up pressure for pintle in case of dry fitting, in N/mm², is to be determined by p_{req1} as given below.
The required push-up pressure for pintle in case of oil injection fitting, in N/mm², is to be determined by the maximum pressure of p_{req1} and p_{req2} as given below:

$$p_{req1} = 0.4\frac{Bd_0}{d_m^2 l} \quad \text{N/mm}^2$$

$$p_{req2} = \frac{6M_{bp}}{l^2 d_m} \times 10^3 \quad \text{N/mm}^2$$

where: B — Supporting force in the pintle, in N;
d_0 — Pintle diameter, in mm, see Figure 3.1.6.3(a);
M_{bp} ——bending moment in the pintle cone coupling to be determined by:

$$M_{bp} = Bl_a \quad \text{N·m}$$

l_a ——length between middle of pintle-bearing and top of contact surface between cone coupling and pintle, see Figure 3.1.7.2..

The push up length Δl_1 is to be calculated similarly as in 3.1.6.4(3) of this Section, using required push-up pressure and properties for the pintle.

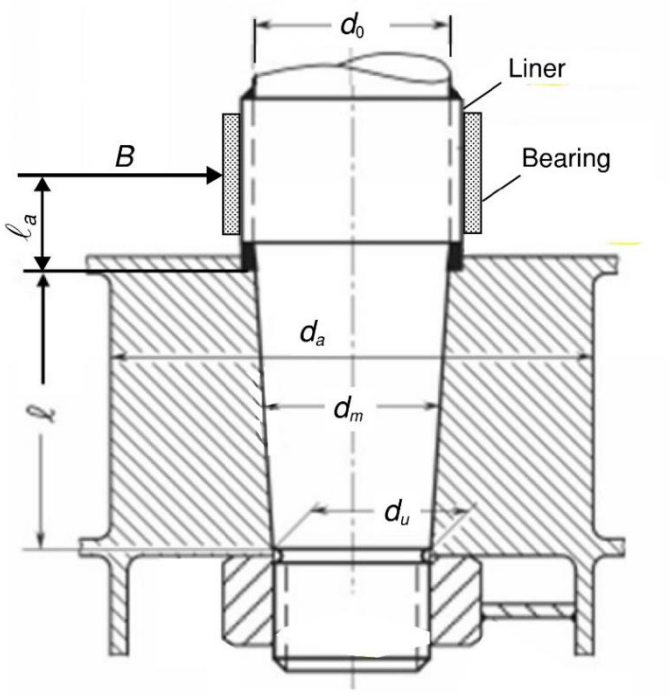


Figure 3.1.7.2 Pintle cone coupling indicating l_a

3.1.7.3 The minimum dimensions of threads and nuts are to be determined according to 3.1.6.3(3).
3.1.7.4 Pintle housing
The length of the pintle housing in the gudgeon is not to be less than the pintle diameter d_p. d_p is to be measured on the outside of shaft sleeves.
The thickness of the pintle housing is not to be less than 0.25 d_p.

3.1.8 Rudder stock bearing, rudder shaft bearing and pintle bearing

3.1.8.1 Liners and bushes

(1) Rudder stock bearing

Liners and bushes are to be fitted in way of bearings. For rudder stocks and pintles having diameter less than 200 mm, liners in way of bushes may be provided optionally. The minimum thickness of liners and bushes t_{min} is to be equal to:

- t_{min} = 8 mm for metallic materials and synthetic material;
- t_{min} = 22 mm for lignum material.

(2) Pintle bearing

The thickness of any liner or bush t, in mm, is not to be less than the minimum thickness defined in 3.1.8.1(1) and the following value:

$$t = 0.01\sqrt{B}$$

where: B— relevant bearing force, in N.

3.1.8.2 Minimum bearing surface

An adequate lubrication is to be provided.

The bearing surface A_b (defined as the projected area: length × outer diameter of liner) is not to be less than:

$$A_b = \frac{P}{q_a} \quad \text{mm}^2$$

where: P — reaction force, in N, in bearing as determined in 3.1.3.2 of this Section;

q_a — allowable surface pressure according to Table 3.1.8.2.

The allowable surface pressure q_a for the various combinations is to be taken as reported in the table below. Higher values than given in Table 3.1.8.2 may be taken in accordance with makers' specifications if they are verified by tests:

Allowable surface pressure q_a **Table 3.1.8.2**

Bush material	q_a (N/mm^2)
Lignum vitae	2.5
White metal, oil lubricated	4.5
Synthetic material with hardness greater than 60 Shore D①	5.5②
Steel③ and bronze and hot-pressed bronze-graphite materials	7.0

Notes:

① Indentation hardness test at 23℃ and with 50% moisture, are to be carried out according to a recognized standard. Synthetic bearing materials are to be of an approved type.

② Surface pressures exceeding 5.5 N/mm^2 may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm^2.

③ Stainless and wear-resistant steel in an approved combination with stock liner.

3.1.8.3 Bearing dimensions

The length/diameter ratio of the bearing surface is not to be greater than 1.2.

The bearing length L_p of the pintle is to be such that $D_P \leq L_P \leq 1.2\ D_P$

where: D_p —Actual pintle diameter measured on the outside of liners, in mm.

3.1.8.4 Bearing clearances

With metal bearings, clearances should not be less than d / 1000 + 1.0 mm (where d is the outer diameter of rudder stock or pintle) on the diameter. If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties. This clearance is not to be taken less than 1.5 mm on bearing diameter unless a smaller clearance is supported by the manufacturer's recommendation and there is documented evidence of satisfactory service history with a reduced clearance.

3.1.9 Strength of rudder horns and rudder trunk

3.1.9.1 Rudder horns

The bending moments and shear forces are to be determined by a direct calculation or in line with the guidelines given in 2.4 and 2.5 of Appendix 1 for semi spade rudder with one elastic support and semi spade rudder with 2-conjugate elastic support respectively.

The section modulus around the horizontal x-axis W is not to be less than:

$$W = M_b K / 67 \quad \text{cm}^3$$

where: M_b — bending moment at the section considered, in N·m.

The shear stress τ is not to be larger than:

$$\tau = 48/K \quad \text{N/mm}^2$$

where: K — material factor as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section.

(1) Equivalent stress

At no section within the height of the rudder horn is the equivalent stress to exceed $120/K$ N/mm^2. The equivalent stress σ_v is to be calculated by the following formula:

$$\sigma_v=\sqrt{\sigma_b^2+3\left(\tau^2+\tau_T^2\right)} \quad \text{N/mm}^2$$

where: $\sigma_b=M_b / Z_x$, in N/mm^2;

Z_x — section modulus of rudder horn at the section considered, in cm^3;

$\tau=B_1/A_h$, in N/mm^2;

B_1 — supporting force in the pintle bearing, in N;

A_h — effective shear area of rudder horn in y-direction, in mm^2;

$\tau_T=M_T 10^3/2A_T t_h$, in N/mm^2;

M_T — torsional moment, in N·m;

A_T — area in the horizontal section enclosed by the rudder horn (including the area of inner hollow area), in mm^2;

t_h — plate thickness of rudder horn, in mm;

(2) Rudder horn plating

The thickness of the rudder horn side plating t is not to be less than:

$$t=2.4\sqrt{LK} \quad \text{mm}$$

where: L — length of the ship, in m;

K — material factor, as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section respectively.

(3) Welding and connection to hull structure

The rudder horn plating is to be effectively connected to the aft ship structure, e.g. by connecting the plating to side shell and transverse/ longitudinal girders, in order to achieve a proper transmission of forces, see Figure 3.1.9.1.

If the connection of rudder horn and hull structure is so designed that the rudder horn is transited to hull plating in the curved way, particular attention is to be made to the effectiveness of the bending of rudder horn and the stress of transverse webs.

Brackets or stringer are to be fitted internally in horn, in line with outside shell plate, as shown in Figure 3.1.9.1.

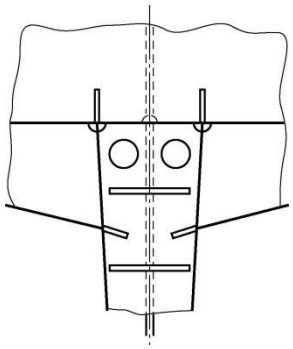


Figure 3.1.9.1 Connection of rudder horn to aft ship structure

Transverse webs of the rudder horn are to be led into the hull up to the next platform deck in a sufficient number.

Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a sufficient connection with the hull.

The centre line bulkhead (wash-bulkhead) in the after peak is to be connected to the rudder horn.

Scallops are to be avoided in way of the connection between transverse webs and shell plating.

The weld at the connection between the rudder horn plating and the side shell is to be full penetration. The welding radius is to be as large as practicable and may be obtained by grinding.

3.1.9.2 Rudder trunk

The requirements in this paragraph apply to trunk configurations which are extended below stern frame and arranged in such a way that the trunk is stressed by forces due to rudder action.

(1) Materials, welding and connection to hull

The steel used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0.23% on ladle analysis or a carbon equivalent C_{EQ} not exceeding 0.41%.

Plating materials for rudder trunks are in general not to be of lower grades than corresponding to class II as defined in Section 3, Chapter 1 of this PART.
The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.
For rudder trunks extending below shell or skeg, the fillet shoulder radius r, in mm (see Figure 3.1.9.2) is to be as large as practicable and to comply with the following formulae:

$r = 0.1 d_c / K$, without being less than:

r =60 mm when $\sigma = 40/K$ N/mm^2

r = 30 mm when $\sigma < 40/K$ N/mm^2

where: d_c — rudder stock diameter axis as defined in 3.1.4.2;

σ — bending stress in the rudder trunk, in N/mm^2;

K — material factor for the rudder trunk as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section.

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld. The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.
Rudder trunks comprising of materials other than steel are to be specially considered by CCS.

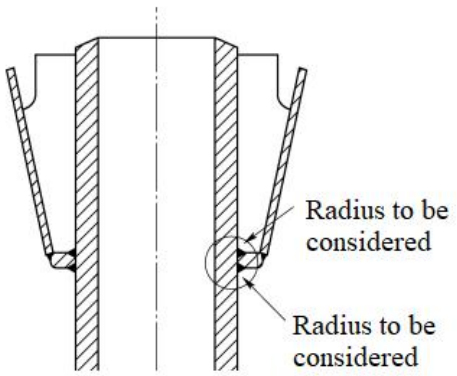


Figure 3.1.9.2

(2) Scantlings
The scantlings of the trunk are to be such that: the equivalent stress due to bending and shear does not exceed 0.35 R_{eH}.
The bending stress on welded rudder trunk σ is to be in compliance with the following formula:

$$\sigma \leqslant 80/K \quad \text{N/mm}^2$$

where: σ — bending stress in the rudder trunk, as defined in 3.1.9.2(1);

K — material factor for the rudder trunk as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section, not to be taken as less than 0.7;

R_{eH} —specified minimum yield stress, in N/mm^2, of the material used.

For calculation of bending stress, the span to be considered is the distance between the mid-height of the lower rudder stock bearing and the point where the trunk is clamped into the shell or the bottom of the skeg.

3.1.10 Others

3.1.10.1 Quadrants and tillers

(1) The section modulus W of the tiller at any section from the centre of the rudder stock about the vertical axis is not to be less than that obtained from the following formula:

$$W = 0.14(1 - \frac{D_S}{R}) D_t^3 (K_t / K_s) \quad \text{mm}^3$$

where: D_s — distance from the section under consideration to the centerline of the stock on the tiller, not greater than the bore diameter of the pin, in mm, see Figure 3.1.10.1;

D_t — stock diameter, in mm, at the tiller, taken not greater than 1.145 times the value calculated according to 3.1.4.1 of this Section;

R — radius of quadrant or length of tiller, in mm;

K_t — material factor of tiller, see 3.1.1.3(5) of this Section;

K_s — material factor of stock, see 3.1.1.3(5) of this Section.

For quadrants having more than one arm, the combined section modulus of the arms is not to be less than that required in the above formula.

For tillers of rectangular section, the breadth to depth ratio is not to be more than 2.

(2) Depth of boss of the quadrant or tiller $h \geq 1.0D_t$, and its outside diameter $D_0 \geq 1.8D_t$, see Figure 3.1.10.1. Where the depth of boss of the tiller h is greater than D_t, the required outer diameter D_0 may be reduced accordingly. It is to ensure that $h \times D_0^2 \geq 3.24D_t^3$, and D_0 is not to be less than $1.6D_t$ in any case. D_t is defined in (1) above.

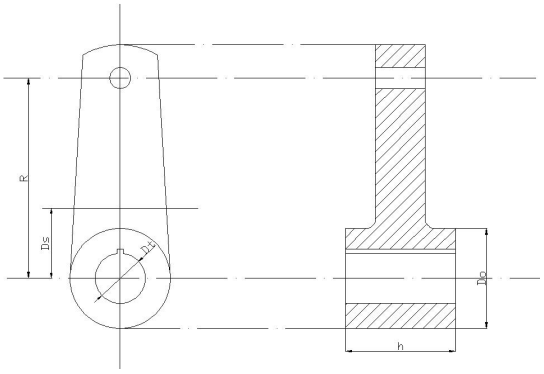


Figure 3.1.10.1

(3) Where the boss of a tiller (quadrant) is composed of two half pieces, at least one key is to be fitted and each end of the key is to be secured by at least 2 bolts. The bolts are to be pretightened and the prestressing force on each bolt is to correspond to 70% of the permissible stress of bolt material. Where double keys are used, the prestressing force may be reduced appropriately. The total cross-sectional area A_b of all bolts is not to be less that obtained from the following formula:

$$A_b = 0.2 \times \frac{D_t^3}{b}(K_b/K_s) \quad \text{mm}^2$$

where: D_t — stock diameter, in mm, at the tiller, taken not greater than 1.145 times the value calculated according to 3.1.4.1 of this Section;

b — distance between centerlines of bolt at both ends, in mm;

K_b — material factor of bolt, see 3.1.1.3(5) of this Section;

K_s — material factor of stock, see 3.1.1.3(5) of this Section.

(4) The cross-sectional area A_r and moment of inertia I_r of the rod connecting the tiller (quadrant) to the tiller are not to be less than those obtained from the following formulas:

$$A_r = 0.12 \times \frac{D_t^3}{R}(K_r / K_s) \quad \text{mm}^2$$

$$I_r = 6.6\frac{D_t^3 l^2}{R} \times 10^{-6}(K_r / K_s) \quad \text{mm}^4$$

where: D_t — diameter of the rudder stock, at the tiller of a passive rudder, taken not greater than 1.145 times the value calculated according to 3.1.4.1 of this Section;

l — length of the connecting rod, in mm;

R — length of the tiller of the passive rudder, in mm;

K_r — material factor of connecting rod, see 3.1.1.3(5) of this Section;

K_s — material factor of stock, see 3.1.1.3(5) of this Section.

(5) For a rotary vane type steering gear, the rotor and blades of the gear are to comply with the requirements of 3.1.10.1(1) and 3.1.10.1(2) for boss of the tiller and the tiller.

3.1.10.2 Connection of rudder tiller to stock

(1) The connection of the rudder tiller to stock is to be such that mechanical forces are transmitted from the steering gear to the rudder stock in any operational condition. The torque T_d transmitted by such connection is not to be less than twice the design torque of the steering gear, but need not be greater than the design yield torque Q_F of the stock calculated according to 3.1.6.3(2) of this Section. The design torque of the steering gear is corresponding to the design pressure in 13.1.6.5 of Chapter 13, PART THREE of the Rules.

(2) For torque transmission by friction, the average surface pressure p_r for the connection of tiller to stock is not to be less than that obtained from the following formula:

$$p_r \geq \frac{2T_{fr}}{\pi D_m^2 lf} \times 10^3 \quad \text{N/mm}^2$$

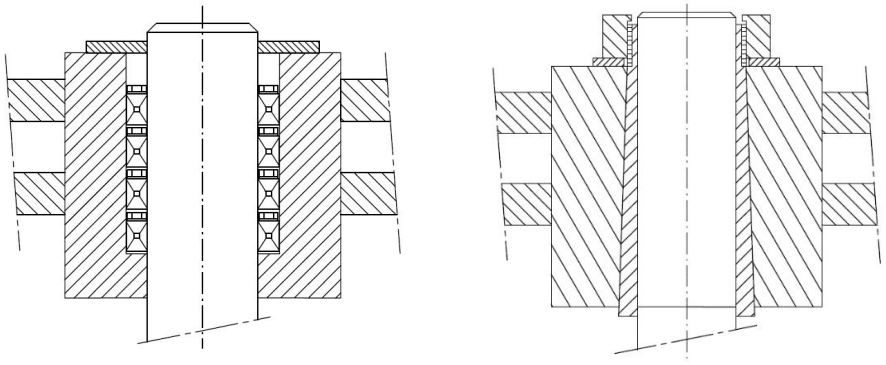
where: T_{fr} — torque transmitted by friction, in N·m;
= T_d, for keyless connection;
= $0.5T_d$, for keyed connection;
T_d — torque transmitted through connection of tiller to stock, in N·m, determined according to 3.1.10.2(1) of this Section;
D_m — diameter of the rudder stock or mean diameter of the taper, in mm;
l — length of the effectively connected portion of the tiller, in mm;
f — coefficient of friction, taken as 0.15 for hydraulic fit or 0.18 for dry fit.

(3) For conical connection, nuts are to be used for securing against axial displacement. It is to be ensured that the size of nuts is to sustain the weight of rudder and rudder stock without considering the force of friction between rudder tiller and rudder stock, and reference may be made to the requirements of 3.1.6.3(3) of this Section.

(4) Where the tiller is connected to the stock by means of several expansion sleeves or conical sleeves, as indicated in Figure 3.1.10.2, the influence of axial forces is also to be taken into account. In this case, the torque T_{d1} transmitted by the connection of tiller to stock is not to be less than that obtained from the following formula:

$$T_{d1}=\sqrt{T_d^2+(2\cdot W\cdot D_m)^2\cdot 10^{-4}} \quad \text{N·m}$$

where: T_d — torque, in N·m, determined according to 3.1.10.2(1) of this Section;
W — weight of rudder and rudder stock, in kg;
D_m — diameter of rudder stock, in mm.



(a) Expansion sleeve (b) Conical sleeve

Figure 3.1.10.2

(5) The taper of cone on diameter is to be not greater than 1:15 for keyless conical connection and not greater than 1:10 for keyed conical connection.

(6) For keyed connection, the shear area As of the key is not to be less than that obtained from the following formula:

$$A_s=\frac{70\left(T_d-k_{key}T_{fr}\right)}{D_k R_{eH}} \quad \text{cm}^2$$

where: T_d — torque transmitted through connection of tiller to stock, in N·m, calculated according to 3.1.10.2 of this Section;
k_{key} — coefficient, determined as follows:
= 0.7 where boss of tiller is composed of two half pieces and secured by bolts;
= 0.9 for hydraulic fitting of tiller to stock;
= 1.0 in other cases.
T_{fr} — torque transmitted by friction, in N·m, calculated according to the following formula:

$$T_{fr}=\frac{\pi p_r D_m^2 lf}{2}\times 10^{-3}$$

where: p_r — average surface pressure for the connection of tiller to stock, in N/mm^2, determined according to 3.1.10.2(2) of this Section. Where hydraulic fitting or shrinkage fit is adopted for the conical connection, the average push-up surface pressure is to be taken;
D_m, l, f — same as in 3.1.10.2(2) of this Section;
D_k — mean diameter, in mm, of rudder stock cone in way of the position where the key is fitted;
R_{eH} — yield stress, in N/mm^2, of key material.

(7) For keyed connections, the compressed area A_k of keys (round edge portion not included) is not to be less than that obtained from the following formula:

$$A_k = \frac{22(T_d - k_{key} T_{fr})}{D_k R_{eH}} \quad \text{cm}^2$$

where: T_d , k_{key}, T_{fr} , D_k — same as in (6) above;

R_{eH} — yield stress, in N/mm^2, of key material.

(8) Where two keys are fitted, the shear area A_s and compressed area A_k of each key may be taken as 2/3 of the value obtained for one key.

(9) The keyway is to have an adequately rounded end. The radius of curvature is usually not to be less than 5% of the thickness of the key. The compressive stress on the stock/tiller keyway is not to exceed 90% of the yield stress of the material used.

(10) Where the hydraulic fitting or shrinkage fit is adopted for the conical connection, the push-up length and the average push-up surface pressure are to be determined in accordance with the following requirements:

① The push-up length S is to meet the following:

$$S_1 \le S \le S_2$$

The minimum push-up length $S_1 = \frac{1}{k_1}[\frac{2 p_r D_m k_2^2}{E(k_2^2 - 1)} + 0.02]$ mm

The maximum push-up length $S_2 = \frac{1}{k_1}[1.6 R_{eH} D_m \frac{k_2^2}{E\sqrt{3k_2^4 + 1}} + 0.02]$ mm

where: p_r — average surface pressure for the connection of tiller to stock, in N/mm^2, determined according to 3.1.10.2(2) of this Section;

k_1 — taper of cone on diameter;

$k_2 = (D_m + 2t_a) / D_m$;

D_m — mean diameter of cone, in mm;

t_a — mean thickness of boss of tiller, in mm;

R_{eH} — yield stress of material of boss of tiller or rudder stock, whichever is less, in N/ mm^2;

E — elastic modulus, to be taken as 2.06×10^5, in N/mm^2.

② The average push-up surface pressure P is to be calculated by the following formula:

$$P = \frac{SE(k_2^2 - 1)k_1}{2D_m k_2^2} \quad \text{N/ mm}^2$$

where: k_1, k_2, D_m and E — same as in ① above;

S — the push-up length to be determined in accordance with ① above, in mm.

3.1.10.3 Strengthening for navigation in ice

(1) For ships with Ice Class notations the scantlings and arrangement of the rudder structures are to comply with the relevant requirements of Chapter 4 of this PART.

Section 2 ANCHORING AND MOORING EQUIPMENT

3.2.1 Equipment number

3.2.1.1 The anchoring equipment for sea-going ships are to be provided in accordance with Tables 3.2.1.1(1) and 3.2.1.1(2), based on the ship type and service area as well as the equipment number derived from 3.2.1.2 of this Section. Requirements of this Section for the number, length and breaking loads of towlines and mooring lines are only as guidance.

For non-self-propelled ships engaged in special work, of which an increased mass of anchors is required by the owner and anchoring operations are carried out by means of other appliances, chain cables may be provided in accordance with the rule requirements for the mass of anchors only.

The requirement for the anchoring equipment in this Section is intended for temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc.

The equipment is therefore not designed to hold a ship off fully exposed coasts in rough weather or to stop a ship which is moving or drifting. In this condition the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large ships.

The anchoring equipment presently required in this Section is designed to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors will be significantly reduced.

The Equipment Numeral (EN) formula for anchoring equipment required in this Section is based on an assumed maximum current speed of 2.5 m/sec, maximum wind speed of 25 m/sec and a minimum scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth. For ships with an equipment length greater than 135 m, alternatively the required anchoring equipment can be considered applicable to a maximum current speed of 1.54 m/s, a maximum wind speed of 11 m/s and waves with maximum significant height of 2 m.

It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

Manufacture of anchors and anchor chain cables is to be in accordance with the relevant requirements of CCS Rules for Materials and Welding.

The bower anchor is to be connected with its chain cable, arranged onboard the ship and ready for use.

In addition to planned anchoring for normal operations, anchoring equipment is also important for ship safety in emergency situations such as loss of maneuverability, unscheduled repairs and other unexpected situations.

Equipment Required **Table 3.2.1.1(1)**

Ship type	Required equipment
Cargo ships, bulk carriers, oil tankers, trailing suction dredgers, ferries, etc.	Using *N*
Tugs	Using *N*
Offshore supply ships	Using *N*, but the chain cables are to be selected 2 grades above *N*
Manned barges	Using *N*
Unmanned barges	Using *N*, but only one bower anchor is required, and 0.5 times the length of chain cables required for *N* may be provided
Floating cranes, floating pile drivers or other similar workboats	Using *N*, but side projections of the crane, pile driver, etc., are to be considered for *N*. If the anchors used comply with the requirements of this Table, they may be used in lieu of bower anchors.

3.2.1.2 The equipment number *N* is to be obtained from the following formula:

$$N = \Delta^{\frac{2}{3}} + 2(Bh + S_{fun}) + \frac{A}{10}$$

where: Δ — moulded displacement, in t, to the summer load waterline;

B — moulded breadth, in m;

h — effective height, in m, from the summer load waterline to the top of the uppermost house, i.e.:

$$h = a + \sum h_i$$

where: a — vertical distance at hull side, in m, measured from the summer load waterline amidships to the upper deck;

h_i — height at the centreline, in m, of each tier of houses having a breadth greater than $B/4$; for the lowest tier h_1 is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck, see Figure 3.2.1.1(1);

A — area, in m², in profile view of the hull, within the length of the vessel, and of superstructures and deckhouses and funnels above the summer load waterline, which are within the length of the vessel, and also having a breadth greater than $B/4$. The side projected area of the funnel is considered in A when A_{FS} is greater than zero. In this case, the side projected area of the funnel should be calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F;

S_{fun} — effective front projected area of the funnel, in m², defined as:

$$S_{fun} = A_{FS} - S_{shield}$$

where: A_{FS}— front projected area of the funnel, in m² , calculated between the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F. A_{FS} is taken equal to zero if the funnel breadth is less than or equal to B/4 at all elevations along the funnel height;

h_F— effective height of the funnel, in m, measured from the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the top of the funnel. The top of the funnel may be taken at the level where the funnel breadth reaches B/4;

S_{shield} — the section of front projected area A_{FS}, in m², which is shielded by all deck houses having breadth greater than B/4. If there are more than one shielded section, the individual shielded sections i.e $S_{shield1}$, $S_{shield\ 2}$ etc as shown in Figure 3.2.1.2(3) to be added together. To determine S_{shield}, the deckhouse breadth is assumed B for all deck houses having breadth greater than B/4 as shown for $S_{shield1}$, $S_{shield2}$ in Figure 3.2.1.2(3). When several funnels are fitted on the ship, the above parameters are taken as follows:

h_F— effective height of the funnel, in m, measured from the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the top of the highest funnel. The top of the highest funnel may be taken at the level where the sum of each funnel breadth reaches B/4;

A_{FS}— sum of the front projected area of each funnel, in m² , calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F. A_{FS} is to be taken equal to zero if the sum of each funnel breadth is less than or equal to B/4 at all elevations along the funnels height;

A — Side projected area, in m², of the hull, superstructures, houses and funnels above the Summer Load waterline which are within the length of the ship. The total side projected area of the funnels is to be considered in the side projected area of the ship, A, when A_{FS} is greater than zero. The shielding effect of funnels in transverse direction may be considered in the total side projected area, i.e., when the side projected areas of two or more funnels fully or partially overlap, the overlapped area needs only to be counted once.

The equipment number of tugs is to be determined by the following formula:

$$N = \Delta^{\frac{2}{3}} + 2(aB + \sum b_i\ h_i) + \frac{A}{10}$$

where: a, B and h_i — same as defined above;

b_i — breadth, in m, of superstructures or of deckhouses of each tier having a breadth greater than B/4.

For tugs under 45 m in length intended for towing service only, one anchor may be used onboard provided that the second anchor and its relevant chain cable holds readily available to be installed. In case of loss of anchor, the tug is to remain in port until replace anchor equipment is installed onboard.

In the calculation of h and A, sheer and trim are to be ignored, i.e. h is the sum of freeboard amidships plus the height (at centreline) of each tier of houses having a breadth greater than B/4.

Screens and bulwarks more than 1.5 m in height are to be regarded as parts of superstructures or deckhouses.

Screens and bulwarks more than 1.5 m in height are to be regarded as parts of superstructures or deckhouses.

If a house having a breadth greater than B/4 is above a house with a breadth of B/4 or less then the wide house is to be included but the narrow house ignored.

The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A. With regard to determining A, when a bulwark is more than 1.5 m high, the area

shown as A_2 in Figure 3.2.1.2(2) is to be included in A. The total length of chain given in Table 3.2.1.1(2) is to be divided in approximately equal parts between the two bower anchors.
For ships of length less than 90 m, alternative methodology using direct force calculation for anchoring equipment described in appendix 3 of this Chapter may be used.

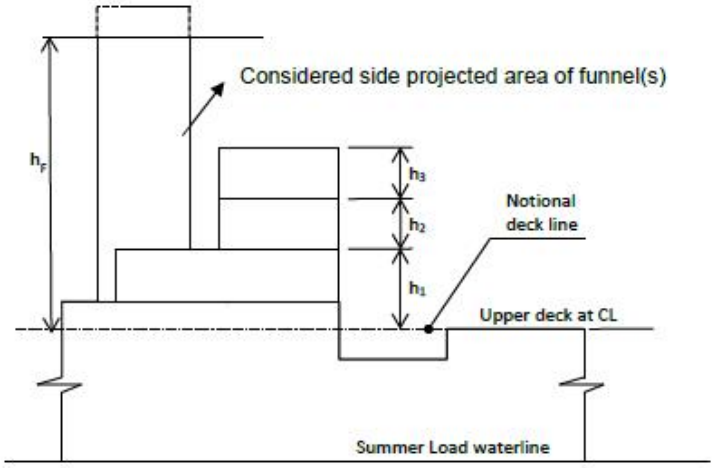


Figure 3.2.1.2(1)

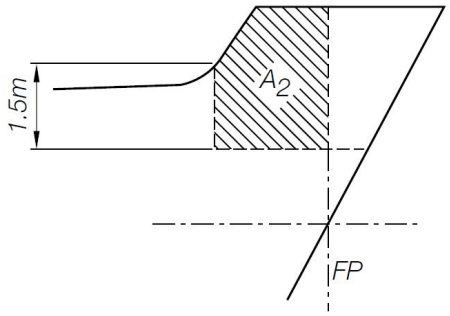


Figure 3.2.1.2(2)

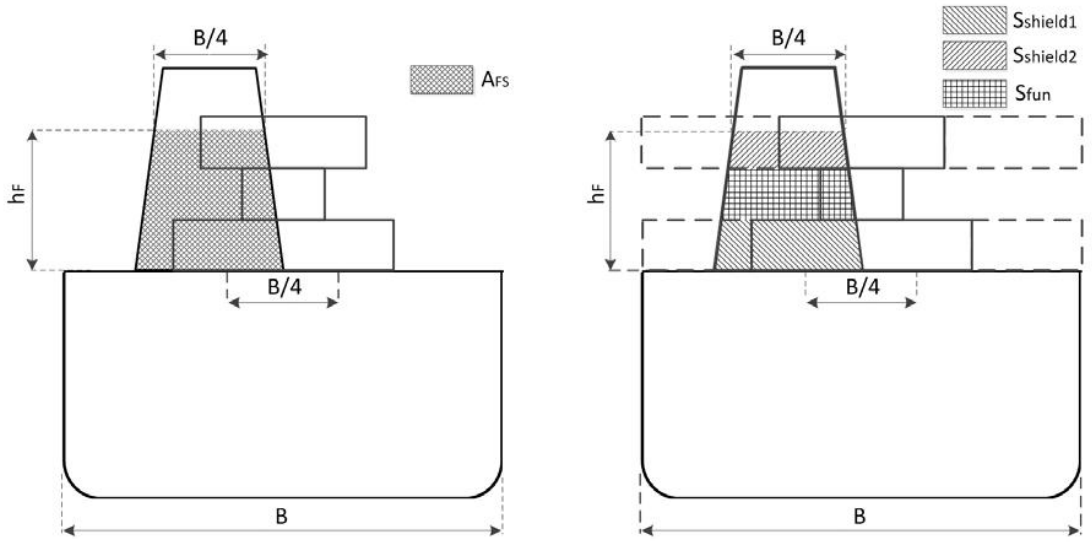


Figure 3.2.1.2(3)

3.2.2 Anchors

3.2.2.1 The mass of individual bower anchors may vary within -7% to +7% of the mass given in Table 3.2.1.1(2) of this Section, provided that the total mass of the bower anchors is not to be less than that would have been required for anchors of equal mass.

3.2.2.2 The mass of the head, including pins and swivels, of an ordinary stockless anchor is not to be less than 60% of the total mass of the anchor.

3.2.2.3 Stocked bower anchors may be used, but the mass excluding the stock is not to be less than 80% of the mass given in Table 3.2.1.1(2) of this Section for ordinary stockless bower anchors.

3.2.2.4 When high holding power anchors are used as bower anchors, the mass of each such anchor may be 75% of the mass given in Table 3.2.1.1(2) of this Section for ordinary stockless bower anchors. When super high holding power anchors of the proven holding power are used as bower anchors, the mass of each such anchor may be reduced to not less than 50% of the mass required for ordinary stockless anchors in Table 3.2.1.1(2) of this Section. See specific requirements of Section 1, Chapter 10 of PART ONE of CCS Rules for Materials and Welding. Where high holding power anchors or very high holding power anchors are used as bower anchors, leading to the reduction in the mass of anchors, the notation RWA may be assigned.

Anchoring and Towing Equipment **Table 3.2.1.1(2)**

Serial No.	Equipment No. N		Bower anchors		Stud link chain cable for bower anchors				Towlines		Mooring lines		
						Diameter							
	Exceeding	Not exceeding	Number	Mass of each anchor (kg)	Total length (m)	CCS grade 1	CCS grade 2	CCS grade 3	Min. length (m)	Ship design Min. breaking load (kN)	Number	Min. length each (m)	Ship design Min. breaking load (kN)
1	50	70	2	180	220	14	12.5		180	98	3	80	37
2	70	90	2	240	220	16	14		180	98	3	100	40
3	90	110	2	300	247.5	17.5	16		180	98	3	110	42
4	110	130	2	360	247.5	19	17.5		180	98	3	110	48
5	130	150	2	420	275	20.5	17.5		180	98	3	120	53
6	150	175	2	480	275	22	19		180	98	3	120	59
7	175	205	2	570	302.5	24	20.5		180	112	3	120	64
8	205	240	2	660	302.5	26	22	20.5	180	129	4	120	69
9	240	280	2	780	330	28	24	22	180	150	4	120	75
10	280	320	2	900	357.5	30	26	24	180	174	4	140	80
11	320	360	2	1020	357.5	32	28	24	180	207	4	140	85
12	360	400	2	1140	385	34	30	26	180	224	4	140	96
13	400	450	2	1290	385	36	32	28	180	250	4	140	107
14	450	500	2	1440	412.5	38	34	30	180	277	4	140	117
15	500	550	2	1590	412.5	40	34	30	190	306	4	160	134
16	550	600	2	1740	440	42	36	32	190	338	4	160	143
17	600	660	2	1920	440	44	38	34	190	370	4	160	160
18	660	720	2	2100	440	46	40	36	190	406	4	160	171
19	720	780	2	2280	467.5	48	42	36	190	441	4	170	187
20	780	840	2	2460	467.5	50	44	38	190	479	4	170	202
21	840	910	2	2640	467.5	52	46	40	190	518	4	170	218
22	910	980	2	2850	495	54	48	42	190	559	4	170	235
23	980	1060	2	3060	495	56	50	44	200	603	4	180	250
24	1060	1140	2	3300	495	58	50	46	200	647	4	180	272

Serial No.	Equipment No. N		Bower anchors		Stud link chain cable for bower anchors				Towlines		Mooring lines		
	Exceeding	Not exceeding	Number	Mass of each anchor (kg)	Total length (m)	Diameter			Min. length (m)	Ship design Min. breaking load (kN)	Number	Min. length each (m)	Ship design Min. breaking load (kN)
						CCS grade 1	CCS grade 2	CCS grade 3					
25	1140	1220	2	3540	522.5	60	52	46	200	691	4	180	293
26	1220	1300	2	3780	522.5	62	54	48	200	738	4	180	309
27	1300	1390	2	4050	522.5	64	56	50	200	786	4	180	336
28	1390	1480	2	4320	550	66	58	50	200	836	4	180	352
29	1480	1570	2	4590	550	68	60	52	220	888	5	190	352
30	1570	1670	2	4890	550	70	62	54	220	941	5	190	362
31	1670	1790	2	5250	577.5	73	64	56	220	1024	5	190	384
32	1790	1930	2	5610	577.5	76	66	58	220	1109	5	190	411
33	1930	2000	2	6000	577.5	78	68	60	220	1168	5	190	437
34	2000	2080	2	6000	577.5	78	68	60	220	1168			
35	2080	2230	2	6450	605	81	70	62	240	1259			
36	2230	2380	2	6900	605	84	73	64	240	1356			
37	2380	2530	2	7350	605	87	76	66	240	1453			
38	2530	2700	2	7800	632.5	90	78	68	260	1471			
39	2700	2870	2	8300	632.5	92	81	70	260	1471			
40	2870	3040	2	8700	632.5	95	84	73	260	1471			
41	3040	3210	2	9300	660	97	84	76	280	1471			
42	3210	3400	2	9900	660	100	87	78	280	1471			
43	3400	3600	2	10500	660	102	90	78	280	1471			
44	3600	3800	2	11100	687.5	105	92	81	300	1471			
45	3800	4000	2	11700	687.5	107	95	84	300	1471			
46	4000	4200	2	12300	687.5	111	97	87	300	1471			
47	4200	4400	2	12900	715	114	100	87	300	1471			
48	4400	4600	2	13500	715	117	102	90	300	1471			
49	4600	4800	2	14100	715	120	105	92	300	1471			
50	4800	5000	2	14700	742.5	122	107	95	300	1471			
51	5000	5200	2	15400	742.5	124	111	97	300	1471			
52	5200	5500	2	16100	742.5	127	111	97	300	1471			
53	5500	5800	2	16900	742.5	130	114	100	300	1471			
54	5800	6100	2	17800	742.5	132	117	102	300	1471			
55	6100	6500	2	18800	742.5		120	107					
56	6500	6900	2	20000	770		124	111					
57	6900	7400	2	21500	770		127	114					
58	7400	7900	2	23000	770		132	117					
59	7900	8400	2	24500	770		137	122					
60	8400	8900	2	26000	770		142	127					
61	8900	9400	2	27500	770		147	132					

Serial No.	Equipment No. N		Bower anchors		Stud link chain cable for bower anchors				Towlines		Mooring lines		
	Exceeding	Not exceeding	Number	Mass of each anchor (kg)	Total length (m)	Diameter			Min. length (m)	Ship design Min. breaking load (kN)	Number	Min. length each (m)	Ship design Min. breaking load (kN)
						CCS grade 1	CCS grade 2	CCS grade 3					
62	9400	10000	2	29000	770		152	132					
63	10000	10700	2	31000	770			137					
64	10700	11500	2	33000	770			142					
65	11500	12400	2	35500	770			147					
66	12400	13400	2	38500	770			152					
67	13400	14600	2	42000	770			157					
68	14600	16000	2	46000	770			162					

3.2.3 Chain cables

3.2.3.1 For ships with *N* less than 90, chain cables may be substituted by studless chains of equivalent proof-load.

3.2.3.2 Wire rope may be used in place of chain cable on ships subject to the following conditions:

(1) with less than 90 m in length and which will need an anchor for emergency purposes, i.e., not intended to use their anchor in normal temporary anchoring operation, or

(2) with the anchoring equipment used for positioning with a minimum of 4 points anchoring, e.g., for cable or pipe laying.

(3) for anchors used for operation of floating cranes, floating pile drivers or other similar workboats as specified in Table 3.2.1.1(1).

3.2.3.3 Use of wire rope is subject to the following conditions:

(1) The wire ropes are to have a total length equal to 1.5 times the corresponding length of stud link chain cables required in Table 3.2.1.1(2), and a minimum breaking load equal to that given for the corresponding stud link chain cable of Grade CCS 1.

(2) The anchor weight shall be increased by 25 % compared to anchor associated with chain cable according to Table 3.2.1.1(2).

(3) A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12.5 m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.

(4) All surfaces being in contact with the wire need to be rounded with a radius of not less than 10 times the wire rope diameter (including stem).

(5) Steel wire shall be selected to fit for purpose based on the manufacturer recommendation and shall be provided with guidance for maintenance and inspection.

3.2.3.4 A swivel is to be provided to the chain cables at the outboard end to which the anchor is connected.

3.2.3.5 The inboard end of the chain cable is to be connected to the structure by fasteners and so arranged that they will be capable of being immediately released from a position easily accessible outside the chain locker. Fasteners and their hull support structures are to be able to withstand breaking load which is not less than 15% and not greater than 30% of the anchor chain fitted.

3.2.3.6 Grade CCS 1 material having a tensile stress of less than 400 N/mm² is not to be used in association with high holding power anchors. Grade CCS 3 material is to be used only for chains of 20.5 mm or more in diameter.

3.2.3.7 The total length of chain given in Table 3.2.1.1(2) is to be divided in approximately equal parts between the two bower anchors.

3.2.4 Towlines and mooring lines

3.2.4.1 The number, length and breaking loads of mooring lines are to be marked on the mooring arrangement plan of the ship. The towlines listed in Table 3.2.1.1(2) are provided on board for the tug or for the use by other ships towing the ship. The lateral projected area of deck cargoes as given by the ship nominal capacity condition is to be taken into account during the calculation of equipment number for

selection of towing lines. As an alternative method to 3.2.4, the number and strength of mooring lines may be determined by means of direct mooring analysis of Appendix 2 of this Chapter.

3.2.4.2 Mooring lines for ships with EN $\leqslant$ 2000 are to be determined according to Table 3.2.1.1(2). For ships having the ratio A/N > 0.9, number of lines given in Table 3.2.1.1(2) is to be added to the number of mooring lines according to the following formulae:

One line where $0.9 < \frac{A}{\mathrm{N}} \leq 1.1$

two lines where $1.1 < \frac{A}{\mathrm{N}} \leq 1.2$

three lines where $1.2 < \frac{A}{\mathrm{N}}$

3.2.4.3 The strength of mooring lines and the number of head, stern, and breast lines (see Figure 3.2.4.2) for ships with an Equipment Number EN > 2000 are based on the side-projected area A_1. Side projected area A_1 is to be calculated similar to the side-projected area A according to 3.2.1.2 but considering the following conditions:

Ballast draft is to be considered for the calculation of the side-projected area A_1. For ship types with small change of draft, e.g. passenger ships and ro-ro ships, the summer load waterline may be used for the calculation of the side-projected area A_1.

Wind shielding of the pier can be considered for the calculation of the side-projected area A_1 unless the ship is intended to be regularly moored to jetty type piers. A height of the pier surface of 3 m over waterline may be assumed, i.e. the lower part of the side projected area with a height of 3 m above the waterline for the considered loading condition may be disregarded for the calculation of the side-projected area A_1.

Deck cargo as given by the nominal capacity condition (as defined in 3.6.2.10 of this Chapter) is to be included for the determination of side-projected area A_1. The summer load waterline may be used for the calculation of condition with deck cargo. Deck cargo may not need to be considered if a ballast draft condition generates a larger side-projected area A_1 than the full load condition with cargo on deck. The larger of both side-projected areas is to be chosen as side-projected area A_1.

(1) The mooring lines as given here under are based on a maximum current speed of 1.0 m/s and the following maximum wind speed, in m/s:

V_W $= 25 - 0.002(A_1 - 2000)$ for passenger ships, ferries, and car carriers with 2000 $m^2 < A_1 \leq 4000$ m^2

$= 21$ for passenger ships, ferries, and car carriers with $A_1 > 4000$ m^2

$= 25$ for other ships

The wind speed is considered representative of a 30 second mean speed from any direction and at a height of 10 m above the ground. The current speed is considered representative of the maximum current speed acting on bow or stern (±10°) and at a depth of one-half of the mean draft. Furthermore, it is considered that ships are moored to solid piers that provide shielding against cross current. Additional loads caused by, e.g., higher wind or current speeds, cross currents, additional wave loads, or reduced shielding from non-solid piers may need to be particularly considered. Furthermore, it is to be observed that unbeneficial mooring layouts can considerably increase the loads on single mooring lines.

Breast line: A mooring line that is deployed perpendicular to the ship, restraining the ship in the off-berth direction.

Spring line: A mooring line that is deployed almost parallel to the ship, restraining the ship in fore or aft direction.

Head/Stern line: A mooring line that is oriented between longitudinal and transverse direction, restraining the ship in the off-berth and in fore or aft direction. The amount of restraint in fore or aft and off-berth direction depends on the line angle relative to these directions.

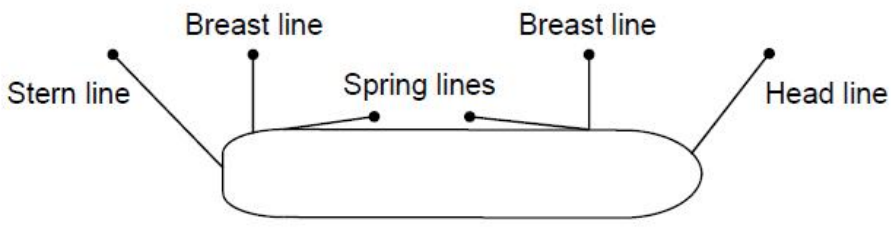


Figure 3.2.4.2 Breast line, spring line, head/stern line

(2) The ship design minimum breaking strength, in kN, of the mooring lines for ships with EN>2000 is not to be less than the value obtained from the following formula and to be limited to 1275 kN:

$$MBL_{SD} = 0.1 \cdot A_1 + 350 \qquad \text{kN}$$

However, in this case the mooring lines are to be considered as not sufficient for the wind speed given in (1), the acceptable wind speed V_W^*, in m/s, can be estimated as follows:

$$V_W^* = V_W \sqrt{\frac{MBL_{SD}^*}{MBL_{SD}}}$$

where: V_w is the wind speed as per (1);

MBL_{SD}^* is the ship design breaking strength of the mooring lines intended to be supplied, to be taken less than corresponding to an acceptable wind speed of 21 m/s:

$$MBL_{SD}^* \geq \left(\frac{21}{V_W}\right)^2 \cdot MBL_{SD}$$

MBL_{SD} — the breaking strength as recommended according to the formula in (2).

If lines are intended to be supplied for an acceptable wind speed V_W^* higher than V_W as per (1), the ship design minimum breaking strength is to be taken as:

$$MBL_{SD}^* = \left(\frac{V_W^*}{V_W}\right)^2 \cdot MBL_{SD}$$

(3) The total number of head, stern and breast lines for ships with EN>2000 is not to be less than:

$$n = 8.3 \cdot 10^{-4} \cdot A_1 + 6$$

For oil tankers, chemical tankers, bulk carriers, and ore carriers the total number of head, stern and breast lines is to be taken as:

$$n = 8.3 \cdot 10^{-4} \cdot A_1 + 4$$

The total number of head, stern and breast lines is to be rounded to the nearest whole number.

(4) The number of head, stern and breast lines may be increased or decreased in conjunction with an adjustment to the strength of the lines. The adjusted strength, MBL_{SD}^{**}, is to be taken as:

$$MBL_{SD}^{**} = 1.2 \cdot MBL_{SD} \cdot n / n^{**} \leq MBL_{SD} \qquad \text{for increased number of lines,}$$

$$MBL_{SD}^{**} = MBL_{SD} \cdot n / n^{**} \qquad \text{for reduced number of lines.}$$

where: MBL_{SD} is MBL_{SD} or MBL_{SD}^* specified in (1) and (2) of this paragraph;

n^{**} is the increased or decreased total number of head, stern and breast lines;

n the number of lines for the considered ship type as calculated by the above formulas without rounding.

(5) The total number of spring lines is to be taken not less than:

Two lines where EN < 5000,

Four lines where EN $\geqslant$ 5000.

The ship design minimum breaking strength of spring lines is to be the same as that of the head, stern and breast lines. If the number of head, stern and breast lines is increased in conjunction with an adjustment to the ship design minimum breaking strength of the lines, the number of spring lines is to be increased in accordance with the following formula, but rounded up to the nearest even number.

$$n_S^* = MBL_{SD} / MBL_{SD}^{**} \cdot n_S$$

where: MBL_{SD} is MBL_{SD} or MBL_{SD}^* specified in (1) and (2) of this paragraph;

n_S is the number of spring lines;

n_S^* is the increased number of spring lines.

3.2.4.4 The length of mooring lines for ships with EN of less than or equal to 2000 may be taken from Table 3.2.1.1(2). For ships with EN > 2000 the length of mooring lines may be taken as 200 m. The lengths of individual mooring lines may be reduced by up to 7% of the above given lengths, but the total length of mooring lines is not to be less than would have resulted had all lines been of equal length.

3.2.4.5 The wire ropes for towlines listed in Table 3.2.1.1(2) of this Section are to be of a flexible, galvanized construction having a breaking strength of not less than 1.37 kN/mm^2 per wire. The construction type of the wire ropes is to be referred to the provisions in Section 4, Chapter 10, PART ONE of CCS Rules for Materials and Welding.

3.2.4.6 Towlines and mooring lines may be of natural fibre, synthetic fibre material or a mixture of wire and natural fibre. In no case is the circumference of the ropes made of natural fibre or synthetic fibre to be less than 63 mm (20 mm in diameter).

3.2.4.7 All ropes having a breaking strength in excess of 736 kN are to be handled by specially designed winches.

3.2.4.8 In engineering ships, service winches may be used in lieu of windlasses, provided that these winches can efficiently handle chain cables.

3.2.5 Strength requirements for securing of windlasses on fore decks

3.2.5.1 Paragraph 3.2.5 of this Section provides strength requirements for the securing of windlasses located on the exposed deck over the forward 0.25L of all ships of 80 m or over in length, where the height of the exposed deck in way of the windlasses is less than 0.1L or 22 m above the summer load waterline, whichever is the lesser.

3.2.5.2 Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

3.2.5.3 The following pressures and associated areas are to be applied (see Figure 3.2.5.3):

(1) Force P_x = 200 kN/m^2 normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction.

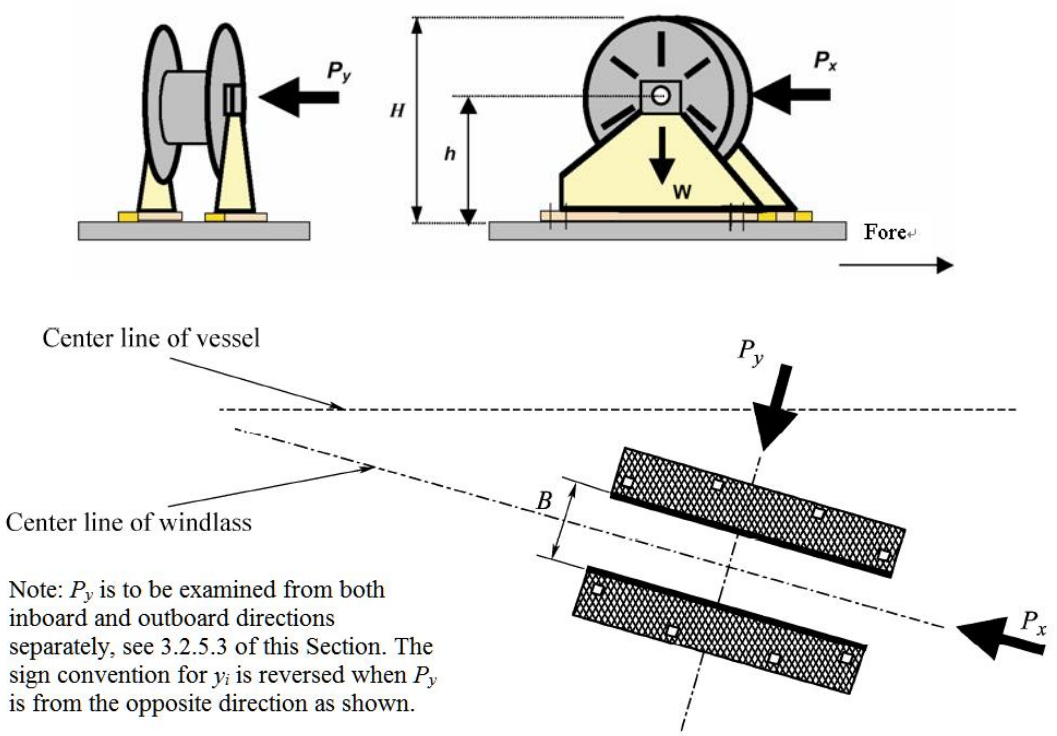
(2) Force P_y = 150 kN/m^2 parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction, where f is defined as:

$$f = 1 + \frac{B}{H}, \text{ but not greater than 2.5}$$

where: B — width of windlass measured parallel to the shaft axis, in m;

H — overall height of windlass, in m.

3.2.5.4 Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by N bolt groups, each containing one or more bolts, see Figure 3.2.5.3.



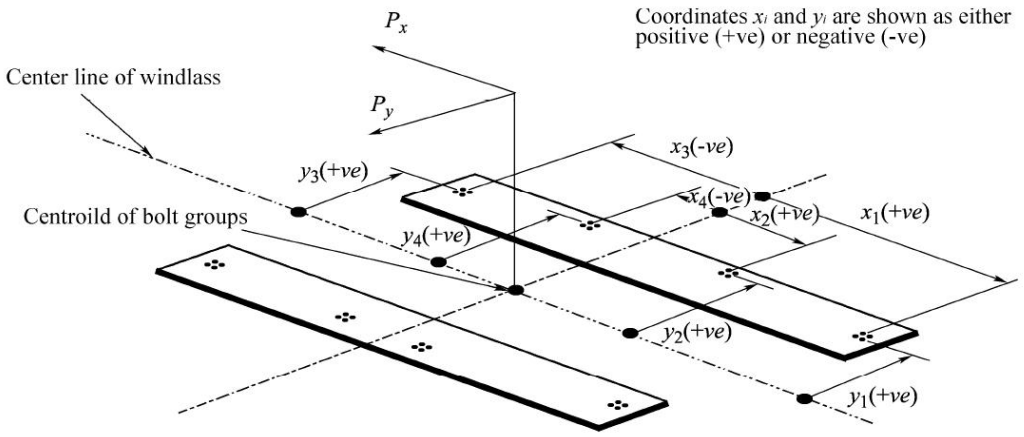


Figure 3.2.5.3

3.2.5.5 The axial force R_i in bolt group (or bolt) i, may be calculated from:

$$R_{xi} = \frac{P_x h x_i A_i}{I_x} \quad \text{kN}$$

$$R_{yi} = \frac{P_y h y_i A_i}{I_y} \quad \text{kN}$$

$$R_i = R_{xi} + R_{yi} - R_{si} \quad \text{kN}$$

where: P_x — force acting normal to the shaft axis, in kN;

P_y — force acting parallel to the shaft axis, in kN, either inboard or outboard, whichever gives the greater force in bolt group i;

h — shaft height above the windlass mounting, in cm;

x_i, y_i — x and y coordinates of bolt group i from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force, in cm;

A_i — cross sectional area of all bolts in group i, in cm^2;

$I_x = \sum A_i x_i^2$, in cm^4, sum of moments of inertia for N bolt groups about y-axis;

$I_y = \sum A_i y_i^2$, in cm^4, sum of moments of inertia for N bolt groups about x-axis;

R_{si} — static reaction at bolt group i, due to weight of windlass, in kN.

3.2.5.6 Shear forces F_{xi}, F_{yi} applied to the bolt group i, and the resultant combined force F_i may be calculated from:

$$F_{xi} = \frac{P_x - agW}{N} \quad \text{kN}$$

$$F_{yi} = \frac{P_y - agW}{N} \quad \text{kN}$$

$$F_i = \sqrt{F_{xi}^{\ 2} + F_{yi}^{\ 2}} \quad \text{kN}$$

where: α — coefficient of friction, taken as 0.5;

W — mass of windlass, in t;

g — gravity acceleration, taken as 9.81m/s^2;

N — number of bolt groups.

3.2.5.7 Axial tensile and compressive forces in 3.2.5.5 of this Section and lateral forces in 3.2.5.6 of this Section are to be considered in the design of the supporting structure.

3.2.5.8 Tensile axial stresses in the individual bolts in each bolt group are to be calculated. The horizontal forces F_{xi} and F_{yi} are normally to be reacted by shear chocks. Where "fitted" bolts are designed to support these shear forces in one or both directions, the equivalent stresses in the individual bolts are to be calculated, and compared to the stress under proof load. The safety factor against bolt proof strength is not to be less than 2.0. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

3.2.5.9 Direct calculation is to be performed for the strength of the deck framing supporting the windlass and its securing bolt loads as defined in 3.2.5.3 to 3.2.5.7 of this Section.

Section 3 CEILINGS AND CARGO BATTENS

3.3.1 Ceiling

3.3.1.1 Wood ceiling is to be laid from the floors to the upper part of the bilge in single bottom ships, and over the bilges in ships having double bottoms. The ceiling is to be arranged so as to be readily removable for inspection.

3.3.1.2 Where ceiling is to be laid on the inner bottom under hatchways, battens are to be laid underneath the ceiling, and the thickness of the battens is to be at least 30 mm. Where the double bottom tank is not intended to carry oil fuel, ceiling may be laid directly on the inner bottom plating embedded in a suitable bituminous solution or other effective coverings.

3.3.1.3 Either in single or double bottom ships, the thickness of the ceiling in cargo holds is to be determined according to the ship's length L as follows:

for $L \leq 60$ m, not less than 50 mm;

for 60 m $< L \leq 90$ m, not less than 55 mm;

for $L > 90$ m, not less than 60 mm.

3.3.1.4 Bottom ceiling or shaft tunnel ceiling under hatchways may be omitted provided that the thickness of the inner bottom plating or shaft tunnel top plating is increased by 2 mm.

3.3.1.5 If cargo is handled by grabs or similar mechanical appliances, double layers of ceiling are to be fitted on the inner bottom under hatchways (the thickness of each ceiling layer is to be in compliance with 3.3.1.3 of this Section); if the thickness of the inner bottom plating is increased by 5 mm, the wood ceiling may be omitted.

3.3.1.6 If cargo is carried in a hold adjacent to a deep oil tank with heating appliances, the hold side of the bulkhead is to be fitted with wood ceiling or insulation. If wood ceiling is fitted, the thickness is to comply with the requirements of 3.3.1.3 of this Section.

3.3.1.7 The covers or fittings of the manholes in cargo holds are, so far as practicable, not to project above the inner bottom plating or bottom ceiling; but if impracticable, they are to be protected by a steel coaming around each manhole, and such coamings together with wood ceiling or steel covers thereon are to be gradually sloped down to the flush surface of the inner bottom plating or bottom ceiling.

3.3.1.8 The external surface of tank top plating or shaft tunnel top plating covered by wood ceiling is to be coated with bituminous solution or other effective coating. Tank top plating and shaft tunnel top plating not covered by wood ceiling are to be coated with paints.

3.3.2 Cargo battens

3.3.2.1 Wood cargo battens are to be fitted at ship sides in cargo holds intended for the carriage of general cargoes. The clear space between adjacent rows of the cargo battens is not to exceed 300 mm, and the thickness and breadth of the cargo battens are to be determined in relation to the ship's length L as follows:

for $L \leq 60$ m, breadth not less than 100 mm, and thickness not less than 30 mm;

for 60 m $< L \leq$ 90m, breadth not less than 120 mm, and thickness not less than 40 mm;

for $L > 90$ m, breadth not less than 150 mm, and thickness not less than 50 mm.

Cargo battens may be made of steel.

Section 4 MASTS OR DERRICK POSTS

3.4.1 General requirements

3.4.1.1 Masts or derrick posts intended to support light derricks are to have at least two points of effective support. The superstructure deck with sufficient strength or the top of a substantial house may be used as one of the points of effective support.

3.4.1.2 Masts or derrick posts are to be effectively attached to the deck plating (at the point of support) where they pass through the deck, and the openings in the deck plating are to be effectively strengthened and compensated.

3.4.2 Wall thickness

3.4.2.1 The relative values between the outside diameter D and wall thickness t of the masts or derrick posts are to be in compliance with those given in the following formulae:

$$D \leq \frac{1000t}{25-t} \quad \text{mm} \quad \text{for } t \leq 15 \text{ mm}$$

$$D \leq 100t \quad \text{mm for } t > 15 \text{ mm}$$

3.4.2.2 The minimum wall thickness of masts or derrick posts is to be 6 mm; if the masts or derrick posts are used as ventilator pipes, the minimum wall thickness is not to be less than 7 mm.

3.4.3 Local strengthening

3.4.3.1 Masts or derrick posts intended to support light derricks are to be increased in thickness or doubled in plating, as appropriate, in way of the lower end, crosstrees, derrick seatings, and fixed eye plates for topping lifts or stays where concentrated loads may be expected to occur. Where strengthening is made by doubling plates, the depth and breadth of the doubling plates are to be slightly greater than those of the above fittings or the outside diameter of the masts or derrick posts in way, as appropriate.

3.4.3.2 The conditions and the factor of safety for strength calculations of masts or derrick posts are to comply with the requirements of the flag State Administration.

Section 5 EMERGENCY TOWING ARRANGEMENTS

3.5.1 Application

3.5.1.1 This Section applies to liquid cargo carriers of 20,000 tons deadweight and over, including oil tankers, chemical tankers and liquefied gas carriers, for being towed out of dangerous areas in emergency cases with the arrangements needed.

3.5.2 Class notations

3.5.2.1 Liquid cargo carriers fitted with emergency towing arrangements complying with this Section will be assigned the class notation of Emergency Towing Arrangements.

3.5.3 Plans and documents

3.5.3.1 The following plans and documents are to be submitted for approval:

(1) Details of emergency towing arrangements;

(2) Details of strongpoints and fairleads of emergency towing arrangements (related calculations are also to be submitted for information);

(3) Local structures supporting strongpoints and fairleads;

(4) Operation manual for emergency towing arrangements.

3.5.4 General requirements

3.5.4.1 The emergency towing arrangements are to be so designed that they are capable of easy operation and rapid connection to the towing vessel in the absence of main power of the ship.

3.5.4.2 The emergency towing arrangements are to be subject to approval by CCS and in accordance with the following requirements:

(1) The aft emergency towing arrangement is to be pre-rigged and capable of being deployed in harbour conditions in not more than 15 min.

(2) The pick-up gear for the aft towing pennant is to be designed at least for manual operation by one person taking into account the absence of power and the potential for adverse environmental conditions. The pick-up gear is to be protected against the weather and other adverse conditions.

(3) The forward emergency towing arrangement is to be designed at least with a means of securing a towline to the chafing gear using a suitably positioned pedestal roller to facilitate connection of the towing pennant.

(4) The forward emergency towing arrangement is to be capable of being deployed in harbour conditions in not more than 1 h.

(5) Forward emergency towing arrangements that comply with the requirements for aft emergency towing arrangements may be accepted.

(6) All emergency towing arrangements are to be clearly marked to facilitate safe and effective use even in darkness and poor visibility.

3.5.5 Arrangement and strength

3.5.5.1 typical details of emergency towing arrangements, see Figure 3.5.5.1.

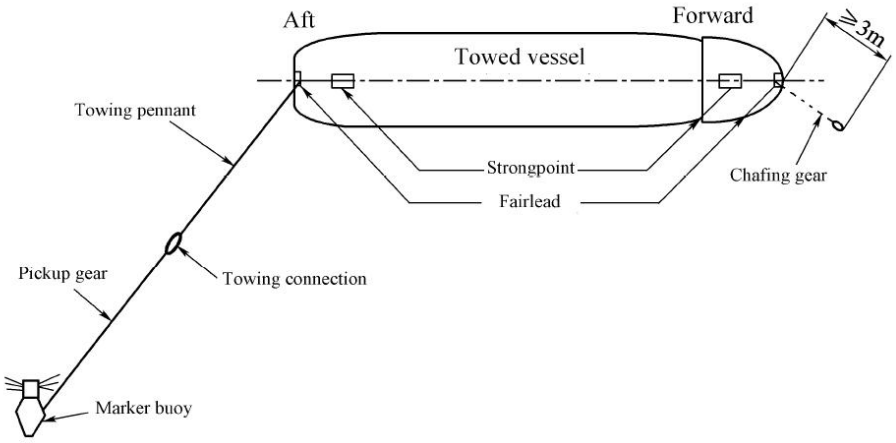


Figure 3.5.5.1 Typical Details of Emergency Towing Arrangements

The bow and stern strongpoint and fairleads are to be located so as to facilitate towing from either side of the bow or stern and minimize the stress on the towing system. Main components of towing arrangements are as shown in Table 3.5.5.1.

Major Components of Towing Arrangements **Table 3.5.5.1**

Major components	Location		Strength requirements
	Forward of ship	Aft of ship	
Pick-up gear	Optional	Yes	–
Towing pennant	Optional	Yes	Yes
Chafing gear	Yes	Depending on design	Yes
Fairlead	Yes	Yes	Yes
Strongpoint	Yes	Yes	Yes
Roller pedestal	Yes	Depending on design	–

3.5.5.2 The strength of towing arrangements is to be sufficient for all relevant angles of towline during towing operations, i.e. up to 90 ° from the ship's centreline to port and starboard and 30 ° vertical downwards. The safety factor of main components of towing arrangements is not to be less than 2. For safe working loads (SWL) of main components of towing arrangements, see Table 3.5.5.2.

Safe Working Load of Components **Table 3.5.5.2**

Deadweight of ship (t)	Safe working load (kN)
20000 to 50000	1000
≥ 50000	2000

3.5.6 Requirements for the arrangements and components

3.5.6.1 The towing pennant is to have a hard eye-formed termination allowing connection to a standard bow shackle. The towing pennant is to have a length of at least $2H$ + 50 m (H being the lightest seagoing ballast freeboard height at the fairlead, in m).

3.5.6.2 Different solutions on design of chafing gear may be used. If a chafing chain is used, the following requirements are to be complied with:

(1) the chafing chain is to be stud link chain and is to extend from the strongpoint to a point at least 3 m beyond the fairlead;

(2) one end of the chafing chain is to be suitable for connection to the strongpoint. The other end is to be fitted with a standard pear-shaped open link allowing connection to the towing pennant via a standard bow shackle. A typical outboard chafing chain end and a pear-shaped open link are shown in Figure 3.5.6.2(2);

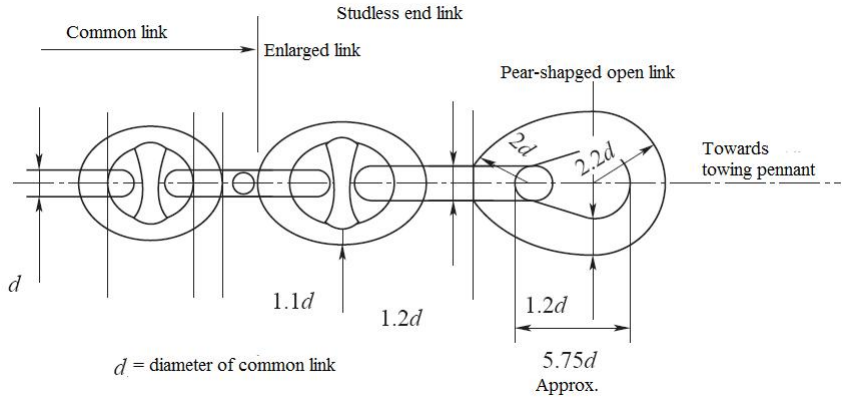


Figure 3.5.6.2(2) Typical Outboard Chafing Chain End

(3) in addition to this Section, the chafing chain is to be designed, manufactured, tested and certified in accordance with the relevant requirements of Section 2, Chapter 10 of PART ONE of CCS Rules for Materials and Welding;

(4) chafing chains are to be made of M2 or M3 chain steel by manufacturers approved by CCS;

(5) the nominal diameter of common links for chafing chains is to comply with the values indicated in Table 3.5.6.2(5) and the nominal diameter of other links are to be determined according to Figure 3.5.6.2(2);

(6) the chafing chain is to be stowed in such a way that it can be rapidly connected to the strongpoint.

Minimum Nominal Diameter of Common Link **Table 3.5.6.2(5)**

Type of emergency towing arrangement (ETA)	Minimum nominal diameter of common link d	
	Grade 2	Grade 3
ETA1000	62 mm	52 mm
ETA2000	90 mm	76 mm

3.5.6.3 The fairleads may be mooring fairleads or fairleads with cable rollers. Fairleads are to have an opening large enough to pass the largest portion of the chafing gear, towing pennant and associated components. The recommended size of such openings is 450 mm × 600 mm. The fairlead is to be located as close as possible to the deck and, in any case, in such a position that the chafing chain is approximately parallel to the deck when it is under strain between the strongpoint and the fairlead. The fairlead is to have an adequate bearing surface, and the bending ratio (towing pennant bearing surface diameter to towing pennant diameter) is not to be less than 7:1.
3.5.6.4 The strongpoint is the inboard end fastening of the towing arrangement and is to be a stopper or bracket or other fitting of equivalent strength. The strongpoint may be designed integral with the fairlead.

Section 6 SHIPBOARD FITTINGS AND SUPPORTING HULL STRUCTURES ASSOCIATED WITH TOWING AND MOORING ON CONVENTIONAL VESSELS

3.6.1 General requirements

3.6.1.1 This Section applies to design and construction of shipboard fittings and supporting structures used for the normal towing and mooring operations.
3.6.1.2 The minimum net scantlings of the supporting hull structure are to comply with the requirements given in 3.6.3.5 and 3.6.4.5 of this Section. The net thicknesses, t_{net}, are the member thicknesses necessary to obtain the above required minimum net scantlings. The required gross thicknesses are obtained by adding the total corrosion additions, t_c, given in 3.6.6 of this Section, to t_{net}.
3.6.1.3 This Section applies to ships the contract of which is placed on or after 1 July 2018.
3.6.1.4 This Section is not applicable to escort towing, canal transit towing and emergency towing for tankers.

3.6.2 Definitions

3.6.2.1 Conventional vessels mean new displacement-type vessels of 500 GT and above, excluding high speed craft, special purpose vessels, and offshore units of all types. Special purpose ship means a mechanically self-propelled ship which by reason of its function carries on board more than 12 special personnel.
3.6.2.2 Shipboard fittings mean those components limited to the following: bollards and bitts, fairleads, stand rollers, chocks used for the normal mooring of the vessel and the similar components used for the normal towing or other towing of the vessel. Other components such as capstans, winches, etc. are not covered by this Section. Any weld or bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and if selected from an industry standard subject to that standard.
3.6.2.3 Supporting hull structures mean that part of the ship structure on/in which the shipboard fitting is placed and which is directly submitted to the forces exerted on the shipboard fitting. The supporting hull structure of capstans, winches, etc. used for the normal towing or other towing and mooring operations mentioned above is also subject to this Section.
3.6.2.4 Industry standard means international standard (ISO, etc.) or standards issued by national association which are recognized in the country where the ship is built.
3.6.2.5 Normal towing means towing operations necessary for manoeuvring in ports and sheltered waters associated with the normal operations of the ship.
3.6.2.6 Other towing means for ships, not subject to Section 5 of this Chapter, but intended to be fitted with equipment for towing by another ship or a tug, e.g. such as to assist the ship in case of emergency.
3.6.2.7 Escort towing means towing service, in particular, for laden oil tankers or LNG carriers, required in specific estuaries. Its main purpose is to control the ship in case of failures of the propulsion or steering system.
3.6.2.8 Canal transit towing means towing service for ships transiting canals.
3.6.2.9 Emergency towing for tankers means towing service to assist tankers in case of emergency, see Section 5 of this Chapter.
3.6.2.10 The nominal capacity condition is defined as the theoretical condition where the maximum possible deck cargoes are included in the ship arrangement in their respective positions. For container ships the nominal capacity condition represents the theoretical condition where the maximum possible number of containers is included in the ship arrangement in their respective positions.

3.6.2.11 Ship Design Minimum Breaking Load (MBLSD) means the minimum breaking load of new, dry mooring lines or tow line for which shipboard fittings and supporting hull structures are designed in order to meet mooring restraint requirements or the towing requirements of other towing service.
3.6.2.12 Line Design Break Force (LDBF) means the minimum force that a new, dry, spliced, mooring line will break at. This is for all synthetic cordage materials.

3.6.3 Towing

3.6.3.1 The strength of shipboard fittings used for normal towing or other towing operations at bow, sides and stern and their supporting hull structures are to comply with the requirements of 3.6.3.2 to 3.6.3.6 of this Section. For fittings intended to be used for, both, towing and mooring, 3.6.4 applies to mooring.
3.6.3.2 Shipboard fittings for towing are to be located on stiffeners and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing load. Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the intended service.
3.6.3.3 Load considerations
The minimum design load applied to supporting hull structures for shipboard fittings is to be:
(1) For normal towing operations, 1.25 times the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan.
(2) For other towing service, the ship design minimum breaking load of the towline corresponding to equipment no. *N* in Table 3.2.1.1(2) is to be applied.
Note: Side projected area including that of deck cargoes as given by the ship nominal capacity condition is to be taken into account for selection of towing lines and the breaking loads of towing lines are used as the design loads.
(3) For fittings intended to be used for, both, normal and other towing operations, the greater of the design loads according to (1) and (2).
(4) When a safe towing load TOW greater than that determined according to 3.6.3.6 is requested by the applicant, then the design load is to be increased in accordance with the appropriate TOW/design load relationship.
(5) The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the towing and mooring arrangements plan. Where the towing line takes a turn at a fitting the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, however, the load need not be more than twice the design load.

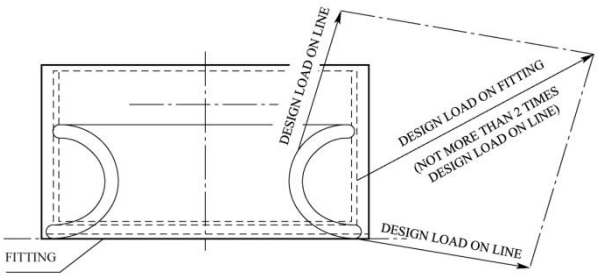


Figure 3.6.3.3(5)

3.6.3.4 Shipboard fittings may be selected from an accepted industry standard and at least based on the following loads.
(1) For normal towing operations, the intended towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan,
(2) For other towing service, the ship design minimum breaking load of the tow line according to Table 3.2.1.1(2) (see Notes in 3.6.3.3(2)),
(3) For fittings intended to be used for, both, normal and other towing operations, the greater of the loads according to (1) and (2).
Towing bitts (double bollards) may be chosen for the towing line attached with eye splice if the industry standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment.
When the shipboard fitting is not selected from an accepted Industry standard, the design load used to assess its strength and its attachment to the ship is to be in accordance with 3.6.3.3 and 3.6.3.5. Towing bitts (double bollards) are required to resist the loads caused by the towing line attached with eye splice.

For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions are to be as defined in 3.6.6. A wear down allowance is to be included as defined in 3.6.7. At the discretion of the Society, load tests may be accepted as alternative to strength assessment by calculations.

3.6.3.5 Supporting hull structure

(1) Arrangement:

The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the towing forces acting upon the shipboard fittings, see Figure 3.6.3.5(1) below for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.

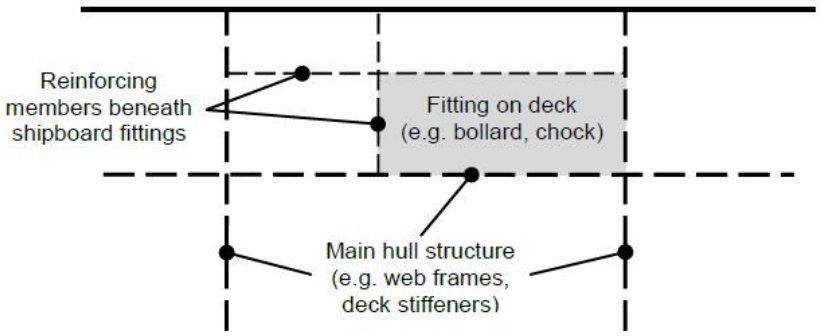


Figure 3.6.3.5(1)

(2) Acting point of towing force:

The acting point of the towing force on shipboard fittings is to be taken at the attachment point of a towing line or at a change in its direction. For bollards and bitts the attachment point of the towing line is to be taken not less than 4/5 of the tube height above the base, see Figure 3.6.3.5(2).

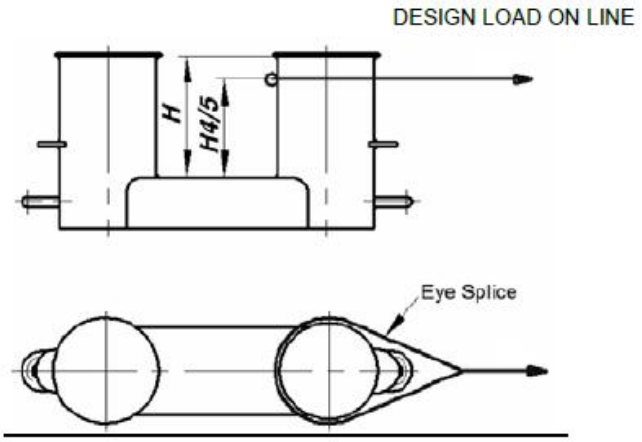


Figure 3.6.3.5(2)

(3) Allowable stresses:

Allowable stresses under the design load conditions as specified in 3.6.3.3 of this Section are as follows:

1) For strength assessment with beam theory or grillage analysis:

Normal stress: $1.0R_{eH}$;

Shearing stress: $0.6R_{eH}$;

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress. No stress concentration factors being taken into account.

(2) For strength assessment with finite element analysis:

Von Mises stress: $1.0R_{eH}$.

For strength calculations by means of finite elements, the geometry is to be idealized as realistically as possible. The ratio of element length to width is not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small openings in girder webs

the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled by using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modeled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.
R_{eH} is the specified minimum yield stress of the material.

3.6.3.6 Safe Towing Load (TOW)

(1) The safe towing load (TOW) is the safe load limit of shipboard fittings used for towing purpose.

(2) TOW used for normal towing operations is not to exceed 80% of the design load per 3.6.3.3 (1).

(3) TOW used for other towing operations is not to exceed 80% of the design load according to 3.6.3.3 (2).

(4) For fittings used for both normal and other towing operations, the greater of the safe towing loads according to (2) and (3) is to be used.

(5) TOW, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing. For fittings intended to be used for, both, towing and mooring, SWL, in t, according to 3.6.4.6 is to be marked in addition to TOW.

(6) The above requirements on TOW apply for the use with no more than one line. If not otherwise chosen, for towing bitts (double bollards) TOW is the load limit for a towing line attached with eye-splice.

(7) The towing and mooring arrangements plan mentioned in 3.6.5 is to define the method of use of towing lines.

3.6.4 Mooring

3.6.4.1 The strength of shipboard fittings used for mooring operations and of their supporting hull structures as well as the strength of supporting hull structures of winches and capstans is to comply with the requirements of 3.6.4.2 to 3.6.4.6 of this Section.

3.6.4.2 Shipboard fittings, winches and capstans for mooring are to be located on stiffeners and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the mooring load. Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the service. For fittings intended to be used for, both, mooring and towing, 3.6.3 applies to towing.

3.6.4.3 Load considerations

(1) The minimum design load applied to supporting hull structures for shipboard fittings is to be 1.15 times the ship design minimum breaking strength of the mooring line according to 3.2.4 of this Chapter.

Note: Side projected area including that of deck cargoes as given by the ship nominal capacity condition is to be taken into account for assessment of transverse wind load, tug arrangement and selection of mooring lines.

(2) The minimum design load applied to supporting hull structures for winches is to be 1.25 times the intended maximum brake holding load, where the maximum brake holding load is to be assumed not less than 80% of the ship design minimum breaking strength of the mooring line according to 3.2.4 of this Chapter. For supporting hull structures of capstans, 1.25 times the maximum hauling-in force is to be taken as design load.

(3) When a safe working load SWL greater than that determined according to 3.6.4.6 is requested by the applicant, then the design load is to be increased in accordance with the appropriate SWL/design load relationship.

(4) The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the towing and mooring arrangements plan. Where the mooring line takes a turn at a fitting the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, refer to Figure 3.6.3.3(5). However, in no case does the design load applied to the fitting need to be greater than twice the design load on the line.

3.6.4.4 Shipboard fittings may be selected from an accepted industry standard and at least based on the ship design minimum breaking strength according to 3.2.4 of this Chapter.

Mooring bitts (double bollards) are to be chosen for the mooring line attached in figure-of-eight fashion if the industry standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment.

When the shipboard fitting is not selected from an accepted Industry standard, the design load used to assess its strength and its attachment to the ship is to be in accordance with 3.6.4.3 and 3.6.4.5 of this Section. Mooring bitts (double bollards) are required to resist the loads caused by the mooring line attached in figure-of-eight fashion. It is to be observed that in this case either of the two posts of the mooring bitt can be subjected to a force twice as large as that acting on the mooring line. For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions are to be as defined in 3.6.6. A wear down allowance is to be included as defined in 3.6.7. At the discretion

of the classification society, load tests may be accepted as alternative to strength assessment by calculations.

3.6.4.5 Supporting hull structure

(1) Arrangement:

Arrangement of the reinforced members beneath shipboard fittings is to consider any variation of direction (horizontally and vertically) of the mooring forces acting upon the shipboard fittings, see Figure 3.6.3.5(1) for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.

(2) Acting point of mooring force:

The acting point of the mooring force on shipboard fittings is to be taken at the attachment point of a mooring line or at a change in its direction. For bollards and bitts the attachment point of the mooring line is to be taken not less than 4/5 of the tube height above the base, see a) in Figure 3.6.4.5(2) a). If fins are fitted to the bollard tubes to keep the mooring line as low as possible, the attachment point of the mooring line may be taken at the location of the fins, see Figure 3.6.4.5(2) b).

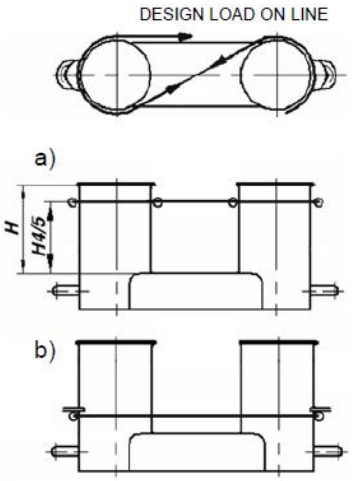


Figure 3.6.4.5(2)

(3) Allowable stresses:

Allowable stresses under the design load conditions as specified in 3.6.4.3 of this Section are as follows:

1) For strength assessment with beam theory or grillage analysis:

Normal stress: $1.0R_{eH}$;

Shearing stress: $0.6R_{eH}$;

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress. No stress concentration factors being taken into account.

2) For strength assessment with finite element analysis:

Von Mises stress: $1.0R_{eH}$.

For strength calculations by means of finite elements, the geometry is to be idealized as realistically as possible. The ratio of element length to width is not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small openings in girder webs the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled by using shell, plane stress, or beam elements.The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modeled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.

3.6.4.6 Safe Working Load (SWL)

(1) The Safe Working Load (SWL) is the safe load limit of shipboard fittings used for mooring purpose.

(2) Unless a greater SWL is requested by the applicant according to 3.6.4.3(3), the SWL is not to exceed the ship design minimum breaking strength according to 3.2.4 of this Chapter.

(3) The SWL, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for mooring. For fittings intended to be used for, both, mooring and towing, TOW, in t, according to 3.6.3.6 is to be marked in addition to SWL.

(4) The above requirements on SWL apply for the use with no more than one mooring line.
(5) The towing and mooring arrangements plan mentioned in 3.6.5 is to define the method of use of mooring lines.

3.6.5 Towing and mooring arrangements plan

(1) The SWL and TOW for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangements plan available on board for the guidance of the Master. It is to be noted that TOW is the load limit for towing purpose and SWL that for mooring purpose. If not otherwise chosen, for towing bitts it is to be noted that TOW is the load limit for a towing line attached with eye-splice.
(2) Information provided on the plan is to include in respect of each shipboard fitting:
1) location on the ship;
2) fitting type;
3) SWL/TOW;
4) purpose (mooring/harbour towing/other towing); and
5) manner of applying towing or mooring line load including limiting fleet angles i.e. angle of change in direction of a line at the fitting.
The purposes and method for applying loads are to be taken into account in the determination of SWL and TOW of fittings and submitted for approval.
Furthermore, information provided on the plan is to include:
1) the arrangement of mooring lines showing number of lines (N);
2) the ship design minimum breaking load (MBL_{SD});
3) the acceptable environmental conditions for ship design minimum breaking load for ships with Equipment Number EN > 2000, including 30 second mean wind speed from any direction and maximum current speed acting on bow or stern (±10°).
(3) The information as given in (2) is to be incorporated into the pilot card in order to provide the pilot proper information on harbour/other towing operations.

3.6.6 Corrosion addition

The total corrosion addition, t_c, in mm, is not to be less than the following values:
(1) For the supporting hull structure, 2 mm;
(2) For pedestals and foundations on deck which are not part of a fitting according to an accepted industry standard, 2.0 mm.
(3) For shipboard fittings not selected from an accepted industry standard, 2.0 mm.

3.6.7 Wear allowance

In addition to the corrosion addition given in 3.6.6 the wear allowance, tw, for shipboard fittings not selected from an accepted industry standard is not to be less than 1.0 mm, added to surfaces which are intended to regularly contact the line.

3.6.8 Survey after construction

The condition of deck fittings, their pedestals or foundations, if any, and the hull structures in the vicinity of the fittings are to be examined in accordance with the Rules.

Section 7 SUPPORT STRUCTURE FOR DECK EQUIPMENT

3.7.1 General requirements

3.7.1.1 Information pertaining to the support structure of deck equipment and fittings, as listed in 3.7.1.2(1) to (5) of this Section, is to be submitted for approval. Support structure means that part of the ship structure on/in which deck equipment and fittings are placed and which is directly subjected to the forces acting on the deck equipment and fittings.
3.7.1.2 This Section includes scantling requirements for the support structure and foundations of the following pieces of equipment and fittings:
(1) anchor windlasses;
(2) anchoring chain stoppers;
(3) deck cranes, derricks and lifting masts;
(4) emergency towing arrangements;
(5) other deck equipment and fittings which are subject to specific approval.

3.7.1.3 Where deck equipment is subject to multiple load cases, such as an operational load and a green seas load, the operational load and green seas load are be applied independently for the evaluation of strength of foundations and support structure. Loads are to be applied in the direction of the anchor chain.

3.7.2 Supporting structures for anchoring windlass and chain stopper

3.7.2.1 The following plans and information are to be submitted for approval:
(1) Details of the supporting structure for the anchor windlass;
(2) Details of the windlass foundation design, including material specifications for holding down bolts and the connection of the foundation to the deck;
(3) Details of the chain stopper foundation design, including material specification and the connection of the foundation to the deck.
3.7.2.2 The following plans and information are also to be submitted:
(1) General arrangement drawing of anchoring equipment;
(2) Design loads as specified in 3.7.2.3 and 3.7.2.4 of this Section and associated reaction forces applied to the foundation and supporting structure.
3.7.2.3 The following load cases are to be examined for the strength of supporting structures of windlasses and chain stoppers:
(1) windlass where chain stopper is provided: 45% of breaking load;
(2) windlass where chain stopper is not provided: 80% of breaking load;
(3) chain stopper: 80% of breaking load.
The breaking load is the minimum breaking load of chain as defined according to Table 3.2.1.1(2) of this Chapter. The loads are to be applied in the direction of chain.
3.7.2.4 For windlasses complying with the requirements of 3.2.5.1 of this Chapter, the strength of securing of windlasses on fore deck is also to be checked in accordance with the requirements of 3.2.5 of this Chapter.
3.7.2.5 When checking the strength of supporting structures and foundations, a three-dimensional finite element model is to be applied as far as possible in the analysis to more exactly describe the distribution of structural response in all directions. Where a beam system is or plate girders are used, the model is to be reasonably simplified and be more conservative. The analysis is to be based on the theory of linear elasticity. The thicknesses of structural members in the model are net ones. Corrosion allowance is in accordance with 1.6.5, Section 5, Chapter 1 of this PART.
3.7.2.6 The principles for extent, element types and boundary conditions of a three-dimensional model are as follows:
(1) Extent and boundary conditions: The structural model is a local three-dimensional one (hereinafter referred to as local model), centred on the centroid of a plane rectangle ($a \times b$) for effects of the foundation and extending outwards for a distance respectively at least one time the length and width corresponding to the rectangle ($3a \times 3b$). This extension reaches vertically from the foundation plane to the first platform (deck) under main deck or at least $D/4$ (D being moulded depth). Where there is no primary support member of the structure at the boundary taken in the above way, the model is to further extend until the boundary is at such support member. Free or fixed support may be taken into account for boundary conditions. Where the boundary conditions or the extent of the model is sensitive to calculation results of the centre area, the extent taken for the local model is to be suitably extended again, provided that calculation results of the centre area will not be affected.
(2) Idealization of local model: The principles for element selection, properties and model meshing etc. are as given in 1.5.6, Section 5, Chapter 1 of this PART.
(1) 3.7.2.7 For all loading conditions, the stresses taken in calculation for supporting structures and foundations are not to exceed the following permissible values:For strength assessment by means of beam theory or grillage analysis:
Normal stress: 1.0 R_{eH}
Shear stress: 0.6 R_{eH}
The normal stress is the sum of bending stress and axial stress. The shear stress to be considered corresponds to the shear stress acting perpendicular to the normal stress. No stress concentration factors are to be taken into account.
(2) For strength assessment by means of finite element analysis:
Von Mises stress: 1.0 R_{eH}
For strength assessment by means of finite element analysis the mesh is to be fine enough to represent the geometry as realistically as possible. The aspect ratios of elements are not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small

openings in girder webs, the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modeled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.
R_{eH} is the specified minimum yield stress of the material.

3.7.3 Supporting structure for cranes, derricks and lifting masts

3.7.3.1 The supporting structures of lifting appliances which are identified as basic features of the ship, such as lifting appliances of floating crane and submersible handling system of submersible supply vessel are to comply with the requirements of CCS Rules for Lifting Appliances of Ships and Offshore Installations.
The supporting structures of other lifting appliances, including cranes, derricks and lifting masts with a safe working load greater than 30 kN, or a maximum overturning moment to the supporting structure greater than 100 kN·m, are to comply with the requirements of this Section.
3.7.3.2 These requirements do not cover the following items:
(1) supports of lifting appliances for personnel or passengers, see 3.7.5.2 of this Section;
(2) the structure of the lifting appliance pedestals or post above the area of the deck connection;
(3) holding down bolts and their arrangement, which are considered part of the lifting appliance.
3.7.3.3 The term lifting appliance is defined as a crane, derrick or lifting mast.
3.7.3.4 The safe working load is defined as the maximum load which the lifting appliance is certified to lift at any specified outreach.
3.7.3.5 The self-weight is the calculated gross self-weight of the lifting appliance, including the weight of any lifting gear.
3.7.3.6 The overturning moment is the maximum bending moment, calculated at the connection of the lifting appliance to the ship structure, due to the lifting appliance operating at safe working load, taking into account outreach and self-weight.
3.7.3.7 The following plans and information are to be submitted for approval:
(1) Details of the supporting structure of the lifting appliance, including its connection of the deck;
(2) Details of the safe working load, self-weight, vertical reaction forces and the maximum overturning moment in the supporting structure of the lifting appliance;
(3) For offshore operation, the maximum sea state in which the lifting appliance is to be used.
3.7.3.8 The general arrangement drawing of the crane/derrick/lifting mast is also to be submitted.
3.7.3.9 For lifting appliances which are limited to use in harbour, the load cases to be examined are to include 130% of the safe working load added to the lifting appliances self-weight.
3.7.3.10 For lifting appliances which may be used for offshore (refers to open waters, the sea condition of which will cause significant motion of the ship, and the wind force at sea normally exceeds Beaufort scale 2) operations, the following are to be submitted for approval:
(1) The maximum sea state in which the lifting appliance is to be used;
(2) The worst case vertical and horizontal accelerations;
(3) The worst case wind loadings for the specified design sea state and wind environment.
(4) The load scenario to be examined is to account for these environmental loads. As a minimum, the 150% of the safe working load added to the lifting appliances self-weight is to be examined.
3.7.3.11 For calculation and analysis requirements and modeling method, refer to 3.7.2.5 and 3.7.2.6 of this Section. The thicknesses of structural members in the model are as built ones.
3.7.3.12 In all conditions, the stresses taken in calculation for the supporting structures and foundations of lifting appliances are not to exceed the permissible values as follows:
(1) Strength assessment by means of beam theory or grillage analysis:

Direct stress: $0.67R_{eH}$

Shear stress:$0.39R_{eH}$

Direct stress means the sum of bending stress and axial stress, with the corresponding shear stress acting perpendicular to the direct stress. Stress concentration factors are not considered.
(2) Strength assessment by means of FE analysis method:

Von Mises stress: $0.80R_{eH}$

R_{eH} is specified minimum yield stress of material, in N/mm^2.
3.7.3.13 In addition to the requirement of 3.7.3.12 of this Section, the capability of the supporting structure to resist buckling failure is to be checked according to the requirements of 1.5.9, Section 5,

Chapter 1 of this PART. In buckling strength assessment, the standard thickness deduction of structural members is to be taken as 1.0 mm and the minimum buckling safety factor taken as 1.0.

3.7.4 Supporting structures for components used in emergency towing arrangements

3.7.4.1 Tankers (including oil tankers, chemical tankers and liquefied gas carriers) carrying flammable liquid cargoes in bulk, having a deadweight of not less than 20,000 tonnes are to be fitted with an emergency towing arrangement at both fore and aft ends.

3.7.4.2 The safe working load of emergency towing arrangements is as follows:

(1) 1,000 kN for vessels having a deadweight greater than or equal to 20,000 tonnes, but less than 50,000 tonnes;

(2) 2,000 kN for vessels having a deadweight greater than or equal to 50,000 tonnes.

3.7.4.3 The following plans are to be submitted for approval:

Details of the supporting structure for the emergency towing arrangement, including the connection to the deck.

3.7.4.4 The following supporting information is also to be submitted:

Details of the emergency towing arrangement showing sufficient detail to enable the position and direction of load actions to be ascertained.

3.7.4.5 The deck in way of strongpoints and fairleads is to have a minimum gross thickness of 15 mm.

3.7.4.6 The design load for the connection of the strongpoint and fittings to the deck and its supporting structure is to be taken as twice the safe working load. The assessment of the structure is to consider lines of action of the applied design load, taking into account the particular arrangements proposed.

3.7.4.7 For calculation and analysis requirements and modeling method, refer to 3.7.2.5 and 3.7.2.6 of this Section. The thicknesses of structural members in the model are as built ones.

3.7.4.8 For the design load specified in 3.7.4.6 of this Section, the stresses induced in the supporting structure and welds, in way of strongpoints and fairleads, are not to exceed the permissible values given in 3.7.2.7 of this Section.

3.7.4.9 The capability of the structure to resist buckling failure is also to be assured.

3.7.5 Supporting structures for other deck equipment or fittings which are subject to specific approval

3.7.5.1 The following requirements relate to other items of deck equipment which are not covered by 3.7.2 to 3.7.4 of this Section. The following details are to be submitted for approval. They may be indicated separately or may be included on the main structural drawings:

(1) Plans showing the supporting structure for deck equipment/fittings;

(2) Details of the loads imposed on the structure by the deck equipment/fittings.

3.7.5.2 Support for lifting appliances for personnel is to be provided as follows:

(1) in general, lifesaving appliances (lifeboats, life rafts and rescue boats) are to be stowed on a purpose built cradle, seat or deployment appliance. The design load imposed on the ship structure is to be established by the supplier of the lifesaving appliance (to include 2.2 times of bearing reaction and torque under maximum working load as a minimum). For calculation and analysis requirements and modeling method, refer to 3.7.2.5 and 3.7.2.6 of this Section. The thicknesses of structural members in the model are as built ones. The calculated stresses are not to exceed the permissible values given in Table 3.7.3.12. The supplier of the life-saving appliance is to provide corresponding calculation information;

(2) the support structure is to be adequate for the design loads. Local stiffening and a local increase in plating thickness is to be provided. Primary supporting members may be required. Additional national and international Regulations are to be applied, where applicable;

(3) support structure for crew lifts is to be provided in way of the anchor points of lift operating equipment;

(4) support structure for boarding (accommodation) ladders is to be provided in way of the anchor points of accommodation ladders.

3.7.5.3 Support for mast structures fitted with navigation aids is to be provided as follows:

(1) adequate primary support members for the mast are to be arranged in the form of bulkheads, deep beams or girders. Such members are to be arranged below or close to the mast structure;

(2) in order to transmit the loads from the mast structure to the primary supporting members, underdeck stiffening members are to be arranged below the mast structure forming the attachment of the mast to the deck;

(3) the deck thickness may be required to be increased to provide an adequate thickness for the weld attachments.

3.7.5.4 Supporting structure for breakwaters is to be designed to withstand the same design load as the breakwater itself. It is to be suitable for transmitting the loads from the breakwater into the main supporting

members of the ship. Efficient underdeck stiffening is to be provided in way of the breakwater structure that forms the deck connection.

3.7.5.5 The supporting structure of towing arrangements of tugs are to comply with the requirements of 10.5.3, Section 5 of Chapter 10 of this PART.

Section 8 ENERGY-SAVING APPENDAGES IN FRONT OF PROPELLERS

3.8.1 General

3.8.1.1 The provisions in this Section is optional and apply to energy-saving appendages installed onboard in front of propellers. Ships applying for notation PSD are to comply with the provisions of this Chapter.

3.8.1.2 Appropriate vibration evaluation and control are recommended in the design and installation of energy-saving appendages in front of propellers. In general, the natural frequency of the energy-saving appendage and propeller excitation frequency are at least to guarantee 10% of the frequency reserve.

3.8.2 Plans and documents

3.8.2.1 The following plans and documents are to be submitted for approval. Where they are already included in the plans and documents required to be submitted for the ship, there is no need to submit them repeatedly:

(1) Structural plan for the energy-saving appendage in front of the propeller.

3.8.2.2 The following plans and documents are to be submitted for information:

(1) Arrangement for the energy-saving appendage in front of the propeller;

(2) Profile for energy-saving appendages in front of the propeller (where applicable);

(3) Structural strength calculation report (including loads for calculation) for the energy-saving appendage in front of the propeller;

(4) Vibration frequency calculation report for the energy-saving appendage in front of the propeller.

3.8.3 Structural strength assessment

3.8.3.1 Structural strength calculation analysis is to be carried out for the energy-saving appendage in front of the propeller. Structural strength analysis for various conditions is to be carried out considering possible loads on the energy-saving appendage in front of the propeller in actual operation.

3.8.3.2 Explanatory notes to the calculation model:

(1) Local three-dimensional structure model is generally used in modeling and analysis of the energy-saving appendage structure to reasonably simulate their shapes;

(2) The general principles for element selection, characteristics and meshing of the energy-saving appendage structure model are to be in accordance with the requirements of 1.5.6, Section 5, Chapter 1, PART TWO of the Rules. In order to better simulate its shape, the calculation model is to adopt appropriate element mesh size, which is recommended not to exceed 200 mm×200 mm.

3.8.3.3 The extent and boundary conditions of the model are as follows:

(1) For the calculation model, the longitudinal extent is generally to include the entire energy-saving appendage in front of the propeller and extends to the aft end wall of the hull engine room; the vertical extent is from the baseline up to the first platform structure near the standard height above the propeller centerline, where the standard height is 1.5 times the distance between the propeller centerline and the highest point of the energy-saving appendage in front of the propeller;

(2) The assumption of boundary conditions is to be based on the principle of not affecting the calculation results of the energy-saving appendage in front of the propeller and its reinforcement structure. Generally free support or fixed support is provided.

3.8.3.4 The loads on the energy-saving appendage in front of the propeller may be obtained from hydrodynamic calculation or model test or obtained as follows; the following loads are to be included as a minimum:

(1) the hydrodynamic wave pressure, calculated according to 1.5.3.3(4), Section 5, Chapter 1, PART TWO of the Rules;

(2) Inertia force of ship motion, calculated according to 1.5.2.2, Section 5, Chapter 1, PART TWO of the Rules;

(3) Lateral rotating force, calculated according to 3.1.2.1(1), Section 1, Chapter 3, PART TWO of the Rules.

3.8.3.5 The calculation conditions are to include the most unfavorable stress condition of the energy-saving appendage structure in front of the propeller, or they can be selected according to experience and actual operation situation, and are to include the following conditions as a minimum:
(1) navigation condition: inertia force of ship motion + hydrostatic pressure + hydrodynamic wave pressure (the wave direction is same as the navigation direction);
(2) rotating condition: inertia force of ship motion + hydrostatic pressure + lateral rotating force.
3.8.3.6 See Table 3.8.3.6 for permissible stress.

Permissible stress **Table 3.8.3.6**

Type of element	Permissible stress
Plate element	$[\sigma_e]=0.5R_{eH}$

Note: R_{eH}—yield stress of material, in N/mm^2.

3.8.4 Welding

3.8.4.1 The steels used in weldment of the energy-saving appendage in front of the propeller are to comply with the relevant provisions in Chapters 3, 5 and 6, PART ONE of CCS Rules for Materials and Welding for hull structural steels, steel forgings, steel castings respectively. Alternative materials may be adopted subject to CCS agreement.
3.8.4.2 Welding is to be performed by welders approved by CCS using welding consumables approved by CCS according to welding procedures approved by CCS. For relevant requirements, see Chapters 2, 3, 4 and 5, PART THREE of CCS Rules for Materials and Welding.
3.8.4.3 The fillet welds inside the energy-saving appendage in front of the propeller are generally to be continuous at both sides and the welding coefficient is to be taken as 0.2. When the surface shell cannot be connected to the internal web by fillet welds directly, a flat bar may be lined between the surface shell and the web. The surface shell and the flat bar can be connected by plug welding and the welding coefficient is to be taken as 0.44, or a groove can be opened on the surface shell, and the flat bar can be butt welded as a liner. Alternatively, other CCS approved welding connection methods may be adopted.
3.8.4.4 As shown in Figure 3.8.4.4, the fillet welds of the connection between the energy-saving appendage in front of the propeller (including the external supporting structure) and the hull as well as the fillet welds of the connection between the guide wheel and guide vane are to be full penetration fillet welds. Where welding at both sides is not possible, single-sided groove can be opened and welded with steel liner inside.

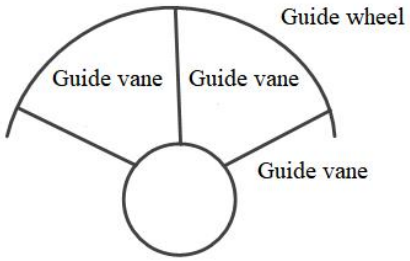


Figure 3.8.4.4 Energy-saving Appendage in Front of the Propeller

3.8.4.5 The joint weld of the energy-saving appendage in front of the propeller and the hull is to be ground smooth and the toes are to have a smooth transition.
3.8.4.6 100% external and at least 80% internal NDT is to be performed in the joint weld of surface shell of the energy-saving appendage in front of the propeller (including the external supporting structure) and the hull.

Appendix 1 GUIDELINES FOR CALCULATION OF BENDING MOMENT AND SHEAR FORCE DISTRIBUTION

1 General

1.1 Application

1.1.1 The evaluation of bending moments, shear forces and support forces for the system rudder– rudder stock may be carried out for some basic rudder types as outlined in 2.1 to 2.5 of this Appendix.

2 The Forces on Rudder–Rudder Stock

2.1 Spade rudder

Data for the analysis

l_{10} – l_{30} = lengths of the individual girders of the system, in m;

I_{10} – I_{30} = moments of inertia of these girders, in cm^4.

Load of rudder body P_R:

$$P_R = C_R / (l_{10} 10^3) \qquad \text{kN/m}$$

Moments and forces

The moments and forces may be determined by the following formulae:

$$M_b = C_R (l_{20} + (l_{10}(2c_1 + c_2) / 3(c_1 + c_2))) \qquad \text{N·m}$$

$$B_3 = \frac{M_b}{l_{30}} \qquad \text{N}$$

$$B_2 = C_R + B_3 \qquad \text{N}$$

where: C_R — rudder force, in N.

The maximum moment, M_c, in top of the cone coupling as shown in Figure 2.1 is applicable for the connection between the rudder and the rudder stock.

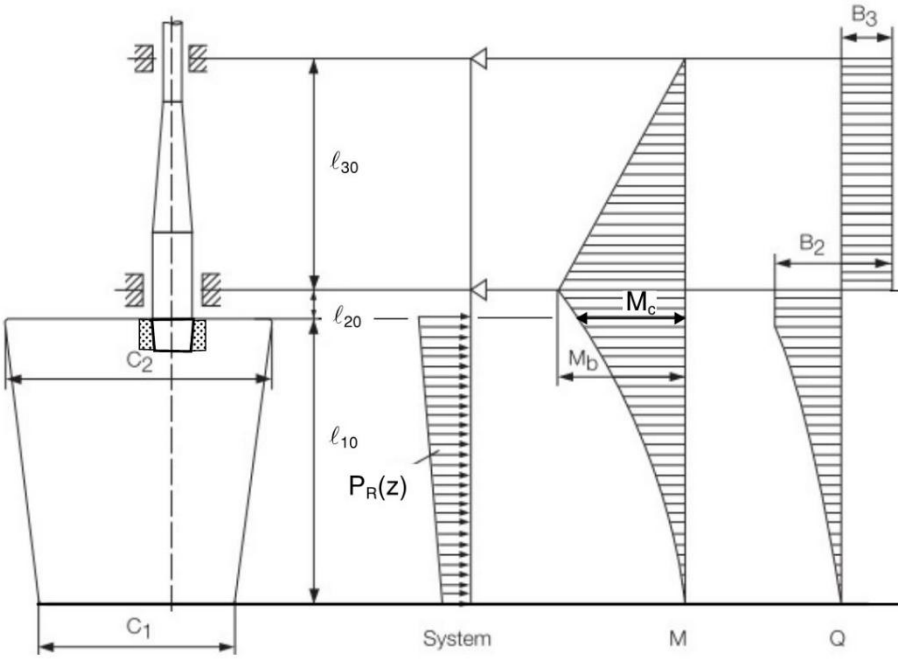


Figure 2.1 Spade rudder

2.2 Spade rudder with trunk

Data for the analysis

l_{10} – l_{30} = lengths of the individual girders of the system, in m;

I_{10} – I_{30} = moments of inertia of these girders, in cm^4.

Load of rudder body P_R:

$$P_R = C_R / ((l_{10} + l_{20})10^3) \qquad \text{kN/m}$$

Moments and forces

For a spade rudder with trunk extending inside the rudder, the strength is to be checked against the following two cases, and the moments and forces for the two cases defined above may be determined according to Figure 2.2(1) and 2.2(2), respectively.

(1) pressure applied on the entire rudder area;

Full rudder force $C_R = C_{R1} + C_{R2}$

total rudder torque $Q_R = Q_{R1} + Q_{R2}$

rudders stock bending moment $M_b = M_{CR2} - M_{CR1}$

(2) pressure applied only on rudder area below the middle of neck bearing.

Rudder force C_{R2} corresponding to rudder torque Q_{R2} acting at rudder blade area A_2 with rudders stock bending moment $M_b = M_{CR2}$

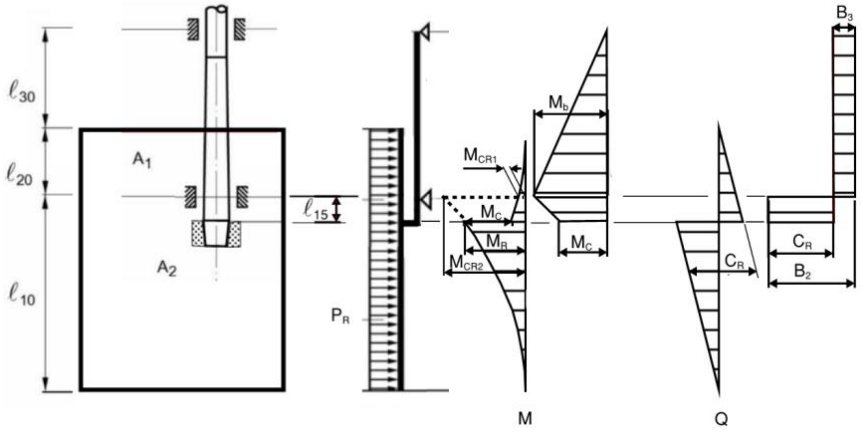


Figure 2.2(1)

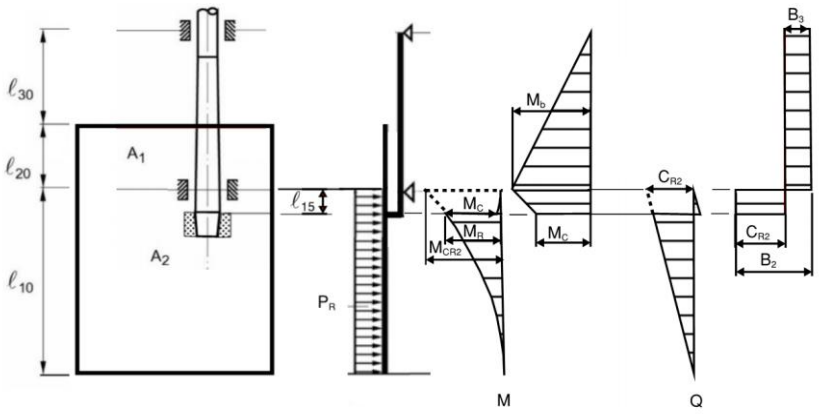


Figure 2.2(2)

$$M_{CR1} = C_{R1}(CG_{1Z} - l_{10}) \qquad \text{N·m}$$

$$M_{CR2} = C_{R2}(l_{10} - CG_{2Z}) \qquad \text{N·m}$$

where: C_{R1}: rudder force over the rudder blade area A_1;

C_{R2}: rudder force over the rudder blade area A_2;

CG_{1Z}: vertical position of the centre of gravity of the rudder blade area A_1;

CG_{2Z}: vertical position of the centre of gravity of the rudder blade area A_2;

$$C_R = C_{R1} + C_{R2} \qquad \text{N}$$

$$B_3 = (M_{CR2} - M_{CR1}) / (l_{20} + l_{30}) \quad \text{N}$$

$$B_2 = C_R + B_3 \quad \text{N}$$

2.3 Rudder supported by sole piece

Data for the analysis

l_{10} – l_{50} = lengths of the individual girders of the system, in m;

$I_{10} – I_{50}$ = moments of inertia of these girders, in cm^4.

For rudders supported by a sole piece the length l_{20} is the distance between lower edge of rudder body and centre of sole piece and I_{20} the moment of inertia of the pintle in the sole piece.

I_{50} = moment of inertia of sole piece around the z-axis, in cm^4;

l_{50} = effective length of sole piece, in m;

Load of rudder body P_R:

$$P_R = C_R / (l_{10} 10^3) \quad \text{kN/m}$$

Z — spring constant of support in the sole piece;

$$Z = 6.18 \times I_{50} / l_{50}^3 \quad \text{kN/m}$$

where: C_R – rudder force, in N.

Moments and forces

Moments and shear forces are indicated in Figure 2.3.

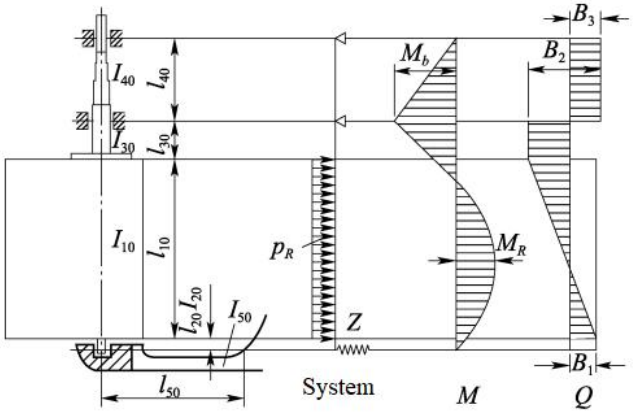


Figure 2.3 Rudder supported by sole piece

2.4 Semi spade rudder with one elastic support

Data for the analysis

l_{10} – l_{40} = lengths of the individual girders of the system, in m;

$I_{10} – I_{40}$ = moments of inertia of these girders, in cm^4.

Z — spring constant of support in the rudder horn:

$Z = 1/(f_b + f_t)$ kN/m, for the support in the rudder horn (see Figure 2.4.1);

f_b — unit displacement of rudder horn, in m, due to a unit force of 1 kN acting in the centre of support:

$$f_b = \frac{1.3 h^3}{6.18 I_n} \quad \text{m/kN (guidance value);}$$

I_n — moment of inertia of horizontal section of rudder horn around the x-axis, in cm^4 (see also Figure 2.4.1);

f_t — unit displacement due to torsion, in m/kN;

$$f_t = \frac{he^2 \sum u_i / t_i}{3.14 \times 10^8 F_T^2} \quad \text{m/kN}$$

F_T — mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn (excluding the area of the inner hollow area), in m^2;

u_i — breadth in [mm] of the individual plates forming the F_T area;
t_i — thickness within the individual breadth u_i, in mm;
h — Height of the rudder horn, in m, defined in Figure 2.4.1. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the lower rudder horn pintle;
e — distance as defined in Figure 2.4.2, in m, measured to $h/2$ of the height of the rudder horn;
Load of rudder body:

$$p_{R10}=\frac{C_{R2}}{l_{10}\times 10^3} \quad \text{kN/m}$$

$$p_{R20}=\frac{C_{R1}}{l_{20}\times 10^3} \quad \text{kN/m}$$

where: C_R, C_{R1}, C_{R2}, see 2.2 of this Appendix.
Moments and forces
Moments and shear forces are indicated in Figure 2.4.1.
Rudder horn
The loads on the rudder horn are as follows:
M_b — bending moment = $B_1 z$, in N·m;
M_{bmax}= $B_1 h$, in N·m;
Q — shear force = B_1, in N;
M_T(z) — torsional moment = $B_1 e(z)$, in N·m.
An estimate for B_1 is:
$B_1 = C_R b / (l_{20} + l_{30})$, in N.

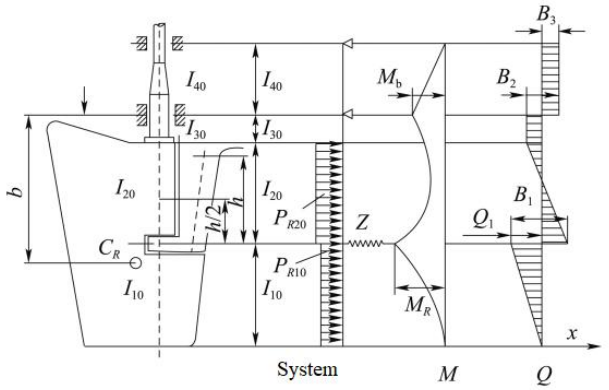


Figure 2.4.1 Semi spade rudder with one elastic support

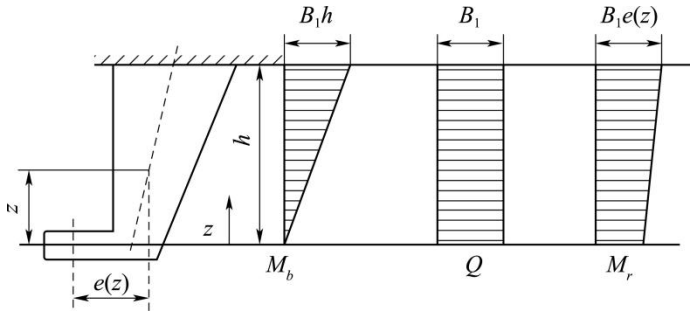


Figure 2.4.2 Rudder horn of semi spade rudder with one elastic support

2.5 Semi spade rudder with 2-conjugate elastic support

Data for the analysis
K_{11}, K_{12}, K_{22}: Rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports (Figure 2.5.1).The 2-conjugate elastic supports are defined in terms of horizontal displacements, y_i, by the following equations:
at the lower rudder horn bearing:

$$y_1 = -K_{12}B_2 - K_{22}B_1$$

at the upper rudder horn bearing:

$$y_2 = -K_{11}B_2 - K_{12}B_1$$

where: y_1, y_2 — horizontal displacements, in m, at the lower and upper rudder horn bearings, respectively;

B_1, B_2 — horizontal support forces, in kN, at the lower and upper rudder horn bearings, respectively;

K_{11}, K_{12}, K_{22} — obtained, in m/kN, from the following formulae:

$$K_{11}=1.3\times\frac{\lambda^3}{3EJ_{1h}}+\frac{e^2\lambda}{GJ_{th}}$$

$$K_{12}=1.3\times\left[\frac{\lambda^3}{3EJ_{1h}}+\frac{\lambda^2(h-\lambda)}{2EJ_{1h}}\right]+\frac{e^2\lambda}{GJ_{th}}$$

$$K_{22}=1.3\times\left[\frac{\lambda^3}{3EJ_{1h}}+\frac{\lambda^2(d-\lambda)}{EJ_{1h}}+\frac{\lambda(h-\lambda)^2}{EJ_{1h}}+\frac{(h-\lambda)^3}{3EJ_{2h}}\right]+\frac{e^2\lambda}{GJ_{th}}$$

where: h — height of the rudder horn, in m, defined in Figure 2.5.1. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the lower rudder horn pintle;

λ— length, in m, as defined in Figure 2.5.2. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those of spring constant Z for a rudder horn with 1-elastic support, and assuming a hollow cross section for this part;

e — rudder-horn torsion lever, in m, as defined in Figure 2.5.1 (value taken at $z = h/2$);

J_{1h} — moment of inertia of rudder horn about the x-axis, in m^4, for the region above the upper rudder horn bearing. Note that J_{1h} is an average value over the length λ (see Figure 2.5.1);

J_{2h} — moment of inertia of rudder horn about the x-axis, in m^4, for the region between the upper and lower rudder horn bearings. Note that J_{2h} is an average value over the length $h - \lambda$ (see Figure 2.5.1);

J_{th} — torsional stiffness factor of the rudder horn, in m^4. For any thin wall closed section:

$$J_{th}=\frac{4F_T^2}{\sum_i \frac{u_i}{t_i}} \quad m^4$$

F_T — mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn (excluding the area of the inner hollow area), in m^2;

μ_i — length, in mm, of the individual plates forming the F_T area;

t_i — thickness, in mm, of the individual plates mentioned above.

Note that the J_{th} value is taken as an average value, valid over the rudder horn height.

Load of rudder body:

$$p_{R10}=\frac{C_{R2}}{l_{10}\times 10^3} \quad kN/m$$

$$p_{R20}=\frac{C_{R1}}{l_{20}\times 10^3} \quad kN/m$$

where: C_R, C_{R1}, C_{R2}, see 2.2 of this Appendix.

Moments and forces

Moments and shear forces are indicated in Figure 2.5.1.

Rudder horn bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formulae:

between the lower and upper supports provided by the rudder horn:

$$M_H = F_{A1}z \quad N\cdot m$$

above the rudder horn upper-support:

$$M_H = F_{A1}z+F_{A2}(z-d_{lu}) \quad N\cdot m$$

where:

F_{A1} — support force at the rudder horn lower-support, in N, to be obtained according to Figure 2.5.1, and taken equal to B_1;

F_{A2} — support force at the rudder horn upper-support, in N, to be obtained according to Figure 2.5.1, and taken equal to B_2;

z — distance, in m, defined in Figure 2.5.2, to be taken less than the distance h, in m, defined in the same figure;

d_{lu} — distance, in m, between the rudder-horn lower and upper bearings (according to Figure 2.5.1, $d_{lu} = h - \lambda$).

Rudder horn shear force

The shear force Q_H acting on the generic section of the rudder horn is to be obtained, in N, from the following formulae:

between the lower and upper rudder horn bearings:

$$Q_H = F_{A1} \qquad \text{N}$$

above the rudder horn upper-bearing:

$$Q_H = F_{A1} + F_{A2} \qquad \text{N}$$

where: F_{A1}, F_{A2} — support forces, in N.

The torque acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formulae:

between the lower and upper rudder horn bearings:

$$M_T = F_{A1} e(\text{z}) \qquad \text{N·m}$$

above the rudder horn upper-bearing:

$$M_T = F_{A1} e(\text{z}) + F_{A2} e(\text{z}) \qquad \text{N·m}$$

where: F_{A1}, F_{A2} — support forces, in N;

$e(z)$ — torsion lever, in m, defined in Figure 2.5.2.

Rudder horn shear stress calculation

For a generic section of the rudder horn, located between its lower and upper bearings, the following stresses are to be calculated:

τ_S — shear stress, in N/mm^2, to be obtained from the following formula:

$$\tau_s = \frac{F_{A1}}{A_H} \qquad \text{N/mm}^2$$

τ_T — torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^{-3}}{2F_T t_H} \qquad \text{N/mm}^2$$

For solid rudder horn, τ_T is to be calculated based on the specific geometrical shape.

For a generic section of the rudder horn, located in the region above its upper bearing, the following stresses are to be calculated:

τ_S — shear stress, in N/mm^2, to be obtained from the following formula:

$$\tau_s = \frac{F_{A1} + F_{A2}}{A_H} \qquad \text{N/mm}^2$$

τ_T — torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^{-3}}{2F_T t_H} \qquad \text{N/mm}^2$$

For solid rudder horn, τ_T is to be calculated based on the specific geometrical shape.

where:

F_{A1}, F_{A2} — support forces, in N;

A_H — effective shear sectional area of the rudder horn, in mm^2, in y-direction;

M_T — torque, in N·m;

F_T — mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn (excluding the area of the inner hollow area), in m^2;

t_H — Plate thickness of rudder horn, in mm. For a given cross section of the rudder horn, the maximum value of τ_T is obtained at the minimum value of t_H.

Rudder horn bending stress calculation

For the generic section of the rudder horn within the length h, the following stresses are to be calculated:

σ_B — bending stress, in N/mm^2, to be obtained from the following formula:

$$\sigma_B = \frac{M_H}{W_X} \qquad \text{N/mm}^2$$

where: M_H — bending moment at the section considered, in N·m;

W_X — section modulus, in cm^3, around the *x*-axis (see Figure 2.5.2).

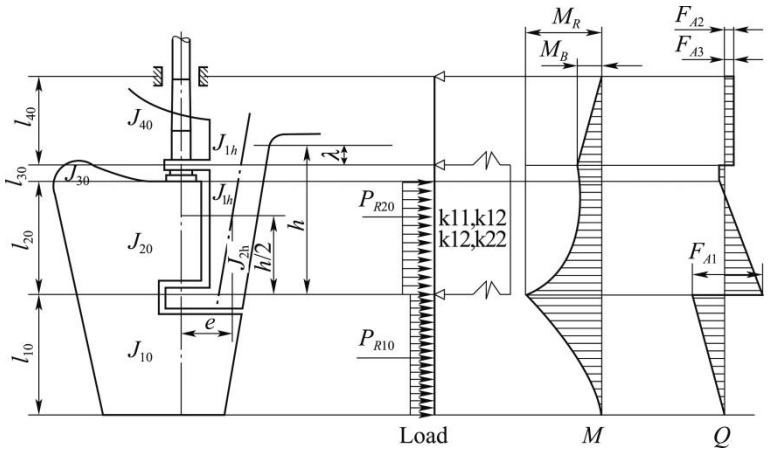


Figure 2.5.1

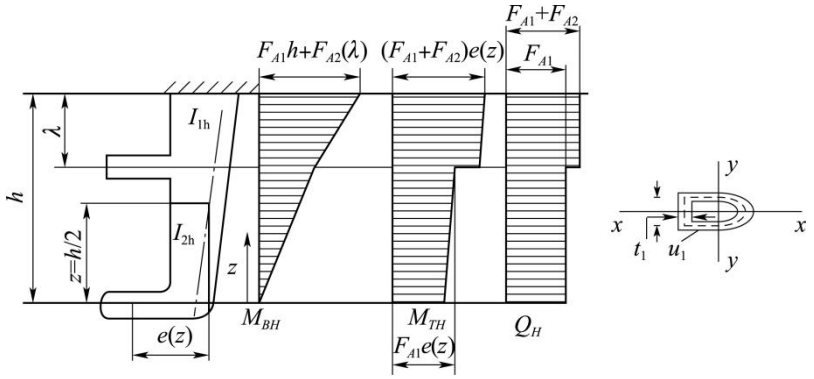


Figure 2.5.2

Appendix 2 DIRECT MOORING ANALYSES

1 General

1.1 As an alternative to the requirements for mooring lines in 3.2.4 of this Chapter, direct mooring analysis may be performed to determine the necessary mooring restraint, i.e. number and strength of mooring lines.

Direct analyses allow to optimize mooring equipment and arrangement for the individual ship and the port mooring facilities typical for the considered ship type and size.

2 Documentation

2.1 The calculations should be documented in a report. The report should include all assumptions made in calculations for the finally chosen mooring equipment, including lines, and its arrangement, reflected in the mooring arrangement plan.

3 Analysis methodology

3.1 Three dimensional quasi-static calculations should be performed to determine the acting mooring line forces. As a minimum, loads from wind and current should be accounted for in the analysis. Geometrical and material nonlinearities of mooring lines and fenders or breasting dolphins should be considered. An iterative calculation procedure should be applied to arrive at a converged solution with forces acting on mooring lines and on fenders or breasting dolphins being in equilibrium with forces and moments applied to the ship.

4 Environmental conditions

4.1 Mooring line forces should be calculated for environmental conditions given in 3.2.4.3 of this Chapter. Additional loads, e.g. wave loads or cross currents, or increased wind and current loads may be considered for certain ship types or for specific ports intended to be regularly called.

5 Steps to be taken in a direct mooring analysis

Direct assessment of mooring forces and determination of the necessary number and strength of mooring lines comprise the following steps:

(1) Determine port mooring facilities representative for the considered ship type and size

(2) Determine shipboard mooring equipment and arrangement

(3) Determine mooring line type(s) to be used

(4) Determine mooring layout(s) to be assessed

(5) Determine ship loading condition(s) to be assessed

(6) Select or determine wind and current drag coefficients

(7) Determine wind and current forces and moments

(8) Compute forces acting on all mooring line

(9) Determine necessary strength of mooring lines

(10) If strength of mooring lines should be altered, modify steps (2), (3) and/or (4) with or without changing the number of mooring lines and repeat steps (8) and (9)

5.1 Port mooring facilities

5.1.1 Characteristics of port mooring facilities have strong influence on the resulting mooring line forces. Mooring analysis should be performed for port mooring facilities representative for the considered ship type and size, i.e. type of berth, type and arrangement of hooks/bollards, type and arrangement of fenders or breasting dolphins and height of pier above waterline.

5.1.2 Fenders or breasting dolphins in many cases may not affect the critical mooring line loads. Hence, initially, generic fender or dolphin arrangements and infinitely stiff load deformation characteristics may be considered. If no fender or dolphin loads occur for load cases yielding the critical mooring line loads, more specific fender or dolphin arrangements and characteristics may be omitted.

5.1.3 If there are substantially different port mooring facilities typically encountered by the considered ship type, additional calculations should be performed to consider these variations.

5.2 Shipboard mooring equipment and arrangement

5.2.1 The mooring equipment and arrangement need to be chosen for the mooring analysis, i.e. location of mooring decks and location of mooring winches and fairleads. As a starting point, mooring equipment for the number of lines as determined by 3.2.4 of this Chapter may be chosen.

5.3 Mooring lines

5.3.1 The mooring analysis should apply the mooring line type(s) intended to be supplied with the vessel. The geometrical and material nonlinearities of the mooring lines should be considered by the mooring analysis. Load-deflection characteristics of mooring lines can be taken from data sheets of rope manufacturers. If given, characteristics of the broken-in ropes should be applied.

5.3.2 To achieve a good distribution of mooring line forces, mooring line type and characteristics should be at least same for lines in the same service, e.g. for head and stern lines, breast lines and spring lines. For very stiff mooring lines, e.g. made of steel or high modulus synthetic fibers, the use of elastic tails should be considered to enhance the elasticity in the mooring system and taken into account for the mooring analysis.

5.4 Mooring layout

5.4.1 For the assessment of forces acting on mooring lines, a realistic mooring layout needs to be assumed, i.e. for each mooring line it needs to be determined from which bollard or winch, along which path, through which fairlead it is led and to which shoreside hook or bollard it is connected. Inboard parts of the mooring lines (between fairlead and shipboard fixation point) contribute to the elongation behavior of the line and should be included in the analysis.

5.4.2 The maximum number of lines connected to one shore mooring point needs to be limited to not load the shore side mooring points unrealistically high. For multipurpose piers the number of lines per shore bollard should be limited to three. For other types of berths, the number mooring lines per shore mooring point is also limited, e.g., by the available number of hooks. Reasonable assumptions should be made based on typical berth types encountered by the considered ship type.

5.4.3 Alternative mooring layouts should also be assessed, considering possible and reasonable options to moor the ship to the assumed port mooring facilities. Also, a different position of the ship relative to the shoreside mooring bollards/hooks should be assessed to find the critical mooring line loads for the normal operation of the ship. Exemptions may be given to e.g. tankers, LNG carriers or ferries if typically moored in the same position relative to the shoreside mooring facilities.

5.5 Loading conditions

5.5.1 Mooring line forces should be calculated for loading conditions given in 3.2.4.3 of this Chapter.

5.6 Wind and current drag coefficients

5.6.1 To calculate the wind and current forces and moments acting on the ship, wind and current drag coefficients are needed for the considered ship type, size and loading condition. Drag coefficients should be as specific as possible for the considered ship and loading conditions.

5.6.2 There are different sources for drag coefficients. Some Industry Guidelines provide drag coefficients for tankers and LNG carriers which can be applied. Due to the similarity of hull forms and superstructures, these coefficients may also be used for bulk carriers and ore carriers. For other ship types drag coefficients may be taken from the literature, if available, or can be determined by CFD calculations or model tests. CFD calculations are to be justified with suitable validation and sensitivity studies.

5.6.3 There are some effects that can influence the drag coefficients, i.e. blockage (limited under keel clearance, solid quay walls), ship draft and wind shielding by solid quays and buildings or cargo stored on quays (e.g. container stacks). Effects from blockage and ship draft can only be accounted for by appropriate coefficients. Drag coefficient should be chosen or determined for realistic water depth to draft ratios and for the considered ship draft(s). Some Industry Guidelines provide current drag coefficients for ballast and loaded draft conditions and for different water depth to draft ratios. Wind shielding effects are typically not considered by the wind drag coefficients. The effect of wind shielding of solid quays may be considered by an equivalent reduction of the lateral wind area of the ship. Shielding by buildings or cargo stored on quays should not be considered as their presence is imponderable.

5.7 Calculation of wind and current forces and moments

5.7.1 Wind and current forces and moments can be calculated for the given environmental conditions with the geometrical particulars of the considered ship and the selected drag coefficients. Usually, the forces in longitudinal and transversal directions as well as the moment about the vertical ship axis (yaw) are calculated.

5.7.2 Wind forces and moments should be calculated for all directions in intervals of preferably 15°, but not more than 30°. Current forces and moments should be calculated for selected directions as per 3.2.4.3 of this Chapter. For ships regularly moored to non-solid piers or jetties, cross current may need to be considered in addition.

5.8 Calculation of mooring line forces

5.8.1 For all considered scenarios and all combinations of applied environmental conditions, the maximum mooring line force should be determined for groups of lines in the same service.

5.8.2 In case of all lines are intended to be attached to winches, brake rendering can be considered to better distribute line loads among all lines in a group of lines in the same service. Then, the average mooring line force of a group of lines may be determined and taken as mooring line force used to determine the necessary strength of the mooring lines according to section 5.9.

5.9 Strength of mooring lines

5.9.1 The necessary strength of mooring lines, i.e., the Ship Design Minimum Breaking Load (MBL_{SD}), results from the calculated maximum mooring line force ($F_{L,\ max}$) divided by the Work Load Limit (*WLL*) factor of mooring lines. The *WLL* factor and the resulting MBLSD for different mooring line materials are shown in the below table.

***WLL* factor and MBL_{SD}** **Table 5.9.1**

Mooring line material	*WLL* factor	MBL_{SD}
Steel wire	0.55	$1.82\times F_{L,max}$
Synthetic fibers	0.5	$2.0\times F_{L,max}$

5.9.2 Preferably, all lines supplied to the ship should have the same characteristics and strength to avoid confusion of lines. However, for significantly different maximum calculated line loads, lines in different service may also have different strength and characteristics, e.g. for head and stern lines other than for spring lines.

Appendix 3 DIRECT FORCE CALCULATION FOR ANCHORING EQUIPMENT

1 General

1.1 As an alternative to the prescriptive approach described in 3.2.1.2 of this Chapter direct force calculation may be performed to determine the necessary anchoring equipment for monohull ships with length less than 90m.

2 Total force F_{EN}

2.1 The total force (static + dynamic) F_{EN} , in kN, induced by wind and current acting on monohull in anchoring condition as defined in A1.1 may be calculated as follows:

$$F_{EN} = 2(F_{SLPH} + F_{SH} + F_{SS})$$

where: F_{SLPH} ——Static force on wetted part of the hull due to current;

F_{SH} ——Static force on hull due to wind;

F_{SS} ——Static force on superstructures due to wind.

2.1.1 Calculation of F_{SLPH}

Static force on wetted part of the hull due to current F_{SLPH} , in kN, is defined according to the following formula:

$$F_{SLPH} = \frac{1}{2}\rho C_f S_m V_c^2 10^{-3}$$

where: ρ ——Water density, equal to 1025kg/m^3;

C_f ——Coefficient equal to:

$$C_f = (1+k)\frac{0.075}{(\log R_e - 2)^2}$$

where: R_e ——Reynolds number equal to:

$$R_e = \frac{(V_c L_{WL})}{1.054 \cdot 10^{-6}}$$

k ——Coefficient equal to:

$$k = 0.017 + 20\frac{C_{bWL}}{L_{WL}^2 T^{-0.5} B_{WL}^{-1.5}}$$

C_{bWL} ——block coefficient at waterline equal to:

$$C_{bWL} = \frac{\Delta}{1.025 L_{WL} B_{WL} T}$$

where: Δ ——Moulded displacement at waterline, in m^3;

S_m ——Total wetted surface of the part of the hull under draught, in m^2. The value of S_m is to be given by the Designer. When this value is not available, S_m may be taken equal to $6 \cdot \Delta^{2/3}$;

V_c ——Speed of the current, in m/s.

2.1.2 Calculation of F_{SH}

Static force on hull due to wind F_{SH} , in kN, is defined according to the following formula:

$$F_{SH} = \frac{1}{2}\rho(C_{hfr}S_{hfr} + 0.02S_{hlat})V_W^2 10^{-3}$$

where: ρ ——Air density, equal to 1.22kg/m^3;

V_W ——Speed of the wind, in m/s;

S_{hfr} ——Front surface of hull and bulwark if any, in m^2, projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship;

S_{hlat} ——Partial lateral surface of one single side of the hull and bulwark if any, in m^2, through the overall length of the ship, projected on a vertical plane parallel to the longitudinal axis of the ship and delimited according to Figure 2.1.2. In Figure 2.1.2, B is the breadth of the hull, in m.

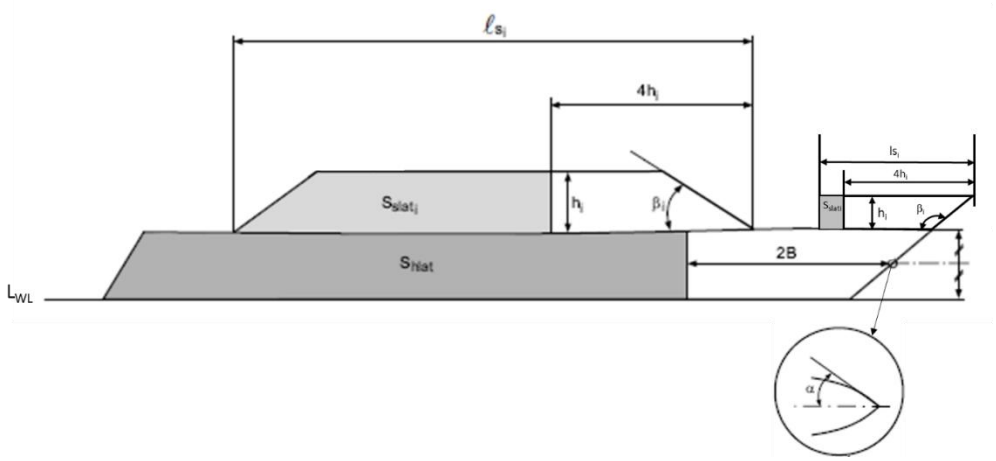


Figure 2.1.2

C_{hfr} ——Coefficient equal to $0.8\sin\alpha$, with α defined in Figure 2.1.2;

The upper part of the hull is the part extending from side to side to the uppermost continuous deck extending over the ship length.

2.1.3 Calculation of F_{SS}

(1) General case

Static force on superstructures and deckhouses due to wind F_{SS}, in kN, is defined according to the following formula:

$$F_{SS} = \frac{1}{2}\rho\sum(C_{sfr_i}S_{sfr_i} + 0.08S_{slat_i})V_W^2 10^{-3}$$

where: ρ ——Air density, equal to 1.22kg/m^3;

V_W ——Speed of the wind, in m/s;

S_{sfr_i} ——Front surface of tier i (superstructure or deckhouse, including bulwark if any), in m^2, projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship;

S_{slat_i} ——Partial lateral surface of one single side of tier i (superstructure or deckhouse, including bulwark if any), in m^2, projected on a vertical plane parallel to the longitudinal axis of the ship and delimited according to Figure 2.1.2. When $4h_i \geq l_{si}$, S_{slat_i} is to be taken equal to 0;

C_{sfr_i} ——Coefficient equal to $0.8\sin\beta_i$, with β_i defined in Figure 2.1.2 without being greater than 90°;

(2) Superstructures in the forward part of the ship

When superstructures are located in the front of the hull with front and side walls of superstructures in the continuity of the side shell, the static force induced by wind applied on these superstructures F_{SS}, in KN, is defined as the sum of the forces applied to each superstructure tier according to the following formula:

$$F_{SS} = \frac{1}{2}\rho\sum(C_{hfr_i}S_{hfr_i} + 0.08S_{slat_i})V_W^2 10^{-3}$$

where: S_{hfr_i} ——Front surface of tier i of the superstructure, in m^2, projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship

C_{hfr_i} ——Coefficient equal to $0.8\sin\alpha_s$, with α_s defined in Figure 2.1.2 and measured at mid height of the superstructure tier located in the front of the hull.

The static force is to be added to the static force calculated for the other superstructures and deckhouses according to 2.1.3(1) of this Appendix.

3 Anchor weight

3.1 The individual mass of anchor, in kg, is to be at least equal to:

for ordinary anchor: $P = (F_{EN}/7)\cdot 10^2$

for high holding power anchor: $P = (F_{EN}/10)\cdot 10^2$

for very high holding power: $P = (F_{EN}/15)\cdot 10^2$

4 Chain cable

4.1 Stud link chain cable scantling

Chain cable diameters are to be based on the minimum breaking load *BL* and proof load *PL* of steel grades.

Chain Cable Diameters **Table 4.1**

	CCS Grade 1	CCS Grade 2	CCS Grade 3
BL	$6F_{EN}$	$6.8F_{EN}$	$7.5F_{EN}$
PL	0.7*BL*		

The chain cable scantling is to be consistent with the mass of the associated anchor. In case the anchor on board is heavier by more than 7% from the mass calculated in 3.1 of this Appendix, the value of F_{EN} to take into account for the calculation of BL and PL is to be deduced from the actual mass of the anchor according to the formulae in 3.1 of this Appendix.

4.2 Length of individual chain cable

The length of chain cable L_{cc}, in m, linked to each anchor is to be at least equal to:

when P<180, $L_{cc} = 30\ln(\mathrm{P}) - 42$

when P≥180, L_{cc} to be selected according to Table 3.2.1.1(2) of this Chapter.

where: P: Anchor weight, in kg, defined in 3.1 of this Appendix for an ordinary anchor according to the considered case.

Chapter 4 STRENGTHENING FOR NAVIGATION IN ICE

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.1 A ship classed with CCS intended to navigate in ice, for which any of the ice class notations as specified in 4.1.1.2 of this Section is desired and the corresponding requirements in Table 4.1.1.2 are complied with, may be assigned corresponding ice class notation. The requirements for ice class notations are in addition to those for the main class.

4.1.1.2 Ships, which comply with the requirements of Section 2 of this Chapter, may be assigned an appropriate ice class notation in accordance with 4.2.1.2, Section 2 of this Chapter; ships, which comply the requirements of Section 3 of this Chapter, may be assigned the notation of Ice Class B.

Table 4.1.1.2

Applicable ice navigation waters	Ice class	Requirements in corresponding chapters of the Rules	Additional requirements for ships having icebreaking capability
Polar sea	PC1 ~ PC7	Sections 1 ~ 2, Chapter 13 of PART EIGHT	–
	Icebreaker	Sections 1 ~ 2, Chapter 13 of PART EIGHT	–
	Icebreaker*	Rules for Heavy Icebreakers	–
Baltic or other sea areas with similar ice conditions in winter	B1*, B1 ~ B3	Section 2, Chapter 4 of PART TWO	Chapter 9 of PART EIGHT
Drift ice sea areas other than large stationary ice such as for coastal ice condition in northern part of China in winter	B	Section 3, Chapter 4 of PART TWO	–

4.1.1.3 An ice class notation may be requested by the Owner in accordance with 4.1.1.2 of this Section, subject to submission of service and operational conditions.

4.1.1.4 The equivalence between ice strengthening requirements for B1*, B1, B2, B3 and B of CCS and the ice classes of Finnish-Swedish Ice Class Rules (FSICR)① is given in Table 4.1.1.4.

Table 4.1.1.4

CCS	FSICR
B1*	IA Super
B1	IA
B2	IB
B3	IC
B	Between II and IC
Ships with the character of classification CSA	II

4.1.1.5 Ships intended to navigate in ice are to observe the local regulations concerning navigation in ice promulgated by the port authorities of respective countries, and attention is to be paid to the special requirements given by international industry organizations and oil companies.

4.1.1.6 In the design of structures, equipment and arrangements related to the safety and operation of the ship, the effect of low temperatures is to be taken into account.

Section 2 ICE STRENGTHENING FOR CLASSES B1*, B1, B2 AND B3

4.2.1 General requirements

4.2.1.1 The provisions of this Section apply to strengthening requirements for hull structures of merchant ships navigating in the Baltic or other sea areas with similar ice conditions in winter.

4.2.1.2 The ice class notations of ships and icebreaker-assisted ships are to be assigned as follows and the requirements for engine output are given in Chapter 14 of PART THREE of the Rules:

B1*– ships with such structure, engine output and other properties that they are normally capable of navigating in difficult ice conditions without the assistance of icebreakers;

① See TRAFICOM/281964/03.04.01.00/2023 for equivalence.

B1 – ships with such structure, engine output and other properties that they are capable of navigating in difficult ice conditions, with the assistance of icebreakers when necessary;
B2 – ships with such structure, engine output and other properties that they are capable of navigating in moderate ice conditions, with the assistance of icebreakers when necessary;
B3 – ships with such structure, engine output and other properties that they are capable of navigating in light ice conditions, with the assistance of icebreakers when necessary.
4.2.1.3 Restrictions on draughts when operating in ice are to be documented and kept on board readily available to the master. The maximum and minimum ice class draughts fore, amidships and aft are to be indicated in the class certificate, loading manual and shell plating expansion.
4.2.1.4 The sides of ship, to which the class notation of B1*, B1, B2 or B3 is assigned, are to be provided with a warning triangle and with an ice class draught mark at the maximum permissible ice class draught amidships (see Figure 4.2.1.4) when the upper ice waterline (UIWL) is lower than the fresh water load line in summer.

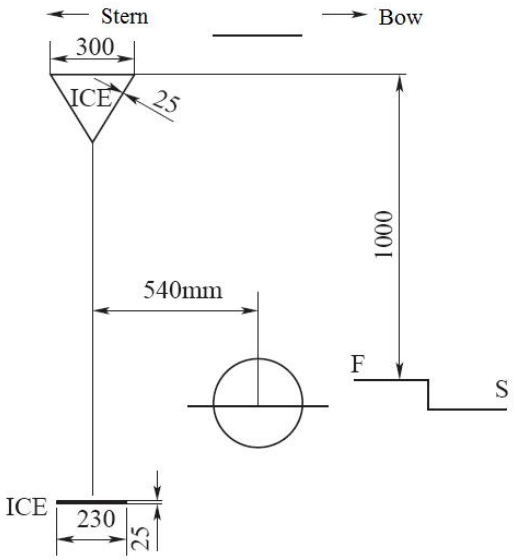


Figure 4.2.1.4 Warning Triangle and Maximum Ice Class Draught Mark (Starboard)

4.2.1.5 The upper edge of the warning triangle is to be located vertically above the "ICE" mark, 1000 mm higher than the summer fresh water load line, but in no case higher than the deck line. The sides of the triangle are to be 300 mm in length.
4.2.1.6 The ice class draught mark is to be located 540 mm abaft the centre of the load line ring or 540 mm abaft the vertical line of the timber load line mark, if applicable.
4.2.1.7 The marks and figures are to be cut out of 5 to 8 mm plate and then welded to the ship marks s. The marks and figures are to be painted in a red or yellow reflecting colour in order to make the marks and figures plainly visible even in ice conditions.
4.2.1.8 The dimensions of all marks and figures are to be the same as those used in the load line mark.

4.2.2 Ice class draught

4.2.2.1 Upper and lower ice waterlines
The upper ice waterline (UIWL) is to be the envelope of the highest points of the waterlines at which the ship is intended to operate in ice. The line may be a broken line.
The lower ice waterline (LIWL) is to be the envelope of the lowest points of the waterlines at which the ship is intended to operate in ice. The line may be a broken line.
4.2.2.2 Maximum and minimum draught fore and aft
The maximum and minimum ice class draughts at fore and aft perpendiculars are to be determined in accordance with the upper and lower ice waterlines.
The draught and trim, limited by the UIWL, must not be exceeded when the ship is navigating in ice. The salinity of the sea water along the intended route is to be taken into account when loading the ship.
The ship is always to be loaded down at least to the LIWL when navigating in ice. Any ballast tank, situated above the LIWL and needed to load down the ship to this water line, is to be equipped with devices to prevent the water from freezing. In determining the LIWL, regard is to be paid to the need for ensuring a reasonable degree of ice-going capability in ballast. The propeller is to be fully submerged, if possible entirely below the ice. The forward draught d_1 is not to be less than that obtained from the following formula:

$$d_1 = (2 + 0.00025\Delta)h_0 \quad \text{m, but need not exceed 4 } h_0,$$

where: Δ — displacement of the ship, in t, on the maximum ice-class draught according to 4.2.2.1 of this Section;

h_0 — level ice thickness, in m, see Table 4.2.4.2(1).

4.2.3 Engine output

The requirements for engine output related to hull structures are given in Chapter 14, PART THREE of the Rules.

4.2.4 Hull structural design

4.2.4.1 General

The method for determining the hull scantlings is based on certain assumptions concerning the nature of the ice load on the structure. These assumptions are from full scale observations made in the northern Baltic.

It has thus been observed that the local ice pressure on small areas can reach rather high values. This pressure may be well in excess of the normal uniaxial crushing strength of sea ice. The explanation is that the stress field in fact is multiaxial.

Further, it has been observed that the ice pressure on a frame can be higher than on the shell plating at midspacing between frames. The explanation for this is the different flexural stiffness of frames and shell plating. The load distribution is assumed to be as shown in Figure 4.2.4.1(1).

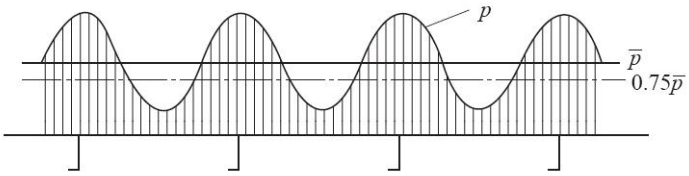


Figure 4.2.4.1(1) Ice Load Distribution on a Ship's Side

The formulae and values given in this Section may be substituted by direct analysis if they are deemed by the Administration or CCS to be invalid or inapplicable for a given structural arrangement or detail. Otherwise, direct analysis is not to be utilized as an alternative to the analytical procedures prescribed by explicit requirements in 4.2.4.3 to 4.2.4.5 of this Section.

Direct analyses are to be carried out using the load patch defined in 4.2.4.2 (p, h and l_a). The pressure to be used is $1.8p$ where p is determined according to 4.2.4.2(2). The load patch is to be applied at locations where the capacity of the structure under the combined effects of bending and shear are minimized. In particular, the structure is to be checked with load centred at the UIWL, $0.5h_0$ below the LIWL, and positioned several vertical locations in between. Several horizontal locations are also to be checked, especially the locations centred at the mid-span or –spacing. Further, if the load length l_a cannot be determined directly from the arrangement of the structure, several values of l_a are to be checked using corresponding values for c_a.

The acceptance criterion for designs is that the combined stresses from bending and shear, using the von Mises yield criterion, are lower than the yield point R_{eH}. When the direct calculation is using beam theory, the allowable shear stress is not to be larger than $0.9\tau_y$, where $\tau_y = R_{eH} / \sqrt{3}$.

If scantlings derived from these provisions are less than those required by other chapters of the Rules for a not ice strengthened ship, the latter is to be used.

Note 1: The frame spacings and spans defined in the following text are normally (in accordance with the appropriate rules for the ship in question) assumed to be measured along the plate and perpendicular to the axis of the stiffener for plates, along the flange for members with a flange, and along the free edge for flat bar stiffeners. For curved members the span (or spacing) is defined as the chord length between span (or spacing) points. The span points are defined by the intersection between the flange or upper edge of the member and the supporting structural element (stringer, web frame, deck or bulkhead). Figure 4.2.4.1(2) illustrates the determination of span and spacing for curved members.

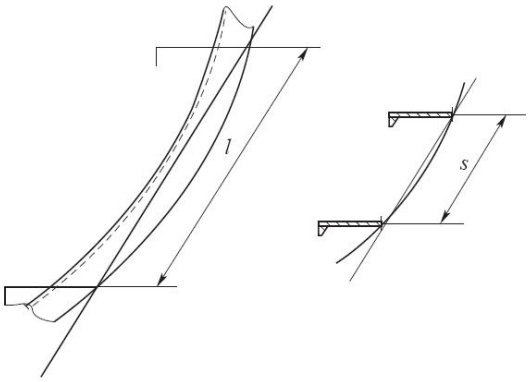


Figure 4.2.4.1(2) Definition of the Frame Span (left) and Frame Spacing (right) for Curved Members

Note 2: The effective breadth of the attached plate to be used for calculating the combined section modulus of the stiffener, stringer and web frame and attached plate is to be taken as the appropriate provisions in Section 2, Chapter 1 of this PART require. The effective breadth is in no case to be more than what is stated in the appropriate provisions above for the ship in question.

Note 3: The requirements for the section modulus and shear area of the frames, stringers and web frames in 4.2.4.4 to 4.2.4.6 are with respect to the effective member cross section. For such cases where the member is not normal to the plating, the section properties are to be calculated in accordance with the appropriate provisions in Section 2, Chapter 1 of this PART for the ship in question.

(1) Hull regions

For the purpose of this Section, the ship's hull is divided into regions as follows (see Figure 4.2.4.1(3)):

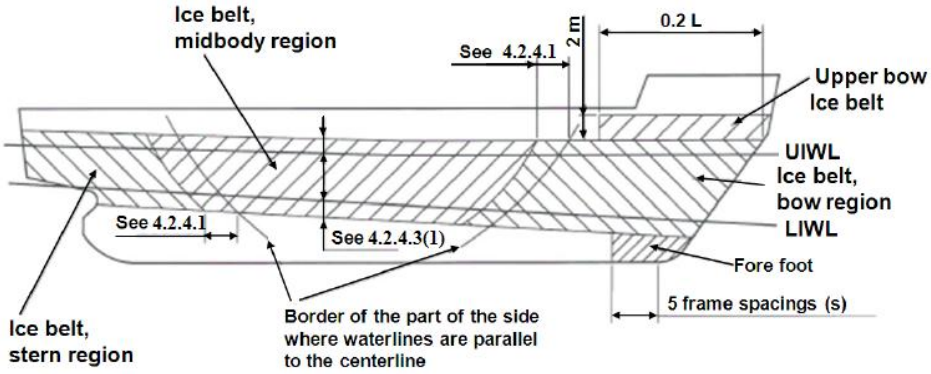


Figure 4.2.4.1(3) Ice Strengthened Regions of the Hull

Bow region: From the stem to a line parallel to and 0.04*L* aft of the forward borderline of the part of the hull where the waterlines run parallel to the centerline. For ice classes B1* and B1 the overlap over the borderline need not exceed 6 m, for ice classes B2 and B3 this overlap need not exceed 5 m.

Midbody region: From the aft boundary of the Bow region to a line parallel to and 0.04*L* aft of the aft borderline of the part of the hull where the waterlines run parallel to the centerline. For ice classes B1* and B1 the overlap over the borderline need not exceed 6 m, for ice classes B2 and B3 this overlap need not exceed 5 m.

Stern region: From the aft boundary of the Midbody region to the stern.

L is rule length of ship, see 1.1.2.1, Chapter 1 of this PART.

4.2.4.2 Ice load

(1) Height of the ice load area — an ice-strengthened ship is assumed to operate in open sea conditions corresponding to a level ice thickness not exceeding h_0 for the ice class in question. The design ice load height h (i.e. ice load height used in design calculation) of the area actually under ice pressure at any particular point of time is, however, assumed to be only a fraction of the ice thickness. The values for h_0 and h are given in Table 4.2.4.2(1).

Design Ice Thickness *h* and Level Ice Thickness h_0 **Table 4.2.4.2(1)**

Ice class	B1*	B1	B2	B3
Design ice thickness *h* (m)	0.35	0.30	0.25	0.22
level ice thickness h_0 (m)	1.0	0.8	0.6	0.4

(2) Ice pressure

The design ice pressure p is not to be less than that obtained from the following formula:

$$p = c_d c_p c_a p_0 \quad \text{MPa}$$

where: c_d — factor which takes account of the influence of the size and engine output of the ship. This factor is taken as maximum $c_d = 1$, to be calculated by the formula:

$$c_d = \frac{ak + b}{1000}$$

where: $k = \frac{\sqrt{\Delta P}}{1000}$;

a, b — see Table 4.2.4.2(2);

Δ — see 4.2.2.2 of this Section;

P —actual continuous engine output of the ship when sailing in ice in accordance with Chapter 14, PART THREE of the Rules, in kW; If additional power sources are available for propulsion power (e.g. shaft motors) in addition to the power of the main engine(s), they are also to be included in the total engine output used as the basis for hull scantling calculations. The engine output used for the calculation of the hull scantlings is to be clearly stated on the shell expansion drawing.

Table 4.2.4.2(2)

	Region			
	Bow		Midbody & Stern	
	$k \le 12$	$k > 12$	$k \le 12$	$k > 12$
a	30	6	8	2
b	230	518	214	286

c_p — factor that reflects the magnitude of the load expected in the hull area in question relative to the bow area, see Table 4.2.4.2(3);

Table 4.2.4.2(3)

Ice class	Region		
	Bow	Midbody	Stern
B1*	1.0	1.0	0.75
B1	1.0	0.85	0.65
B2	1.0	0.70	0.45
B3	1.0	0.50	0.25

c_a — factor which takes account of the probability that the full length of the area under consideration will be under pressure at the same time. It is calculated by the formula:

$c_a = \sqrt{\frac{l_0}{l_a}}$, maximum 1.0, minimum 0.35, l_0 = 0.6 m

where: l_a — see Table 4.2.4.2(4);

Selection of l_a **Table 4.2.4.2(4)**

Structure	Type of framing	l_a (m)
Shell	Transverse	Frame spacing
	Longitudinal	1.7 times frame spacing
Frames	Transverse	Frame spacing
	Longitudinal	Span of longitudinal
Ice stringer		Span of side stringer
Web frame		2 times web frame spacing

P_0 — nominal ice pressure; the value 5.6 MPa is to be used.

4.2.4.3 Shell plating

(1) Vertical extension of ice strengthening for plating (ice belt)

The vertical extension of the ice belt is to comply with Table 4.2.4.3.

Table 4.2.4.3

Ice class	Hull region	Above UIWL	Below LIWL
B1*	Bow	0.60 m	1.20 m

	Midbody		
	Stern		1.00 m
B1	Bow	0.50 m	0.90 m
	Midbody		0.75 m
	Stern		
B2 and B3	Bow	0.40 m	0.70 m
	Midbody		0.60 m
	Stern		

In addition, the following areas are to be strengthened:

Fore foot: For ice class B1*, the shell plating below the ice belt from the stem to a position five main frame spaces abaft the point where the bow profile departs from the keel line is to have at least the thickness required in the ice belt in the midbody region.

Upper bow ice belt: For ice classes B1* and B1 on ships with an open water service speed equal to or exceeding 18 knots, the shell plate from the upper limit of the ice belt to 2 m above it and from the stem to a position at least 0.2 *L* abaft the forward perpendicular, is to have at least the thickness required in the ice belt in the midbody region.

A similar strengthening of the bow region is advisable also for a ship with a lower service speed, when it is, e.g. on the basis of the model tests, evident that the ship will have a high bow wave.

Sidescuttles are not to be situated in the ice belt. If the weather deck in any part of the ship is situated below the upper limit of the ice belt (e.g. in way of the well of a raised quarter decker), the bulwark is to be given at least the same strength as is required for the shell in the ice belt. The strength of the construction of the freeing ports is to meet the same requirements.

(2) Plate thickness in the ice belt

For transverse framing the thickness *t* of the shell plating is not to be less than that obtained from the following formula:

$$t = 667s\sqrt{\frac{f_1 p_{PL}}{R_{eH}}} + t_c \qquad \text{mm}$$

For longitudinal framing the thickness *t* of the shell plating is not to be less than that obtained from the following formula:

$$t = 667s\sqrt{\frac{p}{f_2 R_{eH}}} + t_c \qquad \text{mm}$$

where: p_{PL}= 0.75*p*, *p*—see 4.2.4.2(2) of this Section;

f_1 = $1.3-\left(\frac{h}{s}+1.8\right)^2$, maximum 1.0, where *h* is design ice thickness as given in Table 4.2.4.2(1);

f_2 = $0.6+\frac{0.4s}{h}$, when $\frac{h}{s}\le 1$;

f_2 = $1.4-\frac{0.4h}{s}$, when $1\le\frac{h}{s}\le 1.8$;

s — frame spacing, in m;

t_c— increment for abrasion and corrosion, in mm; normally t_c is to be 2 mm; if a special surface coating, by experience shown capable to withstand the abrasion of ice, is applied and maintained, lower values may be approved.

R_{eH} — yield stress of the material, in N/mm^2. R_{eH} = 235 N/mm^2 for mild steel; R_{eH} = 315 N/mm^2 or higher for higher tensile steel. If steels with different yield stress are used, the actual values may be substituted for the above ones if accepted by CCS.

4.2.4.4 Side framing

(1) Vertical extension of the ice strengthening of the side framing

The vertical extension of the ice strengthening of the side framing is to at least comply with Table 4.2.4.4(1).

Table 4.2.4.4(1)

Ice class	Hull region	Above UIWL	Below LIWL
B1*	Bow	1.2 m	Down to double bottom or below top of the floors
	Midbody		2.0 m
	Stern		1.6 m
B1, B2 and B3	Bow	1.0 m	1.6 m
	Midbody		1.3 m

	Stern		1.0 m

Where an upper bow ice belt is required (see 4.2.4.3(1)), the ice-strengthened part of the framing is to be extended at least to the top of this ice belt.
Where the ice-strengthening would go beyond a deck or the top or bottom plating of a tank or tank top by no more than 250 mm, it can be terminated at that deck or top or bottom plating of the tank or tank top.
(2) Transverse frames
(a) Section modulus and shear area
The section modulus W of a main or intermediate transverse frame is not to be less than that obtained from the following formula:

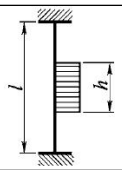
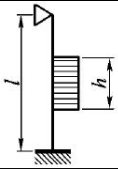
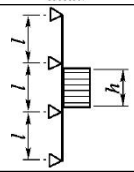
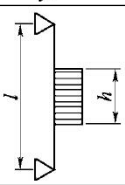
$$W = \frac{pshl}{m_t R_{eH}} \times 10^6 \qquad \text{cm}^3$$

and the effective shear area A is not to be less than that obtained from the following formula:

$$A = \frac{\sqrt{3} f_3 phs}{2R_{eH}} \times 10^4 \qquad \text{cm}^2$$

where: p — see 4.2.4.2(2);
h — see Table 4.2.4.2(1);
s — frame spacing, in m;
l — span of the frame, in m;
m_t = $7\, m_0/(7\text{-}5h/l)$, where m_0 takes the boundary conditions into account. The values are given in Table 4.2.4.4(2);
f_3 — factor which takes into account the maximum shear force versus the load location and the shear stress distribution, $f_3 = 1.2$;
R_{eH} — yield stress of the material, in N/mm^2.

Value m_0 **Table 4.2.4.4(2)**

Boundary condition	m_0	Example
	7	Frames in a bulk carrier with top wing tanks
	6	Frames extending from the tank top to a single deck
	5.7	Continuous frames between several decks or stringers
	5	Frames extending between two decks only

Note: The boundary conditions are those for the main and intermediate frames. Load is to be applied at mid span. Where less than 15% of the span, l, of the frame is situated within the ice-strengthening zone for frames, ordinary frame scantlings may be used.

(b) Requirements for upper end of transverse framing
The upper end of the strengthened part of a main frame and of an intermediate ice frame is to be attached to a deck, top or bottom plating of a tank or an ice stringer.
Where an intermediate frame terminates above a deck or a stringer which is situated at or above the upper limit of the ice belt, the part above the deck or stringer may have the scantlings required in this PART for an non ice-strengthened ship and the upper end of an intermediate frame may be connected to the adjacent frames by a horizontal member having the same scantlings as the main frame.

(c) Requirements for lower end of transverse framing

The lower end of the strengthened part of a main frame and of an intermediate ice frame is to be attached to a deck, top or bottom plating of a tank or an ice stringer.

Where an intermediate frame terminates below a deck, tank top (or tank bottom) or ice stringer which is situated at or below the lower limit of the ice belt, the lower end may be connected to the adjacent main frames by a horizontal member of the same scantlings as the main frames. Note that the main frames below the lower edge of ice belt must be ice strengthened, see 4.2.4.4(1).

(3) Longitudinal frames

The following requirements are intended for longitudinal frames with all end connection:

(a) Frames with brackets

The section modulus W of a longitudinal frame is not to be less than that obtained from the following formula:

$$W=\frac{f_4 phl^2}{mR_{eH}}\times 10^6 \quad \text{cm}^3$$

and effective shear area A of a longitudinal frame is not to be less than that obtained from the following formula:

$$A=\frac{\sqrt{3} f_4 f_5 phl}{2R_{eH}}\times 10^4 \quad \text{cm}^2$$

(In calculation of the actual shear area of the frames, the shear area of the brackets is not to be taken into account.)

where:

p — see 4.2.4.2(2);

l — total span of frame, in m;

m — boundary condition factor; m = 13.3 for a continuous beam with brackets; where the boundary conditions deviate significantly from those of a continuous beam, e.g. in an end field, a smaller boundary factor may be required.

s — spacing of longitudinals, in m;

f_4 — factor which takes account of the load distribution to adjacent frames, $f_4 = (1\text{-}0.2\frac{h}{s})$, where h is design ice thickness as given in Table 4.2.4.2(1);

f_5 — factor which takes into account the maximum shear force versus load location and the shear stress distribution, f_5 = 2.16;

R_{eH} — yield stress of the material, in N/mm^2.

(4) General requirements for side framing

(a) The attachment of frames to supporting structures: within the ice-strengthened area all frames are to be effectively attached to all the supporting structures. A longitudinal frame is to be attached by brackets to all the supporting web frames and bulkheads. When a transversal frame terminates at a stringer or deck, a bracket or similar construction is to be fitted. When a frame is running through the supporting structure, both sides of the web plate of the frame are to be connected to the structure (by direct welding, collar plate or lug). When a bracket is installed, it has to have at least the same thickness as the web plate of the frame and the edge has to be appropriately stiffened against buckling.

(b) Support of frames against instability, in particular tripping:

The frames are to be attached to the shell by double continuous weld. No scalloping is allowed (except when crossing shell plate butts).

The web thickness of the frames is to be at least the maximum of the following:

- $\frac{h_w\sqrt{R_{eH}}}{C}$, h_w is the web height and C = 805 for profiles and C = 282 for flat bars;
- half of the net thickness of the shell plating, $t - t_c$. For the purpose of calculating the minimum web thickness of frames, the required thickness of the shell plating is to be calculated according to 4.2.4.3 using the yield strength R_{eH} of the frames;
- 9 mm.

Where there is a deck, top or bottom plating of a tank, tank top or bulkhead in lieu of a frame, the plate thickness of this is to be calculated as above, to a depth corresponding to the height of the adjacent frames. In such a case, the material properties of the deck, top or bottom plating of the tank, tank top or bulkhead and the frame height h_w of the adjacent frames are to be used in the calculations, and the constant C is to be 805.

Asymmetrical frames and frames which are not at right angles to the shell (web less than 90 degrees to the shell) are to be supported against tripping by brackets, intercostals, stringers or similar at a distance not exceeding 1.3 m. For frames with spans greater than 4 m, the extent of anti-tripping supports is to be applied to all regions and for all ice classes. If the span is less than or equal to 4.0 m, the supports against tripping are required in the following regions:

B1*	All hull regions
B1	Bow and midbody regions
B2 and B3	Bow region.

Direct calculation methods may be applied to demonstrate the equivalent level of support provided by alternative arrangements.

4.2.4.5 Ice stringers

(1) Stringers within the ice belt

The section modulus W of a stringer situated within the ice belt is not to be less than that obtained from the following formula:

$$W = \frac{f_6 f_7 phl^2}{mR_{eH}} \times 10^6 \qquad \text{cm}^3$$

The effective shear area A is not to be less than that obtained from the following formula:

$$A = \frac{\sqrt{3} f_6 f_7 f_8 phl}{2R_{eH}} \times 10^4 \quad \text{cm}^2$$

where: p — see 4.2.4.2(2);

h — see Table 4.2.4.2(1), the product ph is not to be taken as less than 0.15;

m — see 4.2.4.4(3)(a) of this Section;

l — span of the stringer, in m;

f_6 — factor which takes account of the distribution of load to the transverse frames, to be taken as 0.9;

f_7 — safety factor of stringers, to be taken as 1.8;

f_8 — factor that takes into account the maximum shear force versus load location and the shear stress distribution, $f_8 = 1.2$;

R_{eH} — yield stress of the material, in N/mm^2.

(2) Stringers outside the ice belt

The section modulus W of a stringer situated outside the ice belt is not to be less than that obtained from the following formula:

$$W = \frac{f_9 f_{10} phl^2}{mR_{eH}} \left(1 - \frac{h_s}{l_s}\right) \times 10^6 \qquad \text{cm}^3$$

The effective shear area A is not to be less than that obtained from the following formula:

$$A = \frac{\sqrt{3} f_9 f_{10} f_{11} phl}{2R_{eH}} \left(1 - \frac{h_s}{l_s}\right) \times 10^4 \quad \text{cm}^2$$

where: p — see 4.2.4.2(2);

h — see Table 4.2.4.2(1), the product ph is not to be taken as less than 0.15;

m — see 4.2.4.4(3)(a) of this Section;

l — span of the stringer, in m;

h_s — the distance to the ice belt, in m;

l_s — the distance to the adjacent ice stringer, in m;

f_9 — factor which takes account of the distribution of load to the transverse frames, to be taken as 0.80;

f_{10} — safety factor of stringers, to be taken as 1.8;

f_{11} — factor that takes into account the maximum shear force versus load location and the shear stress distribution, $f_{11} = 1.2$;

R_{eH} — yield stress of the material, in N/mm^2.

(3) Deck strips

Deck strips abreast of hatches and serving as ice stringers are to comply with the section modulus and shear area requirements in 4.2.4.5(1) and 4.2.4.5(2) of this Section respectively. In the case of very long hatches CCS may permit the product ph to be taken as less than 0.15 but in no case as less than 0.10.

Regard is to be paid to the deflection of the ship's sides due to ice pressure in way of very long (hatch length more than $B/2$, where B is moulded breadth) hatch openings when designing weather deck hatch covers and their fittings.

4.2.4.6 Web frames

(1) Load

The ice load F transferred to a web frame from an ice stringer or from longitudinal framing is to be calculated by the following formula:

$$F = f_{12} phS \quad \text{MN}$$

where: p — see 4.2.4.2(2), in calculation of c_a however, l_a is to be taken as $2S$;

h — see Table 4.2.4.2(1), the product ph is not to be taken as less than 0.15;

S — distance between web frames, in m;

f_{12} — safety factor of web frames, to be taken as 1.8.

In case the supported stringer is outside the ice belt, the force F is to be multiplied by $1- h_s/l_s$, where h_s and l_s are to be taken as defined in 4.2.4.5(2).

(2) Section modulus and shear area

The effective shear area A is not to be less than that obtained from the following formula:

$$A = \frac{\sqrt{3} f_{13} \alpha Q}{R_{eH}} \times 10^4 \qquad \text{cm}^2$$

where: Q — maximum calculated shear force under the ice load F, as given in 4.2.4.6(1);

f_{13} — factor that takes into account the shear force distribution, $f_{13} = 1.1$;

α — see Table 4.2.4.6(2);

R_{eH} — yield stress of the material, in N/mm^2.

The section modulus W is not to be less than that obtained from the following formula:

$$W = \frac{M}{R_{eH}} \sqrt{\frac{1}{1-(\gamma A / A_a)^2}} \times 10^6 \quad \text{cm}^3$$

where: M — maximum calculated bending moment under the ice load F, this is to be taken as $M = 0.193Fl$, where F is given in 4.2.4.6(1) and l is span of web frames;

γ — see Table 4.2.4.6(2);

A — required shear area calculated in accordance with this paragraph, in cm^2;

A_a — actual cross sectional area of the web frame, $A_a = A_f + A_w$, where are given in Table 4.2.4.6(2)①;

R_{eH} — yield stress of the material, in N/mm^2.

Table 4.2.4.6(2)

$\frac{A_f}{A_w}$	0	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
α	1.50	1.23	1.16	1.11	1.09	1.07	1.06	1.05	1.05	1.04	1.04
γ	0	0.44	0.62	0.71	0.76	0.80	0.83	0.85	0.87	0.88	0.89

Notes: ① A_f is the actual cross section area of free flange and A_w is the actual effective cross section area of web plate.

② If the ratio of A_f/A_w is an intermediate value, a and γ may be obtained by interpolation.

4.2.4.7 Stem

The stem is to be made of rolled, cast or forged steel or of shaped steel plates as shown in Figure 4.2.4.7(1).

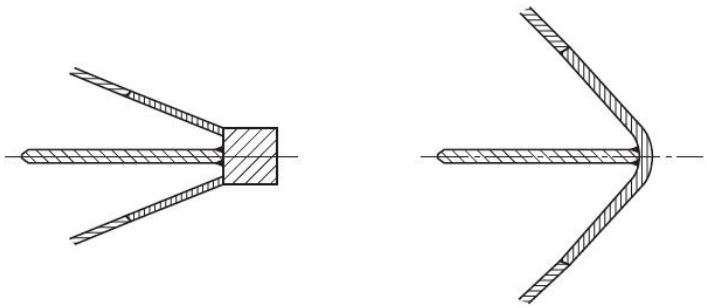


Figure 4.2.4.7(1) Examples of Suitable Stems

The plate thickness of a shaped plate stem and in the case of a blunt bow, any part of the shell where $\alpha \geq 30°$ and $\psi \geq 75°$ is not to be less than the value calculated according to 4.2.4.3 assuming that:

s — spacing of elements supporting the plate, in m;

p_{PL} = p, in MPa, see 4.2.4.3;

l_a — spacing of vertical supporting elements, in m;

α, ψ — see Figure 4.2.4.7(2), where α is the angle of the waterline at $B/4$ in bow region, in °; ψ is flare angle calculated as $\psi = \arctan\left(\frac{\tan\varphi}{\sin\alpha}\right)$ where φ is the rake of the bow at each location, in °; φ_1 is the rake of the stem at the centerline and φ_2 is the rake of the bow at $B/4$.

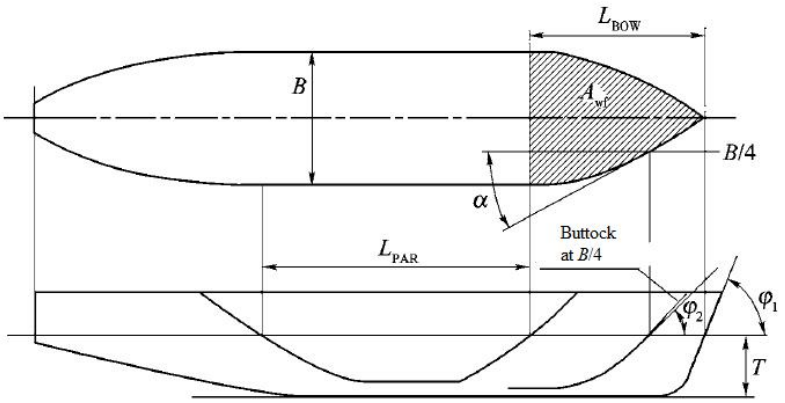


Figure 4.2.4.7(2)

The stem and the part of a blunt bow defined above are to be supported by floors or brackets spaced not more than 0.6 m apart and having a thickness of at least half the plate thickness. The reinforcement of the stem is to extend from the keel to a point 0.75 m above UIWL or, in case an upper bow ice belt is required (4.2.4.3(1)), to the upper limit of this.

4.2.4.8 Stern

The introduction of new propulsion arrangements with azimuthing thrusters, which provide improved manoeuvrability, will result in increased ice loading of the stern region and the stern area. This fact is to be considered in the design of the aft/stern structure.

In order to avoid very high loads on propeller blade tips, the minimum distance between propeller(s) and hull (including stern frame) is at least to satisfy the requirements of 2.14.4.1 of Section 14, Chapter 2 of this PART.

On twin and triple screw ships the ice strengthening of the shell and framing is to be extended to the tank top for 1.5 m forward and aft of the side propellers.

Shafting and stern tubes of side propellers are normally to be enclosed within plated bossings. If detached struts are used, due consideration is to be taken of their design, strength and attachments to the hull.

4.2.5 Rudders and steering arrangements

The scantlings of rudder post, rudder stock, pintles, steering engine as well as the capability of the steering engine are to satisfy the provisions of the relevant Chapters of the Rules. The maximum service speed of the ship to be used in the calculation is not to be less than that given in Table 4.2.5. If the actual maximum service speed of the ship is higher than that given in Table 4.2.5, the actual speed is to be used in the calculation.

Table 4.2.5

Ice Class	Speed (kn)	Ice Class	Speed (kn)
B1*	20	B2	16
B1	18	B3	14

The local scantlings of rudders are to be determined assuming that the whole rudder belongs to the ice belt. Further, the rudder plating and frames are to be designed using the ice pressure p for the plating and frames in the midbody region.

For ice classes B1* and B1, the rudder (rudder stock and the upper part of the rudder) are to be protected from direct contact with intact ice by an ice knife that extends below the LIWL, if practicable (or equivalent means). Special consideration is to be given to the design of the rudder and the ice knife for ships with flap-type rudders.

For ice classes B1* and B1, due regard is to be paid to the large loads that arise when the rudder is forced out of the midship position while going astern in ice or into ice ridges. Suitable arrangement such as rudder stoppers is to be installed to absorb these loads.

Relief valves for hydraulic pressure in rudder turning mechanism(s) are to be installed. The components of the steering gear (e.g. rudder stock, rudder coupling, rudder horn etc.) are to be dimensioned to withstand loads causing yield stresses in the rudder stock.

Section 3 ICE STRENGTHENING FOR CLASS B

4.3.1 Shell plating

4.3.1.1 The longitudinal extent of strengthening of the shell plating within the ice belt is to be from the stem to the greatest breadth of the ship at the full-load waterline but need not exceed 0.2*L*, and the vertical extent is to be from 500 mm above the draught on the fresh water load line in summer to 500 mm below the minimum draught fore. The strengthened area is to be indicated on the plan of shell expansion.

4.3.1.2 The changes in thickness of the shell plating within the ice belt are to be made gradually, and the thickness *t* is not to be less than the value obtained from the following formula:

$$t = 1.25t_0\sqrt{K}$$, but need not be greater than 25 mm

where: t_0— the Rule thickness of amidships shell plating according to Section 3, Chapter 2 of this PART (assumed as ordinary steel), in mm. In calculation, *s* is to be taken as the spacing of longitudinals/frames, (for the actual type of framing in bow region), but the intermediate longitudinals/frames not included;

K— material factor.

4.3.1.3 For ships of ice strengthening for class B, a warning triangle may be provided in accordance with the requirements of 4.2.1.4 as necessary.

4.3.2 Frames and longitudinals

4.3.2.1 If intermediate frames are fitted in the fore peak or within the region from the stem to 0.075*L* (where the latter has a larger scope than the former), the section modulus of the intermediate frames is to be not less than 75% of that of the region where they are fitted. The vertical extent of the intermediate frames is to be from 1,000 mm below the ballast waterline to 1,000 mm above the summer fresh water load line, and the frames need not be connected at their ends.

If intermediate frames are not fitted, the frame spacing is not to exceed 60% of the spacing of the amidships frames, but in no case is to be greater than 0.5 m.

4.3.2.2 For a distance along the line of extension of the stringers, panting beams or perforated platforms in the fore peak tank, starting from their respective connections with side shell and leading aft to the greatest breadth of the ship at the full-load waterline (but not necessarily over 0.2*L*), tripping brackets are to be fitted at each frame.

4.3.2.3 If longitudinal framing is fitted within the region from the stem to 0.075*L* (where the latter has a larger scope than the former) of the ship, the arrangement and scantling of longitudinals within the region are to comply with the following requirements:

(1) Continuous intermediate longitudinals are to be fitted within the region, and the vertical extent is to be the same as that of intermediate frames as specified in 4.3.2.1 of this Section.

(2) The distance between intermediate longitudinals and longitudinals within the region is not to be greater than 0.5 m.

(3) The section modulus of longitudinals and intermediate longitudinals within the region is to comply with applicable requirements of 2.7.5 of Section 7, Chapter 2 of this PART, but the spacing of longitudinals *s* is to be taken as 1.5 times the distance between intermediate longitudinals and adjacent longitudinals in calculation.

Where it is difficult to fit intermediate longitudinals and such longitudinals will be spaced not more than 700 mm apart, they may be dispensed with, provided that the plate thickness *t* within the region complies with the following formula:

$$t = 1.58t_0\sqrt{K}$$, but need not be greater than 25 mm

where: t_0 — the Rule thickness of amidships shell plating according to Section 3, Chapter 2 of this PART(assumed as ordinary steel), in mm. In calculation, *s* is to be taken as the spacing of longitudinals;

K— material factor.

4.3.2.4 Tripping brackets or similar supports against tripping are to be fitted in way of an inclined frame fitted to the ice shell plating in the fore peak or within the region from the stem to 0.075*L* (where the latter has a larger scope than the former) in accordance with 4.2.4.4(4)(b).

4.3.3 Stem

4.3.3.1 The plate thickness of a welded plate stem for 600 mm above the summer fresh water load line is to be 1.1 times the Rule thickness, but need not exceed 25 mm. The thickness of the remainder of the stem may be gradually tapered to that of the shell end at the upper deck.

CHAPTER 5 DOUBLE HULL OIL TANKERS

Section 1 GENERAL PROVISIONS

5.1.1 Application

5.1.1.1 This Chapter applies to the structures of cargo tanks and adjacent pump rooms, ballast tanks and cofferdams (excluding bulkheads not adjacent to cargo tanks) of double hull oil tankers having double bottoms and with machinery spaces being situated aft, intended to carry crude oil and petroleum products having a flash point not exceeding 60℃ (closed cup test) and a Reid vapour pressure which is below the atmospheric pressure. If not covered in this Chapter, the relevant requirements of Chapters 2 and 6 of this PART are to be complied with.

5.1.1.2 The double hull oil tankers intended to carry oils having a flash point exceeding 60℃ (closed cup test) only are also to comply with the requirements of this Chapter. Where the temperature of heated cargo oils is at least 10℃ below their flash point, the requirements of 5.1.4.4 to 5.1.4.8 and 5.4.1.3 of this Chapter may not be applicable. The scantlings and arrangements of tankers intended for cargoes other than the above oil will be specially considered in relation to the characteristics and density of the cargo. For oil tankers intended for the carriage of liquids with a density greater than 1.025 t/m^3, the structural strength of the cargo tank region is to be specially considered.

5.1.1.3 CSR oil tankers are to comply with the relevant requirements of PART NINE of the Rules.

5.1.2 Class notations

5.1.2.1 For oil tankers complying with the requirements of this Chapter, the notation of Oil Tanker, Double Hull, F.P. ≤ 60℃ or Oil Tanker, Double Hull, F.P. > 60℃ may be assigned.

5.1.2.2 For oil tankers complying with the requirements of PART NINE of the Rules, a notation of Oil Tanker, Double Hull, CSR is to be assigned.

5.1.3 Plans and documents

5.1.3.1 The following plans and documents are to be submitted for approval in addition to those required in Section 1 of Chapter 2 of this PART:

(1) Connections of longitudinals with other members;

(2) Details at intersections of transverse and longitudinal framing;

(3) Closing arrangements for all deck openings;

(4) Any dry cargo tanks or tanks for water ballast only, which are empty in the fully loaded condition, are to be indicated on the principal structural and arrangement plans;

(5) The location of all openings in the deck is to be indicated on the structural plan of deck.

5.1.4 Limitations of size and arrangement of cargo tanks

5.1.4.1 The wing cargo tank mentioned here refers to a cargo tank, with inner hull forming one of its boundaries, of an oil tanker with oil-tight longitudinal bulkheads. Other cargo tanks are referred to as centre tanks.

5.1.4.2 With regard to subdivision, size of cargo tanks, distance from side shell to inner hull and depth of double bottom, the requirements of Section 12, Chapter 1 of this PART are to be complied with. For oil tankers with *DW* less than 5,000 tons and the capacity of each cargo oil tank not exceeding 700 m^3, if arranged as double hull, the spacing *W* of double hull is not to be less than:

$$W = 0.4 + 2.4\,DW/20000 \quad \text{m}$$

The minimum value of $W = 0.76$ m

where: *DW* means the deadweight, in t.

5.1.4.3 Segregated ballast tanks, dedicated clean ballast tanks and slop tanks are to be arranged in compliance with the requirements of Section 12, Chapter 1 of this PART.

5.1.4.4 Cofferdams① are to be provided at the forward and aft ends of the cargo tanks region so as to separate oil tanks from engine rooms, boiler rooms, dry cargo holds and accommodation spaces. Cofferdams are to have an adequate spacing between their end bulkheads to permit easy access and cover the whole area of the end bulkheads of the cargo tank region. The spacing between the bulkheads is in general not to be less than 760 mm. For small oil tankers, where it is difficult to arrange cofferdams,

① The Suez Canal Authority requires that only pump rooms, or tanks which can be filled with water or liquids having a flash point greater than 66℃ (closed cup test) may be accepted as cofferdams.

smaller spacing may be accepted, but it is not to be less than 600 mm. Where a corner-to-corner situation occurs, protection may be formed by a diagonal plate across the corner. A pump room, water ballast tank or oil fuel tank may be accepted in lieu of a cofferdam.

5.1.4.5 Any access to spaces adjacent to a cargo tank is to be from the open deck. Passages or tunnels passing through or adjacent to a cargo tank and not separated from it by a cofferdam, are to be provided with mechanical ventilation, and any access is also to be from the open deck.

5.1.4.6 Where the lower portion of the pump room is recessed into the machinery space, the height of the recess is not, in general, to exceed 1/3 of the moulded depth above the baseline except that in the case of ships of not more than 25,000 metric tons deadweight, CCS may permit a recess in excess of such height, but not exceeding one half of the moulded depth of the ship.

5.1.4.7 The wheelhouse, where fitted above the cargo tank region, is to be separated from the cargo tank deck by means of an open space with a height of at least 2 m.

5.1.4.8 Means are to be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by provision of a permanent continuous coaming of not less than 300 mm in height extending from side to side. Special consideration is to be given to the arrangements associated with stern loading and unloading for the prevention of deck spill from flowing over board.

5.1.5 Structural details

5.1.5.1 For oil tankers of over 65 m in length, the deck, bottom and inner bottom within the cargo tank region of tankers are to be longitudinally framed. Where the length of ship exceeds 190 m, the side shell, inner hull and longitudinal bulkheads are generally to be longitudinally framed. The hull structures beyond the cargo tank region may be framed either transversely or longitudinally. Constructional arrangements are to be made to ensure a gradual transition from the longitudinal framing to the transverse framing.

5.1.5.2 The typical midship section of double hull oil tankers and the structural members referred to in this Chapter are as shown in Figure 5.1.5.2.

5.1.5.3 Cargo tanks are enclosed by double bottom, wing ballast tank, empty cofferdams and deck. The loading of cargo and fuel oils is not permitted in the double bottoms and wing ballast tanks.

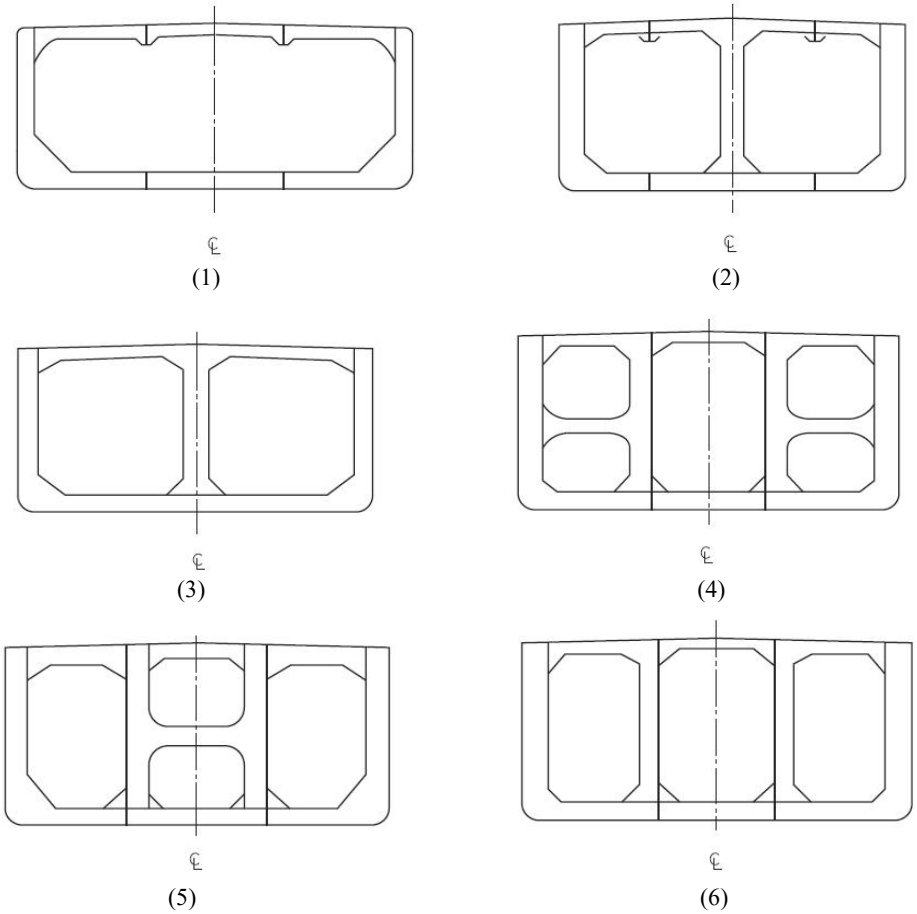
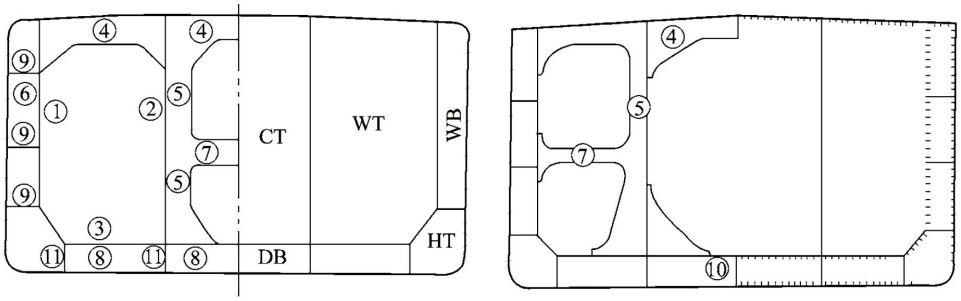
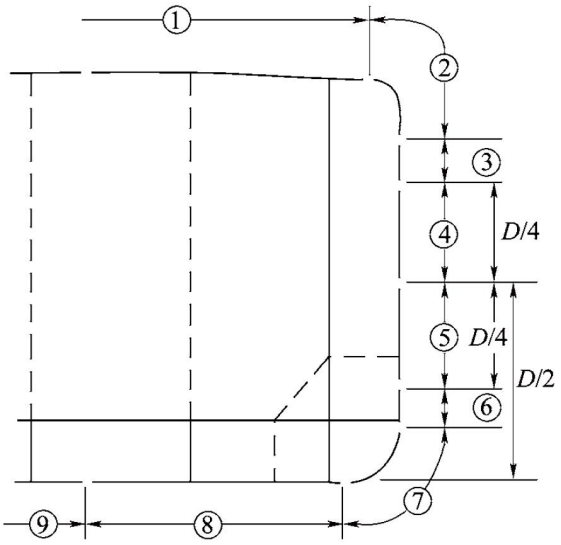


Figure 5.1.5.2(1) Typical Midship Section



1— Inner hull; 2 — Longitudinal bulkhead; 3 — Inner bottom; 4 — Deck transverse; 5 — Vertical web on longitudinal bulkhead; 6 — Vertical web in wing ballast tank; 7 — Cross ties; 8 — Floor; 9 — Horizontal girder in wing ballast tank; 10 — Double bottom girder; 11 —Double bottom side girder; WB — Wing ballast tank; WT — Wing cargo tank; CT — Centre cargo tank; HT — Hopper tank; DB — Double bottom



1— Deck plating; 2 — Deck stringer and sheer strake; 3 — Side shell plating 1; 4 — Side shell plating 2; 5 — Side shell plating 3; 6 — Side shell plating 4; 7 — Bilge plating; 8 — Bottom shell plating; 9 — Plate keel

Figure 5.1.5.2(2) Typical Midship Section and Structural Members

5.1.6 Minimum thickness

5.1.6.1 Within the cargo tank region (including wing ballast tanks, empty cofferdams at the ends of the cargo tank region or between cargo tanks), the minimum thickness t of primary member webs and face plates, shell plating, deck plating, bulkhead plating and inner hull plating is not to be less than that obtained from the following formula:

$$t = 6.5 + L/50 \quad \text{mm, but not less than 7.5 mm}$$

where: L — length of ship, in m, taken not greater than 300 m.

The minimum thickness of secondary structural members are also to comply with the requirements mentioned above, but need not be greater than 11 mm.

5.1.6.2 The minimum thickness t of the members in pump rooms, cofferdams and other void spaces may be 1 mm less than that required in 5.1.6.1, but not less than 7.5 mm.

5.1.7 Longitudinal strength of double hull oil tankers

5.1.7.1 Double hull oil tankers are to comply with the longitudinal strength requirements specified in Section 2, Chapter 2 of this PART.

5.1.8 Direct calculations and fatigue assessment of hull structural strength

5.1.8.1 For oil tankers of 150 m or over in length, direct strength calculations are to be carried out for the primary members (longitudinal or transverse) in the cargo tank region according to the Appendix 1 of this Chapter.

5.1.8.2 For oil tankers of 150 m or over in length, the fatigue strength check is to be carried out for the following structural members in the cargo tank region in accordance with CCS Guidelines for Fatigue

Strength of Ship Structure:
(1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;
(2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;
(3) connections of hopper tanks or inner shell to inner bottoms.

Section 2 SHELL PLATING

5.2.1 General requirements

5.2.1.1 The formulae of this Section are applicable to the determination of thickness of longitudinally framed bottom shell plating, plate keels, bilge plating, side shell plating and shear strakes.

5.2.2 Bottom shell plating

5.2.2.1 The thickness t of bottom shell plating within 0.4L amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.052s(L_1 + 170)\sqrt{\frac{F_b}{K}} \text{ mm}$$

$$t_2 = 4.9s\sqrt{(h_w + 0.8d)K} \text{ mm}$$

where: s — spacing of longitudinals, in m, to be taken as not less than standard spacing of longitudinals;
d — draught, in m;
L_1 — length of ship, in m, to be taken as not more than 190 m;
F_b — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART;
K — material factor;

$$h_w = 0.2B^{0.66} + \left(0.25 + \frac{0.82}{\sqrt{L}}\right)C$$

where: B — breadth of ship, in m;
L — length of ship, in m;
C — see 2.2.3.1 of Section 2, Chapter 2 of this PART.

5.2.3 Plate keels

5.2.3.1 The breadth b of the plate keel within the cargo tank region is not to be less than that obtained from the following formula:

$$b = 900 + 3.5L \quad \text{mm}$$

And the thickness t is not to be less than:

$$t = t_0 + 2.0 \quad \text{mm} \quad L \le 190 \text{ mm}$$
$$t = t_0 + 3.0 \quad \text{mm} \quad L > 190 \text{ mm}$$

where: L — length of ship, in m;
t_0 — the thickness of the bottom shell plating, in mm, as determined in 5.2.2.1 of this Section.

5.2.4 Bilge plating

5.2.4.1 The thickness t of bilge plating within 0.4L amidships is to be the same as that of bottom shell plating.

5.2.4.2 Where longitudinal bottom and side framing is adopted and no longitudinals are fitted at bilge, the thickness of bilge plating is not to be less than $\frac{rF_b}{165K}$ (r being the radius of the bilge, in mm, K being material factor, and F_b being reduction factor of bottom). The framing associated with such an arrangement is to comply with the requirements of 5.4.4.1 of Section 4 of this Chapter.

5.2.5 Side shell plating

5.2.5.1 Where longitudinal side framing is adopted, the thickness t of side shell plating within 0.4L amidships is to comply with the following requirements:

(1) The thickness t of side shell plating above $\frac{3}{4}D$ from the baseline is not to be less than that obtained from the following formulae:

$$t_1 = 0.058s(L + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 7.1s\sqrt{h_w K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, not to be less than standard spacing of longitudinals;
L — length of ship, in m, to be taken as not greater than 190 m;
F_d — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART;
K — material factor;
h_w — see 5.2.2.1 of this Section.

(2) The thickness t of side shell plating below $\frac{1}{4}D$ from the baseline is not to be less than that obtained from the following formulae:

$$t_1 = 0.06s(L+110)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 5.2s\sqrt{(h_w + 0.8d - 0.2D)K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, not to be less than standard spacing of longitudinals;
d — draught, in m;
F_b — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART;
K — material factor;
L — length of ship, in m, to be taken not more than 190 m;
h_w — see 5.2.2.1 of this Section.

(3) The thickness t of side shell plating above $\frac{3}{4}D$ and below $\frac{1}{4}D$ from the baseline is not to be less than that obtained from the following formulae:

$$t_1 = \text{s}\,[t_{11} + (t_{12} - t_{11})h] \quad \text{mm}$$
$$t_2 = \text{s}\,[t_{21} + (t_{22} - t_{21})h] \quad \text{mm}$$

where: $t_{11} = \dfrac{t_{1,z=0.25D}}{s_{z=0.25D}}$

$t_{12} = \dfrac{t_{1,z=0.75D}}{s_{z=0.75D}}$

$t_{21} = \dfrac{t_{2,z=0.25D}}{s_{z=0.25D}}$

$t_{22} = \dfrac{t_{2,z=0.75D}}{s_{z=0.75D}}$

$h = \dfrac{z - 0.25D}{0.5D}$

$s_{z=0.25D}$ — spacing of longitudinals, in m, at $0.25D$, not to be less than the standard spacing of longitudinals;
$s_{z=0.75D}$ — spacing of longitudinals, in m, at $0.75D$, not to be less than the standard spacing of longitudinals;
$t_{1,z=0.25D}$ — thickness t_1 of plating, in mm, at $0.25D$;
$t_{1,z=0.75D}$ — thickness t_1 of plating, in mm, at $0.75D$;
$t_{2,z=0.25D}$ — thickness t_2 of plating, in mm, at $0.25D$;
$t_{2,z=0.75D}$ — thickness t_2 of plating, in mm, at $0.75D$;
s — spacing of longitudinals at the point under consideration, in m, not to be less than the standard spacing of longitudinals;
D — moulded depth, in m;
z — distance between the point under consideration and baseline.

(4) In calculation of t_1, except the minimum range of high tensile steel stipulated in Section 2 of Chapter 2, the material factor K may be taken as 1.

5.2.6 Sheer strakes

5.2.6.1 The breadth of the sheer strakes is to meet the requirements of 2.3.5.1 of Section 3, Chapter 2 of this PART.

5.2.6.2 The thickness t of sheer strakes within $0.4L$ amidships is not to be less than that obtained from the following formulae, also not to be less than that of the adjacent side shell plating:

$$t_1 = 0.06s(L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s\sqrt{(L+75)K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, to be taken not less than standard spacing of longitudinals;
L — length of ship, in m;
L_1 = L, L being the length of ship, in m, to be taken not more than 190 m in calculation;
K — material factor;
F_d — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART.

5.2.7 End shell plating

5.2.7.1 The thickness of shell plating at ends is to be in accordance with the relevant requirements of Section 3, Chapter 2 of this PART.

Section 3 DECKS

5.3.1 General requirements

5.3.1.1 The formulae of this Section are applicable to the determination of thickness of strength deck plating within 0.4L amidships.

5.3.2 Strength deck plating

5.3.2.1 The thickness t of strength deck plating within 0.4L amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.06s(L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s\sqrt{(L+75)K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, to be taken not less than standard spacing of longitudinals;
L — length of ship, in m;
L_1 = L, L being the length of ship, in m, to be taken not more than 190 m in calculation;
K — material factor;
F_d — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART.

5.3.2.2 The thickness of strength deck plating at ends is to comply with the relevant requirements of Section 4 of Chapter 2 of this PART.

5.3.3 Connections of deck stringers to sheer strakes

5.3.3.1 The connections of deck stringers to sheer strakes are to comply with the relevant requirements of Section 3 of Chapter 2 of this PART.

Section 4 DOUBLE BOTTOM STRUCTURE

5.4.1 General requirements

5.4.1.1 The scantlings and arrangement of the double bottoms in cargo tanks are to be as required in Section 6, Chapter 2 of this PART, except as otherwise specified in this Section.

5.4.1.2 The integrity of the double bottom is to be maintained. Manholes are not to be fitted on the inner bottom of cargo tanks and the access is not to be via the engine room. Access to double bottom tanks is to be provided by trunks from the exposed deck.

5.4.1.3 Arrangements are to be provided to enable double bottom tanks situated below cargo tanks to be filled with water ballast to eliminate flammable gases which possibly exist in these tanks.

5.4.1.4 Where a duct keel or pipe tunnel is fitted, the duct keel or pipe tunnel is not to be interconnected with the engine room. At least two accesses to open deck are to be provided at a maximum distance from each other. Where one of such accesses passes through a pump room, the access from the pump room to the duct keel or pipe tunnel is to be provided with a watertight cover.

5.4.1.5 Manholes are to be fitted in floors and side girders in compliance with the requirements in 2.6.1 of Section 6, Chapter 2 of this PART as well as those in Section 12, Chapter 1 of this PART.

5.4.1.6 Drain holes and vent holes are to be fitted in floors, side girders, bottom longitudinals and

inner-bottom longitudinals in compliance with the requirements in 2.6.1 of Section 6, Chapter 2 of this PART.

5.4.2 Bottom girders

5.4.2.1 The centre girders or duct keels are to be arranged at the longitudinal centerline of double bottoms. Side girders are also to be provided at sides.

5.4.2.2 Girders are to be provided below lower stools of the longitudinal or longitudinal corrugated bulkhead, whereas side girders are to be provided below hopper tank slope plating.

5.4.2.3 In way of vertically corrugated transverse bulkheads supported by stools, additional local girders are to be arranged in accordance with the requirements in 5.9.3.2 of Section 9 of this Chapter.

5.4.2.4 The thickness of centre keels is not to be less than that obtained from the following formula, and is also to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART:

$$t = (0.008\,h_0 + 1.0)\sqrt{K} \quad \text{mm}$$

where: h_0 — considered height of centre keels, in mm, see 2.6.2.1 of Section 6, Chapter 2 of this PART;

K — material factor.

5.4.2.5 The thickness of side plating of duck keels is not to be less than that obtained from the following formula, and is also to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART:

$$t = 0.008\,h_0\sqrt{K} \quad \text{mm}$$

where: h_0, K— the same as that in 5.4.2.4 of this Section.

5.4.2.6 The thickness of side girders is not to be less than that obtained from the following formula, and is to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART where side girders are watertight:

$$t = (0.007h_0 + 1.0)\sqrt{K} \quad \text{mm, but need not be greater than 14 mm}$$

where: h_0, K — the same as that in 5.4.2.4 of this Section.

5.4.2.7 For ships whose breadth is greater than 12 m, but not greater than 20 m, at least one side girder is to be provided at each side of the longitudinal centerline (including side girders in way of hopper tanks). For ships whose breadth is greater than 20 m, two side girders may be provided at each side of the longitudinal centerline (including side girders in way of hopper tanks and below longitudinal bulkheads). The number of side girders to be provided may also be determined by direct calculation.

5.4.2.8 Horizontal stiffeners are to be provided at centre girders, duck keels and side girders, of which the section moment of inertia is to comply with the requirements in 5.12.2.5 of this Chapter.

5.4.2.9 Brackets extending to adjacent longitudinals are to be provided at every other frame space at both sides of centre girders between solid floors. The thickness of brackets is to be the same as that of solid floors.

5.4.2.10 The inner framing of duct keels is to comply with the following requirements:

(1) Transverse bottom frames and inner bottom frames are to be provided in way of every other frame space in duct keels, and the section modulus W is not to be less than that obtained from the following formula:

$$W = 22sdl^2K \quad \text{cm}^3$$

where: s — spacing of frames, in m;

d — draft, in m;

l — span, in m, taken as spacing between both side plates of duct keels;

K — material factor.

(2) Both ends of transverse bottom frames and inner bottom frames are to be gradually enlarged and to be connected to side plating of duct keels, with the enlarged height being not be less than 1.5 times that of the frames. Brackets having a plate thickness equal to that of solid floors are to be provided at the corresponding position of outer side of the side plating and to be connected to the bottom and inner bottom longitudinals.

(3) Inner bottom longitudinals and bottom longitudinals are to be fitted within the duct keel on the centreline of the ship, which may be intercostal in way of transverse framing members.

5.4.2.11 For oil tankers of 90 m in length and upwards, the scantlings of centre keels, duct keels and side girders are to be checked by means of direct calculation, which is to comply with the requirements of Appendix 1 of this Chapter. Where the ship length is less than 150 m, other approved equivalent direct calculation methods may be used.

5.4.3 Bottom floors

5.4.3.1 Solid floors are to be provided below lower stools of transverse bulkheads and corrugated

transverse bulkheads.

5.4.3.2 The spacing of solid floors is, in general, to be not greater than $0.006L + 3.2$ in m, L being length of ship.

5.4.3.3 The thickness t of solid floors is not to be less than that obtained from the following formula:

$$t = (0.007h_0 + 1.0)\sqrt{K} \quad \text{mm, but need not be greater than 14 mm}$$

where: h_0, K — the same as that in 5.4.2.4 of this Section.

Watertight solid floors are also to comply with the requirements for deep tanks.

5.4.3.4 For oil tankers of 90 m in length and upwards, the thickness of floors is to be checked by means of direct calculation, which is to comply with the requirements of Appendix 1 of this Chapter. Where the ship length is less than 150 m, other approved equivalent direct calculation methods may be used. Attention is to be given to alignment of the floors when cut apart in way of girders so as to ensure the transverse continuity.

5.4.3.5 Vertical stiffeners are to be provided between bottom longitudinals and inner bottom longitudinals in way of solid floors.

5.4.4 Bilge brackets

5.4.4.1 Where longitudinal bottom and side framing is adopted and no longitudinals are fitted at bilge, an appropriate number of centre bilge brackets are to be provided at bilge between solid floors and connected to longitudinals at upper and lower turns of bilge. The spacing S between bilge brackets and solid floors or between bilge brackets is not to be greater than that obtained from the following formula:

$$S = 8 \times 10^6 \frac{t^2}{Dr}\sqrt{\frac{t}{r}} \quad \text{mm}$$

where: t — thickness of bilge strake, in mm;
D — moulded depth, in m;
r — radius of bilge, in mm.

The thickness of bilge brackets is to be the same as that of solid floors.

5.4.5 Bottom longitudinals

5.4.5.1 The maximum spacing of bottom longitudinals is not to be greater than 1 m.

5.4.5.2 The section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 11.5sdl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
d — draft, in m;
l — span of longitudinal, in m;
K — material factor.

5.4.5.3 Where penetrating non–watertight floors, the longitudinals are to be welded to the floors and vertical stiffeners on the floors.

Where a longitudinal is cut at watertight floors, the longitudinal is to be bracketed to the watertight floors. The size of the brackets is to comply with the requirements in 1.2.6 of this PART. For ships over 190 m in length or where higher tensile steel is adopted for longitudinals, the bottom longitudinals are to penetrate watertight floors, but an appropriate equivalent structure may be adopted as an alternative.

5.4.6 Inner bottom plating and inner bottom longitudinals

5.4.6.1 The thickness t of inner bottom plating is not to be less than that obtained from the following formula:

$$t_1 = \frac{s}{70\sqrt{K}} \times 10^3 \quad \text{mm}$$

where: s — spacing of inner bottom longitudinals, in m;
K — material factor. For higher strength steels, if the material factor of lower strength level could meet the requirements of buckling check for direct strength calculation, the value K of lower strength level may be taken;

$$t_2 = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: K — material factor;
h — vertical distance between inner bottom plating in way of longitudinal centerline and top of the tank, in m.

5.4.6.2 Inner bottom longitudinals and the corresponding bottom longitudinals are to be in the same

vertical section.

5.4.6.3 The section modulus W of inner bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 8.4s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: s, h — see 5.4.6.1 of this Section;
l — span of longitudinals, in m;
K — material factor.

5.4.7 Sloping plating and slope plating longitudinals of hopper tanks

5.4.7.1 The thickness of sloping plating of hopper tanks is not to be less than those obtained from the following formula, and is not to be less than that of the adjacent inner hull plating:

$$t_1 = \frac{s}{70\sqrt{K}} \times 10^3 \quad \text{mm}$$

where: s — spacing of sloping plating longitudinals, in m;
K — material factor. For higher strength steels, if the material factor of lower strength level could meet the requirements of buckling check for direct strength calculation, the value K of lower strength level may be taken;

$$t_2 = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: K — material factor;
h — vertical height, in m, measured from lower edge of strake to the tank top in way of longitudinal centerline.

5.4.7.2 The section modulus of slope plating longitudinals is not to be less than that obtained from the following formula, and not to be less than that of the adjacent inner hull plating longitudinals:

$$W = 8.4s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: s — spacing of sloping plating longitudinals, in m;
h — vertical height, in m, measured from sloping plating longitudinals to the tank top in way of longitudinal centerline;
K — material factor.

Section 5 DOUBLE HULL CONSTRUCTION

5.5.1 General requirements

5.5.1.1 This Section applies to the determination of arrangement and scantlings of frames in double hull within the cargo tank region of double hull oil tankers.

5.5.1.2 Manholes are to be provided in transverse bulkheads and horizontal girders. The manholes may either be round or elliptical. The long axis of elliptical manholes is to be vertical to or along the length of the ship. Except for access openings, the holes on upper and lower adjacent horizontal girders are in general not to be on the same vertical line. The edge around the holes is to be strengthened.

5.5.1.3 For double hull oil tankers with the wing tanks as the ballast tanks, the inner hull structures are to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART.

5.5.2 Structural arrangement of double hull

5.5.2.1 Longitudinal continuous horizontal girders within double hull structures are to be provided at the same height as the transverse bulkhead horizontal girders of cargo tanks. A horizontal girder is to be provided at the top of the hopper tank (manhole may not be provided on the longitudinal girder for the sake of stability). The horizontal girders in wing ballast tanks, on cargo tank transverse bulkheads and on longitudinal bulkheads are to form a horizontal ring structure.

5.5.2.2 Transverse frames or transverse webs are to be provided in wing ballast tanks in line with the transverse bulkheads of cargo tanks.

5.5.2.3 Transverse frames or transverse webs are to be spaced not more than $0.006L + 3.2$ m apart and fitted in wing ballast tanks in line with double bottom transverses. Transverse frames or vertical webs, together with deck transverses of cargo tanks, vertical webs of longitudinal bulkheads, cross ties between inner hull and longitudinal bulkheads or between longitudinal bulkheads (if provided, see Figure 5.1.5.2(2)) of Section 1 of this Chapter) and double bottom transverses, are to form a transverse ring structure.

5.5.3 Side longitudinals

5.5.3.1 The section modulus W of side longitudinals is not to be less than that obtained from the

following formula:

$$W = 7.2s\,(h+1.2)\,l^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
h — vertical distance, in m, measured from longitudinals under consideration to deck at side amidships, but to be taken as not less than $0.25D$;
l — span of longitudinal, in m;
D — moulded depth, in m;
K — material factor.

5.5.3.2 For ships over 150 m in length or where higher tensile steel is adopted for longitudinals, the side longitudinals within $0.1D$ from bottom and strength deck are to penetrate continuously watertight transverse bulkheads.

Where side longitudinals are cut at watertight transverse bulkheads, they are to be bracketed to transverse bulkheads. The brackets are to have face plates and their arm length is to be increased by 20% over that required in 1.2.6 of Chapter 1 of this PART. Where the face plate is flanged, the breadth of the flange is not to be less than 8 times its thickness.

5.5.4 Side frames

5.5.4.1 The section modulus W of side frames is not to be less than that obtained from the following formula:

$$W=7.2s\,(h+1.2)\,l^2K \quad \text{cm}^3$$

where: s — spacing of frames, in m;
h — vertical distance, in m, measured from frames under consideration to deck at side amidships, but to be taken as not less than $0.25D$;
l — span of frame, in m, but not to be less than 2.5 m;
D — moulded depth, in m;
K — material factor.

5.5.4.2 Brackets are to be provided at both ends of side frame. The scantlings of bracket are to comply with the requirements of 1.2.6 of this PART.

5.5.5 Inner hull plating and its stiffeners

5.5.5.1 The inner hull plating is to extend as deep as possible at side or from top of the double bottom to the uppermost deck. The inner hull plating is to be so arranged that all cargo tanks are at the inner side of wing ballast tanks, and the inner shell is to extend as far forward and aft as practicable and effectively connected to the structures in way with adequate transition arrangements.

5.5.5.2 The thickness of inner hull plating is not to be less than that obtained from the following formula:

$$t = 3.75s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;
h — vertical distance, in m, measured from lower edge of strake to the tank top in way of longitudinal centerline, but not less than $0.4D$;
K — material factor;
D — moulded depth, in m.

5.5.5.3 The spacing of inner hull longitudinals is to be the same as that of side longitudinals. The section modulus W of longitudinals is to comply with the requirements of 5.8.4.4, Section 8 of this Chapter.

5.5.5.4 For ships over 150 m in length or where higher tensile steel is adopted for longitudinals, the inner hull longitudinals within $0.1D$ from bottom and deck are to penetrate continuously webs. Where longitudinals are cut at such webs, they are to be bracketed to the webs. The scantlings of the brackets are to comply with the requirements of 5.5.3.2 of this Section.

5.5.5.5 The section modulus W of vertical stiffeners of inner hull plating is to meet the requirements of 5.8.3.3 of Section 8 of this Chapter.

5.5.5.6 Brackets are to be provided at both ends of vertical stiffeners. The scantlings of brackets are to be comply with the requirements of 1.2.6 of this PART.

5.5.6 Horizontal girders

5.5.6.1 The thickness t of non-watertight horizontal girders within double hull structures that are provided at the same height as the transverse bulkhead horizontal girders of cargo tanks is to comply with the requirements of 5.1.6, Section 1 of this Chapter.

5.5.6.2 The scantlings of longitudinals of horizontal girders are to comply with the requirements of 5.12.2.5 of this Chapter.

5.5.6.3 On the horizontal girders, stiffeners are to be provided between side frames and vertical stiffeners of inner hull plating. The scantlings of stiffeners are to meet the requirements of 5.12.2.5 of this Chapter.

5.5.7 Transverse webs in double hull

5.5.7.1 Watertight transverse webs and stiffeners in double hull are to comply with the requirements for deep tanks as specified in Section 13, Chapter 2 of this PART.

5.5.7.2 Side longitudinals and inner hull longitudinals penetrating watertight transverse webs are to comply with the requirements of 5.5.3.2 and 5.5.5.4 of this Section. Stiffeners are to be provided on transverse webs between side longitudinals and inner hull longitudinals.

5.5.7.3 Non-watertight transverse webs supporting side longitudinals and inner hull longitudinals in double hull are to be provided in line with double bottom transverses. The thickness of non-watertight transverse webs is to comply with the requirements of 5.1.6, Section 1 of this Chapter. The side longitudinals and inner hull longitudinals are to penetrate such transverse webs. Compensation plates are to be provided at the openings to connect longitudinals and transverse structures. Stiffeners are to be provided on transverse webs between side longitudinals and inner hull longitudinals.

Section 6 DECK FRAMING

5.6.1 General provisions

5.6.1.1 This Section applies to arrangement method and scantling determination of longitudinal deck framing within cargo oil tanks of double hull oil tankers.

5.6.2 Deck transverses

5.6.2.1 Deck transverses are to be fitted in every plane of the bottom transverses.

5.6.2.2 The section modulus W of deck transverses is not to be less than that obtained from the following formula:

$$W = CLS(l + 1)K \quad \text{cm}^3$$

where: C — coefficient, $C = 1.80$ for centre oil tanks, $C = 1.92$ for wing oil tanks;

S — spacing of deck transverses, in m;

L — length of ship, in m, to be taken as not less than 65 m, but need not be more than 190 m;

l — span of deck transverse, in m;

K — material factor.

5.6.2.3 The section moment of inertia I of the deck transverse is not to be less than that obtained from the following formula:

$$I = 7.5Wl/K \quad \text{cm}^4$$

where: W, l and K — as defined in 5.6.2.2 of this Section.

In addition, the web depth of deck transverses mentioned above is not to be less than 2.5 times the depth of the cut-outs for the passage of deck longitudinals.

5.6.2.4 Stiffeners normal to the face plate are to be fitted on the web plate of deck transverses at alternate longitudinals. Where the web depth of deck transverses exceeds $210t\sqrt{K}$ (t being the thickness of the web plate and K being material factor), an additional horizontal stiffener is to be fitted at a distance of 1/4 web depth from the face plate. The scantlings of stiffeners are to comply with the requirements of 5.12.2.5 of this Chapter.

Tripping brackets, spaced not more than 4.5 m or 20 times the width of the face plate (whichever is the lesser) apart, are generally to be fitted close to the toes of end brackets of deck transverses and elsewhere. The tripping brackets is to comply with the requirements of 1.2.5.4, Chapter 1 of this PART.

5.6.2.5 Deck transverses are to be connected by end brackets to inner hull plating, longitudinal bulkheads, side framing and continuous deck girders. The scantlings of the brackets are to comply with the requirements of 1.2.7, Chapter 1 of this PART. Where connected to continuous deck girders, the brackets are to extend to the face plate of girders and to be welded to it.

5.6.3 Deck girders

5.6.3.1 The section modulus W of the continuous deck girders is not to be less than that obtained from the following formula:

$$W = 0.1Lbl^2K \quad \text{cm}^3$$

where: L — length of ship, in m;

b — mean width of load-bearing area of the continuous deck girders, in m;

l — span of the continuous deck girder, in m;
K — material factor.

5.6.3.2 Where the web height of continuous deck girders are greater than $65t\sqrt{K}$ (where t is web thickness, K is material factor), they are to be stiffened parallel to the girder face plate. The stiffeners are to comply with the requirements of 5.12.2.5 of this Chapter.

Tripping brackets are to be fitted to the continuous deck girders in accordance with the requirements of 1.2.5.4, Chapter 1 of this PART.

5.6.3.3 The connection of deck girders to transverse bulkheads or to the vertical webs on transverse bulkheads is to comply with the requirements of 1.2.7, Chapter 1 of this PART.

5.6.4 Deck longitudinals

5.6.4.1 The section modulus W of deck longitudinals is not to be less than that obtained from the following formula:

$$W = csl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
l — span of longitudinal, in m, but not to be less than 2.5 m;
c — coefficient, to be taken as the greater of the following values: $c = 0.35L$ or $c = 0.12L + 12.6$, where L being the length of ship, in m; for L >190 m, to be taken as 190 m;
K — material factor.

5.6.4.2 Deck longitudinals, in association with the deck plating, may be gradually tapered outside $0.4L$ amidships towards the ends. At $0.075L$ from ends, the section modulus of deck longitudinals is not to be less than 80% of the value obtained from 5.6.4.1 of this Section and in addition, not to be less than that required in 2.8.5.1, Chapter 2 of this PART for deck longitudinals at the ends of ships.

5.6.4.3 Connections of deck longitudinals to transverse bulkheads are to provide adequate fixity and continuity of longitudinal strength. For ships over 150 m in length or where higher tensile steel is adopted for deck longitudinals, the longitudinals are to be continuous through the transverse bulkheads.

Where the deck longitudinals are cut in way of the transverse bulkheads, they are to be bracketed to the bulkheads, and the scantlings of the brackets are to comply with the relevant provisions in 1.2.6, Chapter 1 of this PART. Where flanged face plates are used for the brackets, the breadth of the flange is not to be less than 8 times its thickness.

Deck longitudinals are to be welded to the web of deck transverses, and to be welded to the stiffeners of deck transverses when intersecting the stiffeners.

Section 7 PLANE TRANSVERSE OILTIGHT BULKHEADS

5.7.1 General requirements

5.7.1.1 The stiffening on the plane transverse bulkheads, in general, may be arranged vertically in association with horizontal girders or horizontally in association with vertical webs.

5.7.1.2 Horizontal girders of transverse bulkheads are to be fitted in line with the horizontal girders in double hull and with horizontal girders of longitudinal bulkheads. The vertical stiffeners are to be fitted on the same longitudinal section as bottom and inner bottom longitudinals.

5.7.1.3 Vertical webs, if fitted, are to be fitted on the same longitudinal section as deck girders and bottom girders. The horizontal stiffeners are to be fitted at the same level as side longitudinals and inner hull longitudinals.

5.7.2 Thickness of bulkhead plating

5.7.2.1 The thickness t of the bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.75s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;
h — vertical distance, in m, measured from lower edge of strake to the tank top in way of longitudinal centerline, but not less than $0.4D$;
K — material factor.

5.7.2.2 The thickness t of the bulkhead plating is to comply with the following requirements:

(1) Where horizontal girders and vertical stiffeners are fitted on the bulkhead:

$$t \geq \frac{s}{70\sqrt{K}} \quad \text{mm, for the upper 3/4 of the bulkhead}$$

$$t \geq \frac{s}{60\sqrt{K}} \quad \text{mm, for the lower 1/4 of the bulkhead}$$

(2) Where vertical webs and horizontal stiffeners are fitted on the bulkhead:

$$t \geq \frac{s}{85\sqrt{K}} \quad \text{mm, for the upper 3/4 of the bulkhead}$$

$$t \geq \frac{s}{70\sqrt{K}} \quad \text{mm, for the lower 1/4 of the bulkhead}$$

where: s — spacing of stiffeners, in m;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

5.7.3 Horizontal girders and vertical stiffeners

5.7.3.1 The section modulus W of horizontal girders is not to be less than that obtained from the following formula:

$$W = 10.5b\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: b — width of plating supported by the girder, i.e. half the sum of the lengths of the intersected vertical stiffener above and below the horizontal girder, in m;

h — vertical distance, in m, measured from horizontal girder to the tank top in way of longitudinal centreline;

l — span of horizontal girder, in m;

K — material factor.

The web depth of the horizontal girder is not to be less than 2.5 times the depth of the cut-outs for the passage of vertical stiffeners.

5.7.3.2 Where the horizontal girders together with the horizontal girders on longitudinal bulkheads and the horizontal girders in double hull do not form a ring structure, the brackets at both ends of the horizontal girders are to extend to the adjacent vertical web or webs. The thickness of the brackets is to be the same as the web thickness of the horizontal girders, and the face plate of the brackets is to be the same as that of the horizontal girders.

5.7.3.3 End brackets, which are to comply with the requirements of 1.2.7 of Section 2, Chapter 1 of this PART, are to be fitted at both ends of horizontal girders. Supporting brackets are to be additionally fitted at the other side of the bulkhead in line with the end brackets.

5.7.3.4 Tripping brackets, spaced not more than 4.5 m or 15 times the width of the face plate (whichever is the lesser) apart, are generally to be fitted close to the toes of end brackets of horizontal girders and elsewhere. The tripping brackets are to comply with the requirements of 1.2.5.4, Chapter 1 of this PART.

5.7.3.5 The web thickness of horizontal girders is not to be less than s/80 (s being the spacing of stiffeners, in m). Stiffeners normal to the face plate are to be fitted on one side of every vertical stiffener on the web plate of horizontal girders. Where the web depth of horizontal girders exceeds 165t (t being the thickness of the web plate), an additional stiffener is to be fitted parallel to and at a distance of 1/4 web depth from the face plate.

5.7.3.6 Where continuous deck girders are fitted in way of the longitudinal centreline on deck, a vertical centreline web is also to be fitted. The scantlings are to be determined by direct calculation. The connection between them is to comply with the requirement of 1.2.7, Chapter 1 of this PART.

5.7.3.7 The section modulus W of vertical stiffeners is not to be less than that obtained from the following formula:

$$W = 7.2s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from mid- span of stiffeners to the tank top in way of longitudinal centerline, but to be taken as not less than 0.25D;

l — span of stiffener, in m;

K — material factor.

5.7.3.8 The stiffeners are to be connected to the inner bottom and deck longitudinals by brackets at both ends. The brackets are to comply with the requirements of 1.2.6, Chapter 1 of this PART. The stiffeners are to be welded to the web of horizontal girders and vertical stiffeners on the web when penetrating horizontal girders.

5.7.4 Vertical webs and horizontal stiffeners

5.7.4.1 The section modulus W of vertical webs is not to be less than that obtained from the following formula:

$$W = Cb\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: b — width of plating supported by the vertical web, i.e. half the total length of the horizontal stiffener intersecting the vertical web, in m;

h — vertical distance, in m, measured from mid- span of the vertical web to the tank top in way of longitudinal centreline;

l — span of vertical web, in m;

C — coefficients: $C = 11$, for the vertical web at the centreline; $C = 8.8$, for the vertical web not on the centreline but supporting the horizontal stiffeners;

K — material factor.

The web depth of vertical webs is not to be less than 2.5 times the depth of the cut-outs for the passage of horizontal stiffeners.

5.7.4.2 Where vertical webs, bottom girders and deck girders do not form a ring structure, the brackets at both ends of the vertical web are to extend to the adjacent deck transverse or bottom transverse. The thickness of the brackets is to be the same as the web thickness of the vertical webs, and the face plate of the brackets is to be the same as that of the vertical webs, or an alternative effective structural configuration is to be adopted to ensure the continuity of the structure.

5.7.4.3 End brackets, which are to comply with the requirements of 1.2.7 of Section 2, Chapter 1 of this PART, are to be fitted at both ends of the vertical webs. Supporting brackets are to be additionally fitted at the other side of the bulkhead in line with the end brackets.

5.7.4.4 Tripping brackets, spaced not more than 4.5 m or 15 times the width of the face plate (whichever is the lesser) apart, are generally to be fitted close to the toes of end brackets of vertical webs and elsewhere. The tripping brackets are to comply with the requirements of 1.2.5.4, Chapter 1 of this PART.

5.7.4.5 Vertical webs are to be fitted with stiffeners parallel to the girder face plate and spaced not more than 60 $\sqrt{K}$ (K being material factor) times the web thickness apart. When horizontal stiffeners on transverse bulkheads are supported by vertical girders, stiffeners normal to the face plate are to be fitted at every horizontal stiffener. The scantlings of stiffeners are to comply with the requirements of 5.12.2.5 of this Chapter.

5.7.4.6 The section modulus W of horizontal stiffeners is not to be less than that obtained from the following formula:

$$W = 7.2s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the stiffener to the tank top in way of longitudinal centreline, but not to be less than $0.25D$, in m;

l — span of stiffener, in m;

K — material factor.

5.7.4.7 The stiffeners are to be connected to the inner hull and the horizontal stiffeners of longitudinal bulkheads by brackets having the scantlings as required in 1.2.6, Chapter 1 of this PART. Horizontal stiffeners are to be welded to the web plate and stiffeners of the vertical webs.

Section 8 PLANE LONGITUDINAL OILTIGHT BULKHEADS

5.8.1 General requirements

5.8.1.1 Longitudinal bulkheads are to be continuous throughout all cargo tanks, and are to extend as far forward and aft as possible. Where the longitudinal bulkheads are cut, large brackets or other longitudinal transitional members are to be fitted to ensure effective continuity.

5.8.1.2 The stiffening on the longitudinal bulkheads may be arranged vertically in association with horizontal girders or horizontally in association with vertical webs. Horizontal girders are to be fitted at the same level as those of transverse bulkheads, and vertical stiffeners are to be fitted on the transverse section of transverse frames. Vertical webs are to be fitted on the same transverse section as bottom floors, and horizontal stiffeners are to be fitted at the same level as side longitudinals.

5.8.1.3 Continuous girders are to be fitted in double bottom at plane longitudinal bulkheads.

5.8.2 Thickness of bulkhead plating

5.8.2.1 The thickness t of the longitudinal bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.75s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of strake to the tank top in way of longitudinal centreline; but not less than $0.4D$, in m;

K — material factor;

D — moulded depth of ship, in m.

5.8.2.2 The thickness of the longitudinal bulkhead plating within $0.1D$ from deck need not exceed the sheer strake thickness with the same frame spacing.

5.8.3 Horizontal girders and vertical stiffeners

5.8.3.1 The section modulus of horizontal girders is to be calculated in accordance with 5.7.3.1 of this Chapter and to comply with relevant requirements, but the span under consideration is not to be less than 3 m.

5.8.3.2 Horizontal girders and those of transverse bulkheads are to be connected as required in 1.2.7 of this PART.

5.8.3.3 The section modulus W of vertical stiffeners is not to be less than that obtained from the following formula:

$$W = 7.2s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: s, h, l and K are the same as that in 5.7.3.7 of this Chapter.

5.8.3.4 Stiffeners are to be bracketed at both ends. These brackets are to extend to the nearest inner bottom and deck longitudinals and the scantlings of these brackets are to comply with the requirements of 1.2.6 of this PART, but the depth of the lower bracket along the stiffener is not to be less than 15% of the distance between the ship's bottom and the adjacent horizontal girder. Vertical stiffeners are to be welded to the web plate and stiffeners of the horizontal girders.

5.8.4 Vertical webs and horizontal stiffeners

5.8.4.1 Where one longitudinal bulkhead is fitted, vertical webs symmetrical to the longitudinal centerline are to be fitted in line with floors. The vertical webs may also to be fitted at one side of the longitudinal bulkhead. Where two longitudinal bulkheads are fitted, vertical webs are to be fitted in compartments with cross ties.

5.8.4.2 The section modulus of vertical webs is not to be less than that obtained from the following formula:

$$W = CS\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: S — spacing of vertical webs, in m;

h — vertical distance, in m, measured from the mid-span of vertical webs to tank top;

l — span of vertical webs, in m;

C — coefficient: C = 11, without horizontal cross tie; C = 3.2, with 1 horizontal cross tie; C = 3, with 2 horizontal cross ties;

K — material factor.

5.8.4.3 The end brackets of vertical webs are to comply with the requirements of 1.2.7, Chapter 1 of this PART.

5.8.4.4 The section modulus W of horizontal stiffeners is not to be less than that obtained from the following formula:

$$W = 7.2s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from stiffeners to tank top at longitudinal centerline, but not less than $0.25D$;

l — span of stiffener, in m;

K — material factor.

5.8.4.5 For ships over 150 m in length or where higher tensile steel is adopted, the horizontal stiffeners on longitudinal bulkheads within $0.1D$ from bottom and deck are to be continuous through transverse bulkheads. Where the horizontal stiffeners are cut at the transverse bulkheads, they are to be bracketed to the transverse bulkheads. Where the transverse bulkheads are stiffened vertically, the brackets at the ends of horizontal stiffeners are to extend to the nearest vertical stiffeners of the transverse bulkheads; the scantlings of the brackets are to be in accordance with the requirements of 5.5.3.2 of this Chapter.

Horizontal stiffeners are to be welded to the web plate and stiffeners of the vertical webs.

5.8.5 Cross ties

5.8.5.1 In oil tankers having two longitudinal bulkheads, horizontal cross ties are to be arranged in the transverse ring structure as shown in Figure 5.1.5.2(2). The cross ties are to be located as follows: where one horizontal cross tie is arranged, the centerline of the cross tie is to be between 0.5D and 0.7D from deck; where two horizontal cross ties are arranged, the centerline of the upper one is to be between 0.4D and 0.5D from deck, while the centerline of the lower one is to be between 0.7D and 0.8D from deck. Cross ties may be omitted in transverse ring structures adjacent to watertight transverse bulkheads.

5.8.5.2 The sectional area A and section moment of inertia I of the horizontal cross ties are not to be less than those obtained from the following formulae:

$$A = 1.1Kbs(h + 1.2) + 50K \quad \text{cm}^2$$

$$I = 2.1bs\ (h + 1.2)\ l^2 \quad \text{cm}^4$$

where: b — width of plating supported, in m, taken as half of the moulded depth when one cross tie is arranged or half the distance from deck or bottom to the adjacent cross tie when two cross ties are arranged;

h — vertical distance, in m, measured from the centerline of the cross tie to deck at side;

s — spacing of transverse ring structures, in m;

K — material factor;

l — length of cross ties, in m.

5.8.5.3 Substantial vertical and horizontal brackets are to be fitted at ends of cross ties for connection of cross ties to the vertical webs of inner hull and longitudinal bulkheads. The vertical brackets are to be in line with the cross tie web plates, and the horizontal brackets are to be in line with the cross tie face plates.

5.8.5.4 Stiffeners parallel to the face plate are to be fitted on the web plate of cross ties. Where $L \leq 90$ m, the distance between the stiffener and the face plate or between two stiffeners is not to exceed 80 $t\sqrt{K}$ (t being the thickness of cross tie webs, K being material factor); where $L \geq 190$ m. the distance is not to exceed 55 $t\sqrt{K}$. Intermediate values are to be obtained by interpolation.

Brackets are to be fitted on the web plate of cross ties to support the face plate and horizontal stiffeners.

5.8.5.5 Cross ties are to be subject to buckling check.

Section 9 CORRUGATED TRANSVERSE OILTIGHT BULKHEADS

5.9.1 General requirements

5.9.1.1 Except where otherwise specified, the symbols for dimensions of corrugations are shown in Figure 1.2.4.3 of Chapter 1 of this PART.

5.9.1.2 Vertical corrugations are generally to be adopted for corrugated transverse bulkheads except in special cases. The angle between flange and web portions of the corrugation is not to be less than 40º.

5.9.1.3 For oil tankers of 190 m or over in length, lower stools and in general, upper stools are to be provided for vertical corrugated bulkheads.

5.9.2 Corrugation dimensions and bulkhead plating

5.9.2.1 The thickness of transverse corrugated bulkheads is to be determined according to 5.7.2.1 of this Chapter. In calculation, s is to be taken as the width of corrugation flange or that of corrugation web, whichever is the greater, and is to comply with the following formula:

$$t \geq \frac{s}{70\sqrt{K}} \quad \text{mm}$$

where: s — the width of corrugation flange or that of corrugation web, in mm, whichever is the greater;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

5.9.2.2 The section modulus W and moment of inertia I of a corrugation of bulkheads are not to be less than those obtained from following formulae respectively:

$$W = 8.8s\ (h + 1.2)\ l^2K \text{ cm}^3$$

$$I = 3.2Wl/K \quad \text{cm}^4$$

where: s — breadth of a corrugation, in m;

h — vertical distance, in m, measured from the mid- span of the corrugation to the tank top in way of longitudinal centerline;

l — span of corrugation, in m;

K — material factor.

5.9.3 Lower stools

5.9.3.1 Lower stools are to comply with the requirements of 8.9.4.1 of this PART.

5.9.3.2 Where the spacing of longitudinal girders in double bottom under the lower stool is greater than 3.8 m, local girders are to be provided. Longitudinal webs are to be provided at center girders, side girders and local girders in the lower stool.

5.9.4 Upper stools

5.9.4.1 Upper stools are to comply with the requirements of 8.9.4.1 of this PART.

5.9.5 Arrangement of structure with no lower stool or upper stool

5.9.5.1 Where no upper stool or lower stool is fitted, the upper and lower structures of transverse bulkheads are to be arranged as required in 8.9.4.1 of this PART.

5.9.6 Horizontal girders

5.9.6.1 Where horizontal girders are provided for corrugated transverse bulkheads, the scantlings and structures of the horizontal girders are to comply with the requirements for plane bulkhead horizontal girders specified in 5.7.3 of this Chapter.

5.9.6.2 The considered depth of the web of horizontal girders is to be taken as the minimum distance between the face plate and the bulkhead.

Section 10 CORRUGATED LONGITUDINAL OILTIGHT BULKHEADS

5.10.1 General requirements

5.10.1.1 Except where otherwise specified, the symbols for dimensions of corrugations are shown in Figure 1.2.4.3 of Chapter 1 of this PART.

5.10.1.2 The angle between web and flange of the corrugation is generally not to be less than 40º.

5.10.1.3 Corrugated longitudinal bulkheads are not recommended for oil tankers of 190 m or over in length.

5.10.1.4 Corrugated longitudinal bulkheads may be horizontally or vertically corrugated. Any arrangement, with both longitudinal and transverse bulkheads being horizontally corrugated, is to be avoided.

5.10.2 Vertically corrugated longitudinal bulkheads

5.10.2.1 The thickness of plating of corrugated longitudinal bulkheads is to comply with the requirements of 5.8.2.1 of this Chapter. In calculation, s is to be taken as the width of corrugation flange or that of corrugation web, whichever is the greater, and is to comply with the following formula:

$$t \geq \frac{s}{70\sqrt{K}} \quad \text{mm}$$

where: s — the width of corrugation flange or that of corrugation web, in mm, whichever is the greater;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

5.10.2.2 The section modulus W and moment of inertia I of a corrugation of bulkheads are not to be less than those obtained from following formulae:

$$W = 8.8s\,(h + 1.2)\,l^2K \text{ cm}^3$$

$$I = 3.2Wl/K \quad \text{cm}^4$$

where: s — breadth of a corrugation, in m;

h — vertical distance, in m, measured from the mid- span of the corrugation to the tank top in way of longitudinal centerline; h is not to be less than 2.5 m;

l — span of corrugation, in m;

K — material factor.

5.10.2.3 Upper stools and lower stools are generally to be fitted at vertically corrugated longitudinal oiltight bulkheads.

5.10.2.4 The height of the lower stools is generally not to be less than 3 times the depth of the corrugations. The thickness and material grade of the stool top plate are not to be less than those required

for the bulkhead plating above. The thickness and material grade of the upper portion of vertical or sloping stool side plating, within the depth equal to the corrugation flange width from the stool top, are not to be less than the flange plate thickness and material grade needed to meet the bulkhead stiffness requirements at the lower end of the corrugation.

The distance from the edge of the stool top plate to the surface of the corrugation flange is not to be less than 1.5 times the corrugation flange plate thickness. The stool bottom is to be fitted in line with duct keels in double bottoms and is to have a width not less than 2.5 times the mean depth of the corrugation.

Vertical stiffeners are to be fitted on the lower stool side plating in line with the frames mentioned in 5.4.2.10 of this Chapter. Both ends of the stiffeners are to be bracketed to upper and lower ends of the stool.

Horizontal stiffeners, of which the moment of inertia I may be determined according to 5.12.2.5(2) of this Chapter, are also to be fitted on the lower stool side plating. Diaphragms, the thickness of which is to be the same as that of double bottom solid floors, are to be fitted inside the lower stool in line with solid floors.

Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

5.10.2.5 The upper stool is to have a height generally between 2 and 3 times the depth of corrugations. Rectangular stools are to have a height generally equal to 2 times the depth of corrugations, but greater than the height of deck transverses. The width of the stool bottom plate is generally to be the same as that of the lower stool top plate. The top of non-rectangular stools is to have a width not less than 2 times the depth of corrugations. The side plating of the upper stool may be connected directly to the deck, and to be bracketed transversely to beams.

The thickness and material of the stool bottom plate are to be the same as those of the bulkhead plating below. The thickness of the stool side plating is not to be less than 80% of that required for the upper part of the bulkhead plating where the same material is used. Where vertical stiffeners are fitted at side plating of the upper stool, both ends of the stiffeners are to be bracketed to the upper and lower ends of the stool.

Horizontal stiffeners are also to be fitted at side plating of the upper stool. Diaphragms, the thickness of which is to be the same as that of the web of deck transverses, are to be fitted inside the stool in line with deck transverses.

Scallops in the brackets and diaphragms in way of the connection to the stool top plate are to be avoided.

5.10.2.6 If no bottom stool is fitted, the corrugation flanges are to be in line with the side plating of duct keels and connected to the inner bottom plating by full penetration welds.

5.10.2.7 Where horizontal girders are fitted, they are to comply with the requirements of 5.9.6 of this Chapter.

5.10.3 Horizontally corrugated longitudinal bulkheads

5.10.3.1 The thickness of plating of horizontally corrugated longitudinal bulkheads is to comply with the requirements of 5.8.2.1 of this Chapter. In calculation, s is to be taken as the width of corrugation flange or that of corrugation web, whichever is the greater.

5.10.3.2 The section modulus of a corrugation of the bulkhead is to be determined according to 5.10.2.2 of this Chapter.

5.10.3.3 The flat bottom of horizontally corrugated bulkheads is to be in line with longitudinal girders in double bottom and connected to the inner bottom plating by full penetration welds. The top is welded directly to deck. Both the width of bottom and top flat portion are not to be less than $0.1D$ for ships of more than 150 m in length.

5.10.3.4 Where the width of the flat bottom and top is greater than that of corrugation flange or web, an appropriate stiffening structure is to provided.

5.10.3.5 Vertical webs of horizontally corrugated bulkheads are to be fitted in line with solid floors, and are to comply with the requirements of 5.8.4 of this Chapter. The web depth of the vertical webs is to be taken as the minimum distance between the face plate of vertical webs and the bulkhead.

Section 11 NON-OILTIGHT BULKHEADS AND WASH BULKHEADS

5.11.1 General requirements

5.11.1.1 Where transverse non-oiltight or wash bulkheads are fitted in the cargo tanks, they are to have an area of perforations not less than 10% of the total area of the bulkhead, and the area of perforations is not to be more than 25% of the total area of the bulkhead for longitudinal non-oiltight bulkheads.

5.11.1.2 Where non-oiltight bulkheads support the bottom centre girder, the perforations are to be so arranged as not to impair the efficiency of the bulkhead as a support to the hull structure. Essential openings (such as openings for pipes, access, etc.) in the lower portion of bulkheads are to be circular with edge stiffening.

5.11.1.3 Non-oiltight or wash bulkheads are to be provided with access openings not less than 600 mm × 800 mm in size.

5.11.2 Bulkhead plating and stiffening

5.11.2.1 The thickness of bulkhead plating is not to be less than that required in 5.1.6 of this Chapter. The thickness of the transverse bulkhead plating supporting centre girders, in addition, is to meet the requirements of 5.7.2.2 of this Chapter and in no case are the panel dimensions to exceed 180 times the thickness of the bulkhead plating.

5.11.2.2 The net vertical sectional area A of the non-oiltight transverse bulkhead supporting centre girders is not to be less than that obtained from the following formula:

$$A = 0.14 l_x b D_x K \quad \text{cm}^2$$

where: l_x — the distance, in m, between the bulkheads (oiltight or non-oiltight) adjacent to the non-oiltight bulkhead under consideration;

b — overall breadth of oil tank, in m;

D_x — actual depth of non-oiltight transverse bulkheads or transverse wash bulkheads, in m;

K — material factor.

5.11.2.3 The section modulus W of stiffeners is not to be less than that obtained from the following formula:

$$W = 125 s l^2 K \frac{l_x}{L} \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

l — span of stiffener, in m;

K — material factor;

l_x — see 5.11.2.2 of this Section;

L — length of ship, in m.

5.11.2.4 Stiffeners are to be bracketed at their ends. The scantlings of the brackets are to comply with the requirements of 1.2.6, Chapter 1 of this PART.

5.11.3 Vertical webs and horizontal girders

5.11.3.1 Horizontal girders, vertical webs or stiffeners are to be fitted on the non-oiltight or wash bulkheads in line with the strength members which are supported by the bulkheads.

5.11.3.2 The section modulus of vertical webs is not to be less than one half of that required for the vertical webs of oiltight bulkheads arranged in the same way.

5.11.3.3 The section modulus W of horizontal girders is not to be less than that obtained from the following formula:

$$W = 150 b l^2 K \frac{l_x}{L} \quad \text{cm}^3$$

where: b — width of plating supported by the girder, in m, i.e. half the sum of the lengths of the intersected stiffener above and below the girder, in m;

l — span of girder, in m;

K — material factor;

l_x — see 5.11.2.2 of this Section;

L — length of ship, in m.

Section 12 SPECIAL REQUIREMENTS

5.12.1 General requirements

5.12.1.1 The symmetrical section is to be adopted as far as applicable for side longitudinals and inner hull longitudinals between 2 m below the ballast waterline and 2 m above the full-loaded waterline. The symmetrical section is also recommended for longitudinals within the above-mentioned extent of longitudinal bulkheads to avoid additional torsional stress. Where higher tensile steel is adopted for side longitudinals and vertical stiffeners or brackets on primary transverse structural webs are connected directly to side longitudinals, the toes of stiffeners or brackets within the above-mentioned extent are to be well radiused (see Figure 5.12.1.1). Where CCS fatigue assessment requirements are complied with, other structural arrangements will be considered.

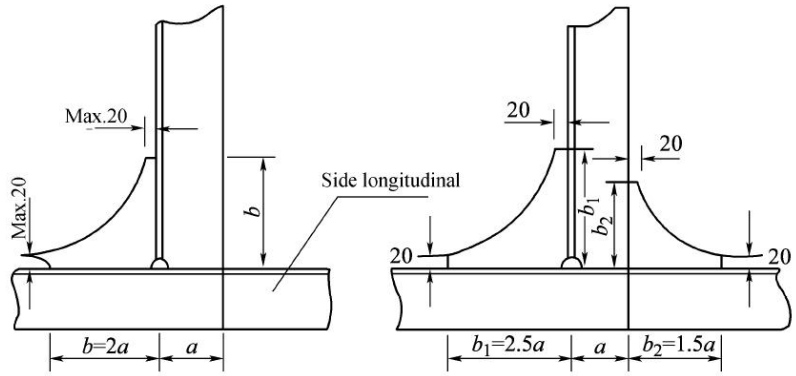
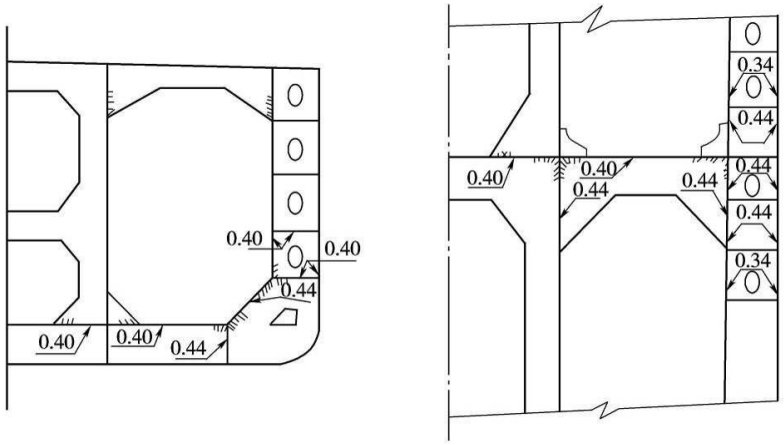


Figure 5.12.1.1

5.12.1.2 Where side longitudinals of higher tensile steel pass through watertight transverse bulkheads in the cargo tank region, radiused brackets of the same material are to be fitted on both the fore and aft sides of the connection between the upper edge of bilge and 0.8*D* above the draft line, and attention is to be given to ensure the alignment of the brackets.

5.12.1.3 For oil tankers greater than 250 m in length, special attention is to be given to the alignment for connection of the transverse ring system and transverse bulkhead horizontal girders as shown in Figure 5.12.1.3 to relevant adjacent members and to the application of full penetration or increased throat thickness for fillet welds. The length of the increased throat thickness is not to be less than 2*s* or 1.2 m, whichever is the greater, where *s* is spacing of secondary members, in m.



Note: Deep penetration welds are required for shadow areas, and increased throat thickness based on weld factors as shown in the Figure is required for other areas.

Figure 5.12.1.3

5.12.2 Structure details

5.12.2.1 Where flat steel is adopted for longitudinals, the ratio of height to thickness is not to be greater than $18\sqrt{K}$ (*K* being material factor) for the longitudinals penetrating bulkheads and not greater than $15\sqrt{K}$ for the longitudinals cut at bulkheads. Where flat steel is adopted for stiffeners, the ratio of height to thickness is not to be greater than $18\sqrt{K}$.

5.12.2.2

(1) The diameter of lightening holes of primary members is not to be greater than 20% of the web height. The distance between the edge of the hole and face plate is not to be less than 40% of the web height, and an equal distance is in general to be kept from the edge of the hole to the corner of notches for the passage of frames. The holes are to be kept clear of notches and bracket toes. The edge of holes are to be well rounded with smooth edges.

(2) Openings with a diameter larger than that specified above are subject to check by direct calculation according to the requirements in Appendix 1 of this Chapter.

(3) Lightening holes are not to be provided on webs of primary members (e.g. side girders, longitudinal bulkhead horizontal girders) in way of cross ties and their end connections.

5.12.2.3 The holes on webs of primary longitudinal members within 0.1*D* (*D* being moulded depth) from deck and bottom are generally to be strengthened. Access holes on deep longitudinal and transverse girders

are to be provided with suitable compensation, so as to satisfy the requirement for resistance to local deformation and shear buckling in the web.

5.12.2.4 The lower edge of holes cut for oil heating piping is not to be less than 100 mm from the shell plating; where notches are cut for the passage of longitudinals, adjacent to such holes, the notches are to be collared.

5.12.2.5 The web depth of stiffeners of primary members is not to be less than 75 mm. Where stiffeners are to be provided both parallel and vertical to the face plate, the scantlings of stiffeners parallel to the face plate are not to be less than those of stiffeners vertical to the face plate. The section moment of inertia of stiffeners is to comply with the following requirements respectively:

(1) The section moment of inertia I of stiffeners vertical to the face plate of primary members is not to be less than that obtained from the following formula:

$$I = 0.175\left(\frac{h}{s}\right)^{2.4} st^3 \quad \text{cm}^4$$

where: h — spacing of horizontal stiffeners for main structural member, or depth of web without stiffeners, in m;

s — spacing of stiffeners, in m;

t — thickness of web, in mm.

In calculation, 1 is to be taken for $h/s < 1$ and 3.3 for $h/s > 3.3$.

(2) The section moment of inertia I of stiffeners parallel to the face plate of primary members is not to be less than that obtained from the following formula:

For longitudinal stiffeners:

$$I = 1.62l^2 A \quad \text{cm}^4$$

For other stiffeners:

$$I = 0.82l^2 A \quad \text{cm}^4$$

where: l — spacing of stiffeners, in m;

A — sectional area of stiffeners with attached plates, in cm².

5.12.2.6 Stiffeners are to be provided for large brackets so that the side length of the non-stiffened triangle of the bracket is not greater than 100 times the thickness of the bracket. Stiffeners are to be parallel to the face plate. The distance from the stiffeners near the face plate to the face plate is not to be greater than 30 times the thickness of the bracket. The spacing of other stiffeners may not be greater than 45 times the thickness of bracket plating. The face plate and stiffeners are to be appropriately supported against tripping. Where the face plate is non-continuous at the structural member, both ends of the face plate are to be sniped.

5.12.2.7 The height of bracket stiffeners is not to be less than 75 mm, and their section moment of inertia I is specified as follows:

For the brackets of deck stringers and keel, not to be less than:

$$I = 3l^2 A \quad \text{cm}^4$$

For those of other primary members, not to be less than:

$$I = 2l^2 A \quad \text{cm}^4$$

where: l — span of stiffeners, in m;

A — sectional area of stiffeners with attached plates, in cm².

5.12.2.8 In the cargo tank region, integral brackets with continuous face plates are to be adopted as far as practicable for end brackets of primary members. Where the thicknesses of face plates connecting two primary members are different, the primary member with the larger face plate is to have the width of its face plate being maintained to the mid-point of the free side of the bracket and gradually tapered to the smaller face plate of the other primary member. The taper is generally not to exceed 1:3 and where the width of the face plate is greater than 500 mm, the taper is not to exceed 1:4. Where a thick face plate is connected to a thinner one, the difference in thickness is not to exceed 4 mm and in the event that the difference exceeds 4 mm, the taper on thickness is to be 1:3.

Section 13 CARGO TANK HATCHWAYS

5.13.1 General requirements

5.13.1.1 Cargo tank hatchways and ladders are to be fitted in compliance with Section 12, Chapter 1 of this PART.

5.13.2 Requirements for cargo tank hatchways

5.13.2.1 The height of the hatch coaming is not to be less than 600 mm, and the thickness of the coaming plating is not to be less than 10 mm. Where the height of coaming exceeds 600 mm, the coaming is to be increased in thickness and reinforced by horizontal stiffeners on the upper portion.

5.13.2.2 The thickness of hatch covers is not to be less than 12 mm. Where the area of the cover exceeds 1.2 m^2, the cover is to be reinforced by stiffeners or increased in thickness.

5.13.2.3 Hatch covers are to be secured by bolts spaced generally not more than 460 mm apart, and not more than 230 mm from hatch corners.

5.13.2.4 Sighting ports having a diameter not less than 150 mm are to be provided in the covers. These holes are to be provided with effective closing appliances to ensure oil-tightness.

Appendix 1 DIRECT STRENGTH CALCULATION OF DOUBLE HULL OIL TANKERS

1 GENERAL

1.1 Application

1.1.1 This Appendix applies to direct calculations, required by this Chapter, of the structural strength of double hull oil tankers.

1.1.2 Where not stipulated in this Appendix, the relevant requirements of Section 5, Chapter 1 of this PART are to be complied with.

1.1.3 For partially filled cargo tanks, consideration is to be given to the sloshing strength under the sloshing pressure due to liquid motion.

2 DESIGN LOADS

2.1 General requirements

2.1.1 Unless stipulated otherwise in the Appendix, the design loads are to be referred to in Section 5, Chapter 1 of this PART.

2.1.2 Unless stipulated otherwise in the Appendix, the still water bending moment in the global load condition is to be taken as the allowable value $\overline{M}_s$ provided by the designer; the wave bending moment M_w is to be calculated according to 1.5.6.1(2) of Section 5, Chapter 1 of this PART.

2.1.3 For harbour conditions, the effect of wave loads (pressure and bending moment) is not considered; the allowable still water bending moment $\overline{M}_{sp}$ is determined by the designer, but is to envelop the design still water bending moment under the loading and unloading conditions in harbour given in the loading manual.

3 LOADING CONDITIONS

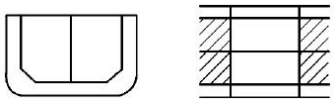
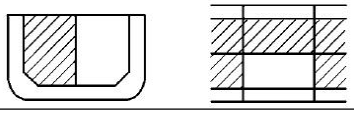
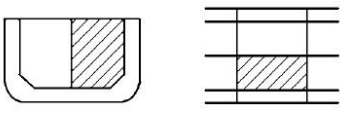
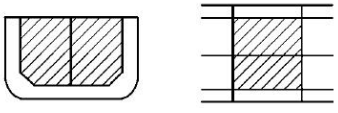
3.1 General requirements

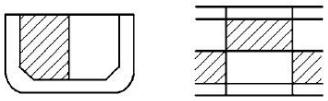
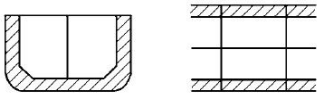
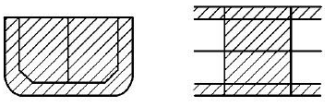
3.1.1 Normally, the corresponding loading conditions are to be selected from Tables 3.2.1 to 3.2.3 of this Appendix for check. For other more severe loading conditions in the loading manual which are not covered by these Tables, direct strength calculation is also to be carried out.

3.2 Loading conditions

3.2.1 The loading conditions of oil tankers with one longitudinal bulkhead are referred to in Table 3.2.1. For the conditions of LC2, LC3, LC5, LC6, if the structures are not symmetrical to the longitudinal centreline, the loading conditions of tanks on starboard and port sides are to be included respectively.

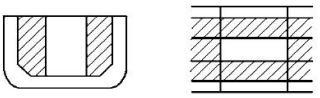
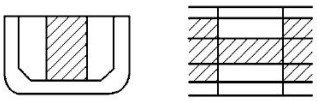
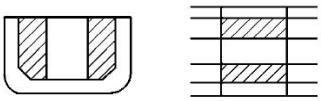
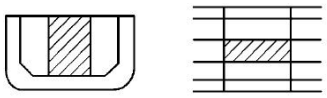
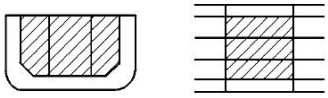
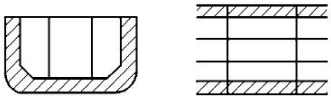
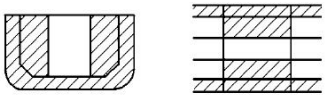
Loading Conditions **Table 3.2.1**

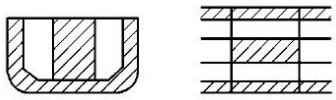
Loading condition	Draught	Still water bending moment	Wave bending moment	Mode of loading
LC1	d	$\overline{M}_s$	M_w	
LC2	d	$\overline{M}_s$	M_w	
LC3	0.35D	$\overline{M}_{sp}$	–	
LC4	0.35D	$\overline{M}_{sp}$	–	

Loading condition	Draught	Still water bending moment	Wave bending moment	Mode of loading
LC5	d	$\overline{M}_s$	M_w	
LC6	0.25D	$\overline{M}_{sp}$	–	
LC7	Ballast draught	$\overline{M}_s$	M_w	
LC8	Heavy ballast draught	$\overline{M}_s$	M_w	

3.2.2 For oil tankers with two longitudinal bulkheads, loading conditions are referred to in Table 3.2.2.

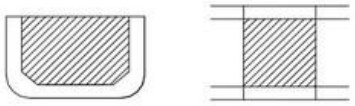
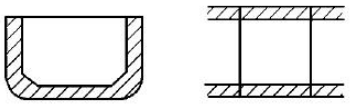
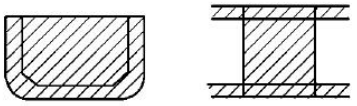
Loading Conditions **Table 3.2.2**

Loading condition	Draught	Still water bending moment	Wave bending moment	Mode of loading
LC1	d	$\overline{M}_s$	M_w	
LC2	d	$\overline{M}_s$	M_w	
LC3	d	$\overline{M}_s$	M_w	
LC4	0.25D	$\overline{M}_{sp}$	–	
LC5	0.25D	$\overline{M}_{sp}$	–	
LC6	0.35D	$\overline{M}_{sp}$	–	
LC7	0.35D	$\overline{M}_{sp}$	–	
LC8	Ballast draught	$\overline{M}_s$	M_w	
LC9	Heavy ballast draught	$\overline{M}_s$	M_w	

Loading condition	Draught	Still water bending moment	Wave bending moment	Mode of loading
LC10	Heavy ballast draught	$\overline{M}_s$	M_w	

3.2.3 For oil tankers without longitudinal bulkheads, loading conditions are referred to in Table 3.2.3.

Loading Conditions **Table 3.2.3**

Loading condition	Draught	Still water bending moment	Wave bending moment	Mode of loading
LC1	d	$\overline{M}_s$	M_w	
LC2	0.35D	$\overline{M}_{sp}$	–	
LC3	Ballast draught	$\overline{M}_s$	M_w	
LC4	Heavy ballast draught	$\overline{M}_s$	M_w	

4 STRUCTURAL MODELING

4.1 General requirements

4.1.1 Unless stipulated otherwise in this Appendix, the requirements for structural modeling are to be referred to in Section 5, Chapter 1 of this PART (for typical finite element model, see Figure 4.1.1).

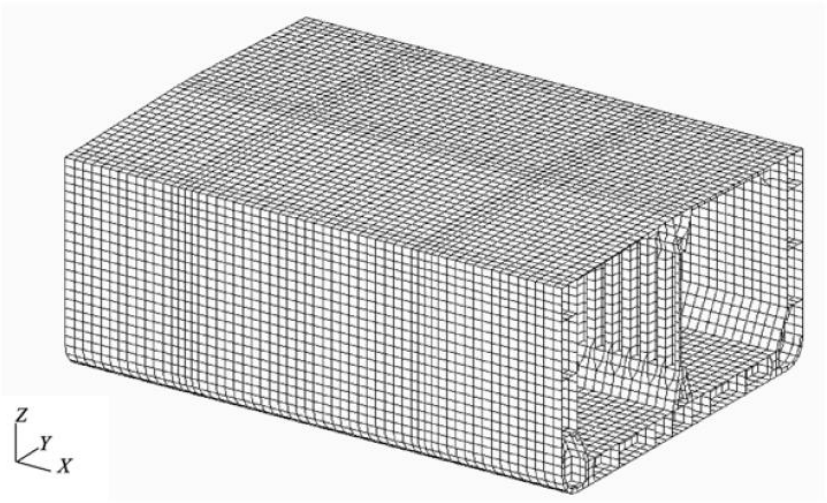


Figure 4.1.1 Finite Element Model

4.2 Boundary conditions

4.2.1 Boundary condition with the structures symmetrical to longitudinal centerline section

4.2.1.1 If a half-breadth FE model is used, the displacements in transverse direction of nodes on the longitudinal centerline section and the rotations around the two coordinate axes on the longitudinal centerline section are restrained, i.e.: $\delta_y = \theta_x = \theta_z = 0$.

4.2.1.2 If a full-breadth FE model is used, the displacements in transverse direction of intersection G of the longitudinal centerline section in way of forward and aft bulkheads of midship cargo tanks and bottom plating are restrained, i.e.: $\delta_y = 0$.

4.2.2 Boundary conditions for local loads (see Table 4.2.2)

4.2.2.1 Symmetrical conditions are applied respectively to end planes A and B, the displacements in the longitudinal direction of nodes and the rotations around the two coordinate axes within the end plane are to be restrained, i.e.: $\delta_x = \theta_y = \theta_z = 0$.

4.2.2.2 Vertical spring elements are to be provided at intersections of side shell plating, inner hull plating and longitudinal bulkhead with forward and aft bulkheads in midship cargo tanks. The coefficient of elasticity of spring elements is to be distributed evenly and calculated by the following formula:

$$K = \frac{5GA}{6l_H n} \quad \text{N/mm}$$

where: G — shear modulus of elasticity of material, $G = 0.792 \times 10^5$ N/mm^2 for steel;

A — shearing area of side shell plating, inner hull plating or longitudinal bulkhead plate in way of forward and aft bulkheads, in mm^2;

l_H — length of midship cargo tank, in mm;

n — number of nodes on vertical intersections of side shell plating, inner hull plating or longitudinal bulkhead plate.

Boundary Conditions for Local Loads **Table 4.2.2**

Position	Displacement constraint			Rotation constraint		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Longitudinal centerline section (half-breadth model)	–	Constraint	–	Constraint	–	Constraint
Node *G* (full-breadth model)	–	Constraint	–	–	–	–
End planes *A*, *B*	Constraint	–	–	–	Constraint	Constraint
Intersection line *C*	–	–	Spring	–	–	–

4.2.3 Boundary conditions for global load (see Table 4.2.3)

4.2.3.1 An independent point *H* is to be set in way of intersection of the neutral axis with the longitudinal centerline section within end planes *A* and *B*, the longitudinal bending moment is to be applied on the point *H*, and the degrees of freedom δ_x, δ_y and δ_z of each member node for end planes is linked to the independent point.

4.2.3.2 The displacements of the independent point *H* within end planes *A* and *B* in transverse direction, vertical direction, and the rotation around longitudinal axes are restrained, i.e.: $\delta_y = \delta_z = \theta_x = 0$; the displacement of the independent point *H* within the end plane *A* in longitudinal direction is restrained, i.e.: $\delta_x = 0$.

Boundary Conditions for Global Load **Table 4.2.3**

Position	Displacement constraint			Rotation constraint		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Longitudinal centerline section (half-breadth model)	–	Constraint	–	Constraint	–	Constraint
Node *G* (full-breadth model)	–	Constraint	–	–	–	–
End planes *A*, *B*	Link	Link	Link	–	–	–
Independent point *H* (end plate *A*)	Constraint	Constraint	Constraint	Constraint	Bending moment	–
Independent point *H* (end plate *B*)	–	Constraint	Constraint	Constraint	Bending moment	–

4.2.4 For boundary conditions of the model, see Figure 4.2.4.

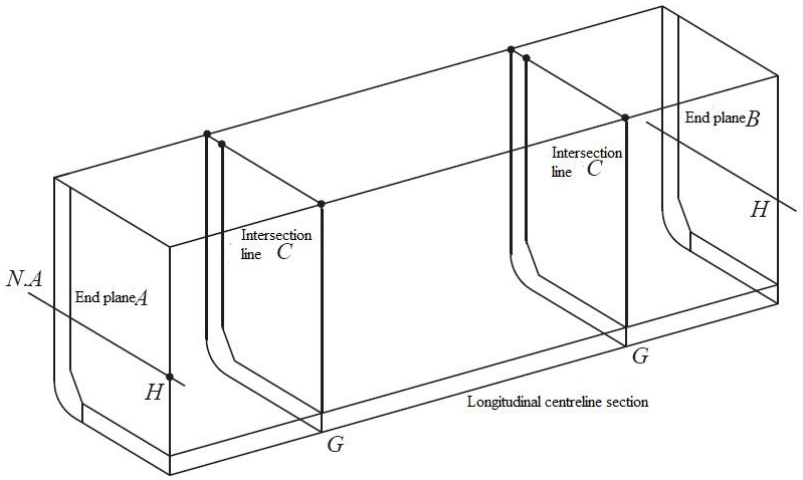


Figure 4.2.4 Boundary Conditions

5 YIELD STRENGTH EVALUATION

5.1 Allowable stresses

5.1.1 Strength evaluation is to be carried out for all primary members in the cargo tanks amidships (including bulkheads) within the longitudinal extent. The evaluation is to be based on the combined stress, which are derived from local load case and global load case in accordance with 1.5.1.9(2) of Chapter 1 of this PART.

5.1.2 The allowable stresses for primary structural members are given in Table 5.1.2.

Allowable Stresses **Table 5.1.2**

Structural member	Allowable stress（N/mm^2）	
	$[\sigma_e]$	$[\tau]$
Deck	220/ K	–
Bottom shell plating, inner bottom plating	220/ K	–
Side shell plating, inner hull plating, sloping plating of hopper tank, longitudinal bulkhead, horizontal girder in double hulls	220/ K	115/ K
Bottom girder	235/ K	115/ K
Double bottom floor	175/ K	95/ K
Transverse bulkhead	175/ K	95/ K
Side plating of lower, upper stools	195/ K	95/ K
Transverse web frame	195/ K	95/ K
Others	195/ K	–

Note: K— material factor.

6 BUCKLING STRENGTH EVALUATION

6.1 Buckling safety factors

6.1.1 The standard thickness deduction of members is given in Table 6.1.1.

Standard Thickness Deduction **Table 6.1.1**

Position		Standard thickness deduction (mm)
Within 1.5 m below weather deck	Deck and shell plating	1.0
	Inner hull and longitudinal bulkhead	2.0
	Internal structure including transverse bulkhead①	2.0
Elsewhere	Shell plating	1.0
	Inner hull and longitudinal bulkhead	1.0
	Internal structure including transverse bulkhead①	1.0

Note:
① In uncoated tanks for refined oils where an inert gas system is not fitted, the thickness deduction is to be increased by 1 mm.

6.1.2 The safety factor λ against plate panel buckling is not to be less than the minimum one in Table 6.1.2.

Minimum Buckling Safety Factor **Table 6.1.2**

Structural member	Minimum buckling safety factor
Deck	0.8
Bottom plating, inner bottom plating	0.8
Side shell plating, inner hull plating, sloping plating of hopper tank, longitudinal bulkhead	0.8
Double bottom girder, horizontal girder in double hulls	1.0
Transverse bulkhead, lower stool, upper stool	0.8
Web plating of transverse structure including midship web frame and bulkhead horizontal and vertical webs	1.0

CHAPTER 6 SINGLE HULL OIL TANKERS

Section 1 GENERAL PROVISIONS

6.1.1 Application

6.1.1.1 This Chapter applies to the structures of cargo tanks and adjacent pump rooms, ballast tanks and cofferdams (excluding bulkheads not adjacent to cargo tanks) of oil tankers with single hull and single bottom or with single hull and double bottom.

6.1.1.2 Those not covered in this Chapter are to comply with the relevant provisions in Chapter 2 and Chapter 5 of this PART.

6.1.2 Class notations

6.1.2.1 For oil tankers complying with the provisions of this Chapter, a notation of Oil Tanker, F.P. ≤ 60°C or Oil Tanker, F.P. > 60°C will be assigned.

6.1.3 Structural arrangement

6.1.3.1 Cargo tanks, double bottom, etc., are to be arranged in compliance with Section 12, Chapter 1 of this PART.

6.1.3.2 For oil tankers of 65 m or over in length, deck, bottom and inner bottom in the cargo tank region are to be longitudinally framed, while the sides may either be longitudinally framed or transversely framed. For oil tankers of less than 65 m in length, all such framing may be transverse.

6.1.4 Minimum thickness

6.1.4.1 The minimum thicknesses of structural members in cargo tank regions, pump rooms, cofferdams and other void spaces are to comply with the requirements of 5.1.6 of Section 1, Chapter 5 of this PART.

Section 2 SHELL PLATING AND DECKS

6.2.1 General requirements

6.2.1.1 The thickness of transversely framed shell plating and decks in the cargo tank region may be determined by the relevant provisions of this Section.

6.2.2 Bottom shell plating and bilge strake

6.2.2.1 The thickness t of bottom shell plating within $0.4L$ amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.072sE^{-1}(L+170)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 7.0s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

d — draft, in m;

L — length of ship, in m;

F_b — reduction factor, see 2.2.5.6, Chapter 2 of this PART;

K — material factor;

$E = 1+\frac{s^2}{S^2}$, S being spacing of bottom girders or keels, in m;

h_1 — $0.26C$, to be taken as not greater than $0.2d$;

C — coefficient, see 2.2.3.1, Chapter 2 of this PART.

6.2.2.2 The thickness of bilge strakes is not to be less than that of bottom shell plating obtained from the calculation in 6.2.2.1 and not to be less than the actual thickness of the adjacent bottom shell plating.

6.2.3 Plate keels

6.2.3.1 The breadth of plate keels is not to be less than the requirements in 5.2.3.1, Chapter 5 of this PART, while the thickness of plate keels is not to be less than that of bottom shell plating as required in this Section plus 2 mm and not less than that of the adjacent bottom shell plating.

6.2.4 Side shell plating

6.2.4.1 The thickness t of side shell plating within 0.4L amidships is to comply with the following requirements:

(1) The thickness t of side shell plating above 3D/4 from the base line is not to be less than that obtained from the following formulae:

$$t_1 = 0.075sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 4.2s\sqrt{(d+h_2)K} \quad \text{mm}$$

(2) The thickness t of side shell plating below D/4 from the baseline is not to be less than that obtained from the following formulae:

$$t_1 = 0.075sE^{-1}(L+110)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 6.3s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: s, d, L, h_1, K — see 6.2.2.1 of this Section;

F_b, F_d — reduction factors, see 2.2.5.6, Chapter 2 of this PART;

h_2 — 0.5C, but not to be greater than 0.36d; C being coefficient to be taken from 2.2.3.1, Chapter 2 of this PART;

E = $1+\frac{s^2}{S^2}$, S being spacing of side stringers, in m.

(3) The thickness of side shell plating above D/4 and below 3D/4 from the baseline is to be determined by interpolation from the values obtained from (1) and (2) above.

(4) For calculation of t_1, except for the minimum scope of higher tensile steels specified in Section 2 of Chapter 2, the material factor K may be taken as 1.

6.2.5 Shear strakes

6.2.5.1 The breadth of the shear strakes is not to be less than 0.1D. The thickness of the shear strake plating is not to be less than that of the adjacent side shell plating.

6.2.5.2 The thickness t of shear strakes within 0.4L amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.086sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 1.05s\sqrt{(L+75)K} \quad \text{mm}$$

where: s, d, L, F_d, E, S, K — see 6.2.4.1 of this Section.

6.2.6 Strength deck plating

6.2.6.1 The thickness t of strength deck plating within 0.4L amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.086sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 4.2s\sqrt{DK} \quad \text{mm}$$

where: s — spacing of transverses, in m, to be taken as not less than the standard spacing of frames;

D — moulded depth, in m;

E = $1+\frac{s^2}{S^2}$, S being spacing of deck girders, in m;

L, F_d,K— see 6.2.5.2 of this Section.

6.2.6.2 The thickness of strength deck plating is generally not to be less than that of side shear strakes obtained from the calculation in 6.2.5.2 of this Section.

Section 3 LONGITUDINAL BOTTOM FRAMING

6.3.1 General requirements

6.3.1.1 This Section applies to longitudinally framed single bottom structure.

6.3.2 Bottom longitudinals

6.3.2.1 The section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 10sDl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
D — moulded depth, in m;
l — span of longitudinal, in m;
K — material factor.

6.3.2.2 The connections of bottom longitudinals to bulkheads are to provide adequate fixity and continuity of longitudinal strength. Where higher tensile steels are adopted, longitudinals are to be continuous through the transverse bulkheads.

6.3.2.3 Where the bottom longitudinals are cut in way of the bulkheads, the longitudinals are to be bracketed to the bulkheads. The scantlings of the bracket are to comply with the requirements of 1.2.6, Chapter 1 of this PART, and the flange width of the bracket is not to be less than 8 times the thickness of the bracket.

Bottom longitudinals are to be welded to the web and vertical stiffeners of bottom transverses.

6.3.3 Bottom transverses

6.3.3.1 The spacing of bottom transverses is not to be greater than 3.6 m.

6.3.3.2 Where one longitudinal bulkhead is fitted in the cargo tank region at the centerline of the ship, the section modulus W and the section moment of inertia I of the bottom transverses are not to be less than those obtained from the following formulae:

$$W = 11SDl^2K \quad \text{cm}^3$$
$$I = 10.5Wl/K \quad \text{cm}^4$$

where: S — spacing of bottom transverses, in m;
D — moulded depth, in m;
l — span of bottom transverse, in m;
K — material factor.

6.3.3.3 Where the continuous centerline girder complying with 6.3.4.2 of this Section are fitted in way of centre tanks of ships having two longitudinal bulkheads within the cargo tank region, the section modulus W of the bottom transverses of the centre tanks and the net sectional area A of the associated webs at span points of the longitudinal bulkheads are not to be less than those obtained by the following formulae:

$$W = C_1SDl^2K \quad \text{cm}^3$$
$$A = C_2SDlK \quad \text{cm}^2$$

where: S — spacing of bottom transverses, in m;
D — moulded depth, in m;
l — span of bottom transverse, in m;
K — material factor.

The bending moment factor C_1 and shear factor C_2 for centerline girders and bottom transverses are based on the number of bottom transverses in the tank and factor C, as given in Table 6.3.3.3 (intermediate values are to be obtained by interpolation). The factor C is to be calculated as follows:

$$C = \frac{l_G^3 I_F}{l_F^3 I_G}$$

where: l_G — span of centerline girder, in m;
l_F — span of bottom transverse, in m;
I_G — section moment of inertia of centerline girder, in cm^4;
I_F — section moment of inertia of bottom transverse, in cm^4.

Table 6.3.3.3

C			0.02	0.06	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
3 bottom transverses	Girder	C_1	8.99	8.99	8.53	7.60	6.91	6.20	5.74	5.27	4.96	4.65	4.43	4.19
		C_2	0.84	0.84	0.81	0.73	0.68	0.62	0.59	0.54	0.51	0.48	0.46	0.45
	Bottom transverse	C_1	1.55	1.74	1.98	2.48	2.85	3.22	3.47	3.66	3.84	4.03	4.15	4.28
		C_2	0.31	0.33	0.35	0.39	0.42	0.45	0.47	0.49	0.50	0.51	0.52	0.53
5 bottom transverses	Girder	C_1	12.71	12.25	11.63	10.23	9.24	8.22	7.53	6.82	6.29	5.74	5.43	5.12
		C_2	1.43	1.39	1.33	1.21	1.12	1.03	0.97	0.91	0.87	0.83	0.80	0.77
	Bottom transverse	C_1	1.55	1.86	2.23	2.79	3.16	3.53	3.78	4.03	4.22	4.40	4.53	4.59
		C_2	0.32	0.34	0.37	0.41	0.44	0.47	0.49	0.51	0.53	0.54	0.55	0.56

Notes: (1) In the case of 2 bottom transverses, calculation may be performed as that for 3 bottom transverses, with C_1 being reduced by 20% and C_2 by 25% for centerline girders.
(2) In the case of 4 bottom transverses, the factor may be obtained by interpolation.

The net sectional area A of the web at mid-span of the bottom transverse is not to be less than $\left(\frac{1}{1.6C_2}-1\right)A$.

The above W and A may also be determined by direct calculation.

6.3.3.4 For ships having two longitudinal bulkheads within the cargo tank region, the scantlings (including the section modulus and the net sectional area of webs at span points) of bottom transverses of wing tanks are generally to be the same as those of bottom transverses of centre tanks.

6.3.3.5 The web depth of the bottom transverses is not to be less than 2.5 times the depth of the slot for the bottom longitudinals.

6.3.3.6 The ends of bottom transverse are to be bracketed to longitudinal bulkheads or ship side. The brackets are to comply with the requirements of 1.2.7, Chapter 1 of this PART. Where connected to ship side, the brackets are as far as possible to form a ring system.

Where the side shell and longitudinal bulkheads are framed transversely in wing cargo tanks, the raised ends of bottom transverse in the tank are to extend to the lowest side stringer and to the lowest horizontal girder of the longitudinal bulkhead. Where the side shell and longitudinal bulkheads are framed longitudinally in wing cargo tanks, the bottom transverses in the tank together with web frames, longitudinal bulkhead vertical webs and deck transverses are to form a transverse framing structure. The radius of rounded corners of the connection of the transverse framing structure to bottom transverses in the tank is generally not to be less than the web depth of adjacent members. The face plate at the connection is to be continuous and have a sectional area not less than that of the face plate of bottom transverses.

6.3.3.7 The web thickness of bottom transverses is not to be less than s/80 (s being the spacing of stiffeners). Vertical stiffeners are generally to be fitted on one side of the web plate of bottom transverses in line with the longitudinals. Where the web depth of bottom transverses exceeds $165t\sqrt{K}$ (t being the web thickness, K being material factor), an additional stiffener is to be fitted parallel to and at a distance of 1/4 web depth from the face plate.

The scantlings of vertical and horizontal stiffeners are to comply with the relevant requirements of 5.12.2.5, Chapter 5 of this PART.

6.3.3.8 Bottom transverses are generally to be fitted with tripping brackets close to the toes of end brackets and elsewhere according to the relevant requirements in 1.2.5.4, Chapter 1 of this PART.

6.3.4 Bottom centerline girder and bottom side girders

6.3.4.1 Where the length of the ship exceeds 70 m and one centerline longitudinal bulkhead is fitted, one intercostal bottom side girder is generally to be fitted at about 1/4B from the centerline on each side.

6.3.4.2 For oil tankers without the centreline longitudinal bulkhead, a continuous bottom centerline girder is to be fitted. The section modulus of the continuous centerline girder and the net sectional area A of the web at any section are not to be less than those obtained from the following formulae:

$$W = 10SDblK \quad \text{cm}^3$$
$$A = 1.45bDSK \quad \text{cm}^2$$

where: b — supporting breadth, in m, taken as half the distance between span points of the bottom transverse at both sides;
S — spacing of bottom transverses, in m;
D — moulded depth, in m;
l — span of the centerline girder, in m;
K — material factor.

6.3.4.3 The web depth of the bottom centerline girder is not to be greater than that of the bottom transverses. The web thickness of the bottom centerline girder is not to be less than that of the bottom transverses plus 2 mm.

6.3.4.4 The web thickness and face plate scantlings of the intercostal bottom side girders are to be the same as those of the bottom transverses in way, while the depth may be half of that of the bottom transverses.

6.3.5 Strengthening and end connections of bottom centreline girder

6.3.5.1 Docking brackets are to be fitted on both sides of the bottom centreline girder, midway between the bottom transverses or between the bottom transverse and the transverse bulkhead, and are to be connected to a suitable bottom longitudinal. These brackets are to have a face plate or a flange. The thickness of the brackets is to be the same as that of the web plate of the bottom centreline girder. The

bracket on one side of the centreline girder is to be extended and welded to the face plate of the centreline girder but on the other side may be terminated at a suitable horizontal stiffener.
Tripping brackets are also to be fitted close to the toes of end brackets of the continuous bottom centreline girder.
6.3.5.2 Horizontal stiffeners are to be fitted on one side of the web of the continuous centreline girder. Additional vertical stiffeners are to be suitably fitted in way of vertical webs and end brackets.
The horizontal stiffeners are to be spaced not more than $50t\sqrt{K}$ apart (t being the web thickness of the centreline girder, K being material factor), and the scantlings of the horizontal stiffeners and vertical stiffeners are to comply with the relevant requirements of 5.12.2.5, Chapter 5 of this PART.

Section 4 TRANSVERSE BOTTOM FRAMING

6.4.1 General requirements

6.4.1.1 This Section applies to transversely framed single bottom structure.

6.4.2 Bottom transverses

6.4.2.1 The solid floor is to be fitted at each bottom transverse. The web depth h, thickness t and face plate sectional area A are not to be less than those obtained from the following formulae:

$h = 42(B + d) - 70$ mm

$t = (0.01h + 3)\sqrt{K}$ mm, but need not be greater than 14 mm

$A = (4.8d - 3)K$ cm²

where: B — breadth of ship, in m;
d — draft, in m;
K — material factor.

6.4.2.2 The thickness of the face plate of bottom transverses is not to be less than the web thickness of bottom transverses, while the breadth of the face plate is not to be less than 10 times its thickness, but need not be greater than 15 times.

6.4.3 Bottom centerline girder and bottom side girders

6.4.3.1 For oil tankers without the centreline longitudinal bulkhead, a continuous bottom centerline girder is to be provided. The web thickness t and face plate sectional area A of the centerline girder throughout the cargo tank region are not to be less than those obtained from the following formulae:

$t = \sqrt{LK} + 2$ mm, and not less than 6 mm

$A = 0.67LK$ cm^2, and not less than 12.5 cm^2

where: L — length of ship, in m;
K — material factor.

6.4.3.2 The bottom centerline girder is generally to be going through the whole ship. Where terminated in way of a transverse bulkhead, the web plating of the bottom centerline girder is gradually to rise to the bulkhead within one frame space, with the raised depth being twice the original one. The face plate of the bottom centerline girder is to be extended to the bulkhead, and to have 15° scarfing as shown in Figure 6.4.3.2.

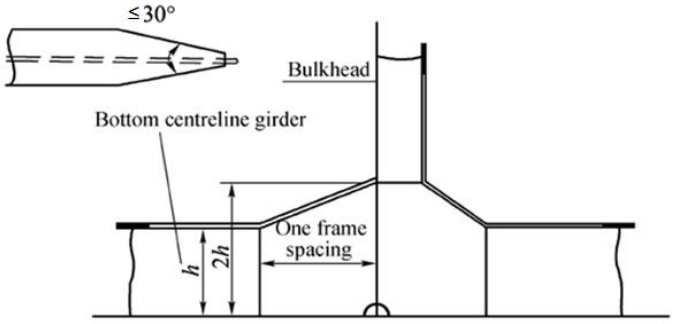


Figure 6.4.3.2

6.4.3.3 Where the breadth of the ship is equal to or less than 7 m, bottom side girders may not be provided; where the breadth is greater than 7 m but less than 12 m, at least one bottom side girder is to be provided at each side of the bottom centerline girder. Where the breadth of the ship is greater than 12 m, at

least two bottom side girders are to be provided at each side of the bottom centerline girder. The bottom side girders are to be uniformly fitted so far as practicable and extended in the fore and aft direction.

6.4.3.4 The depth of bottom side girders is to be the same as that of the bottom transverses in way. The web thickness t and the face plate area A are not to be less than those obtained from the following formulae:

$$t = \sqrt{LK} \quad \text{mm, and not less than 6 mm}$$

$$A = 0.25L + 5 \quad \text{cm}^2\text{, and not less than 10 cm}^2$$

where: L — length of ship, in m;

K — material factor.

Section 5 LONGITUDINAL SIDE FRAMING

6.5.1 Side longitudinals

6.5.1.1 The section modulus W of the side longitudinals is not to be less than that obtained from the following formula:

$$W = 8.4s\,(h + 1.2)\,l^2\,K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

h — vertical distance, in m, measured from the longitudinal under consideration to deck at side amidships, but not to be less than 2.5 m;

l — span of longitudinal, in m;

K — material factor.

6.5.1.2 The scantlings of bilge longitudinals are to be graduated between those required for the bottom and lowest side longitudinals.

6.5.1.3 Where longitudinal bottom and side framing is adopted, but bilge longitudinals are omitted, the spacing of transverses or equivalent bilge brackets are to comply with the requirements of 5.4.4.1, Chapter 5 of this PART.

6.5.1.4 Where the side longitudinals are cut at transverse bulkheads, these longitudinals are to be attached to the bulkheads by brackets. The arm length of the brackets are to be increased by 20% of that required in 1.2.6, Chapter 1 of this PART, and the flange width of the brackets is not to be less than 8 times their thickness.

Side longitudinals are to be welded to the web plate of side transverses.

6.5.2 Side transverses

6.5.2.1 Side transverses are to be fitted in line with each solid floor in the longitudinally framed bottom.

6.5.2.2 The section modulus W of side transverses is not to be less than that obtained from the following formula:

$$W = CS\,(h + 1.2)\,l^2\,K \quad \text{cm}^3$$

where: S — spacing of side transverses, in m;

h — vertical distance, in m, measured from the mid-span of the side transverse to deck at side;

l — span of side transverse, in m;

C — coefficient: $C = 11$, without horizontal cross ties; $C = 3.2$, with one horizontal cross tie; $C = 3$, with two horizontal cross ties;

K — material factor.

6.5.2.3 The section moment of inertia I of side transverses is not to be less than that obtained from the following formula:

$$I = 7.5Wl/K \quad \text{cm}^4$$

where: W — section modulus of side transverses, in cm^3;

l — span of side transverse, in m;

K — material factor.

6.5.2.4 Tripping brackets are generally to be fitted close to the toes of end brackets of side transverses, in way of cross ties and elsewhere in accordance with the relevant requirements of 1.2.5.4, Chapter 1 of this PART.

6.5.2.5 The web thickness of side transverses is not to be less than $s/80$ (s being the spacing of stiffeners or the depth of unstiffened web, in mm). Stiffeners normal to the face plate are generally to be fitted on one side of the web plate of side transverses in line with every side longitudinal. Where the web depth of side transverses exceeds $165t\sqrt{K}$ (t being the thickness of the web plate, K being material factor), an additional stiffener is to be fitted parallel to and at a distance of 1/4 web depth from the face plate. The scantlings of stiffeners are to comply with the requirements of 5.12.2.5, Chapter 5 of this PART.

6.5.2.6 The connection of side transverses to deck transverses and bottom transverses is to form a transverse framing structure so far as practicable. The radius of rounded corners of the connection of the transverse framing structure is generally not to be less than the web depth of adjacent members. Where independent brackets are used at upper ends of side transverses, the scantlings of the brackets are to comply with the requirements of 1.2.7, Chapter 1 of this PART.
The brackets connected to bottom transverses are to comply with the relevant requirements of 6.3.3.6 of this Chapter.

6.5.3 Cross ties

6.5.3.1 Where horizontal cross ties are to be arranged between side transverses and the vertical webs of longitudinal bulkheads, the scantlings, stiffening and end connection of the horizontal cross ties are respectively to comply with the relevant requirements of Chapter 5 of this PART.

Section 6 TRANSVERSE SIDE FRAMING

6.6.1 Side frames

6.6.1.1 The section modulus W of side frames is not to be less than that obtained from the following formula:

$$W = 11s\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: s — spacing of side frames, in m;
h — vertical distance, in m, measured from the mid-span of the side frame to deck at side, but not to be less than 2.5 m;
l — span of side frame, in m, but not to be less than 2.5 m;
K — material factor.

Where side transverses are fitted, the section modulus of side frames may be reduced by 15% from that obtained from the above formula.
It is recommended that the section modulus of side frames fitted in line with the bottom and deck transverses be suitably increased.
6.6.1.2 The depth and breadth of the brackets connecting the side frames to deck transverses are, in general, not to be less than the depth of the web of the deck transverses.
6.6.1.3 Side frames not in line with the bottom and deck transverses are to be attached to the deck and bottom plating by brackets. The arm length of these brackets is to be 20% more than that required in 1.2.6, Chapter 1 of this PART. The brackets connected to deck are to have face plates or flanges not less than 80 mm, and are to extend to the nearest longitunudal of the deck and welded to it.
The bilge brackets are to be extended to the nearest bottom longitudinal and welded to it, covering the entire bilge. The breadth of face plates of bilge brackets is not to be less than 120 mm.
6.6.1.4 Where the lower end of side frames is lapped to the bilge brackets, the length of overlap is not to be less than twice the depth of the frames. Side frames are to be welded to the web plate of side stringers.

6.6.2 Side transverses

6.6.2.1 Where the moulded depth D exceeds 11 m, or where the spacing of oiltight or non-oiltight transverse bulkheads exceeds 15 m, side transverses complying with the requirements of 6.5.2 of this Chapter are to be fitted in line with the solid floors in the longitudinally framed bottom. Where the side transverse does not support side stringers, the section modulus of the side transverse may be reduced by 20% from that required in 6.5.2.2 of this Chapter.
For the tripping brackets fitted to the web plate of side transverses, see 6.5.2.4 of this Chapter.
For the stiffeners fitted to the web plate of side transverse, see 6.5.2.5 of this Chapter.
For brackets connecting the side transverse to deck and bottom transverses, see 6.5.2.6 of this Chapter.

6.6.3 Side stringers

6.6.3.1 Where the moulded depth is less than or equal to 7.5 m, one side stringer is to be fitted; where the moulded depth is less than 6.0 m, however, side stringers may be omitted.
Where the moulded depth is more than 7.5 m, two side stringers are generally to be fitted.
6.6.3.2 The section modulus W of side stringers is not to be less than that obtained from the following formula:

$$W = 12b\,(h + 1.2)\,l^2K \quad \text{cm}^3$$

where: b — width of supported plating, in m, to be taken as half the total length of the intersected side frame above and below the side stringer under consideration;

h — vertical distance, in m, measured from side stringer to the tank top in way of longitudinal centreline;

l — span of side stringer, in m, taken as the spacing of side transverses where side transverses are fitted;

K — material factor.

Where two or more side stringers are fitted, the section modulus of the uppermost one is to be increased by 20% above that obtained from the above formula.

6.6.3.3 The web depth of side stringers is not to be less than 2.5 times the depth of the slot for the side transverses.

6.6.3.4 Tripping brackets are generally to be fitted close to the toes of end brackets of side stringers, in way of cross ties and elsewhere in accordance with the relevant requirements of 1.2.5.4, Chapter 1 of this PART.

6.6.3.5 The web thickness of side stringers is not to be less than $s/80$ (s being the spacing of stiffeners or the depth of unstiffened web, in m). Stiffeners normal to the face plate are generally to be fitted on one side of the web plate of side stringers in line with every frame. Where the web depth of side stringers exceeds $165\,t\sqrt{K}$ (t being the thickness of the web plate, K being material factor), an additional stiffener is to be fitted parallel to and at a distance of 1/4 web depth from the face plate. The scantlings of stiffeners are to comply with the relevant requirements of 5.12.2.5, Chapter 5 of this PART.

6.6.3.6 The connection of ends of side stringers to transverse bulkheads are to comply with the following requirements: where side stringers are connected to transverse bulkhead plating, they are to gradually rise to the depth of twice the original one within the depth of about one web plate from bulkhead plating. The web plates of the stringers are to be welded to bulkhead plating. The face plates of the stringers are to extend to bulkheads. Where side stringers are connected to the horizontal girders of transverse bulkheads, they are to comply with the requirements of 1.2.7, Chapter 1 of this PART.

6.6.4 Cross ties

6.6.4.1 Where horizontal cross ties are to be arranged between side stringers and horizontal webs of longitudinal bulkheads, the scantlings, stiffening and end connection of the horizontal cross ties are respectively to comply with the relevant requirements of Chapter 5 of this PART.

Section 7 TRANSVERSE DECK FRAMING

6.7.1 Deck transverses

6.7.1.1 The section modulus W and moment of inertia I of deck transverses in the cargo tank region are not to be less than those obtained from the following formulae:

$$W = 10.8shl^2K \quad \text{cm}^3$$
$$I = 2.3Wl/K \quad \text{cm}^4$$

where: s — spacing of transverses, in m;

h — design deck head, in m, to be determined according to 2.8.1.1, Chapter 2 of this PART, but not to be less than design pressure of the breathing valves of oil tanks;

l — span of transverse, in m, but not less than 2.5 m;

K — material factor.

6.7.1.2 Deck transverses are to be bracketed to side frames. The scantlings of the brackets are to comply with the requirements of 6.6.1.3 of this Chapter. Deck transverses are to penetrate continuous deck girders, and are to be welded to them.

6.7.2 Deck girders

6.7.2.1 On strength deck, continuous deck girders are generally to be fitted longitudinally in line with bottom girders.

6.7.2.2 The section modulus W and moment of inertia I of continuous deck girders are not to be less than those obtained from the following formulae:

$$W = 12bhl^2K \text{cm}^3$$
$$I = 2.5Wl/K \ \text{cm}^4$$

where: b — mean breadth, in m, of areas supported by deck girders;

h — design deck head, in m, the same as that in 6.7.1.1 of this Section;

l — span of deck girder, in m;

K — material factor.

6.7.2.3 The web depth of deck girders is generally not to be less than 2.5 times the depth of deck transverse opening.
6.7.2.4 The connection of deck girders to transverse bulkheads or vertical webs of transverse bulkheads is to comply with the requirements of 1.2.7, Chapter 1 of this PART.
6.7.2.5 Deck girders are to be fitted with tripping brackets as specified in 1.2.5.4, Chapter 1 of this PART.

Section 8 TRUNK STRUCTURE

6.8.1 General requirements

6.8.1.1 The trunk structure is as shown in Figure 6.8.1.2. As a part of strength deck, the trunk structure is to be efficiently scarfed into the main hull structure.
6.8.1.2 Where a trunk is fitted, design moulded depth D_1 is to be measured from the baseline to equivalent deck, the position of which is to be determined from the following formulae:

$$D_1 = D + 0.6\frac{b_t h_t}{B}, \qquad \text{for}\ \frac{b_t}{B} \le 0.8$$

$$D_1 = D + h_t\left(2.6\frac{b_t}{B} - 1.6\right), \quad \text{for}\ \frac{b_t}{B} > 0.8$$

where: D, B — moulded depth and breadth of ship respectively, in m;
b_t, h_t — mean breadth and height of trunk, in m, see Figure 6.8.1.2.

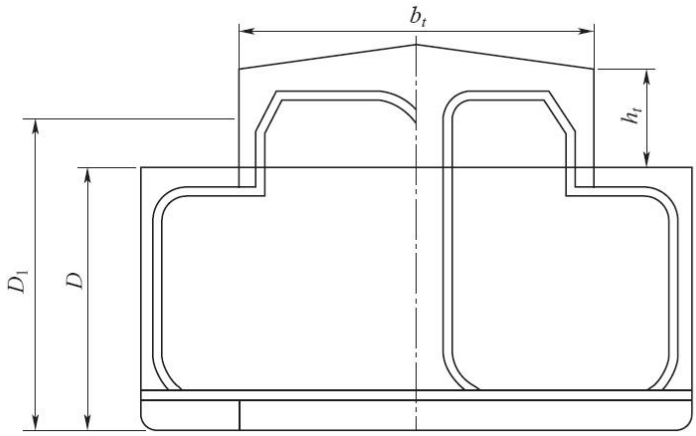


Figure 6.8.1.2

6.8.1.3 In calculation of side, deck, bottom and bulkhead scantlings where the moulded depth D is involved, it is to be replaced by the design moulded depth D_1; where the design pressure head is measured to deck at side, it is to be increased by D_1-D.

6.8.2 Structural arrangement

6.8.2.1 The trunk structure is generally to extend over the full length of the cargo tanks and effectively in the fore and aft direction. The extension length of the trunk side plating at both ends is not to be less than 1.5 times the height of the trunk, and the ends are to form radiused extension brackets which are to have a face plate or flange.
6.8.2.2 The trunk deck and sides are generally to be longitudinally framed. Transverse strength members of the trunk deck are to be arranged in line with deck transverses.
6.8.2.3 The structural arrangement at the connection of the trunk side to deck transverses is to be such as to ensure adequate rigidity and continuity of strength.
6.8.2.4 Where deck is longitudinally framed and ship side is transversely framed, web frames are to be fitted in way of deck transverses. The considered span for the determination of the scantlings of deck transverses is to be measured from the span point at side to the longitudinal bulkhead. In addition, continuous deck girders are to be provided at trunk sides. The web depth of the continuous deck girders is not to be less than that of deck transverses. The sectional area of the face plate of continuous deck girders is not to be less than that of deck transverses.
6.8.2.5 Extension brackets and strengthened vertical stiffeners or equivalent structures are to be provided at fore and aft ends of the trunk so as to ensure the continuity of strength from the trunk structure into the

main hull and superstructures. At fore and aft end bulkheads, the strength deck is to have radiused transition at corners of deck openings as required in 2.4.4, Chapter 2 of this PART.

6.8.2.6 Where strength members or longitudinal stiffeners are fitted externally to the trunk, the arrangements and scantlings of the members are to be specially considered.

6.8.3 Scantlings of members

6.8.3.1 The thickness of the trunk top and side plating as well as that of the strength deck outside the trunk sides are to comply with the requirements of Section 3, Chapter 5 of this PART.

6.8.3.2 The scantlings of trunk longitudinals and web beams are not to be less than those of the strength deck framing as required in Section 6, Chapter 5 of this PART.

6.8.3.3 The hull section modulus, at the trunk and keel, for each transverse section within 0.4*L* amidships is to comply with the relevant requirements of Section 2, Chapter 2 of this PART. All continuous longitudinal members in the trunk may be considered for the hull section modulus amidships.

CHAPTER 7 CONTAINER SHIPS

Section 1 GENERAL PROVISIONS

7.1.1 Application

7.1.1.1 This Chapter applies to ships for the carriage of standard containers in holds and on deck. Container ships engaged in unrestricted service and of 150 m and over in length are to satisfy the requirements of CCS Rules for Structures of Container Ships.

7.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

7.1.1.3 Where the hull structural higher tensile steels of more than 50 mm and up to 100 mm in thickness with the minimum yield strength greater than 355 N/mm^2 are used on board container ships, the requirements of CCS Guidelines for Application of Thick Higher Strength Steel Plates for Ships are to be complied with.

7.1.1.4 Where the hull structural higher tensile steels with the yield strength 390 N/mm^2 are used for strength deck and coaming plating on board container ships, the material factor K may be taken as 0.66 in accordance with 1.3.1 of Section 3, Chapter 1 of this PART, provided that:

(1) the plating thickness is to be more than 50 mm;

(2) the areas of higher tensile steels with 390 N/mm^2 is to be evaluated by means of fatigue spectrum analysis, the positions under evaluation are to include the connection between hatch coamings and supporting members, and other key positions with more severe response of bending moment and torque by hull girders, in addition to those as required in 4.1.5, Appendix 2 of this Chapter;

(3) the key positions of deck and hatch coaming are to be subject to construction monitoring in accordance with the requirements of CCS Guidelines for Construction Monitoring of Hull Structures.

7.1.2 Class notation

7.1.2.1 Container ships complying with the requirements of this Chapter and fitted with the container securing arrangements complying with the requirements of Appendix 1 of this Chapter will be eligible to be assigned the class notation: Container Ship.

7.1.3 Plans and documents

7.1.3.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, the following are to be submitted to CCS for approval:

(1) Stowage arrangement of containers;

(2) Details of reinforcement to structure in way of container corners/supports;

(3) Arrangement and structural connections of cell guides.

7.1.4 Arrangement and structural configuration

7.1.4.1 The basic structural configuration required by this Chapter includes a double bottom, and a double side skin construction with an efficient torsion box girder fitted at the topsides. Where the strength of the hull structure is ensured, a double bottom and a single side skin construction with the torsion box girder or an alternative equivalent structure may be adopted.

7.1.4.2 Longitudinal framing is to be adopted for the topside and also in the double bottom for ships over 100 m in length.

7.1.4.3 Under the hydrodynamic torque of the hull, the average torsional angle of hatch openings in the strength deck is generally not to exceed 0.006°/m and the elongation of the hatch opening diagonal is generally not to exceed 35 mm, except for open-top container ships.

7.1.5 Direct strength calculation and fatigue strength assessment for hull structure

7.1.5.1 For ships of 150 m or over in length or of the width of hatch openings in the strength deck greater than 0.85B (B being the breadth of ship), direct FE strength calculation for cargo holds is to be carried out according to the requirements of Appendix 2 of this Chapter.

For container ships of 150 m or over in length, the fatigue strength check is to be carried out for the following structural members in the cargo area in accordance with CCS Guidelines for Fatigue Strength of Ship Structure:

(1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;

(2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;

(3) connections of inner shell to inner bottoms.

7.1.5.2 For container ships complying with one of the following conditions, direct FE strength calculation and fatigue strength assessment for the whole ship are to be carried out according to the requirements of Appendix 2 of this Chapter:
(1) 250 m or over in length;
(2) where the breadth of ship is greater than 32.36 m;
(3) where the width of hatch openings in the strength deck greater than 0.85B (B being the breadth of ship);
(4) where the structural arrangement is of non-conventional type.

Section 2 LONGITUDINAL STRENGTH

7.2.1 General requirements

7.2.1.1 Application

(1) Application

This Section applies to the following types of ships of 90 m and over in length: container ships and ships dedicated primarily to carry their loads in containers. For container ships up to or greater than 65 m but less than 90 m in length, the requirements of longitudinal strength are referred to in Section 2 of Chapter 2 of this PART.

(2) Load limitations

The wave loads as given in 7.2.2.3 of this Section apply to ships meeting the following criteria:

Length	$90\ \text{m} \le L \le 500\ \text{m}$;
Proportion	$5 \le L/B \le 9$; $2 \le B/d \le 6$;
Block coefficient at scantling draught	$0.55 \le C_b \le 0.9$.

For ships that do not meet all of the aforementioned criteria, special considerations such as direct calculations of wave induced loads may be required by CCS.

(3) Longitudinal extent of strength assessment

The stiffness, yield strength, buckling strength and hull girder ultimate strength assessment are to be carried out in way of 0.2L to 0.75L with due consideration given to locations where there are significant changes in hull cross section, e.g. changing of framing system and the fore and aft end of the forward bridge block in case of two-island designs.

In addition, strength assessments are to be carried out outside this area. As a minimum assessments are to be carried out at forward end of the foremost cargo hold and the aft end of the aft most cargo hold.

(4) For container ships of 90 m and over in length and ships dedicated primarily to carry their loads in containers, the minimum section moduls W_0 at amidship of hull girder is to comply with the requirements of Section 2, Chapter 2 of this PART.

7.2.1.2 Symbols and definitions

(1) Symbols

L length of ship, in m, see 1.1.2 of Chapter 1;

B moulded breadth of ship, in m, see 1.1.2 of Chapter 1;

C wave parameter, see 7.2.2.3(1);

d draught, in m, see 1.1.2 of Chapter 1;

C_b block coefficient, see 1.1.2 of Chapter 1;

C_w waterplane coefficient at scantling draught d, to be taken as:

$$C_W = A_W / (LB);$$

A_w waterplane area at scantling draught d, in m^2;

R_{eH} minimum yield stress of material, in N/mm^2;

K material factor;

E Young's modulus, in N/mm^2. to be taken as $E = 2.06 \times 10^5$ N/mm^2 for steel;

M_S vertical still water bending moment in seagoing condition, in kN·m, at the cross section under consideration;

M_{Smax}, M_{Smin} permissible maximum and minimum vertical still water bending moments in seagoing condition, in kN·m, at the cross section under consideration, see 7.2.2.2(2);

M_W vertical wave induced bending moment, in kN·m, at the cross section consideration;

F_S vertical still water shear force in seagoing condition, in kN, at the cross section under consideration;

F_{Smax}, F_{Smin} permissible maximum and minimum vertical still water shearing forces in seagoing condition, in kN, at the cross section under consideration, see 7.2.2.2(2);

F_W vertical wave induced shearing force, in kN, at the cross section under consideration;

q_v shear flow along the cross section under consideration, to be calculated according to Appendix 3 of this Chapter;

$f_{NL\text{-}Hog}$ non-linear correction factor for hogging, see 7.2.2.3(2);

$f_{NL\text{-}Sag}$ non-linear correction factor for sagging, see 7.2.2.3(2);

f_R factor related to the operational profile, see 7.2.2.3(2);

t_{net} net thickness, in mm, see 7.2.1.3(1);

t_{res} reserve thickness, to be taken as 0.5 mm;

I_{net} net vertical hull girder moment of inertia at the cross section under consideration, to be determined using net scantlings as defined in 7.2.1.3, in m^4;

σ_{HG} hull girder bending stress, in N/mm^2, as defined in 7.2.2.5;

τ_{HG} hull girder shearing stress, in N/mm^2, as defined in 7.2.2.5;

X longitudinal coordinate of a location under consideration, in m;

z vertical coordinate of a location under consideration, in m;

z_n distance from the baseline to the horizontal neutral axis, in m.

(2) Fore end and aft end

The fore end (FE) of the rule length of ship (L), see Figure 7.2.1.2(1), is the perpendicular to the scantling draught waterline at the forward side of the stem.

The aft end (AE) of the rule length of ship (L), see Figure 7.2.1.2(1), is the perpendicular to the scantling draught waterline at a distance L aft of the fore end (FE).

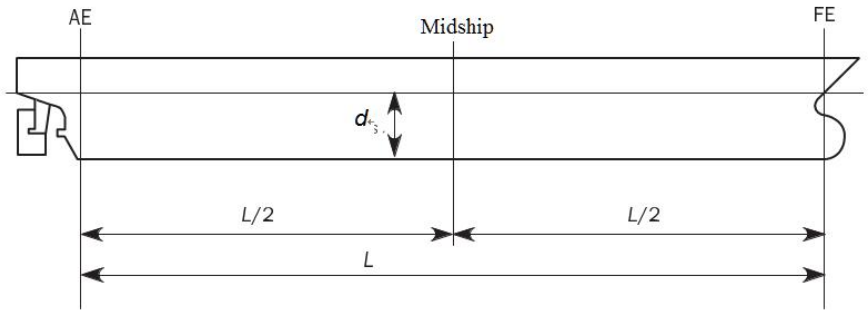


Figure 7.2.1.2(1) Ends of lenth of ship (L)

(3) Reference coordinate system

The ships geometry, loads and load effects are defined with respect to the following righthand coordinate system (see Figure 7.2.1.2(2)):

Origin: At the intersection of the longitudinal plane of symmetry of ship, the aft end of L and the baseline.

x axis: longitudinal axis, positive forwards.

y axis: transverse axis, positive towards portside.

z axis: vertical axis, positive upwards.

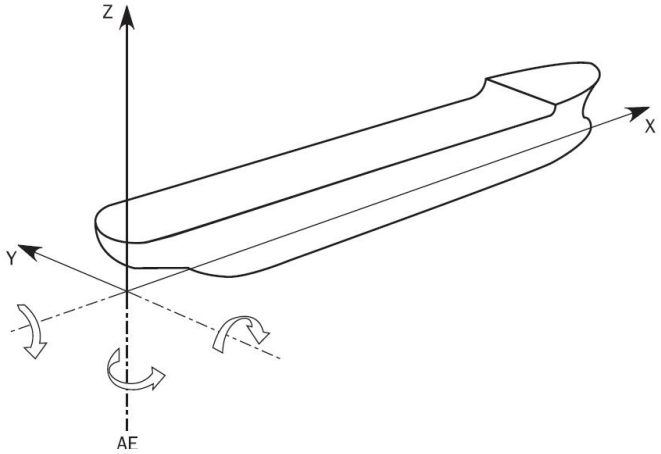


Figure 7.2.1.2(2) Reference coordinate system

7.2.1.3 Corrosion margin and net thickness

(1) Net scantling definition

The strength is to be assessed using the net thickness approach on all scantlings.
The net thickness, t_{net}, for the plates, webs and flanges is obtained by subtracting the voluntary addition t_{vol_add} and the factored corrosion addition t_c from the as built thickness t_{as_built}, as follows:

$$t_{net} = t_{as_built} - t_{vol_add} - \alpha t_c$$

where α is a corrosion addition factor whose values are defined in Table 7.2.1.3(1).
The voluntary addition, if being used, is to be clearly indicated on the drawings.

Values of corrosion addition factor **Table 7.2.1.3(1)**

Structural requirement	Property/analysis type	α
Strength assessment (7.2.3)	Section property	0.5
Buckling strength (7.2.4)	Section property (stress determination)	0.5
	Buckling capability	1.0
Hull girder ultimate strength (7.2.5)	Section property	0.5
	Buckling/collapse capacity	0.5

(2) Determination of corrosion addition
The corrosion addition for each of the two sides of a structural member, t_{c1} or t_{c2} is specified in Table 7.2.1.3(2). The total corrosion addition, t_c, in mm, for both sides of the structural member is obtained by the following formula:

$$t_c = (t_{c1} + t_{c2}) + t_{res}$$

For an internal member within a given compartment, the total corrosion addition, t_c is obtained from the following formula:

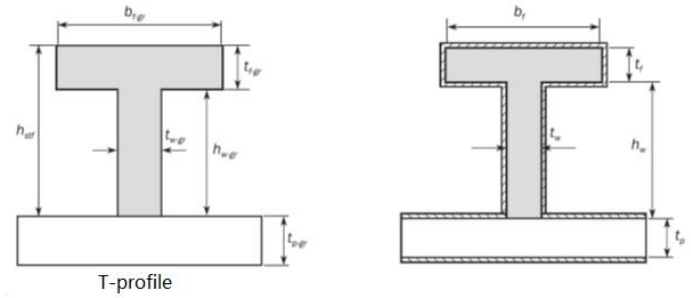
$$t_c = 2t_{c1} + t_{res}$$

The corrosion addition of a stiffener is to be determined according to the location of its connection to the attached plating.

Corrosion addition for one side of structural member **Table 7.2.1.3(2)**

Compartment type	One side corrosion addition t_{c1} or t_{c2} (mm)
Exposed to sea water	1.0
Exposed to atmosphere	1.0
Ballast water tank	1.0
Void and dry spaces	0.5
Fresh water, fuel oil and lube oil tank	0.5
Accommodation spaces	0.0
Container holds	1.0
Compartment types not mentioned above	0.5

(3) Determination of net section properties
The net section modulus, moment of inertia and shear area properties of a supporting member are to be calculated using the net dimensions of the attached plate, web and flange, as defined in Figure 7.2.1.3. The net cross-sectional area, the moment of inertia about the axis parallel to the attached plate and the associated neutral axis position are to be determined through applying a corrosion magnitude of 0.5 αt_c deducted from the surface of the profile cross-section.



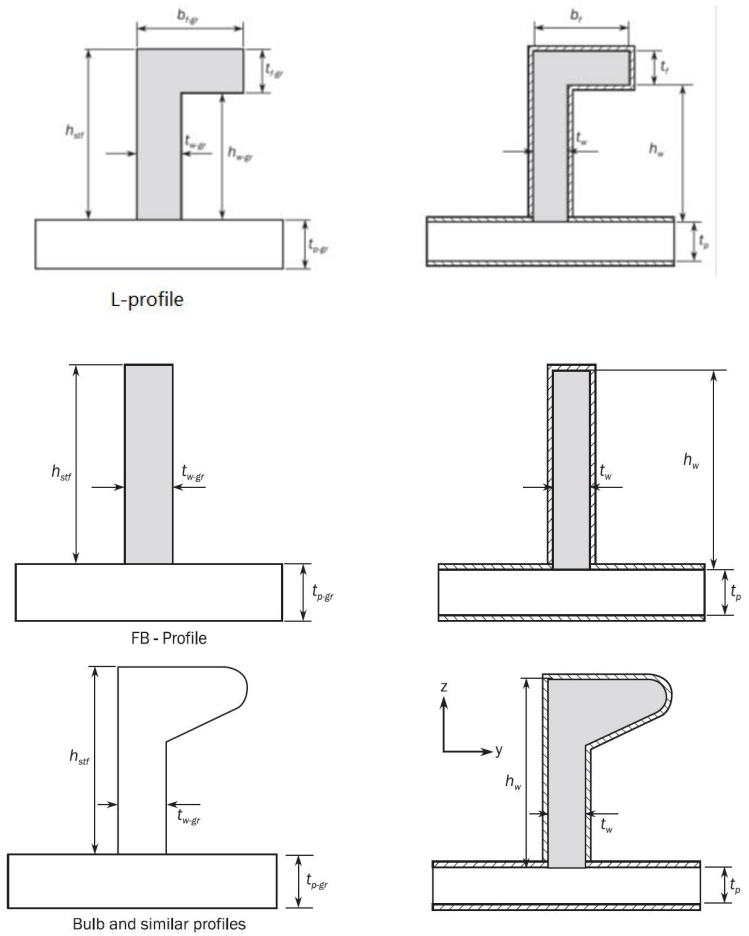


Figure 7.2.1.3 Net sectional properties of supporting members

7.2.2 Loads

7.2.2.1 Sign convention for hull girder loads

The sign conventions of vertical bending moments and vertical shear forces at any ship transverse section are as shown in Figure 7.2.2.1, namely:

- The vertical bending moments M_S and M_W are positive when they induce tensile stresses in the strength deck (hogging bending moment) and negative when they induce tensile stresses in the bottom (sagging bending moment).
- The vertical shear forces F_S, F_W are positive in the case of downward resulting forces acting aft of the transverse section and upward resulting forces acting forward of the transverse section under consideration. The shear forces in the directions opposite to above are negative.

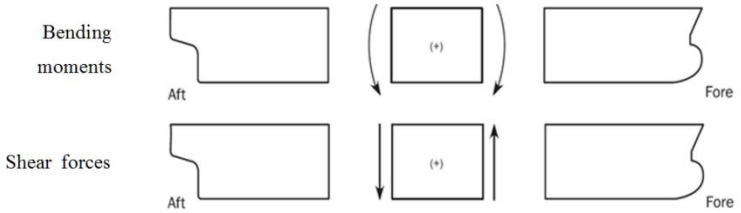


Figure 7.2.2.1 Sign conventions of bending moments and shear forces

7.2.2.2 Still water bending moments and shear forces

(1) General requirements

Still water bending moments, M_S in kN·m, and still water shear forces, F_S in kN, are to be calculated at each section along the ship length for design loading conditions as specified in 7.2.2.2(2).

(2) Design loading conditions

In general, the design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the M_S and F_S calculations. Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe,

calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or de-ballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or de-ballasting any ballast tank are to be submitted and where approved included in the loading manual for guidance.

The permissible vertical still water bending moments M_{Smax} and M_{Smin} and the permissible vertical still water shear forces F_{Smax} and F_{Smin} in seagoing conditions at any longitudinal position are to envelop:

- the maximum and minimum still water bending moments and shear forces for the seagoing loading conditions defined in the Loading Manual;
- the maximum and minimum still water bending moments and shear forces specified by the designer.

The Loading Manual is to include the relevant loading conditions, which envelop the still water hull girder loads for seagoing conditions, including those specified in 2.2.2.3 of Section 2, Chapter 2 of this PART.

7.2.2.3 Wave loads

(1) Wave parameter

The wave parameter is defined as follows:

$$C = 1 - 1.50\left(1 - \sqrt{\frac{L}{L_{ref}}}\right)^{2.2}, \text{ for } L \le L_{ref}$$

$$C = 1 - 0.45\left(\sqrt{\frac{L}{L_{ref}}} - 1\right)^{1.7}, \text{ for } L > L_{ref}$$

where: L_{ref} — reference length of ship, in m, taken as:

$L_{ref} = 315C_W^{-1.3}$ for the determination of vertical wave bending moments according to 7.2.2.3(2);

$L_{ref} = 330C_W^{-1.3}$ for the determination of vertical wave shear forces according to 7.2.2.3(3).

(2) Vertical wave bending moments

The distribution of the vertical wave induced bending moments, M_W in kN·m, along the ship length is given in Figure 7.2.2.3(2), where:

$$M_{W-Hog} = +1.5 f_R L^3 C C_W \left(\frac{B}{L}\right)^{0.8} f_{NL-Hog}$$

$$M_{W-Sag} = -1.5 f_R L^3 C C_W \left(\frac{B}{L}\right)^{0.8} f_{NL-Sag}$$

where: f_R —factor related to the operational profile, to be taken as:

$f_R = 0.85$;

$f_{NL\text{-}Hog}$ — non-linear corrosion for hogging, to be taken as:

$f_{NL-Hog} = 0.3\dfrac{C_B}{C_W}\sqrt{d}$, and not more than 1.1;

$f_{NL\text{-}Sag}$ — non-linear corrosion for sagging, to be taken as:

$f_{NL-Sag} = 4.5\dfrac{1 + 0.2 f_{Bow}}{C_W\sqrt{C_B}L^{0.3}}$, and not less than 1.0;

f_{Bow} —bow flare shape coefficient, to be taken as:

$f_{Bow} = \dfrac{A_{DK} - A_{WL}}{0.2Lz_f}$;

A_{DK} — projected area in horizontal plane of uppermost deck, in m^2, including the forecastle deck, if any, extending from 0.8L forward (see Figure 7.2.2.3(1)). Any other structures, e.g. plated bulwark, are to be excluded;

A_{WL} —waterplane area, in m^2, at draught T, extending from 0.8L forward;

z_f — vertical distance, in m, from the waterline at draught d to the uppermost deck (or forecastle deck), measured at FE (see Figure 7.2.2.3(1)). Any other structures, e.g. plated bulwark, are to be excluded.

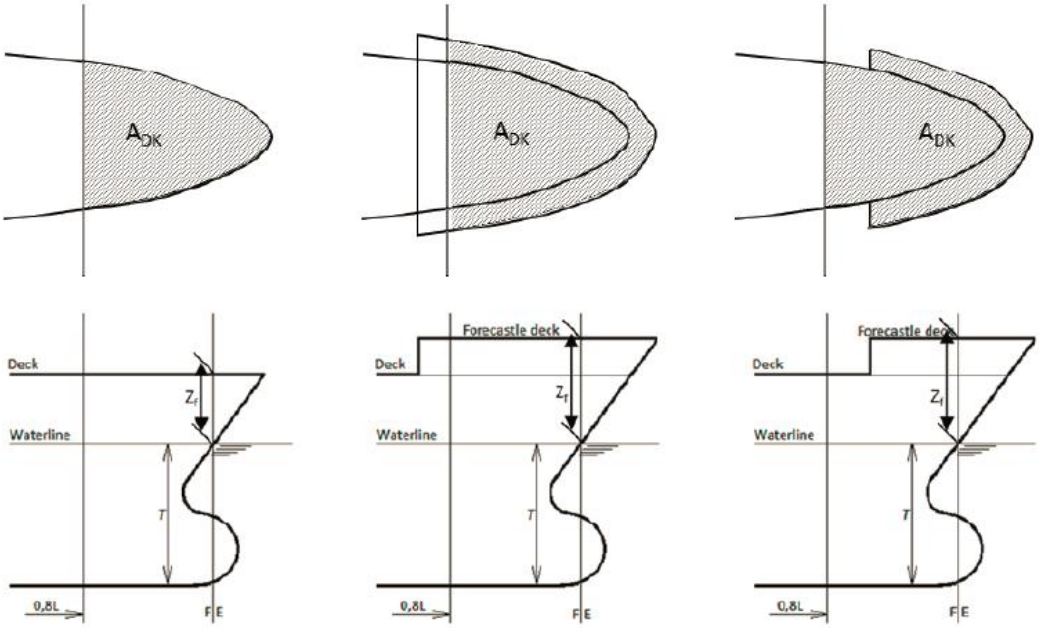


Figure 7.2.2.3(1) Projected area A_{DK} and vertical distance z_f

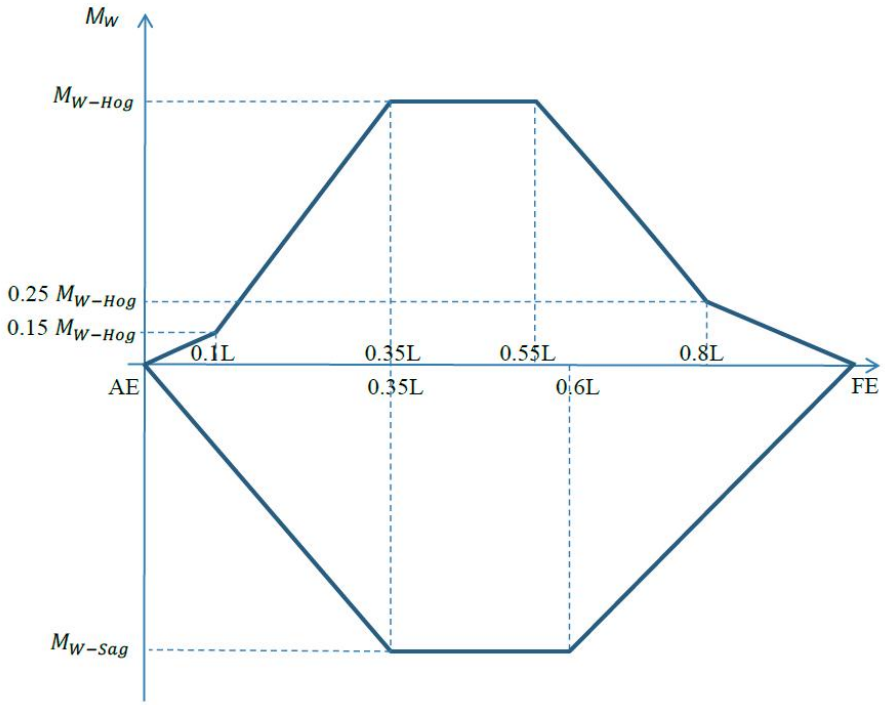


Figure 7.2.2.3(2) Distribution of vertical wave bending moment M_W along the ship length

(3) Vertical wave shear force

The distribution of the vertical wave induced shear forces, F_W in kN, along the ship length is given in Figure 7.2.2.3(3), where,

$$Fw_{Hog}^{Aft} = +5.2 f_R L^2 C C_W \left(\frac{B}{L}\right)^{0.8} \left(0.3 + 0.7 f_{NL-Hog}\right)$$

$$Fw_{Hog}^{Fore} = -5.7 f_R L^2 C C_W \left(\frac{B}{L}\right)^{0.8} f_{NL-Hog}$$

$$Fw_{Sag}^{Aft} = -5.2 f_R L^2 C C_W \left(\frac{B}{L}\right)^{0.8} \left(0.3 + 0.7 f_{NL-Sag}\right)$$

$$Fw_{Sag}^{Fore} = +5.7 f_R L^2 C C_W \left(\frac{B}{L}\right)^{0.8} \left(0.25 + 0.75 f_{NL-Sag}\right)$$

$$Fw^{Mid} = +4.0 f_R L^2 C C_W \left(\frac{B}{L}\right)^{0.8}$$

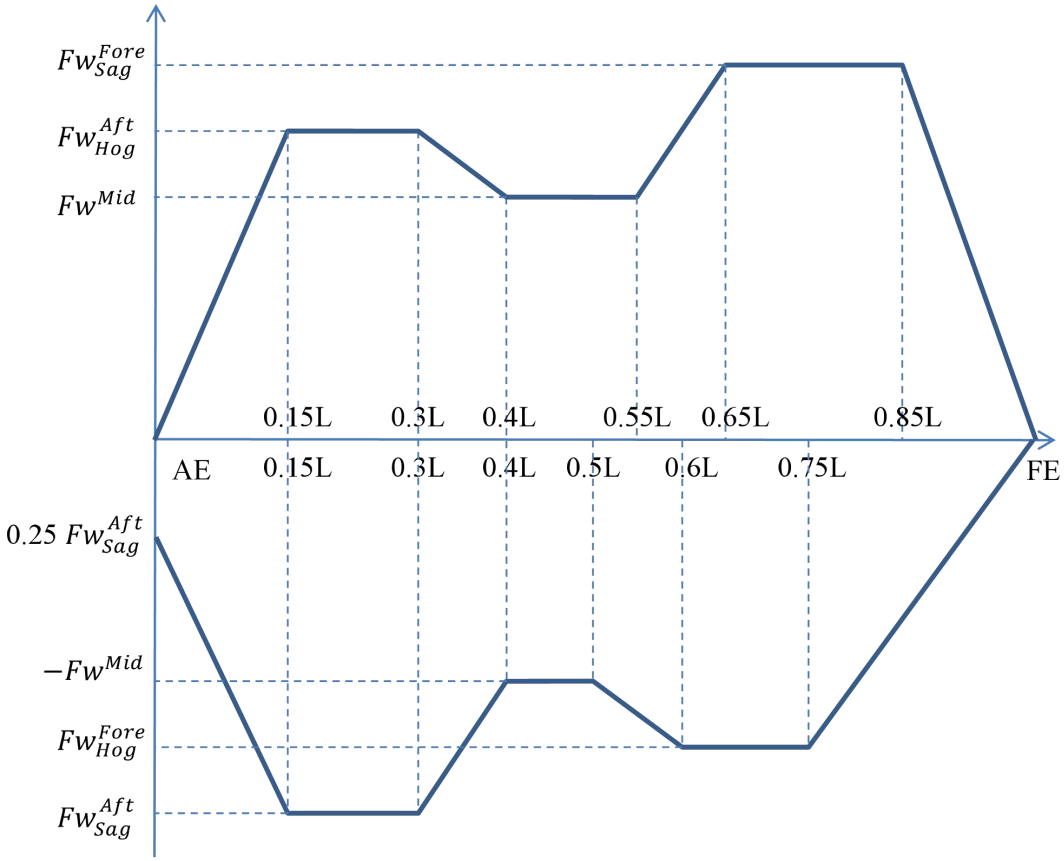


Figure 7.2.2.3(3) Distribution of vertical wave shear force FW along the ship length

7.2.2.4 Load cases

For the strength assessment, the maximum hogging and sagging load cases given in Table 7.2.2.4 are to be checked. For each load case the still water condition at each section as defined in 7.2.2.2 is to be combined with the wave condition as defined in 7.2.2.3, refer also to Figure 7.2.2.4.

Combination of still water and wave bending moments and shear forces Table 7.2.2.4

Load case	Bending moment		Shear force	
	M_S	M_W	F_S	F_W
Hogging	M_{Smax}	M_{WH}	F_{Smax} for $x \leq 0.5L$	F_{Wmax} for $x \leq 0.5L$
			F_{Smin} for $x > 0.5L$	F_{Wmin} for $x > 0.5L$
Sagging	M_{Smin}	M_{WS}	F_{Smin} for $x \leq 0.5L$	F_{Wmin} for $x \leq 0.5L$
			F_{Smax} for $x > 0.5L$	F_{Wmax} for $x > 0.5L$

M_{WH}: Wave bending moment in hogging at the cross section under consideration, to be taken as the positive value of M_W as defined in Figure 7.2.2.3(2).

M_{WS}: Wave bending moment in sagging at the cross section under consideration, to be taken as the negative value of M_W as defined Figure 7.2.2.3(2).

F_{Wmax}: Maximum value of the wave shear force at the cross section under consideration, to be taken as the positive value of F_W as defined Figure 7.2.2.3(3).

F_{Wmin}: Minimum value of the wave shear force at the cross section under consideration, to be taken as the negative value of F_W as defined Figure 7.2.2.3(3).

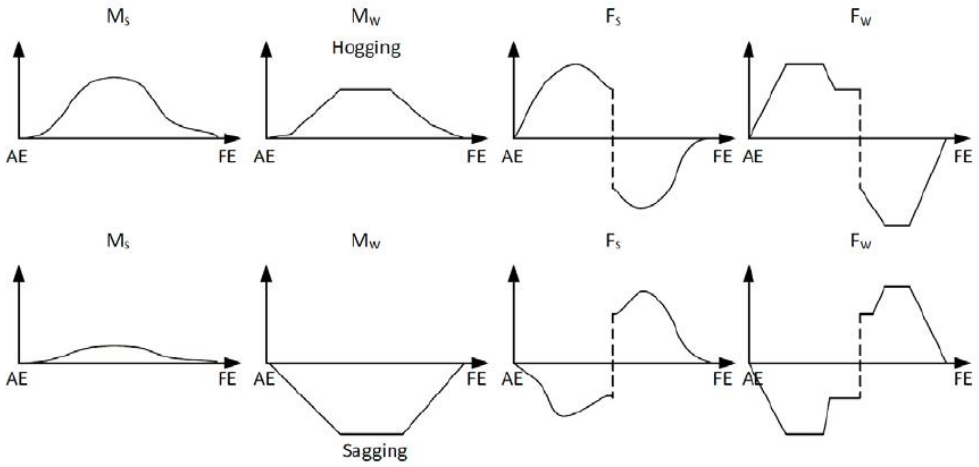


Figure 7.2.2.4 Load combination to determine the maximum hogging and sagging load cases as given in Table 7.2.2.4

7.2.2.5 Hull girder stress

The hull girder stresses, in N/mm^2, are to be determined at the load calculation point under consideration, for the "hogging" and "sagging" load cases defined in 7.2.2.4 as follows:

Bending stress:

$$\sigma_{HG} = \frac{\gamma_S M_S + \gamma_W M_W}{I_{net}}(z - z_n)10^{-3}$$

Shear stress:

$$\tau_{HG} = \frac{\gamma_S F_S + \gamma_W F_W}{t_{net} / q_v}10^3$$

where: γ_S, γ_W — partial safety factor, to be taken as:

$\gamma_S = 1.0$

$\gamma_W = 1.0$

7.2.3 Strength assessment

7.2.3.1 General requirements

Continuity of structure is to be maintained throughout the length of the ship. Where significant changes in structural arrangement occur adequate transitional structure is to be provided.

7.2.3.2 Stiffness criterion

The two load cases "hogging" and "sagging" as listed in 7.2.2.4 are to be checked.

The net moment of inertia, I_{net}, in m^4, is not to be less than:

$$I_{net} \geq 1.55L\left|M_S + M_W\right|10^{-7}$$

7.2.3.3 Yield strength assessment

(1) General acceptance criteria

The yield strength assessment is to check, for each of the load cases "hogging" and "sagging" as defined in 7.2.2.4, that the equivalent hull girder stress σ_{eq}, in N/mm^2, is less than the permissible stress σ_{perm}, in N/mm^2, as follows:

$$\sigma_{eq} < \sigma_{perm}$$

where: $\sigma_{eq} = \sqrt{\sigma_x^2 + 3\tau^2}$

$$\sigma_{perm} = \frac{R_{eH}}{\gamma_1 \gamma_2}$$

γ_1 — partial safety factor for material, to be taken as $\gamma_1 = K\frac{R_{eH}}{235}$;

γ_2 — partial safety factor for load combinations and permissible stress, to be taken as:

- $\gamma_2 = 1.24$, for bending strength assessment according to 7.2.3.3(2);
- $\gamma_2 = 1.13$, for shear stress assessment according to 7.2.3.3(3).

(2) Bending strength assessment

The assessment of the bending stresses is to be carried out according to 7.2.3.3(1) at the following locations of the cross section:

- at bottom;
- at deck;
- at top of hatch coaming;
- at any point where there is a change of steel yield strength.

The following combination of hull girder stress as defined in 7.2.2.5 is to be considered:

$$\sigma_x = \sigma_{HG}$$

$$\tau = 0$$

(3) Shear strength assessment

The assessment of shear stress is to be carried out according to 7.2.3.3(1) for all structural elements that contribute to the shear strength capability①.

The following combination of hull girder stress as defined in 7.2.2.5 is to be considered:

$$\sigma_x = 0$$

$$\tau = \tau_{HG}$$

7.2.4 Buckling strength

7.2.4.1 Application

These requirements apply to plate panels and longitudinal stiffeners subject to hull girder positive bending and shear stresses. For the positive stress acted on plate panels and longitudinal stiffeners induced by hull girder bending, the buckling strength is to be taken into account only when the positive stress is the compression stress.

Definitions of symbols are given in Appendix 4 “Buckling Capacity”.

7.2.4.2 Buckling criteria

The acceptance criterion for the buckling assessment is defined as follows:

$$\eta_{act} \le 1$$

where: η_{act} — maximum utilisation factor as defined in 7.2.4.3.

7.2.4.3 Buckling utilisation factor

The utilisation factor, η_{act} , is defined as the inverse of the stress multiplication factor at failure γ_c, see Figure 7.2.4.3.

$$\eta_{act} = \frac{1}{\gamma_c}$$

Failure limit states are defined in:

- Appendix 4 of this Chapter, 2 for elementary plate panels;
- Appendix 4 of this Chapter, 3 for overall stiffened panels;
- Appendix 4 of this Chapter, 4 for longitudinal stiffeners.

Each failure limit state is defined by an equation, and γ_c is to be determined such that it satisfies the equation.

Figure 7.2.4.3 illustrates how the stress multiplication factor at failure γ_c , of a structural member is determined for any combination of longitudinal and shear stress, where:

σ_x, τ — applied stress combination for buckling given in 7.2.4.4(1);

σ_c, τ_c— critical buckling stresses to be obtained according to Appendix 4 of this Chapter for the stress combination for buckling σ_x and τ.

① Where the shear strength is checked beyond the range of 0.2L to 0.75L, the permissible stress is generally to be in accordance with 7.2.3.3(1).

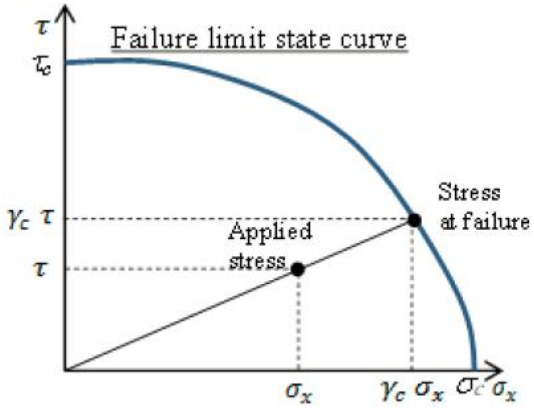


Figure 7.2.4.3 Example of failure limit state curve and stress multiplication factor at failure

7.2.4.4 Stress determination

(1) Stress combinations for buckling assessment

The following two stress combinations are to be considered for each of the load cases "hogging" and "sagging" as defined in 7.2.2.4. The stresses are to be derived at the load calculation points defined in 7.2.4.4(2).

(a) Longitudinal stiffening arrangement:

Stress combination 1 with:

$$\sigma_x = -\sigma_{HG}$$

$$\sigma_y = 0$$

$$\tau = 0.7\tau_{HG}$$

Stress combination 2 with:

$$\sigma_x = -0.7\sigma_{HG}$$

$$\sigma_y = 0$$

$$\tau = \tau_{HG}$$

(b) Transverse stiffening arrangement:

Stress combination 1 with:

$$\sigma_x = 0$$

$$\sigma_y = -\sigma_{HG}$$

$$\tau = 0.7\tau_{HG}$$

Stress combination 2 with:

$$\sigma_x = 0$$

$$\sigma_y = -0.7\sigma_{HG}$$

$$\tau = \tau_{HG}$$

(2) Load calculation points

The hull girder stresses for elementary plate panels (EPP) are to be calculated at the load calculation points defined in Table 7.2.4.4.

Load calculation points (LCP) coordinates for plate buckling assessment

Table 7.2.4.4

LCP coordinates	Hull girder bending stress		Hull girder shear stress
	Non horizontal plating	Horizontal plating	
x ordinate	Middle length of the EPP		
y coordinate	Both upper and lower ends of EPP (points A1 and A2 in Figure 7.2.4.4)	Outboard and inboard ends of EPP (points A1 and A2 in Figure 7.2.4.4)	Middle point of EPP (point B in Figure 7.2.4.4)
z coordinate	Corresponding to *x* and *y* values		

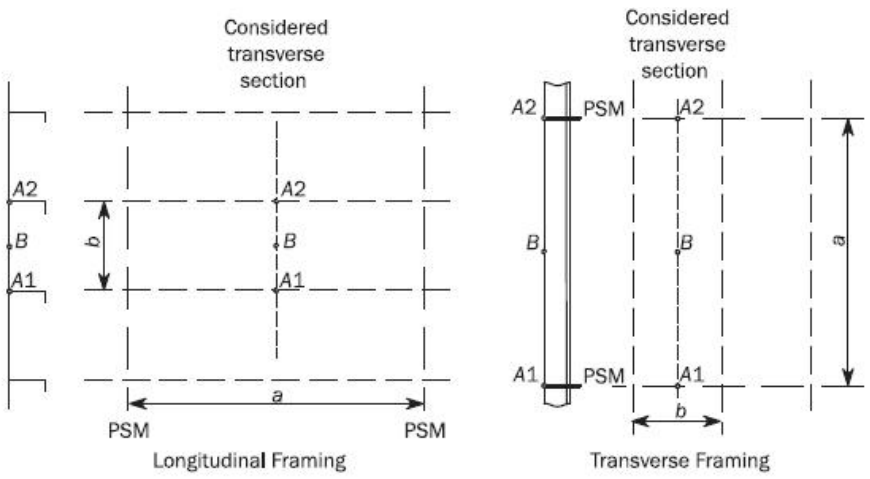


Figure 7.2.4.4 LCP for plate buckling assessment (PSM stands for primary supporting members)

The hull girder stresses for longitudinal stiffeners are to be calculated at the following load calculation point:

- at the mid length of the considered stiffener;
- at the intersection point between the stiffener and its attached plate.

7.2.5 Hull girder ultimate strength

7.2.5.1 General requirements

The hull girder ultimate strength is to be assessed for ships with length L equal to or greater than 150 m.

The acceptance criteria, given in 7.2.5.4 are applicable to intact ship structures.

The hull girder ultimate bending capacity is to be checked for the load cases "hogging" and "sagging" as defined in 7.2.2.4.

7.2.5.2 Hull girder ultimate bending moments

The vertical hull girder bending moment, M in hogging and sagging conditions, to be considered in the ultimate strength check is to be taken as:

$$M = \gamma_S M_S + \gamma_W M_W$$

where: M_s — permissible still water bending moment, in kN·m, defined in 7.2.2.2;

M_w — vertical wave bending moment, in kN·m, defined in 7.2.2.3;

γ_S — partial safety factor for the still water bending moment, to be taken as: γ_S = 1.0;

γ_W — partial safety factor for the vertical wave bending moment, to be taken as:

γ_W = 1.2.

7.2.5.3 Hull girder ultimate bending capacity

(1) General requirements

The hull girder ultimate bending moment capacity, M_U is defined as the maximum bending moment capacity of the hull girder beyond which the hull structure collapses.

(2) Determination of hull girder ultimate bending moment capacity

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment M versus the curvature χ of the transverse section considered (M_{UH} for hogging condition and M_{US} for sagging condition, see Figure 7.2.5.3). The curvature χ is positive for hogging condition and negative for sagging condition.

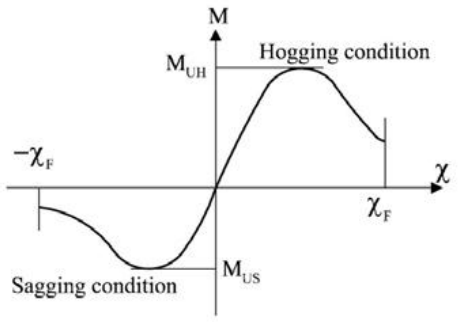


Figure 7.2.5.3 Bending moment M versus curvature χ

The hull girder ultimate bending moment capacity M_U is to be calculated using the incremental-iterative method as given in Appendix 5 of this Chapter or using an alternative method as indicated in Appendix 5.

7.2.5.4 Acceptance criteria

The hull girder ultimate bending capacity at any hull transverse section is to satisfy the following criteria:

$$M \leq \frac{M_U}{\gamma_M \gamma_{DB}}$$

where: M — vertical bending moment, in kN·m, to be obtained as specified in 7.2.5.2

M_U — hull girder ultimate bending capacity, in kN·m, to be obtained as specified in 7.2.5.3;

γ_M — partial safety factor for the hull girder ultimate bending capacity, covering material, geometric and strength prediction uncertainties, to be taken as: γ_M =1.05;

γ_{DB} — partial safety factor for the hull girder ultimate bending moment capacity, covering the effect of double bottom bending, to be taken as:

- for hogging condition: γ_{DB} = 1.15;
- for sagging condition: γ_{DB} = 1.0.

For cross sections where the double bottom breadth of the inner bottom is less than that at amidships or where the double bottom structure differs from that at amidships (e.g. engine room sections), the factor γ_{DB} for hogging condition may be reduced based upon agreement with CCS.

7.2.6 Additional requirements for large container ships

7.2.6.1 General requirements

The requirements of 7.2.6.2 and 7.2.6.3 are applicable, in addition to requirements of 7.2.3 to 7.2.5, to container ships with a breadth B greater than 32.26 m.

7.2.6.2 Yielding and buckling assessment

Yielding and buckling assessments are to be carried out taking into consideration additional hull girder loads (wave torsion, wave horizontal bending and static cargo torque), as well as local loads. All in-plane stress components (i.e. bi-axial and shear stresses) induced by hull girder loads and local loads are to be considered. See 3 of appendix 2 to this Chapter for detailed analysis methods.

7.2.6.3 Whipping

Hull girder ultimate strength assessment is to take into consideration the whipping contribution to the vertical bending moment. For detailed methods, see CCS Guidelines for Direct Calculation Assessment of Hull Structure Including Springing and Whipping.

Section 3 DECK STRUCTURE

7.3.1 General requirements

7.3.1.1 In addition to the requirements of Sections 4 and 8, Chapter 2 of this PART, the scantlings of the deck structure are to comply with the requirements for the longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter.

7.3.1.2 The strength deck throughout the region of container holds is to be longitudinally framed and the scantlings of the structural members of the strength deck determined in accordance with the hull section modulus required in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter are to be kept unchanged over the region of container holds.

7.3.1.3 In order to ensure the hull structural strength, particular attention is to be paid to continuity of the deck structure and abrupt changes of shape, section or plate thickness are to be avoided. Effective transition arrangements are to be fitted at both end structures of the deck opening length. Arrangement in way of hatch corners and openings are to be such as to minimize the creation of stress concentrations.

7.3.1.4 Where the difference between the thicknesses of plating inside and outside the line of strength deck openings exceeds 12 mm, a transition plate with a thickness equal to the mean of the adjacent plate thicknesses is to be fitted.

7.3.1.5 Where the lower deck acts as a primary support for the side framing, the deck plating thickness may be required to be suitably increased.

7.3.2 Cross deck strips

7.3.2.1 Where the cross deck strips of the strength deck form the top of a transverse bulkhead, their breadth b is not to be less than that obtained from the following formula:

$$b = 1000 + 1.5L \quad \text{mm}$$

where: L — length of ship, in m.

7.3.2.2 Where a transverse bulkhead top box is fitted, a reduced width of cross deck strips of the strength deck may be considered by calculation as appropriate.

7.3.2.3 In addition to complying with the requirement of 2.4.2.2, Chapter 2 of this PART, the thickness t of cross deck strips of the strength deck is not to be less than that obtained from the following formula:

$$t = 10 + 0.01L \quad \text{mm}$$

where: L — length of ship, in m.

7.3.2.4 The thickness t of cross deck strips of the second tier deck below the strength deck is not to be less than that obtained from the following formula, but not less than 8 mm:

$$t = 12s \quad \text{mm}$$

where: s — spacing of beams, in m, to be taken as not less than the standard spacing of beams.

7.3.2.5 The thickness of cross deck strips of other decks below the second tier deck may be 8 mm.

7.3.2.6 The cross deck strips are to be sufficiently stiffened in the transverse direction, and the thickness of the strips is to be increased locally in way of stress concentration.

7.3.2.7 The ends of cross deck strips are to be effectively connected to the torsion box structures.

7.3.3 Strength deck girders

7.3.3.1 Girders supporting the longitudinal coaming plating are to be fitted under the strength deck (except where torsion box structures are fitted).

7.3.3.2 The strength deck girders are to be continuous throughout the container hold area, including the engine room where this is situated between container holds.

7.3.3.3 The ends of strength deck girders are to be integrated into the structures outside the container hold area. Special consideration is to be given to the connection of the girders with the transverse box girders.

7.3.4 Deck openings

7.3.4.1 The corners of hatchway openings in the strength deck are to be rounded. The radius of hatch corners near the ship's sides is not to be less than $0.35 + 0.0005L$ m (L being the length of ship, in m), and the radius of hatch corners in way of the intersection of deck girders with cross deck strips is not to be less than 0.25 m. For rounded corners with negative radii, the designer is to provide technical reasons.

7.3.4.2 The radius of the hatch corners of the cargo hatchway openings adjacent to the engine room is to be made as large as practicable, with a radius of approximately $0.04B$ mm (B being the breadth of ship, in m).

7.3.4.3 Insert plates are required at the hatch corners and to have a thickness increased by 15% above that of the strength deck plating. For container holds adjacent to the engine room, such insert plates are to be increased in thickness by 25% above that of the strength deck plating but not less by 4 mm and not more than 7 mm, and they are to be made of the same material as the strength deck. If the thickness of the insert plate can not meet above requirements, direct calculation method covering yield, buckling and fatigue is to be adopted for verification. The extension of the insert plates is to comply with Figure 7.3.4.3 (R is the radius of hatch corner, e is not to be less than 760 mm and for longitudinal framing, not to be less than one longitudinal spacing).

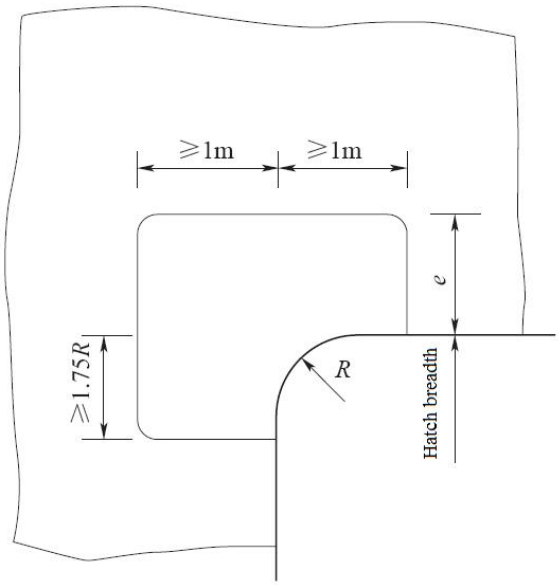


Figure 7.3.4.3

7.3.4.4 Openings are generally not to be arranged in the strength deck outside the line of hatch openings in the region of container holds.

7.3.5 Hatch coamings

7.3.5.1 Where the hatch coaming is to be continuous over the entire opening area, the ends of the coaming are to have an appropriate structural transition.

7.3.5.2 The structure of hatch coamings is to comply with the relevant requirements in Section 20 of Chapter 2 of this PART.

Section 4 SHELL PLATING

7.4.1 Bottom plating and bilge strakes

7.4.1.1 In addition to the requirements of Section 3 of Chapter 2 of this PART, the thickness of bottom plating is to comply with the requirements for longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter.

7.4.1.2 For transversely framed bottom plating and bilge strakes, special attention is to be paid to their buckling strength.

7.4.2 Sheer strake and side shell plating

7.4.2.1 In addition to the relevant requirements of Section 3 of Chapter 2 of this PART, the thickness of sheer strake and side shell plating is to comply with the requirements for longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter. At positions where high forces are present and at positions of the side shell plating where the double side skin structures terminate, local increases in thickness may be required.

7.4.2.2 The difference in thickness between the sheer strake and the shell plating below is not to exceed 1/2 of the thickness of sheer strake.

Section 5 SIDE FRAMING

7.5.1 Single side skin framing

7.5.1.1 The arrangement and the scantlings of side framing are to comply with the requirements of Section 7, Chapter 2 of this PART. CCS may require that direct calculation be carried out for checking the strength of the primary supporting members.

7.5.1.2 Where longitudinal side framing is adopted, the web frames are to be arranged in line with the solid floors in the double bottom and the transverse frames in the torsion box to form a ring system so as to ensure the transverse strength of the ship.

7.5.2 Double side skin framing

7.5.2.1 The minimum plate thickness t of transverse frames and horizontal flats (including perforated flats) within the double side skin construction is not to be less than that obtained from the following formula, but need not be greater than 9 mm:

$$t = 7.5 + 0.015L \quad \text{mm}$$

where: L — length of ship, in m.

7.5.2.2 Transverse frames and horizontal flats are to be fitted with stiffening members and their thickness is to be increased locally where high shear forces are present.

Section 6 DOUBLE BOTTOM

7.6.1 General requirements

7.6.1.1 Unless otherwise stated by this Section, the scantlings of structural members of double bottom are to comply with the relevant provisions of Section 6, Chapter 2 of this PART, but local stiffening is to be required under container corner seatings. Where the double bottom is interconnected with side tanks or deep cofferdams, the watertight floors and watertight girders are to comply with the requirements for deep tanks in Section 13 of Chapter 2 of this PART.

7.6.1.2 The requirements of 2.6.9.2(2), Section 6, Chapter 2 of this PART do not apply to the cargo holds carrying containers only.

7.6.1.3 For container ships of 150 m and over in length, the double bottom structure may comply with the requirements of 7.9.10 of this Chapter, except 7.9.10.12.

7.6.2 Girders and floors

7.6.2.1 Side girders are to be arranged under container corner seatings.

7.6.2.2 Vertical or horizontal stiffeners are to be fitted for girders in region of container holds, the height of stiffener is normally not less than 150 mm. When the length of ship is less than 150 m, the height of stiffener is not to be less than L (mm) but not less than 50 mm.

7.6.2.3 For double bottoms longitudinally framed, solid floors are to be fitted under transverse bulkheads and below mid-hold or quarter-length-of-hold supporting structures.

7.6.2.4 The thickness of solid floors in region of container holds is to comply with the following requirements:

(1) The thickness t of solid floor is not to be less than the value obtained from the following formula, but need not be greater than 12 mm:

$$t = 0.6\sqrt{LK} + 2.5 \quad \text{mm}$$

where: L — length of ship;

K— material factor.

(2) In addition to complying with the requirements of (1) of this paragraph, the thickness t of watertight floors is not to be less than that obtained from the following formula:

$$t = 0.02L\sqrt{K} + 7 \quad \text{mm}$$

where: L and K are defined in (1) of this paragraph.

7.6.2.5 For longitudinally framed containership, the thickness t of the centre girders in region of container holds is not to be less than:

$$t = f_{db}\left(0.0077h_0 + 4\right)\sqrt{K} \quad \text{mm}$$

The thickness t of side girder in region of container holds is not to be less than the value obtained from the following formula:

$$t = f_{db}\left(0.0077h_0 + 1\right)\sqrt{K} \quad \text{mm}$$

where: f_{db} —correction factor of height of double bottom;

$f_{db} = 1$ when L<150m;

$f_{db} = h_0/h_a$ when $L \geq$150m, but not to be less than 0.9; Where the longitudinal girder complies with the requirements for direct calculation of global strength of ship in Appendix 2, $f_{db} = h_0/h_a$ but not to be less than 0.85.

h_0 — considered height of double bottom, in mm, see Section 6 of Chapter 2;

h_a — actual height of double bottom, in mm;

K — material factor.

7.6.2.6 Where container holds are fitted between engine room and aft peak tank, the primary members at bottom are to comply with relevant requirements in Section 6, Chapter 2 of this PART.
7.6.2.7 For double bottom framed longitudinally and fitted with center girders, brackets leading to adjacent longitudinals are to be fitted respectively at both sides of the center girder between the solid floors.
7.6.2.8 Where torsion box center girder is used for double bottom framed longitudinally, the arrangement and the section modulus of web frame ring are to comply with relevant requirements of 7.9.10.6 of Section 9 of this Chapter.

7.6.3 Supporting structure of double bottom

7.6.3.1 Where mid-hold or quarter-length-of-hold supports for the double bottom structure are arranged, these are to take the form of an efficiently stiffened transverse box or other equivalent structures.

Section 7 BULKHEADS

7.7.1 Inner skin longitudinal bulkheads

7.7.1.1 In addition to the relevant requirements of Sections 12 and 13 of Chapter 2 of this PART, the scantlings of inner skin longitudinal bulkheads are to comply with the requirements for longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter.
7.7.1.2 The longitudinal members of inner skin longitudinal bulkheads are to be continuous throughout the container hold area and maintained continuous in way of the machinery space where this is situated between container holds.
7.7.1.3 Where the inner skin bulkheads are stepped, the scarfing arrangements in way of the steps are to be sufficient to ensure an efficient overlap having a length of not less than 3 frame spacings for transition.
7.7.1.4 Adequate transition arrangements are to be fitted at both ends of the inner skin longitudinal bulkhead.
7.7.1.5 The difference in thickness between the top strake and the bulkhead plating below (at the torsion box) is not to exceed 25 mm.

7.7.2 Watertight transverse bulkheads

7.7.2.1 In general, a transverse box structure is to be arranged at the top and bottom of watertight transverse bulkheads. In addition, vertical webs and horizontal girders are to be fitted on the bulkheads to support bulkhead stiffeners. The upper and lower ends of vertical webs are to be aligned with strength deck girders and double bottom side girders respectively. Where the depth to breadth ratio of the bulkhead is large, the scantlings of such vertical webs are to be determined by direct calculation.

Section 8 BOW SIDE STRUCTURE STRENGTHENING

7.8.1 General requirements

7.8.1.1 The bow (including forecastle) side structure is to be strengthened within 0.1L aft of the fore perpendicular above the summer load line. Where the maximum flare angle α at 0.15L from forward perpendicular (see Figure 7.8.1.3(1)) is greater than 40 degrees, the strengthened longitudinal extent is to be extended to 0.15L from forward perpendicular. The scantlings of side members in the strengthened area are to comply with the requirements of this Section.
7.8.1.2 In addition to the requirements of this Section, the bow side structure is to comply with the other relevant requirements in this PART.
7.8.1.3 The bow slamming head h_s under consideration is to be obtained from the following formula:

$$h_s = C_s \left(0.22 + 0.15 \tan\alpha\right)\left(0.4V \sin\beta + 0.6\sqrt{L}\right)^2 \quad \text{m}$$

where: C_s = 0.144 (C – 0.5h_1), and not to be greater than 0.8;
where: h_1 — vertical distance between summer load line and the point under consideration, in m, see Figure 7.8.1.3(1). For shell plating, the point is to be taken at centre of plate panel; for members, the point is to be taken at mid-span;
C — coefficient of wave, see 2.2.3.1 of this PART;
α — flare angle at the point under consideration, defined as angle (°) between vertical line and shell plating tangent in the cross section, see Figure 7.8.1.3(1);

β — entrance angle at the point under consideration, defined as angle (°) between centreline and shell plating tangent in the horizontal plane, see Figure 7.8.1.3(2);
V — maximum service speed, in kn;
L — length of ship, in m, but need not be taken as greater than 250 m.

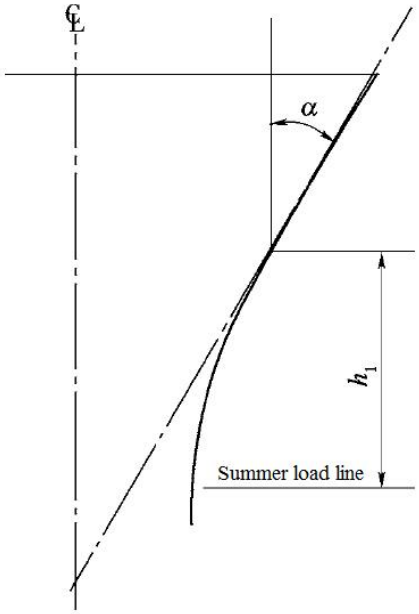


Figure 7.8.1.3(1)

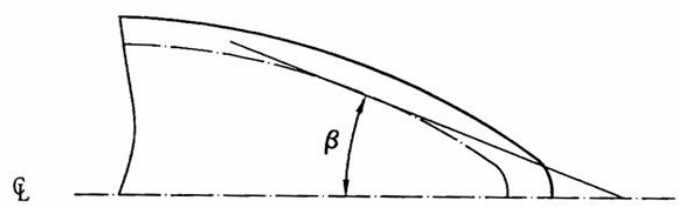


Figure 7.8.1.3(2)

7.8.2 Shell plating

7.8.2.1 The thickness t of shell plating is not to be less than that obtained from the following formula:

$$t = 3.2\, b_{r1}\, s\sqrt{h_s K} + 1.5 \quad \text{mm}$$

where: b_{r1} — coefficient, to be taken from the following, and not to be less than 0.72:

$$b_{r1} = 1.0 \qquad \frac{s}{l} \le 0.4$$

$$b_{r1} = 1.187 - 0.467\frac{s}{l} \qquad \frac{s}{l} > 0.4$$

where: s — spacing of secondary members, in m;
l — span of secondary member, in m;
h_s — bow slamming head under consideration, see 7.8.1.3 of this Section;
K — material factor.

7.8.3 Secondary members

7.8.3.1 The section modulus W and the web sectional area A of secondary members such as side longitudinals or side frames are not to be less than those obtained from the following formulae:

$$W = 2.7 s h_s l^2 K \quad \text{cm}^3$$
$$A = 0.38 b_{r2} l s h_s K \quad \text{cm}^2$$

where: $b_{r2} = 1 - \frac{s}{2l}$;
s — spacing of secondary members, in m;
h_s — bow slamming head under consideration, see 7.8.1.3 of this Section;
l — span of secondary member, in m;

K — material factor.

7.8.3.2 Where the angle between web plating and shell plating of secondary members such as side longitudinals or side frames is less than 70º, tripping brackets are to be provided at mid-span of the members to improve the transverse stability of plate panels.

7.8.4 Primary members

7.8.4.1 The section modulus W and the web sectional area A of primary members such as side horizontal girders or vertical webs are not to be less than those obtained from the following formulae:

$$W = 2.1Sh_s l^2 K \quad \text{cm}^3$$

$$A = 0.265Sh_s l K \quad \text{cm}^2$$

where: S — spacing of girders or webs, in m;

h_s — bow slamming head under consideration, see 7.8.1.3 of this Section;

l — span of girder or web, in m;

K — material factor.

Section 9 ADDITIONAL REQUIREMENTS FOR CONTAINER SHIPS OF GREATER THAN 250 M IN LENGTH

7.9.1 General requirements

7.9.1.1 This Section applies to large full container ships of more than 250 m in length.

7.9.1.2 Those not covered in this Section are to comply with the relevant requirements of Chapters 1 and 2 of this PART.

7.9.1.3 The bow (including forecastle) side structure strengthening is to comply with the requirements of Section 8 of this Chapter.

7.9.2 Longitudinal strength

7.9.2.1 The longitudinal strength is to comply with the requirements of Section 2 of this Chapter.

7.9.3 Deck structure

7.9.3.1 The deck structure is to comply with the relevant requirements of Sections 4 and 8, Chapter 2 of this PART.

7.9.3.2 The primary members of the deck structures in the region of container holds are to be verified by direct calculations.

7.9.3.3 The minimum thickness $t_{\min}$ of strength deck is to be calculated by the following formula:

$$t_{\min} = (0.02L + 5.5)\sqrt{K} \quad \text{mm}$$

where: L — length of ship, in m;

K — material factor.

7.9.3.4 Where the difference between the thicknesses of plating inside and outside the line of strength deck openings is large, two intermediate transition plates are at least to be fitted inside the line of opening. The difference between the thicknesses of adjacent plates, in general not exceeding 1/2 of the thickness of the thicker plate, is to be gradually reduced towards the inside of the line of opening. In general the higher edge of the thicker plate is tapered in way of connections with a ratio not more than 1:4.

7.9.4 Box cross deck structure

7.9.4.1 The box cross deck structure means the transverse box girder structure at the top of transverse bulkheads of container holds.

7.9.4.2 The width and structural scantling of box cross deck structure are to be verified by direct calculations.

7.9.4.3 During the initial design, the width of box cross deck structure may be calculated by the following formula:

$$b = \max(32.5B + 400, 1000) \quad \text{mm}$$

where: B — breadth of ship, in m.

7.9.4.4 In the strength deck plane, the minimum deck thickness of box cross deck structure is to be calculated by the following formula:

$$t = (10 + 0.01L)\sqrt{K} \text{ mm, but not to be less than 12 mm}$$

where: L — length of ship, in m, L need not be taken as greater than 300 m in calculation;

K — material factor.

7.9.4.5 The minimum thickness of bottom plating of box cross deck structure is to be calculated by the following formula:

$$t = 10s\sqrt{K} \quad \text{mm, but not less than 8 mm}$$

where: s — spacing of stiffeners, in m, to be taken not less than 0.95 m in calculation;

K — material factor.

7.9.4.6 The side plating of box cross deck structure (see Figure 7.9.4.6) is to comply with the following requirements:

(1) The thickness t_1 of side plating is not to be less than that obtained from the following formula:

$$t_1 = 12s \quad \text{mm, but not less than 10.5 mm}$$

where: s — spacing of stiffeners of side plating, in m.

(2) The thickness t_2 of the end insert plate is not to be less than that obtained from the following formula:

$$t_2 = 12s \quad \text{mm, but not less than 14.5 mm}$$

where: s — spacing of stiffeners of side plating, in m.

(3) The minimum scope of end insert plate is calculated by the following formulae:

$$a_1 = 1.75R \quad \text{m}$$

$$a_2 = 0.5b_s \quad \text{m}$$

where: R — radius of the hatch corners of the cargo hatchway opening in the strength deck plane, in m;

b_s — width of double side skin, in m.

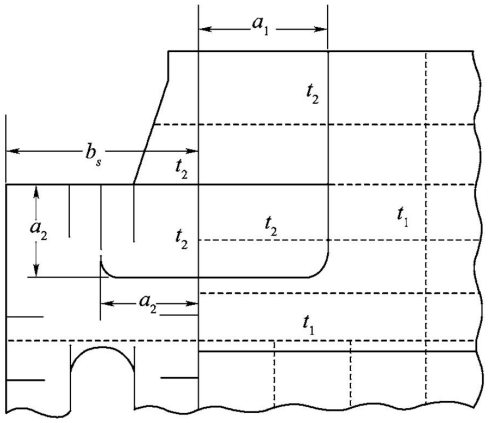


Figure 7.9.4.6

7.9.5 Strength deck openings

7.9.5.1 The corners of hatchway opening in the strength deck are to be rounded or rounded corners with negative radii. The design of hatch corners is to be verified by direct calculations.

7.9.5.2 For rounded corners near the ship's sides, their radius is not to be less than that obtained from the following formula:

$$R = 0.35 + 0.0005L \quad \text{m}$$

where: L — length of ship, in m.

7.9.5.3 The radius of rounded corners in way of the intersection of deck girders with box cross deck structures is not to be less than 0.25 m.

7.9.5.4 For strength deck, insert plates are required at the hatch corners, generally extending to the extent not less than the requirements of Figure 7.9.5.4. The thickness of insert plates is to be greater than or equal to that of adjacent strength deck. The strengthening of the strength deck at the hatch corners is to be verified by means of fatigue assessment.

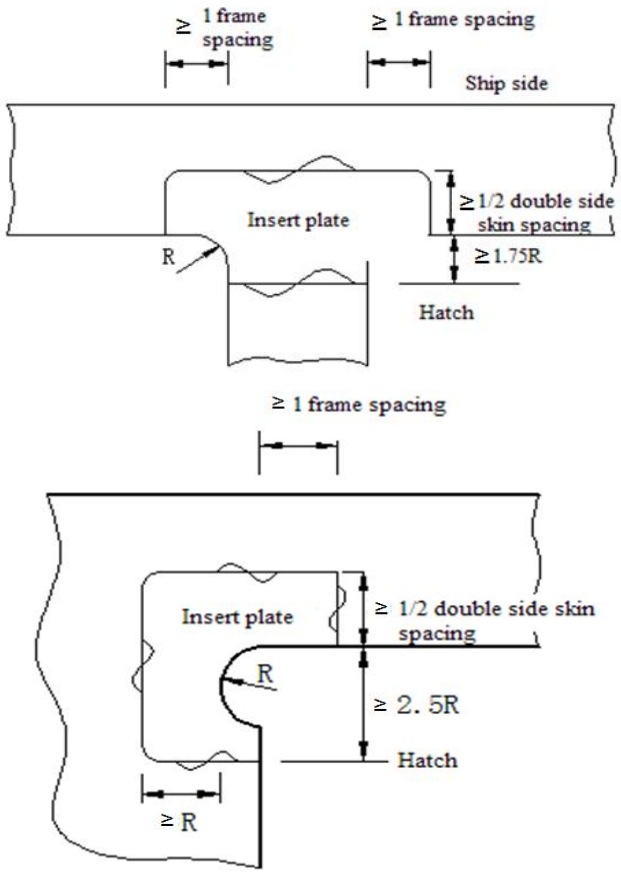


Figure 7.9.5.4

7.9.5.5 Large access openings are generally not to be arranged in the strength deck outside the line of hatch openings in the region of container holds.

7.9.5.6 Small openings, such as those for ventilation pipes or scuppers, are to be kept clear of hatch corners, ends of longitudinal hatch coamings, ends of box cross deck structures and other locations of stress concentration.

7.9.6 Hatch coamings of container hold

7.9.6.1 The hatch coaming is to be continuous over the entire opening area except for the engine room area. The ends of the coaming are to have an appropriate structural transition.

7.9.6.2 The structure of coaming is to comply with relevant requirements of Section 20 of Chapter 2 of this PART.

7.9.6.3 Hatch coamings are to be provided with brackets spaced not more than 3.15 m apart, and they are also to be provided with face plates. However, the spacing between brackets is not to exceed 6.3 m upon direct strength calculation. The brackets of hatch coamings are to be capable of effectively supporting the face plates. The toe ends of brackets are to terminate at the strength deck longitudinals. Brackets of hatch coamings in way of box cross deck structures are also to comply with 7.9.4.6 of this Section.

7.9.6.4 For face plates of hatch coamings, insert plates are required at the hatch corners, and the scope is shown in Figure 7.9.6.4. The thickness of insert plates is to be greater than or equal to that of adjacent face plates of hatch coamings. The strengthening of face plates of hatch coamings at hatch corners is to be verified by means of fatigue assessment.

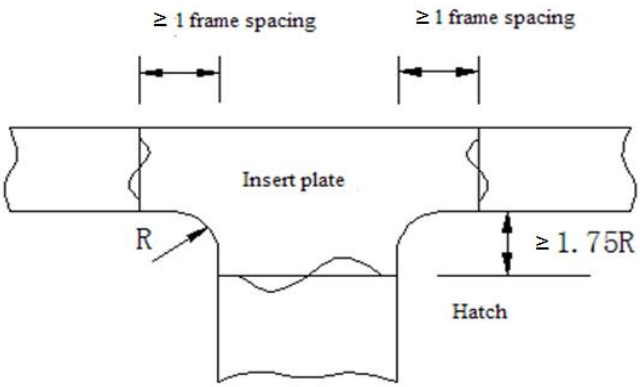


Figure 7.9.6.4

7.9.7 Shell plating

7.9.7.1 Except where stated by this Section, the shell plating is to comply with relevant requirements of Section 3, Chapter 2 of this PART.

7.9.7.2 In addition to 7.9.7.1 of this Section, the thickness of shell plating is not to be less than that obtained from the following formula:

$$t = \sqrt{LK} \quad \text{mm, but need not be greater than 16 mm}$$

where: L — length of ship, in m;

K — material factor.

7.9.7.3 The difference in thickness between the sheer strake and the adjacent shell plating is in general not to exceed 1/2 of the thickness of the thicker plate. In general the higher edge of the thicker plate is tapered in way of connections with a ratio not more than 1:4.

7.9.8 Structural arrangement of double side skin construction

7.9.8.1 Double side skins are to be fitted throughout the container hold area. The inner skin structure is to extend as far forward and aft as possible and effectively connected with the structures in way with adequate transition arrangements. The supporting members of inner skin are to be fitted in the double side skin, instead of in the container hold.

7.9.8.2 The inner skin is to be of continuous construction, and also maintained continuous in way of the engine room area. The inner skin may be stepped along the ship's length, considering the change of lines and arrangement of container bays. The scarfing arrangements in way of the steps are to be sufficient to ensure an efficient overlap of inner skin bulkheads having a length of not less than 3 frame spacings for transition.

7.9.8.3 Considering the change of lines and arrangement of container bays, the inner skin may be stepped horizontally in the vertical direction.

7.9.8.4 A transverse ring structure or vertical web is to be provided in line with the transverse watertight bulkheads of container holds in the double side skin. Watertight vertical webs are to be provided as far as practicable below the freeboard deck. Wash bulkheads are to be provided for ballast tanks.

7.9.8.5 A transverse ring structure or vertical web is to be provided in line with the transverse non-watertight pillar bulkheads of container holds in the double side skin.

7.9.8.6 A transverse ring structure or vertical web in the double side skin is to be provided in line with the floors in the double bottom.

7.9.8.7 Manholes are to be provided in vertical webs and horizontal girders. The manholes may either be round or elliptical. The long axis of elliptical manholes is to be vertical or along the length of the ship. Except for access openings, the holes on upper and lower adjacent horizontal girders are not to be on the same vertical line. The edge around the holes is to be strengthened.

7.9.9 Scantling of double side skin construction

7.9.9.1 The primary members of double side skin construction include side shell platings, vertical transverse webs, horizontal flats, inner skin longitudinal bulkhead platings. The scantling of primary members is to be verified by direct calculations.

7.9.9.2 The inner skin plating is to comply with the following requirements:

(1) The minimum thickness t of inner skin plating is to be calculated by the following formula:

$$t = 7 + 0.02L\sqrt{K} \quad \text{mm}$$

where: L — length of ship, in m, L need not be taken as greater than 300 m in calculation;
K — material factor.

(2) The inner skin plating is to comply with the requirements of 7.9.11.4 of this Section.

(3) The thickness t of inner skin plating forming boundary of tanks within 0.4 L amidships is, in addition to complying with the requirement of (4), not to be less than:

$$t = (4 + 0.6\frac{z - z_n}{D - z_n})s\sqrt{hK} + 2.5 \quad \text{mm, above the horizontal neutral axis}$$

$$t = \left(4 + 0.2\frac{z_n - z}{z_n}\right)s\sqrt{F_b hK} + 2.5 \quad \text{mm, below the horizontal neutral axis}$$

where: s — spacing of stiffeners, in m;
h — vertical distance, in m, measured from a third of the height from the lower edge of the plate in a strake to the top of the tank, or half the distance to the top of overflow, whichever is the greater;
D — moulded depth, in m;
Z_n — the height of horizontal neutral axis, from base line, of hull cross section, in m;
Z — the height of calculation point from base line, in m;
F_b — reduction factor, see 2.2.5.6, Chapter 2 of this PART;
K — material factor.

(4) The thickness t of inner skin plating forming boundary of tanks is not to be less than:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;
h — vertical distance, in m, measured from a third of the height from the lower edge of the plate in a strake to the top of the tank, or half the distance to the top of overflow, whichever is the greater;
K — material factor.

(5) The difference in thickness between the top strake of inner skin and the strake below is in general not to exceed 25 mm, and the maximum difference in thickness is not to exceed 35 mm. In general the higher edge of the thicker plate is tapered in way of connections with a ratio not more than 1:4.

7.9.9.3 Longitudinals (ship's side, inner skin) are to comply with relevant requirements of Chapter 2 of this PART. The minimum thickness of webs of longitudinals is 10 mm. Longitudinals are to penetrate continuously vertical transverse webs. Where side longitudinals are determined according to 2.7.5.1, Chapter 2 of this PART, the calculated pressure head h is to be obtained from following formulae:

$$h = 0.26C + d - \frac{Z}{D_F}d \quad \text{m, if } Z<D_F$$

$$h = 0.2C + 0.06C\frac{D - Z}{D - D_F} \quad \text{m, if } Z\geq D_F$$

where: D — moulded depth, in m;
D_F — minimum moulded depth, in m, in the middle of ship length, vertical distance from upper edge of flat keel to upper edge of side freeboard deck beam;
d — draught, in m;
C — coefficient, see 2.2.3.1, Chapter 2 of this PART;
Z— height of longitudinal to baseline, in m.

7.9.9.4 The thickness t of vertical transverse webs and horizontal flats forming boundary of tank is not to be less than:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;
h — vertical distance, in m, measured from a third of the height from the lower edge of the plate in a strake to the top of the tank, or half the distance to the top of overflow, whichever is the greater;
K — material factor.

The minimum thickness of vertical transverse webs and horizontal flats is to be 10 mm. The minimum thickness of watertight flats is 11 mm.

7.9.10 Double bottom

7.9.10.1 Except where stated by this Section, the double bottom structure is to comply with the relevant requirements of Section 6, Chapter 2 of this PART.

7.9.10.2 The primary members of double bottom include inner bottom platings, solid floors, girders and bottom platings. The scantlings and arrangements of primary members are to be verified by direct calculations.

7.9.10.3 Where mid-hold or quarter-length-of-hold supports for the double bottom structure are arranged, these are to take the form of an efficiently stiffened transverse box or open section structure.

7.9.10.4 The side plates of the duct keel are in general not to be spaced more than 2 m apart; However, where the direct strength assessment has been carried out, the maximum spacing between the side pates are not to be greater than 3 m.

7.9.10.5 Bottom and inner bottom longitudinals are to be fitted within the region of duct keels. The longitudinals are to be maintained continuous. The bottom longitudinals at the center line of the ship are to be suitably increased in scantling.

7.9.10.6 A strength frame ring is to be provided to the duct keel in the plane of solid floors and the middle of spacing of solid floors. For transverse girders of inner bottom in the strength frame ring, their section modulus is not to be less than 85% of those of ship's bottom. The section modulus W of transverse girders of ship's bottom is not to be less than that obtained from the following formula:

$$W = 10.6Sdl^2K \quad \text{cm}^3$$

where: S — spacing of the strength frame ring, in m;
d — draught, in m, to be taken not less than 0.66 times the vertical distance from the ship's bottom to the freeboard deck;
l — span, in m, to be taken as the spacing between two side plates;
K — material factor.

7.9.10.7 At least three side girders spaced apart generally not more than 3.5 m are to be fitted on each side of the centreline. Forward of 0.2L from the F.P., the spacing of side girders is not to be greater than 4 longitudinal spaces. Side girders are to be equally spaced and extend forward and aft as far as practicable.

7.9.10.8 Side girders are to be arranged and local stiffening is to be required under container corner seatings.

7.9.10.9 Solid floors in the region of container holds are to comply with the following requirements:

(1) Solid floors are to be fitted under transverse watertight bulkheads, transverse non-watertight pillar bulkheads/mid-hold supports, under container corners at hold quarter length locations and at other locations. Solid floors are in general to be spaced not more than 3.6 m apart.

(2) The thickness t of solid floors is to comply with relevant requirements of Section 6 of this Chapter and not to be less than that obtained from the following formula:

$$t = 10s\sqrt{\frac{R_{eH}}{235}} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;
R_{eH} — yield stress of the material, in N/mm^2.

(3) In addition to complying with the requirements of (2) of this paragraph, the thickness t of watertight floors is to comply with relevant requirements of Section 6 of this Chapter.

7.9.10.10 The thickness t of inner bottom plating of container holds is not to be less than that obtained from the following formula:

$$t = 1.36(s + 0.66)\sqrt[4]{LdK^2} \quad \text{mm}$$

where: L — length of ship, in m;
d — draught, in m;
s — spacing of longitudinals, in m;
K — material factor.

The thickness t of inner bottom plating of container holds forming boundary of tanks is also to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART.

7.9.10.11 The section modulus W of inner bottom longitudinals of container holds is not to be less than that obtained from the following formula:

$$W = \frac{9.54dsl^2K}{2.1 - F_b} \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
l — span of longitudinals, in m;
d — draught, in m;

F_b — reduction factor at calculation point;
K — material factor.

7.9.10.12 Strengthening of bottom forward is to comply with the relevant requirements of 2.15.3 of Section 15, Chapter 2 of this PART. In the strengthening region, for the strengthening of double bottom framed longitudinally, 2.15.3.3(1) of Section 15, Chapter 2 of this PART may not be required, but the spacing of plate floors is not to exceed 3.2 m or 4 times the spacing of longitudinals (whichever is the greater).

7.9.10.13 The thickness of center girders and side girders in region of container holds and the arrangement of supporting bracket of center girders are to comply with relevant requirements of Section 6 of this Chapter.

7.9.11 Transverse bulkhead of container hold

7.9.11.1 The primary members of transverse bulkhead include bulkhead platings, vertical webs and horizontal girders. The scantling of primary members is to be verified by direct calculations.

7.9.11.2 The web thickness t of girders of transverse bulkhead is not to be less than that obtained from the following formula:

$$t = 10s\sqrt{\frac{R_{eH}}{235}} + 0.5 \quad \text{mm , and not less than 9 mm}$$

where: s — spacing of web stiffeners, in m;
R_{eH} — yield stress of the material, in N/mm^2.

7.9.11.3 In general, a transverse box structure is to be arranged at the top and bottom of watertight transverse bulkheads. In addition, vertical webs and horizontal girders are to be fitted on the bulkheads to support bulkhead stiffeners. The upper and lower ends of vertical webs are to be aligned with strength deck girders and double bottom side girders respectively.

7.9.11.4 The scantlings of watertight transverse bulkhead platings and stiffeners are to be determined in accordance with the requirements of Section 12, Chapter 2 of this PART. The design head h is to be determined in accordance with the following requirements:

(1) For watertight transverse bulkhead platings, the design head h is to be determined in accordance with the following requirements (whichever is the greatest):

① vertical distance measured from the lower edge of the plate in a strake to the deepest equilibrium waterline obtained from the applicable damage stability calculations;

② vertical distance measured from the lower edge of the plate in a strake to the freeboard deck;

③ 2.5 m.

(2) For stiffeners, the design head h is to be determined in accordance with the following requirements (whichever is the greatest):

① vertical distance measured from the mid-span of stiffeners to the deepest equilibrium waterline obtained from the applicable damage stability calculations;

② vertical distance measured from the mid-span of stiffeners to the freeboard deck;

③ 2 m.

7.9.11.5 The minimum thickness of watertight transverse bulkhead platings is 8 mm.

7.9.11.6 One non-watertight transverse pillar bulkhead is to be fitted at every two 20 feet container bays along the ship's length in the container hold. The non-watertight transverse pillar bulkhead generally consists of vertical webs and horizontal girders.

7.9.12 Design verification

7.9.12.1 Except where otherwise stated, the design verification is not to lower the requirements for hull structures of this Section. The design verification of hull structures includes:

(1) direct calculation of strength assessment;

(2) fatigue strength assessment.

7.9.12.2 Direct calculations are to be carried out for strength assessment of the whole ship, primary structures of cargo holds and local structure of deck hatch corner under specified loads in accordance with Appendix 2 of this Chapter.

7.9.12.3 Fatigue strength assessment is to be carried out to the container hold structures in accordance with CCS Guidelines for Fatigue Strength of Ship Structure.

Section 10 LONGITUDINAL STRENGTH OF COMBINED BENDING AND TORSIONAL MOMENTS FOR SHIPS WITH LARGE OPENINGS

7.10.1 General requirements

7.10.1.1 For ships with large openings on deck, the longitudinal strength of combined bending and torsional moments is to be checked by the following:

(1) for length $L \leq 250$ m, the method defined in this Section or the method defined in (2);

(2) for length $L > 250$ m, the direct strength calculation of whole ship defined in Appendix 2;

7.10.1.2 Stresses are to be calculated for at least seven transverse sections in the cargo area as follows:

(1) at the forward end of the engine room;

(2) at the forward end of the opening length, opening length being the distance from the aft end of the cargo hatch before the engine room to the forward end of the foremost cargo hatch;

(3) at five intermediate sections within the opening length, at least three of which are to be within 0.4L amidships. The intermediate sections are to be arranged as far as possible in way of abrupt changes of longitudinal structures.

7.10.1.3 In addition, the stresses at transverse sections in way of abrupt changes of any other longitudinal structures beyond the requirements of 7.10.1.2 of this Section are to be calculated.

7.10.2 Wave bending moment

7.10.2.1 The vertical wave bending moment M_v is to be calculated by the following formula:

$$M_v = 9.81MKFL^2B(C_b + 0.7)\times 10^{-2} \qquad \text{kN·m}$$

where: L — length of ship, in m;

B — breadth of ship, in m;

M — distribution factor of bending moment, see 2.2.3.1 of Section 2, Chapter 2 of this PART;

C_b — block coefficient, taken as 0.6 for actual C_b less than 0.6;

$$K = 4.47(\frac{L}{1000} - 0.230)^2 + 0.817$$

F—factor, obtained from the following formulae:

$F = 9.4 - 0.95(\frac{300 - \mathrm{L}}{100})^{3/2}$, for $L \leq 300$ m;

$F = 9.4$, for $300 < L < 350$ m;

$F = 9.4 - 0.45(\frac{\mathrm{L} - 350}{100})^{3/2}$, for $350 \leq L \leq 500$ m.

7.10.2.2 The midship horizontal wave bending moment M_H is to be calculated by the following formula:

$$M_H = 0.431L^2B \qquad \text{kN·m}$$

where: L, B — see 7.10.2.1 of this Section.

M_H is equal to zero at ends, and the distribution of M_H along the length of the ship is to follow a straight line.

7.10.3 Torque

7.10.3.1 The hydrodynamic torque $M_T(x)$ at any cross section along the length of the ship is to be calculated by the following formula:

$$M_T(x) = 9.81e^{-0.00295L}\frac{LB^3C_T}{20000}(1.75 + 1.5\frac{\varepsilon}{D})(1 - \cos\frac{2\pi}{L}x) \quad \text{kN·m}$$

where: e — base of natural logarithms;

L — length of ship, in m;

B — breadth of ship, in m;

D — moulded depth, in m;

$C_T = 13.2 - 43.4C_W + 78.9{C_W}^2$;

where: C_w — the water plane area coefficient, need not be greater than $0.165 + 0.95C_b$;

ε — the distance measured from the shear centre below the baseline of the ship to the baseline, in m;

x — distance from any one cross-section to A.P., in m;

C_b — block coefficient, see 7.10.2.1 of this Section.

7.10.3.2 Cargo torque is caused by the uneven transverse distribution of cargoes, consumables or ballast. Unless any other loading case is specified, the cargo torque M_{TC} amidships is to be calculated by the following formula:

$$M_{TC} = 15.7Bn_Bn_t \quad \text{kN·m}$$

where: B — breadth of ship, in m;

n_B — number of stacks of containers in cargo holds amidships along the breadth of ship;

n_t — number of tiers of containers in cargo holds amidships, excluding the containers on deck and on hatch covers.

M_{TC} is equal to zero at ends and the distribution of M_{TC} along the length of the ship is to follow a straight line.

7.10.4 Stress calculation and criteria

7.10.4.1 The still water bending stresses σ_s is to be calculated by the following formula:

$$\sigma_s = \frac{M_s}{W_V} \times 10^3 \quad \text{N/mm}^2$$

where: M_s — permissible still water bending moment, in kN·m;

W_V — vertical bending section modulus at deck or bottom, in cm³, to be calculated in accordance with the relevant requirements of Section 2, Chapter 2 of this PART.

The permissible still water bending stress $[\sigma_s]$ at strength deck and keel is $88/K$, in N/mm², where K is material factor.

7.10.4.2 The combined vertical bending stress σ_c for ships under the heading wave condition is to be calculated by the following formula:

$$\sigma_c = \frac{M_s + M_V}{W_V} \times 10^3 \quad \text{N/mm}^2$$

where: M_s, W_v — same as defined in 7.10.4.1 of this Section;

M_V — vertical wave bending moment, in kN·m, see 7.10.2.1 of this Section.

The permissible combined vertical bending stress $[\sigma_c]$ is $157/K$ at the strength deck, in N/mm² and $150/K$ at the keel, in N/mm², where K is referred to 7.10.4.1.

7.10.4.3 The combined stress for ships under the oblique sea condition is to be the sum of the following stresses:

(1) The combined vertical bending stress σ_c is to be determined by the following formula:

$$\sigma_c = \frac{M_s + 0.6M_V}{W_V} \times 10^3 \quad \text{N/mm}^2$$

where: M_s, W_v — same as defined in 7.10.4.1 of this Section;

M_V — see 7.10.2.1 of this Section.

(2) The horizontal bending stress σ_H is to be determined by the following formula:

$$\sigma_H = \frac{yM_H}{I_H} \times 10^5 \quad \text{N/mm}^2$$

where: M_H — horizontal wave bending moment, in kN·m, see 7.10.2.2 of this Section;

y — horizontal distance from the point under consideration to centreline of the transverse section, in m;

I_H — horizontal moment of inertia, in cm⁴.

(3) The warping stress due to the hydrodynamic torque M_T and cargo torque M_{TC}.

The permissible combined stresses at strength deck and bottom is $157/K$, in N/mm², where K is referred to 7.10.4.1.

Appendix 1 CONTAINER SECURING

1 General Requirements

1.1 Application

1.1.1 Container stowage and securing requirements in this Appendix are based on containers manufactured in compliance with ISO 1496-1:2013.

This Appendix sets forth the survey requirements for the initial installation of container securing systems aboard vessels classed by CCS. It is to be clearly understood that no representation is made as to the ability of any container to withstand the loads allowed. The allowable loads have been derived from successful usage over a number of years and may exceed the design loads set forth in ISO Standard. It is the responsibility of the shipowner, or operator to ascertain that the containers used in the system can withstand the loads applied to them.

1.1.2 External dimensions, rated weights and corner fitting locations for common freight containers are given in Table 1.1.2.

External Dimensions, Rated Weights and Corner Fitting Locations for Common Freight Containers①

Table 1.1.2

Nominal Size	Container Designation	Length (mm)	Width (mm)	Height (mm)	Dimensions Center to Center of Corner Fittings(longitudinal) (mm)	Dimensions Center to Center of Corner Fittings(transverse)(mm)	Rated Weight (kg)
20 ft ISO668	1CC	6058	2438	2591	5853	2259	30480 (24000)②
	1C			2438			
	1CX			<2438			
40 ft ISO668	1AAA	12192	2438	2896	11985	2259	30480
	1AA			2591			
	1A			2438			
	1AX			<2438			
45 ft ISO668	1EEE	13716	2438	2896	11985 13509	2259	30480
	1EE			2591			
43 ft		13103	2438	2591	11985	2259	30480
48 ft		14630	2591	2908	11985 14422	2259	30480
53 ft		16154	2591	2908	11985 15947	2259	30480

Notes: ① The statistics of containers of ISO standard in the Table are determined according to ISO 668:2013.

② The rated weight for containers of 20 ft manufactured in accordance with the previous version of Amd 1:2005 of ISO 668:1995 is 24,000 kg. In the design of securing system, the recommended weights of empty containers are as follows:

20 ft container	2.5 t
40 ft container	3.5 t
43 ft and 45 ft container	4.0 t
48 ft and 53 ft container	4.5 t

1.2 Class notation

1.2.1 Ships other than container ships, fitted with container securing arrangements complying with the requirements of 1 to 5 of this Appendix, will be assigned the class notation “Equipped with Container Securing Arrangements”.

1.2.2 Where the ship has onboard container lashing program which has the ability to evaluate the safety of container stowage and lashing arrangement according to the requirements of 1 to 4 of this Appendix, and the lashing program is installed and maintained in accordance with the requirements of 6 of this Appendix, the notation CLC may be assigned upon application by the shipowner.

1.2.3 In addition to the requirements for CLC, the notation CLC(V) may be assigned, taking into account of the requirements for specific routes in 7.1 of this Appendix.

1.2.4 In addition to the requirements for CLC(V), the notation CLC(V,W) may be assigned, taking into account of the seasons and weather factors of specific routes in 7.2 of this Appendix.

1.3 Plans and documents

1.3.1 The following plans and documents are to be submitted for approval:
(1) General arrangement plan showing the disposition and design weights of the containers;
(2) Details of the cell guide structure, where fitted;
(3) Plans of lashing bridges, where fitted;
(4) Plans of stanchions on the deck, where fitted;
(5) Plans of securing arrangements of containers not associated with cell guides, where fitted;
(6) Details of securing devices (fixed and portable equipment, including safe working load);
(7) Arrangement plan of fixed securing devices and plan of hull supporting structure;
(8) Container securing manual/arrangement plan (container securing manual/arrangement plan approved by CCS is to be kept on board).

1.4 Limitation on ship handling

Improper ship handling related to course and speed or threshold phenomena like parametric rolling can create adverse loads acting on the ship and the cargo which are in excess of the loads determined on the basis of 4 of this Appendix. It is the responsibility of the master to apply good seamanship in order to mitigate excessive ship motions to reduce loads acting on the cargo stowage arrangements.

1.5 Definitions

1.5.1 **Bay**: An indication of the longitudinal position of a stack on ship. An athwartship block of containers associated with a hatch or hatch cover containing multiple stacks (or rows).
1.5.2 **Cell Guides**: A rigid securing system of vertical steel angles, spaced with some margin on container length and width that provides alignment and horizontal restraint for container stacks.
1.5.3 **Container Block**: A number of container stacks interconnected by double cones and/or bridge fittings.
1.5.4 **Container Stac**k: A single vertical stack of containers which may be secured by lock fittings, lock fittings plus lashings, or cell guides.
1.5.5 **Corner Fittin**g: A fixture, typically a casting, consisting of standard apertures and faces, which provide a common interface for handling and securing containers. It is an integral part of the container end frame structure and is generally in compliance with ISO Standard 1161. A similar fitting can also be found at intermediate posts located some distance from the end frame structure (such as at the 40-ft location on a 45-ft container).
1.5.6 **Corner Post**: Reinforced vertical structure between the corner fittings at the ends of containers designed to take the compressive and tensile forces exerted by lifting, stacking, and securing. Some containers also have intermediate 'corner' posts located some distance in from their ends at a nominal 40-ft spacing.
1.5.7 **Design Breaking Load**: The design breaking load of a component is determined by prototype testing. The design breaking load is not to be more than the last load recorded during the test prior to failure.
1.5.8 **Design GM Value**: The *GM* values used in the lashing calculations of containers are determined by the designer and specified in the container securing manual/arrangement plan. At least the minimum value and the maximum value are to be included. The minimum value is not to be less than the *GM* value in the condition where the maximum number of containers is loaded and the maximum value is not to be less than the maximum value of all expected container loading conditions. In the initial design, the minimum design *GM* value may be taken as 0.025*B*, and the maximum design *GM* value may be taken as 0.075*B,* where *B* is the breadth of the ship.
1.5.9 **ISO Freight Container**: Containers meeting the design dimensions and rated weights of ISO container standards such as:
ISO 1496-1 Series 1 freight containers
ISO 668 External dimensions and ratings
ISO 1161 Corner fittings and specifications
1.5.10 **Lashing Assembly**: A tension element made-up of a rod, wire rope or chain, a tensioning device, and a lashing point; used to secure a stack of containers.
1.5.11 **Lashing Point**: Fittings welded to the deck, hatch cover, stanchion, and lashing bridge, connecting lashing devices to the vessel structure or hatch covers. These include D-rings, lashing eyes plates, etc.
1.5.12 **Lashing Bridge**: An athwartship, elevated platform on deck from which container stacks on the hatch covers or deck may be secured with lashing assemblies.
1.5.13 **Safe Working Load (SWL)**: The SWL of a securing device is the design breaking load divided by an appropriate safety factor. The maximum resultant load upon a component is not to exceed the SWL.
1.5.14 **Proof Load**: A test load applied to a container securing device during production testing. The

minimum proof load is to be determined according to Table 2.2.1.
1.5.15 **Row/Stack**: An indication of the transverse position of a container in a stack.
1.5.16 **Racking**: Distortion of the container end or side due to horizontal forces.
1.5.17 **Securing Devices**: The general name of all fixed and portable devices used to secure and support containers.
1.5.18 **Tier**: An indication of the vertical position of a container in a stack. The first tier is the lowest position in the stack.
1.5.19 **Turnbuckle**: A specific type of Tensioning Device, used to connect the lashing rod and the lashing point.
1.5.20 **Twist lock**: A fitting inserted into corner fittings and used to secure containers stacked on top of each other in tension, compression, and shear.

1.6 Special Requirements
1.6.1 For containers not covered by ISO Standard 1496-1 as well as special ways of containers arrangement, the securing of such containers is to be considered according to the parameters and allowable loads as specified in 4.8 of this Appendix.

2 Materials and Testing

2.1 Materials
2.1.1 Steels used for the construction of the cell guides and the fixed securing devices attached to the hull are to comply with the relevant requirements of CCS Rules for Materials and Welding.

2.2 Prototype testing
2.2.1 Except for cell guides, prototype tests are to be carried out to determine the breaking loads of securing devices. The testing is to be carried out on at least two randomly selected samples of each item. The relationship between design breaking load and safe working load is to be as indicated in Table 2.2.1. No permanent deformation (other than that due to initial embedding of component parts) is to be induced by test loads up to the proof load given in the Table.

Design Breaking Loads and Proof Loads

Table 2.2.1

Item	Min. design breaking load (kN)		Min. proof load (kN)	
	$SWL \leq 400$	$SWL > 400$	$SWL \leq 400$	$SWL > 400$
Lashings:				
Wire rope	$3 \times SWL$			
Rod (higher tensile steel)	$2 \times SWL$		$1.5 \times SWL$	
Chain (mild steel)	$3 \times SWL$			
Chain (higher tensile steel)	$2.5 \times SWL$			
Other securing devices	$2 \times SWL$	$SWL + 400$	$1.5 \times SWL$	SWL + 200

Notes: ① The yield stress of higher tensile steel is not to be less than 315 N/mm^2.
② Breaking and proof loads for lashings of material other than steel will be specially considered.
③ *SWL* means the safe working load, in kN.

2.2.2 Where one of the two test samples fails before the design breaking load is reached, an additional sample is to be tested. The prototype testing may be accepted provided that the following conditions are met:
(1) The failure load is not less than 95% of the design breaking load;
(2) An additional sample is tested satisfactorily;
(3) The average failure load of the three samples, taking the additional sample into account, is not less than the design breaking load.
2.2.3 Securing devices may be tested in accordance with Table 2.2.3.

Test Mode

Table 2.2.3

Securing device	Test mode	Recommended minimum value (kN)		
		SWL	Proof load	Breaking load
Lashing rod (higher tensile steel)		180	270	360
Lashing rod		250	375	500
Lashing chain (higher tensile steel)		80	—	200
Lashing chain		100	—	300
Lashing wire		120	—	360
Turnbuckle		250	375	500
Twist lock		200	300	400
		250	375	500
Cone		200	300	400
Embedded stacking device		250	375	500
Stacking device		250	375	500
		200	300	400
D-ring		250	375	500
Lashing eye plate		250	375	500
Buttress		*SWL* is to be the individual calculation result of the stowage arrangement and test load is to be determined according to Table 2.2.1.		

2.3 Product testing

2.3.1 For production by a manufacturer in batches according to the plans and documents of the securing devices which have been accepted in the prototype testing, such products are to be subjected to testing according to one of the following requirements.

(1) Batch testing: For securing devices except for chain or wire rope lashings, one randomly selected sample from every 50 pieces, or from each batch if less than 50 pieces, is to be proof loaded to 1.5 times the safe working load. For chain or wire rope lashings, one randomly selected sample from every 50 pieces, or from each batch if less than 50 pieces, is to be tested to breaking.

(2) Individual testing: Every securing device is to be proof loaded to the safe working load of the item. In addition, one randomly selected sample from every batch of chain or wire rope lashings is to be tested to breaking prior to delivery.

2.3.2 For production test carried out in accordance with 2.3.1(1) of this Appendix, permanent deformation will not be accepted within the range of loading up to:

(1) $1.5 \times SWL$, where $SWL < 250$ kN;

(2) $SWL + 125$, where $SWL \geq 250$ kN.

2.3.3 In the event of premature failure or serious plastic deformation occurring in a test sample, two further samples are to be selected for testing. In the event that these samples are found to be satisfactory, the associated batch may be accepted.

2.3.4 For production test carried out in accordance with 2.3.1(2) of this Appendix, permanent deformation will not be accepted.

3 Stowage and Securing of Containers

3.1 General requirements

3.1.1 Containers are to be secured by one, or a combination of the following systems: corner locking devices, lashings, cell guides, buttresses, shores or equivalent structural restraint.

3.1.2 The method of securing containers is to be determined by calculating the forces acting on the containers in accordance with 4 of this Appendix and is to be capable of ensuring the strength of containers and securing devices.

3.2 Arrangements for stowage and securing on exposed decks

3.2.1 The stowage of containers on exposed decks is to satisfy the following requirements.

(1) The arrangements are to be such as to permit safe access for personnel in the necessary working of the ship, and to provide sufficient access for installation and inspection of the securing devices.

(2) Containers stowed on deck or on hatch covers are generally to be aligned in the fore and after direction.

(3) Containers are to be stowed so that they do not extend beyond the ship's side; adequate support is to be provided where they overhang hatch coamings or other deck structures.

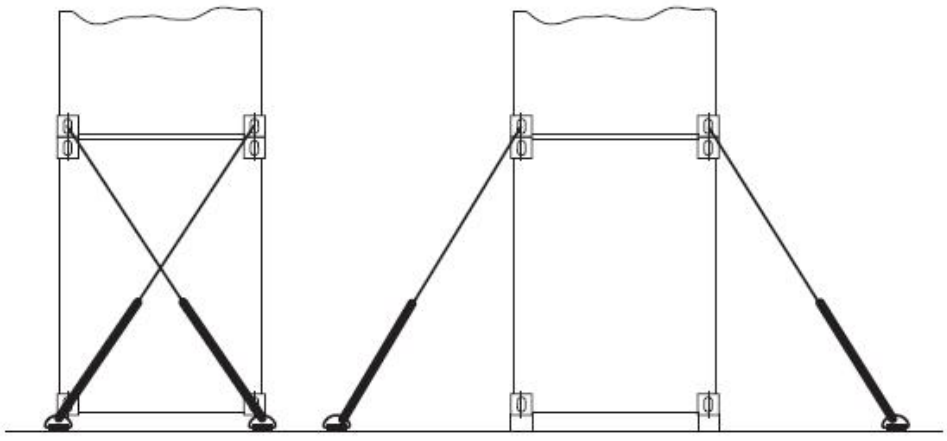
(4) Where containers are stowed on hatch covers, the covers are to be effectively restrained against sliding by approved type stoppers or equivalent.

3.2.2 The securing for containers stowed on the exposed deck is to comply with the following requirements:

(1) Twist locks and/or lashing arrangements are to be used for securing containers.

(2) In order to improve the lashing efficiency, the fixed lashing points can be arranged on the lashing bridge. In such case, the relative displacement between the structure of lashing bridge and the container stack is to be considered for calculating the lashing force.

(3) Normally, the internal lashing type is to be used for securing, as shown in Figure 3.2.2(a). For the external lashing type as shown in Figure 3.2.2(b), when the corner fitting connected to the lashing rod is in tension, due to the clearance existing between the twist locks and the container corner fittings, the twist locks will not be subject to the pulling force until such clearance between the twist lock and corner fitting of container is closed. In such case, the lashing rod may be broken as a result of excessive pulling force. When the external lashing type is selected, this situation is to be considered in securing calculation. Where no actual data is available, 12 mm vertical clearance is to be considered for semi-automatic twist lock and 20 mm vertical clearance for automatic twist lock.



(a) Internal lashing (b) External lashing

Figure 3.2.2 Internal lashing and external lashing

3.2.3 Cell guides may be used.

3.2.4 Up to a calculated remaining lifting force of 375 kN a vertical lashing can be applied for securing containers.

3.3 Arrangements for stowage and securing in holds

3.3.1 Without cell guides

(1) Containers are generally to be stowed in holds and 'tween decks in the fore and after direction.

(2) Containers may be secured by locking devices only or by a combination of locking devices, buttresses, shores or lashings, and the method of securing may be referred to 3.2 of this Appendix.
(3) Where the calculations indicate that remaining lifting forces could occur at any particular level, twist locks are to be fitted at that level. Elsewhere, consideration will be given to the use of double stacking cones.
(4) Where the calculations indicate that remaining lifting forces will not occur between containers at any level, consideration will be given to the use of double stacking cones in lieu of locking devices throughout.
(5) Buttresses are to be securely attached to the ship's structure. Where practicable, the attachment to the ship's structure is to include means for vertical adjustment of the buttresses to match container stacks of different heights.
(6) Shores of the compression type only may be permanently attached to the ship's structure or they may be hinged or portable and the ship's structure in way is to be reinforced as necessary. The shores are to abut the container corner fittings with minimal clearance.
(7) Adjacent stacks of containers are to be linked in line with buttresses or shores in order to transmit lateral loads, and the fittings used for these linkages are to be of adequate strength as buttresses or shores.
(8) The ship's structure supporting shores and buttresses is to be reinforced as necessary.

3.3.2 Using cell guides

(1) The cell guides are not to form an integral part of the ship's structure; the guide system is to be so designed as to keep it free from the main hull stresses.
(2) Cell guides are to be of robust construction; they are to be designed to resist loads caused by loading and unloading of the containers, to prevent shifting of the containers and to transmit the loads caused by motions of the ship into the main hull structure. The thickness of guides is not to be less than 12 mm.
The allowable stresses of cell guides are to be as follows (R_{eH} being the yield stress of the material, in N/mm^2):

Allowable shear stress: $[\tau] = 0.4R_{eH}$
Allowable normal stress: $[\sigma] = 0.67R_{eH}$

(3) Cell guides are generally to be fabricated from steel plate and rolled sections; the guides are to be adequately supported at their upper ends.
(4) Athwartship cross ties are to be fitted between cell guides as a spacing determined from the loading on the guides but, generally, not more than 5 m apart. Wherever possible, cross ties are to be arranged in line with the corners of the containers as stowed and are to be supported against fore and after movement at a minimum of two points across the breadth of the hold. Where, however, the maximum fore and after deflection in the cross tie can be shown not to exceed 20 mm, then one support point may be accepted.
(5) The intersection between cell guide and cross ties is to provide adequate torsional stability.
(6) Intermediate brackets are to be fitted to vertical cell guides at suitable intervals.
(7) Longitudinal tie bars may be required to be fitted where shown necessary by the force calculations for the structure. Where fitted, they are to comply with the requirements for spacing and deflection as specified in 3.3.2(4) of this Appendix.
(8) Where, at the sides or ends of holds, the guide rails are fitted to transverse or longitudinal bulkheads, the bulkhead is to be locally reinforced to resist the additional loads.
(9) The cell guides are to give a total clearance between the container and guide bars not exceeding 25 mm in the transverse direction and 40 mm in the longitudinal direction. Attention is to be given to the accuracy in fitting cell guides so as to ensure smooth loading and unloading of containers.
(10) A device to pre-centre the container and direct it into the cell guides is to be of robust construction, and is normally to be fitted at the top of the guide bars.
(11) Where containers of different height are stacked in the cargo holds, the horizontal force acting at the middle of each two cross ties needs to be considered for the strength of guides.

3.4 Mixed stacks of 20 ft and 40 ft containers

3.4.1 Where the cell guides are arranged for the carriage of 40 ft containers, provision may be made for the installation of temporary intermediate cell guides for 20 ft containers. The permanent structure is to be designed such that it is suitable for either loading pattern.
3.4.2 Alternatively, permanent means for the support of 20 ft containers at the mid-length of a cell arranged for 40 ft containers will be considered.
3.4.3 Where it is desired to stow 20 ft containers in the lower tiers without external support at the mid-bay location, the following requirements are to be complied with.
(1) Overall stacked container weights allowed for 20 ft containers stowed in cell guides with no 40 ft container overstowed can be derived from Tables 3.4.3(1) depending on the acceleration and the number of tiers in the stack.

(2) Overall stacked container weights allowed for 20 ft containers stowed in cell guides with at least one 40 ft container overstowed can be derived from Table 3.4.3(2) depending on the acceleration and the number of tiers in the stack.
(3) Racking forces acting on end walls of 20 ft containers stowed in the lowest tier at the mid-length of a cell arranged for 40 ft containers are not to exceed 185 kN. The orientation of the containers is to ensure as far as possible that all door ends or closed ends are facing in one direction. Weights listed in Table 3.4.3(1) and Table 3.4.3(2) apply to 20 ft containers the maximum rated weight of which is 30,480 kg.
(4) Stacking cones are to be fitted between each tier of the 20 ft containers and between the 20 ft containers and bottom of the hold to prevent transverse sliding.
(5) Where fore and aft tension/pressure adapter cones are used to link two 20 ft containers to equate to a 40 ft container, the storage of 40 ft containers above is not required.

Stowage Weights of 20 ft Containers (t)

Table 3.4.3(1)

a_t (g) / tiers	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40
12	168.9	163.5	158.4	153.6	149.1	144.8	140.8	137.0	133.4	129.9	126.7
11	168.8	163.4	158.2	153.5	148.9	144.7	140.7	136.9	133.3	129.8	126.6
10	168.4	163.0	157.9	153.1	148.6	144.3	140.3	136.5	133.0	129.5	126.3
9	167.4	162.0	156.9	152.2	147.7	143.5	139.5	135.7	132.1	128.8	125.5
8	166.7	161.3	156.3	151.5	147.1	142.9	138.9	135.1	131.6	128.2	125.0
7	166.4	161.0	156.0	151.3	146.8	142.6	138.7	134.9	131.4	128.0	124.8
6	164.8	159.5	154.5	149.8	145.4	141.2	137.3	133.6	130.1	126.7	123.6
5	152.5	152.5	152.5	149.3	144.9	140.8	136.9	133.2	129.7	126.4	123.2
4	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	121.5
3	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

a_t (g) / tiers	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.50	0.51
12	123.6	120.7	117.9	115.2	112.6	110.2	107.8	105.6	103.4	101.4	99.4
11	123.5	120.6	117.8	115.1	112.5	110.1	107.7	105.5	103.3	101.3	99.3
10	123.2	120.3	117.5	114.8	112.3	109.8	107.5	105.3	103.1	101.0	99.1
9	122.5	119.6	116.8	114.1	111.6	109.2	106.8	104.6	102.5	100.4	98.5
8	122.0	119.1	116.3	113.6	111.1	108.7	106.4	104.2	102.0	100.0	98.0
7	121.8	118.9	116.1	113.5	110.9	108.5	106.2	104.0	101.9	99.8	97.9
6	120.6	117.7	115.0	112.3	109.8	107.5	105.2	103.0	100.9	98.9	96.9
5	120.2	117.3	114.6	112.0	109.5	107.1	104.8	102.7	100.6	98.6	96.6
4	118.5	115.7	113.0	110.4	108.0	105.6	103.4	101.2	99.2	97.2	95.3
3	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

a_t (g) / tiers	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62
12	97.5	95.6	93.8	92.1	90.5	88.9	87.4	85.9	84.5	83.1	81.7
11	97.4	95.5	93.8	92.1	90.4	88.8	87.3	85.8	84.4	83.0	81.7
10	97.2	95.3	93.6	91.9	90.2	88.6	87.1	85.6	84.2	82.8	81.5
9	96.6	94.7	93.0	91.3	89.7	88.1	86.6	85.1	83.7	82.3	81.0
8	96.2	94.3	92.6	90.9	89.3	87.7	86.2	84.7	83.3	82.0	80.6
7	96.0	94.2	92.4	90.8	89.1	87.6	86.1	84.6	83.2	81.8	80.5
6	95.1	93.3	91.5	89.9	88.3	86.7	85.2	83.8	82.4	81.0	79.7
5	94.8	93.0	91.3	89.6	88.0	86.5	85.0	83.5	82.1	80.8	79.5
4	93.4	91.7	90.0	88.3	86.8	85.2	83.8	82.4	81.0	79.7	78.4
3	91.5	89.8	88.2	86.6	85.0	83.5	82.1	80.7	79.4	78.1	76.8
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

a_t (g) / tiers	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.70	0.71	0.72	0.73
12	80.4	79.2	78.0	76.8	75.6	74.5	73.4	72.4	71.4	70.4	69.4
11	80.4	79.1	77.9	76.7	75.6	74.5	73.4	72.3	71.3	70.3	69.4
10	80.2	78.9	77.7	76.5	75.4	74.3	73.2	72.2	71.2	70.2	69.2
9	79.7	78.5	77.3	76.1	74.9	73.8	72.8	71.7	70.7	69.7	68.8
8	79.4	78.1	76.9	75.8	74.6	73.5	72.5	71.4	70.4	69.4	68.5
7	79.2	78.0	76.8	75.6	74.5	73.4	72.3	71.3	70.3	69.3	68.4
6	78.5	77.2	76.0	74.9	73.8	72.7	71.6	70.6	69.6	68.7	67.7
5	78.2	77.0	75.8	74.7	73.5	72.5	71.4	70.4	69.4	68.4	67.5

4	77.1	75.9	74.8	73.6	72.5	71.5	70.4	69.4	68.4	67.5	66.6
3	75.6	74.4	73.2	72.1	71.1	70.0	69.0	68.0	67.1	66.1	65.2
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0
a_t (g) / tiers	0.74	0.75	0.76	0.77	0.78	0.79	0.80	0.81	0.82	0.83	0.84
12	68.5	67.6	66.7	65.8	65.0	64.1	63.3	62.6	61.8	61.1	60.3
11	68.4	67.5	66.6	65.8	64.9	64.1	63.3	62.5	61.8	61.0	60.3
10	68.3	67.4	66.5	65.6	64.8	64.0	63.2	62.4	61.6	60.9	60.1
9	67.9	67.0	66.1	65.2	64.4	63.6	62.8	62.0	61.2	60.5	59.8
8	67.6	66.7	65.8	64.9	64.1	63.3	62.5	61.7	61.0	60.2	59.5
7	67.5	66.6	65.7	64.8	64.0	63.2	62.4	61.6	60.9	60.1	59.4
6	66.8	65.9	65.0	64.2	63.4	62.6	61.8	61.0	60.3	59.6	58.8
5	66.6	65.7	64.8	64.0	63.2	62.4	61.6	60.8	60.1	59.4	58.7
4	65.7	64.8	63.9	63.1	62.3	61.5	60.7	60.0	59.3	58.5	57.8
3	64.3	63.5	62.6	61.8	61.0	60.3	59.5	58.8	58.1	57.4	56.7
2	61.0	61.0	60.3	59.5	58.7	58.0	57.2	56.5	55.8	55.2	54.5

Note: In the above table, "tiers" is the number of tiers of 20 ft containers and "a_t" the transverse acceleration of the stack in the intermediate tier. For example, where 7 tiers of 20 ft containers are stacked with no 40 ft containers overstowed, if the transverse acceleration of the stack in the intermediate tier a_t is 0.45g, then the overall weight of the stack is not to exceed 110.9 t, but the weight of container of each tier of stack may be different.

At least One Tier of 40 ft Containers Stowed above 20 ft Containers (t)

Table 3.4.3(2)

a_t (g) / tiers	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40
12	210.8	209.9	209.2	208.4	207.6	206.8	205.9	205.3	204.5	203.6	203.5
11	218.4	217.6	216.8	216.1	215.3	214.6	213.9	213.0	209.8	204.5	200.4
10	227.4	226.7	225.9	225.3	224.7	223.5	217.4	211.5	206.0	200.8	197.0
9	238.6	237.9	237.2	232.1	225.3	218.9	212.8	207.1	201.7	196.5	193.1
8	244.0	243.1	235.5	228.4	221.7	215.3	209.3	203.7	198.3	193.2	188.4
7	213.5	213.5	213.5	213.5	213.5	209.1	203.3	197.8	192.6	187.7	183.0
6	183.0	183.0	183.0	183.0	183.0	183.0	183.0	183.0	183.0	181.4	176.8
5	152.5	152.5	152.5	152.5	152.5	152.5	152.5	152.5	152.5	152.5	152.5
4	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0
3	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0
a_t (g) / tiers	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.50	0.51
12	198.5	193.8	189.3	185.0	180.9	177.0	173.2	169.6	166.1	162.8	159.6
11	195.5	190.8	186.4	182.1	178.1	174.2	170.5	167.0	163.6	160.3	157.1
10	192.2	187.6	183.2	179.1	175.1	171.3	167.6	164.1	160.8	157.6	154.5
9	188.3	183.9	179.6	175.5	171.6	167.9	164.3	160.9	157.6	154.4	151.4
8	183.8	179.4	175.3	171.3	167.5	163.8	160.4	157.0	153.8	150.7	147.8
7	178.5	174.3	170.2	166.4	162.7	159.1	155.7	152.5	149.4	146.4	143.5
6	172.5	168.4	164.5	160.8	157.2	153.8	150.5	147.4	144.4	141.5	138.7
5	152.5	152.5	152.5	152.5	150.5	147.3	144.1	141.1	138.2	135.5	132.8
4	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0
3	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0
a_t (g) / tiers	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62
12	156.5	153.6	150.7	148.0	145.4	142.8	140.3	138.0	135.7	133.4	131.3
11	154.1	151.2	148.4	145.7	143.1	140.6	138.2	135.8	133.6	131.4	129.3
10	151.5	148.6	145.9	143.2	140.7	138.2	135.8	133.5	131.3	129.2	127.1
9	148.5	145.7	143.0	140.4	137.9	135.5	133.1	130.9	128.7	126.6	124.6
8	144.9	142.2	139.6	137.0	134.6	132.2	129.9	127.7	125.6	123.5	121.6
7	140.8	138.1	135.6	133.1	130.7	128.4	126.2	124.1	122.0	120.0	118.1
6	136.0	133.5	131.0	128.6	126.3	124.1	122.0	119.9	117.9	116.0	114.1
5	130.3	127.8	125.4	123.2	121.0	118.8	116.8	114.8	112.9	111.0	109.3
4	122.0	121.1	118.9	116.7	114.6	112.6	110.7	108.8	107.0	105.2	103.5
3	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0
a_t (g) / tiers	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.70	0.71	0.72	0.73

12	129.2	127.2	125.2	123.3	121.5	119.7	118.0	116.3	114.6	113.1	111.5
11	127.2	125.2	123.3	121.4	119.6	117.9	116.1	114.5	112.9	111.3	109.8
10	125.1	123.1	121.2	119.4	117.6	115.9	114.2	112.5	111.0	109.4	107.9
9	122.6	120.7	118.8	117.0	115.3	113.6	111.9	110.3	108.8	107.3	105.8
8	119.6	117.8	115.9	114.2	112.5	110.8	109.2	107.7	106.1	104.7	103.2
7	116.2	114.4	112.6	110.9	109.3	107.6	106.1	104.6	103.1	101.7	100.3
6	112.3	110.5	108.8	107.2	105.6	104.0	102.5	101.1	99.6	98.2	96.9
5	107.5	105.8	104.2	102.6	101.1	99.6	98.2	96.8	95.4	94.1	92.8
4	101.9	100.3	98.8	97.3	95.8	94.4	93.0	91.7	90.4	89.2	87.9
3	91.5	91.5	91.5	90.4	89.0	87.7	86.4	85.2	84.0	82.8	81.7
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0
a_t (g) / tiers	0.74	0.75	0.76	0.77	0.78	0.79	0.80	0.81	0.82	0.83	0.84
12	110.0	108.5	107.1	105.7	104.4	103.0	101.8	100.5	99.3	98.1	96.9
11	108.3	106.9	105.4	104.1	102.7	101.4	100.2	98.9	97.7	96.6	95.4
10	106.5	105.0	103.7	102.3	101.0	99.7	98.5	97.3	96.1	94.9	93.8
9	104.4	103.0	101.6	100.3	99.0	97.8	96.5	95.3	94.2	93.0	91.9
8	101.8	100.5	99.2	97.9	96.6	95.4	94.2	93.0	91.9	90.8	89.7
7	98.9	97.6	96.3	95.1	93.8	92.7	91.5	90.4	89.3	88.2	87.1
6	95.6	94.3	93.1	91.9	90.7	89.5	88.4	87.3	86.3	85.2	84.2
5	91.5	90.3	89.1	88.0	86.8	85.7	84.7	83.6	82.6	81.6	80.6
4	86.7	85.6	84.5	83.4	82.3	81.3	80.2	79.3	78.3	77.3	76.4
3	80.6	79.5	78.5	77.5	76.5	75.5	74.5	73.6	72.7	71.9	71.0
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

Note: In the above table, "tiers" is the number of tiers of 20 ft containers, excluding the number of 40 ft containers stacked on the top, and "a_t" the transverse acceleration of the stack in the intermediate tier. For example, where 7 tiers of 20 ft containers are stacked with at least a tier of 40 ft containers overstowed, if the transverse acceleration of the stack in the intermediate tier a_t is 0.45g, then the overall weight of the stack is not to exceed 162.7 t, excluding the number of 40 ft containers stacked on the top, but the weight of container of each tier of stack may be different.

4 Determination of Forces Acting on Containers and Strength of Securing Arrangements

4.1 General requirements

4.1.1 The forces acting on the containers are to be determined according to loading conditions and associated motions of the ship. The following forces are to be taken into account: inertial forces of the containers generated by accelerations due to roll, pitch and heave motions of the ship, static gravity forces, wind forces, forces imposed by the securing arrangements and wave impact forces.

4.1.2 The resultant force acting on the containers can be divided into three components as F_x, F_y and F_z, as shown in Figure 4.1.2, where ox is the central axis of roll and F_x, F_y and F_z act on the centre of the container, which means that the centre of gravity of the container is assumed to be at the centre of the container. In securing calculation, it may be accepted that the centre of gravity of the container is at 45% of container height.

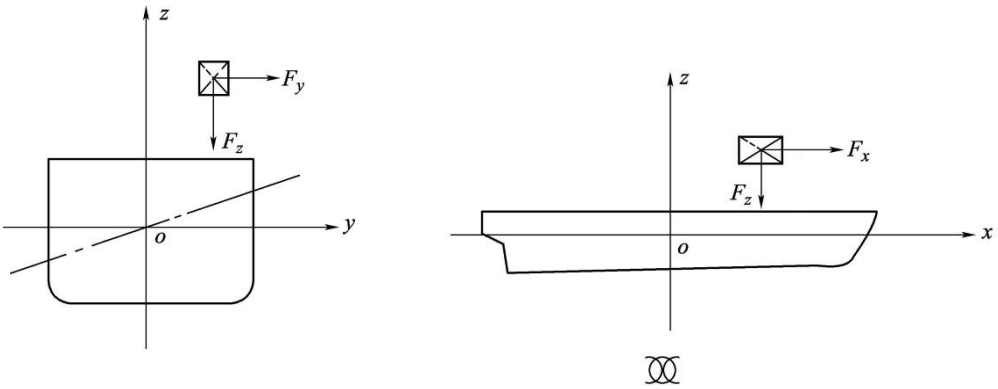


Figure 4.1.2 Forces Acting on Containers

4.2 Container securing acceleration

4.2.1 The transverse acceleration a_t for container securing calculation is calculated as follows:

$$a_t = (g + b_v) \cdot \sin\phi_m + b_h \cdot \cos\phi_m + (\frac{2\pi}{T_R})^2 \cdot \phi_m \cdot (z - z_{ROLL}) \quad \text{m/s}^2$$

where: g—gravity acceleration, to be taken as 9.81 m/s^2;
b_v—acceleration of vertical motion due to pitch and heaving, in m/s^2;
b_h—acceleration of transverse motion due to yawing and swaying, in m/s^2;
φ_m —rolling angle of ship, in rad;
T_R—rolling period of ship, in s;
z—height from container gravity center position to baseline, in m;
z_{ROLL}—height from ship rolling centerline to baseline, in m.

In above calculation formula of transverse acceleration, b_v and b_h are determined by main dimension, block coefficient and speed of ship, and rolling angle and rolling period are determined by main dimension and metacentric height of ship. Transverse acceleration a_t may be determined through CCS ship calculation system.

4.2.2 The vertical acceleration a_v for container securing calculation is calculated as follows:

$$a_v = 0.866 k_x \cdot g \qquad \text{m/s}^2$$

where: g—gravity acceleration, to be taken as 9.81 m/s^2;
k_x—longitudinal distribution coefficient which can be determined through CCS ship calculation systems.

4.2.3 The longitudinal acceleration a_l for container securing calculation is calculated as follows:

$$a_l = g \cdot (0.4 - 0.001 L_{BP}), \text{ but need not be less than 1.5 m/s}^2$$

where: g—gravity acceleration, to be taken as 9.81 m/s^2;
L_{BP}—length between perpendiculars, in m.

4.3 Forces acting on containers

4.3.1 The transverse force component F_y parallel to deck is to be calculated as follows:

$$F_y = G a_t + Q \qquad \text{kN}$$

where: G—gross weight of the container, in t;
a_t—transverse acceleration, in m/s^2, see 4.2.1 of this Appendix;
$Q = qA$, in kN, where q is the wind pressure, to be taken as 0.95 kPa for outermost containers at side (for containers at bottom, a splash force of 0.95 kPa is also to be taken into consideration), and as zero for others; A is the projected side area of containers bearing the wind pressure, in m^2. If the distance between adjacent container stacks is not more than 1 m, the wind load at containers inside can be omitted. If the distance between adjacent container stacks is 5 m or over, the wind load at containers inside is to be included in its entirety. If the distance is between 1 m and 5 m, linear interpolation is needed. If the exposed area is less than 1/3 of the side area, the wind load can be omitted.

4.3.2 The vertical force component F_z normal to deck is to be calculated as follows:
When checking the strength of the vertical supporting structure of containers:

$$F_z = G a_v \qquad \text{kN}$$

where: G — see 4.3.1 of this Appendix;
a_v — see 4.2.2 of this Appendix.

4.3.3 The longitudinal force component F_x parallel to deck is to be calculated as follows:

$$F_x = G a_l \qquad \text{kN}$$

where: G — see 4.3.1 of this Appendix;
a_l — see 4.2.3 of this Appendix.

4.4 Distribution and combination of forces acting on containers

4.4.1 The forces acting on each container are distributed as follows.

(1) The transverse component F_y of force is transmitted to the supporting point x from fore and after end walls of the container. The transverse force H_i transmitted from each end wall of the no. i container is to be obtained from the following formula:

$$H_i = F_{yi}/2 \qquad \text{kN}$$

The distribution of force H_i: if the center of gravity of the container is assumed to be the center of the container, H_i /2 acting on top of end wall and H_i /2 on bottom of end wall of the container; if the center of gravity of the container is assumed to be 45% height of the container, 0.45 H_i acting on top of end wall and 0.55 H_i on bottom of end wall of the container.

where: F_{yi} — transverse component of force, see 4.3.1 of this Appendix.

(2) The vertical component F_z of force is transmitted to the supporting structure from the four lower corners of the container. The vertical force *Vi* at each lower corner of the no. *i* container is to be obtained from the following formula:

$$V_i = F_{zi}/4 \qquad \text{kN}$$

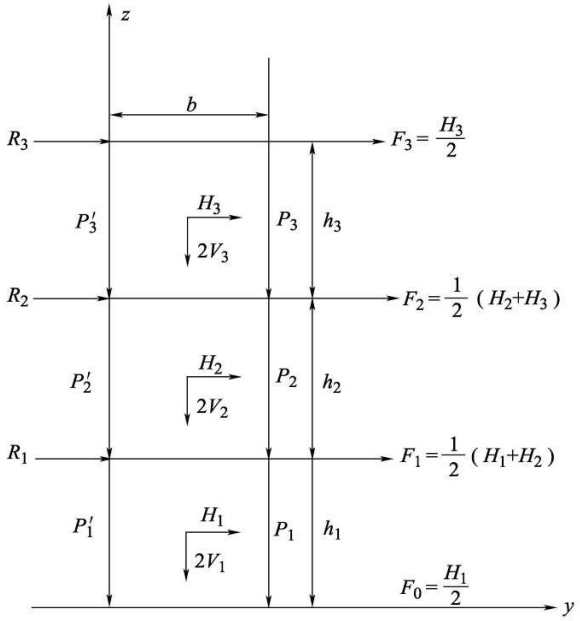
where: F_{zi} — vertical component of force of the no. *i* container, see 4.3.2 of this Appendix.

(3) The longitudinal component of force is transmitted to the supporting point *x* from both side walls of the container. The longitudinal component force L_i transmitted from each side wall of the no. *i* container is to be obtained from the following formula:

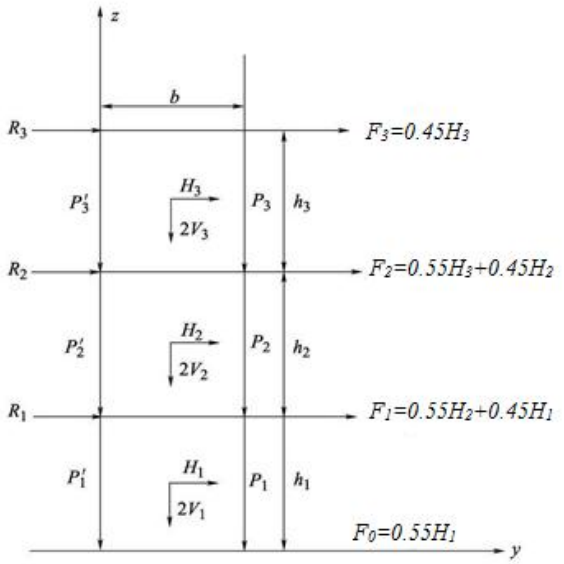
$$L_i = F_{xi}/2 \qquad \text{kN}$$

where: F_{xi} — longitudinal component of force of the no. *i* container, see 4.3.3 of this Appendix.

4.4.2 For containers in a three tier stack, the distribution of force at closed ends is given in Figure 4.4.2 and Table 4.4.2. The distribution of force on side walls may be treated in the same way.



(a) Gravity center at container center



(b) Gravity center at 45% height of container

Figure 4.4.2 Distribution of Force at Closed Ends of Containers

Distribution of Force at Closed Ends of Containers of Each Tier

Table 4.4.2

Force \ Tier	1st tier	2nd tier	3rd tier
Transverse racking force R_i per container end	$F_3 + F_2 + F_1$	$F_3 + F_2$	F_3
Maximum vertical pressure P_i per bottom corner	$V_3 + \frac{F_3}{b}(h_3 + h_2 + h_1) + V_2 + \frac{F_2}{b}(h_2 + h_1) + V_1 + \frac{F_1}{b} h_1$	$V_3 + \frac{F_3}{b}(h_3 + h_2) + V_2 + \frac{F_2}{b} h_2$	$V_3 + \frac{F_3}{b} h_3$
Minimum vertical pressure $P_i^{'}$ per bottom corner	$V_3 - \frac{F_3}{b}(h_3 + h_2 + h_1) + V_2 - \frac{F_2}{b}(h_2 + h_1) + V_1 - \frac{F_1}{b} h_1$	$V_3 - \frac{F_3}{b}(h_3 + h_2) + V_2 - \frac{F_2}{b} h_2$	$V_3 - \frac{F_3}{b} h_3$
Shear force S_i per bottom corner	$0.55(H_3 + H_2 + H_1)$	$0.55(H_3 + H_2)$	$0.55 H_3$

Note: Where $P_i^{'}$ indicates a negative value, it is a lifting force.

4.5 Calculation for lashings

4.5.1 Wire ropes, steel rods or steel chains may be adopted for lashings, the safe working load of which may be determined according to the breaking loads listed in Table 2.2.1 of this Appendix.

4.5.2 Figure 4.5.2 shows a two tier stack of containers, in which internal lashing is arranged to the second tier. If the center of gravity of the container is assumed to be the center of the container, for the selection of the effective sectional area A of the lashing, the residual racking force T (T being as required in 4.7.2 (2) of this Appendix) acting on the containers may be calculated in accordance with the following formula:

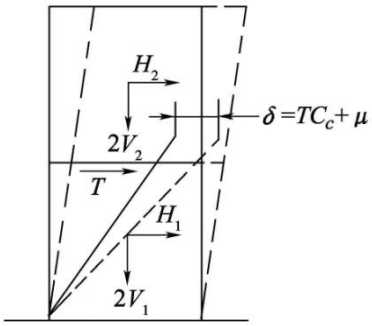


Figure 4.5.2 Two-Tier Stack

$$T = \frac{\frac{1}{2} H_1 + H_2 - \frac{AEI_y^2}{l^3}\mu}{\frac{AEI_y^2}{l^3} C_c + 1} \qquad \text{kN}$$

where:

H_1, H_2 — see 4.4.1 (1) of this Appendix;

l — overall length of lashing assembly, which is to include torsion element, turnbuckle and eye plate. l can be obtained as follows: $l = \sqrt{l_x^2 + l_y^2 + l_z^2}$, in mm;

l_x — longitudinal length component of lashing assembly, in mm;

l_y — transverse length component of assembly, in mm;

l_z — vertical length component of lashing assembly, in mm;

E — elastic modulus of lashings, to be taken as 10,000 kN/cm^2 for steel wire rope, 4,000 kN/cm^2 for steel chain based on its nominal diameter, 14,000 kN/cm^2 for steel rod (lashed to top of 1st tier containers or bottom of 2nd tier containers), or 17,500 kN/cm^2 for steel rod (lashed to top of 2nd tier containers or bottom of 3rd tier containers) or 19,000 kN/cm^2 for steel rod (lashed to top of 3rd tier containers or bottom of 4th tier containers);

A — effective sectional area of lashings, in cm^2;

μ — sliding at lower corners of container, in mm, to be taken as 4 mm for 1st and 2nd tier of container door end and 0 for closed end;

C_c — spring constant for container transverse frame, if no actual information available, 0.27 mm/kN for door end, 0.06 mm/kN for closed end and 0.168 mm/kN for side wall.

4.5.3 The lashing forces generated by the lashings are not to exceed the allowable loads as required in 4.7.2 (1) of this Appendix on container corner fittings.

4.6 Shoring forces

4.6.1 Where rigid shoring is used for the stowage of containers in holds without cell guide systems, the shoring forces may be determined by the following calculation.

The shoring forces Q_3 and Q_5 as shown in Figure 4.6.1 are to be calculated as follows:

$$Q_3 = \frac{1}{h_1}[H_4(h_1 - Z_4) + H_5(h_1 - Z_5)] + \frac{1}{h_2}[H_1Z_1 + H_2Z_2 + H_3Z_3] \quad \text{kN}$$

$$Q_5 = \frac{1}{h_1}(H_4Z_4 + H_5Z_5) \quad \text{kN}$$

where: for H_1, H_2, H_3, H_4 and H_5, see 4.4.1(1) of this Appendix.

Q_i is the shoring force for a stack of containers. Where there are n stacks of containers arranged in the transverse direction and the number n does not exceed 4, the shoring force is to be nQ_i; where n exceeds 4, the shoring force Q_i (n) may be calculated as follows:

$$\text{If } n-m \le 4, \quad Q_i(n) = Q_i \cdot \left[1 - \frac{(n-4)^2}{2 \cdot n \cdot m}\right]$$

$$\text{If } n-m > 4, \quad Q_i(n) = Q_i \cdot \left(\frac{8+m}{2 \cdot n}\right)$$

where: n—number of stacks using the same transverse support;

m—maximum tiers of all container stacks.

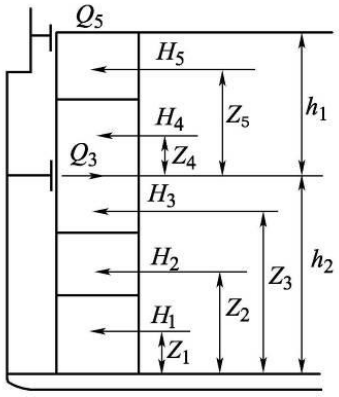


Figure 4.6.1 Rigid Shoring Forces

4.6.2 Where elastic shoring is used for the stowage of containers in holds, the shoring forces may be determined by the following calculation:

As shown in Figure 4.6.2, there are three elastic shoring points in one stack of containers, i.e. i, j and k; and the shoring forces are expressed as Q_i, Q_j and Q_k respectively. The shoring forces may be obtained according to the principle that the displacement of the elastic shoring points is equal to the total displacement of containers, with consideration being given to the mutual influence between the shoring forces. The shoring forces Q_i, Q_j and Q_k may be obtained as follows:

$$Q_k(C_{sk} + kC_c) + (kQ_i + kQ_j)C_c + \delta_k = C_c[(H_{k+1} + H_{k+2} + H_{k+3} + H_{k+4})k + \sum_{r=1}^{k} H_r(r - \frac{1}{2})]$$

$$Q_j(C_{sj} + jC_c) + jQ_iC_c + \delta_j = C_c[(H_{j+1} + H_{j+2})j + \sum_{r=1}^{j} H_r(r - \frac{1}{2})]$$

$$Q_i(C_{si}+iC_c)+\delta_i=C_c[H_{i+1}i+\sum_{r=1}^{i}H_r(r-\frac{1}{2})]$$

where: C_{si}, C_{sj}, C_{sk} — spring constants of shoring points i, j, k respectively, in mm/kN;
δ_i, δ_j, δ_k — initial gaps at shoring points i, j, k respectively;
C_c — see Table 4.5.2.

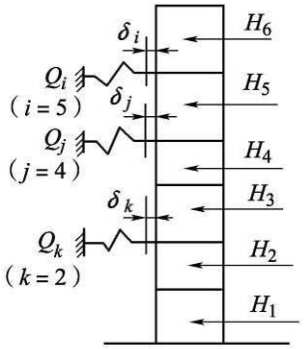


Figure 4.6.2 Elastic Shoring Forces

4.7 Allowable loads on containers

4.7.1 Forces acting on containers are not to exceed the allowable loads on containers irrespective of the methods of securing arrangements for containers.

4.7.2 As shown in Figure 4.7.2, the allowable loads on freight containers of ISO Standard Series 1 are as follows:

(1) lashing forces acting on the corner fittings:

the horizontal component of force on each end or side wall is not to exceed 150 kN or 225kN, the criteria value depends on the direction of horizontal component, see Figure 4.7.2a) for details;

the vertical component of force on each end or side wall is not exceed 300 kN;

in no case is the resultant of horizontal and vertical components of force to exceed 300 kN.

(2) Racking forces acting on end or side walls:

the transverse racking force on each end or side wall is not to exceed 150 kN;

the vertical racking force on each end or side wall is not to exceed 100 kN.

(3) Vertical tensile and compressive forces acting on the corner fittings:

the vertical tensile force acting at each top corner is not to exceed 250 kN;

the vertical tensile force acting at each bottom corner is not to exceed 250 kN;

the compressive force at each corner post is not to exceed 848 kN.

(4) Transverse compressive and tensile forces acting on the corner fittings:

the transverse compressive (tensile force) at each top corner of 20 ft containers is not to exceed 225 kN;

the transverse compressive (tensile force) at each top corner of 40 ft containers is not to exceed 340 kN;

the transverse compressive (tensile force) at each bottom corner of 20 ft containers is not to exceed 350 kN;

The transverse compressive (tensile force) at each bottom corner of 40 ft containers is not to exceed 500 kN.

Where a buttress supports the stack at an intermediate level, the total transverse compressive (tensile) force acting at the level is not to exceed 575 kN for 20 ft containers and 840 kN for 40 ft containers.

(5) For 45 ft containers, vertical compressive forces acting on the corner fittings:

if the container is stacked at 45 ft position and supported in 45 ft position, the compressive force at bottom corner post is not to exceed 942 kN;

if the container is stacked at 40 ft position and supported in 40 ft position, the compressive force at bottom corner fitting is not to exceed 404 kN.

For 45 ft containers, other allowable loads are the same as those for 40 ft containers.

(6) For containers with special dimensions (e.g. 43 ft, 48 ft and 53 ft), test results need to be submitted.

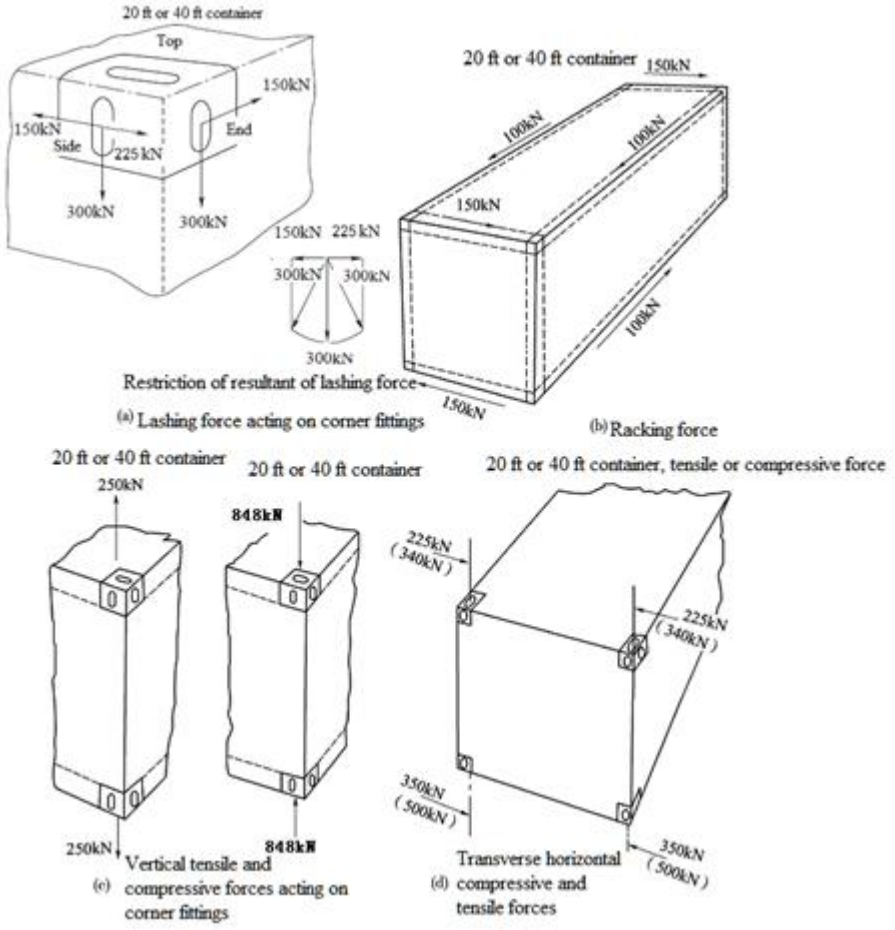


Figure 4.7.2 Allowable Loads on 20/40 ft Containers

4.8 Direct calculation of container securing

4.8.1 General requirements

4.8.1.1 2-dimensional beam model may be used to model containers and calculate the strength of containers and their lashings.

4.8.1.2 Each stack may be analysed separately unless there are connections between the stacks such as double cones or similar.

4.8.1.3 The flange thickness of twist locks or cones are to be included in clearances between container stacks.

4.8.2 Modelling of geometry

4.8.2.1 Beam elements are used to model container frames according to the dimension of containers.

4.8.2.2 The spring constant of the door end and of closed end are to be obtained respectively by adjusting the cross sectional area of the corner post as indicated by Figure 4.8.2.2:

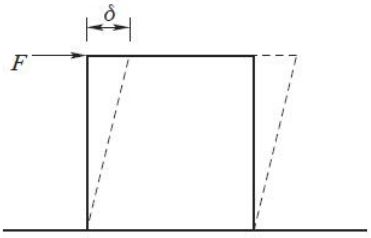


Figure 4.8.2.2 Spring Constant of Door End and of Closed End

For example: If the spring constant of the door end of the container is 0.291 mm/kN, when F=1,000 kN, the deflection of the frame is 291 mm.

4.8.2.3 Twist locks between two tiers of containers are to be modeled as rigid elements, with a hinge at one end to avoid transfer of bending moments.

4.8.2.4 Cones between two tiers of containers are to be modeled as non-linear elements capable of taking compression but not tension.

4.8.2.5 Lashing rods are to be modeled according to actual elastic modulus and cross sectional area.
4.8.3 Boundary conditions and loading
4.8.3.1 Elements attached to the ship structure are to be restricted from translation.
4.8.3.2 Loads should be applied as point loads in the corners of the containers. The transverse forces are applied to the top and bottom corners while vertical forces are only applied to the bottom corners of the container.
4.8.4 Calculation results
4.8.4.1 Results are to be extracted from the model to check whether the containers comply with the allowable loads of containers specified in 4.7 of this Appendix and whether the loads on the securing devices exceed their SWL.

5 Strength Evaluation of Container Securing Structure

5.1 General requirements
5.1.1 These requirements apply to the lashing bridge and stanchion structure and supporting structure of fixed securing devices (lashing eye plate, deck ring, etc.) on the deck of container ships.

5.2 Lashing bridge
5.2.1 The SWL of lashing rods (50% of the breaking load) is theoretically the maximum load to check the strength of lashing bridges.
5.2.2 To check the strength of a lashing bridge, loads are to be applied according to the condition where the maximum lashing force may occur in the container securing manual/arrangement plan, and the lashing force is to be obtained by calculating according to the container securing manual/arrangement plan. The lashing force is to be applied in line with the lashing rods and can be decomposed into force components in longitudinal, transverse and vertical direction. The lashing force is applied to the securing eye plate of the lashing bridge. In calculating lashing forces, the relative displacement between the lashing bridge and the container stacks are to be taken into account, which is not to exceed the values given in Table 5.2.2.

Relative displacement between lashing bridge and container stacks

Table 5.2.2

Lashing bridge of 1-tier container height	Lashing bridge of 2-tier container height	Lashing bridge of 3-tier container height
10 mm	25 mm	35 mm

5.2.3 In the initial design, forces may be applied according to the condition where the maximum lashing force may occur in reality. The lashing force is to be taken as 60% safe working load of each lashing rod (or other securing devices).
5.2.4 When checking the strength of lashing bridges, conditions where lashing forces are applied to forward and aft part lashing bridges together as well as respectively are to be calculated.
5.2.5 To better describe the force distribution of each structural part in each direction, strength checking of lashing bridge is to adopt 3-dimensional finite element structural analysis. The extent of the model, the elements and the boundary conditions are based on the following principles:
(1) The finite element model is to include all lashing bridges above the deck or hatch cover. The boundary conditions are to restrict all translations between elements and deck or hatch cover.
(2) The mesh size of the plate element is generally 100 mm × 100 mm, and triangle elements are to be avoided as far as possible in high stress areas and high stress changing areas.

5.3 Deck stanchion
5.3.1 In design of deck stanchion, the most critical conditions are to be taken into account, as well as the transverse load and vertical load acting on the stanchion.
5.3.2 Where lashing points are arranged on the stanchion, the horizontal and vertical components of lashing forces are also to be taken into account.

5.4 Fixed securing device
5.4.1 SWL of the connected securing device is to be used as the design load of supporting structure of fixed securing device.

5.5 Strength criteria
5.5.1 Allowable stresses for lashing bridge structures, deck stanchion structures and supporting structures

of fixed cargo securing devices under various conditions are as follows:

Allowable shear stress: $[\tau] = 0.4\ R_{eH}$

Allowable equivalent stress: $[\sigma] = 0.88\ R_{eH}$

where R_{eH} is the yield stress of the material, in N/mm^2.

6 Lashing Software

6.1 General requirements

6.1.1 All seagoing dedicated container ships are to be provided with lashing software complying with the requirements of this section.

6.1.2 Lashing software is an electronic data processing tool for onboard analysis of forces in container stacks and thereby reflects the parameters of the lashing system as described in the Cargo Securing Manual.

6.1.3 An approved lashing software is not a substitute for the approved Cargo Securing Manual. It is considered as a supplement to the approved Cargo Securing Manual.

6.1.4 The lashing software is a ship specific tool, and the results of the calculations are only applicable to the ship for which it has been approved.

6.2 Operation manual

6.2.1 An operation manual is to be provided for the lashing software and be kept on board, which is to be approved by CCS.

6.2.2 The language of the operation manual is to be the same as the language of the approved Cargo Securing Manual. A translation into another language considered appropriate may be required.

6.2.3 The operation manual is to contain descriptions and instructions, as appropriate, as per the following list:

(1) a general description of the lashing software;

(2) installation;

(3) function keys;

(4) menu displays;

(5) input and output data;

(6) required minimum hardware to operate the software;

(7) instruction on testing the lashing software with the test loading condition;

(8) a list of all terms, definitions, error messages and warnings likely to be encountered by the user; and

(9) in the case of error messages and warnings, there are to be unambiguous user instructions for subsequent action to be taken in each case.

6.3 Functional requirements

6.3.1 The lashing software is to be capable of calculating forces on containers and container securing equipment for any loading conditions for each container stack.

6.3.2 It is also to be capable of indicating the respective permissible values in order to assist the master in his/her judgement on whether the ship is loaded within the approved limits. The following parameters are to be presented:

(1) summary of ship particulars such as IMO No., length, and breadth;

(2) summary of loading conditions showing relevant input parameters such as draught and GM;

(3) stack and container positions;

(4) actual stack weights verified against permissible stack weights;

(5) relevant properties of securing devices, including permissible loads;

(6) accelerations and other external forces such as wind containers are exposed to;

(7) listing of all calculated forces on containers and container securing equipment, and evaluation of compliance of the calculated forces with the corresponding allowable values.

6.3.3 The container and lashing arrangements in each bay on deck and in holds are to be shown graphically.

6.3.4 The data are to be presented on screen and in hard copy printout in a clear and unambiguous manner.

6.3.5 A clear warning is to be given on screen and in hard copy printout if any of the allowable forces are exceeded.

6.3.6 In addition to the printout content, each page of the printout is to contain ship's identification, lashing software name and version number, date and time of the printout, and the title of the loading

condition. The printout is to be paginated sequentially, and the total number of printout pages are to be shown.
6.3.7 Units of measurement are to be clearly identified and used consistently.
6.3.8 Incorrect data input by the users, such as negative draught values, are to be prohibited. An error message is to be prompted on screen and in hard copy printout in a clear and unambiguous manner.

6.4 Test Loading Conditions

6.4.1 The lashing software is to be delivered with test loading conditions for selected stacks and bays covering applicable stowage patterns for containers of different dimensions contained in the Cargo Securing Manual. It is generally to cover the container stacking of the ship's bow, amidships and stern bay, including at least one lashing calculation for the conditions listed in the Cargo Securing Manual. For ships assigned the CLC (V) or CLC (V,W) notation, the corresponding additional conditions are to be supplemented.
6.4.2 The test loading conditions and their results are to be permanently stored in the computer where the lashing software is installed and be protected against unintentional or unauthorized modifications and access.

6.5 Approval of Lashing Software

6.5.1 The lashing software is subject to approval and is to include:
(1) verification of type approval, if any;
(2) verification that the latest ship data has been used;
(3) verification and approval of the test loading conditions and their results;
(4) verification if requirements of 6.3 are satisfied;
(5) checking of proper installation, and verification of the instrument on board in accordance with the approved test loading conditions;
(6) checking the availability of the operation manual on board.
6.5.2 In case of modifications implying changes in the ship’s design or container securing arrangement, the software is to be modified accordingly and re-approved.
6.5.3 Any changes in software version related to the container securing calculations are to be reported and be approved.
6.5.4 Upon installation, the lashing software is to be verified with the approved test loading conditions in the presence of surveyor. It is to be checked that the operation manual for the lashing software is available on board.
6.5.5 Verification does not absolve the shipowner of responsibility for ensuring that the information supplied into the lashing software is consistent with the current condition of the ship and approved Cargo Securing Manual.

6.6 Acceptable Tolerances

6.6.1 The results of the lashing software are compared with those of the CCS plan approval software. The tolerance of the accuracy of the results from the lashing software is to be below 1.0% of the allowable values. However, deviations may be accepted provided that there is a satisfactory explanation for the deviation and that there will be no adverse effects on the safety of the ship.

6.7 Annual and Special Survey

6.7.1 At each annual and special survey, it is to be checked that the operation manual is available on board.
6.7.2 The lashing software is to be checked for accuracy annually by the ship's Master by applying the test loading conditions. If the surveyor is not present for lashing software check, a copy of the test loading condition results obtained by this check is to be retained on board as documentation of satisfactory testing for the surveyor's verification at the next scheduled survey.
6.7.3 At each special survey this checking is to be done in the presence of surveyor.

7 Specific Route and Season

7.1 Transverse acceleration for specific route

7.1.1 For container securing of specific route, transverse acceleration a_{vt} is to be calculated as follows:

$$a_{vt} = a_t \cdot f_{route} \qquad \text{m/s}^2$$

where: a_t — transverse acceleration calculated according to 4.2.1 of this Appendix, in m/s^2;

f_{route} —specific route factor.

7.1.2 For each specific route, CCS will determine route factor f_{route} by statistical calculation of ship motion. CCS will develop specific wave scatter diagram based on acceptable wave statistical data to obtain f_{route}. For each specific route, latitude and longitude coordinates of a series of points along the route is to be provided by the shipowner or the information on sea areas passed by the route is to be provided. Division of sea areas and statistical data of wave in sea area are to be agreed by CCS. For each passed sea area, at least one point is to be given. If possible, time percentage for each passed sea area is to be provided.

7.1.3 For container securing of short voyage (port to port, navigation time within 72 hours), the specific route factor may be calculated as follows:

$$f_{route} = 1 - (H_s - 13)^2 / 240$$

where: H_s — the maximum expected significant wave height on the route during the navigation time, in m.

7.2 Transverse acceleration for specific season

7.2.1 For container securing of specific season, transverse acceleration a_{wt} is to be calculated as follows:

$$a_{wt} = a_{vt} \cdot f_{season} \qquad \text{m/s}^2$$

where: a_{vt} — transverse acceleration of specific route which is calculated in accordance with 7.1.1 of this Appendix, in m/s^2;

f_{season}—specific season factor.

7.2.2 Specific season factor f_{season} is the ratio of transverse acceleration calculated in accordance with the wave statistical data of a specific route in different seasons to transverse acceleration calculated in accordance with the wave statistical data throughout the year.

8 Approval and Certification of Container Securing Systems

8.1 General requirements

8.1.1 All seagoing dedicated container ships are to comply with the requirements of this section.

8.1.2 It is important for the safety of the ship and the protection of the cargo and personnel that the cargo is secured properly especially accounting for strength of the supporting structures and securing fittings. Hereto, a scope containing the following for approval and/or certification of container securing systems is defined:

(1) fixed and portable container securing fittings;

(2) arrangement plan of fixed container securing fittings;

(3) drawings of container supporting structures (container stanchions, hatch covers, lashing bridges, and cell guides, if any);

(4) cargo safe access plan;

(5) container stowage and securing plan;

(6) lashing software.

8.2 Fixed and Portable Container Securing Fittings

8.2.1 Fixed container securing fittings are used to secure and support containers and are permanently welded to the ship structure.

8.2.2 Portable1 container securing fittings are used to secure containers and are not categorised as fixed container securing fittings.

8.2.3 Minimum Breaking Load corresponds to the minimum load at which the first crack appears in the tested representative samples.

8.2.4 Minimum Proof Load corresponds to the test load below which visible permanent deformation is not allowed.

8.2.5 Drawings of fixed and portable container securing fittings are to show dimensions, materials, design loads, and manufacturer's markings.

8.2.6 Each fixed and portable container securing fitting type is subject to prototype testing to determine the minimum breaking loads. The minimum breaking load obtained from prototype testing is to be equal to

or exceed the design minimum breaking load. Requirements for prototype testing are given in 2.2 of this Appendix.

8.2.7 Fixed and portable container securing fittings are subject to production testing prior to delivery or installation. A number of samples from a batch of the container securing fittings is to be loaded to minimum proof load of the fittings. The production testing approval documents of delivered container securing fittings are to be kept on board and may be included in the approved Cargo Securing Manual. Requirements for production testing are given in 2.3 of this Appendix.

8.2.8 The plan detailing the arrangement of the fixed container securing fittings is to be approved. The arrangement plan is to include the following for all areas where the fittings are installed:

(1) The type of fixed container securing fittings such as container foundations and lashing eye plates;

(2) Unambiguous location of installed fittings such as their location relative to clearly described locations of the ship structures.

8.3 Drawings of Container Supporting Structures

8.3.1 The drawings of the structures necessary for conducting container stowage and securing are subject to approval. The drawings are to be detailed enough to allow their model generation for structural analyses. A plan is to be provided showing all relevant design loads for structural assessment of the container supporting structures and their foundations.

8.3.2 Structures involved in container stowage and securing include hatch covers, container stanchions, lashing bridges and cell guides.

8.4 Cargo Safe Access Plan

8.4.1 The cargo safe access plan is to be examined for its compliance with the requirements prescribed in MSC.1/Circ.1353/Rev.2 (refer to CCS Guidelines for the Preparation of the Cargo Securing Manual).

8.5 Container Stowage and Securing Plan

8.5.1 If the stowage and securing plan, as referred to in MSC.1/Circ.1353/Rev.2 4.2.1 and 4.2.2 (refer to CCS Guidelines for the Preparation of the Cargo Securing Manual), is required by the Administration, the plan is subject to approval in accordance with 8.5.2 and 8.5.3.

8.5.2 The container stowage plan is to include at least the following information for each container type the ship is designed for:

(1) longitudinal and athwartship views of under deck and on deck stowage locations of containers including reefers as appropriate;

(2) alternative stowage patterns for containers of different dimensions;

(3) maximum stack masses;

(4) maximum stack heights with respect to approved sight lines; and

(5) maximum nominal container capacity.

8.5.3 The container securing arrangement plan is to contain all information necessary to prepare lashing calculations. The container securing arrangement plan is to include at least the following information:

(1) summary of ship particulars such as IMO No., length and breadth;

(2) summary of loading conditions showing relevant input parameters such as draught and GM;

(3) longitudinal views of under deck and on deck stowage locations of containers as appropriate showing nominal capacity;

(4) maximum stack masses;

(5) relevant properties of securing fittings, including permissible loads;

(6) graphical presentation of container and lashing arrangements in each bay on deck and in holds for sample loading conditions for each container type the ship is allowed to carry;

(7) stack total mass and the sequence of masses in a stack;

(8) minimum quantity of fittings required to secure containers for the presented sample loading conditions.

8.6 Lashing Software

8.6.1 If the ship is provided with lashing software on board, the approval is to follow the requirements of Section 6 of this Appendix.

Appendix 2 DIRECT STRENGTH CALCULATION OF CONTAINER SHIPS

1 General

1.1 Application

1.1.1 This Appendix applies to direct strength calculations of container ships as required by this Chapter.

1.1.2 For those not covered in this Appendix, the relevant requirements of Section 5, Chapter 1 of this PART are to be complied with.

2 DIRECT CALCULATIONS OF STRENGTH OF PRIMARY STRUCTURES OF CARGO AREA

2.1 General requirements

2.1.1 The direct strength calculations for cargo holds are applicable to the evaluation of the strength of the following primary structures within cargo area in typical loading conditions:

(1) double bottom structure (bottom plating, inner bottom plating, girders, floors);

(2) double side structure (side shell plating, inner hull plating, longitudinal stringers and transverse web frames);

(3) Transverse bulkhead structure (transverse bulkhead plating, bulkhead webs);

(4) Deck structure (deck, torsion box).

2.1.2 Where fuel oil tanks are arranged between cargo holds amidships, strength evaluation is to be carried out for fuel oil tank area in accordance with 2.8 of this Appendix.

2.2 Structural modeling

2.2.1 Unless stipulated otherwise in this Appendix, see Section 5, Chapter 1 of this PART for requirements for structural modeling.

2.2.2 Normally, the longitudinal extent is to cover the length of 1/2 hold + 1 hold + 1/2 hold within the cargo area amidships, namely the length of one 40 ft bay + two 40 ft bays + one 40 ft bay. The vertical extent is to be taken up to the hatch coaming. A full-breadth model is to be required for transverse extent.

2.2.3 The model is generally to cover transverse watertight bulkheads and transverse support bulkheads. The transverse support bulkheads are at both ends and the middle of the model, and typical finite element models are shown in Figures 2.2.3(1) to (3).

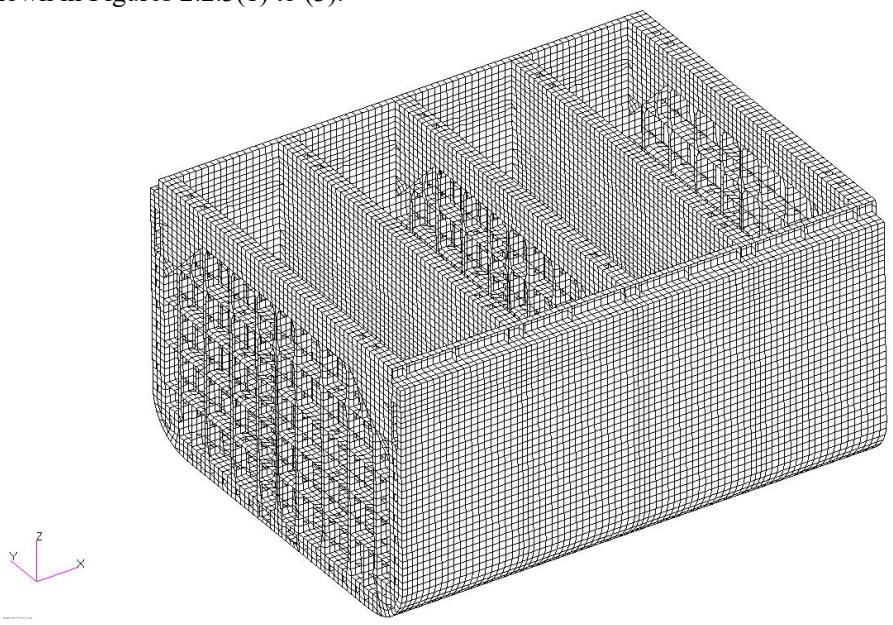


Figure 2.2.3(1) Typical finite element model

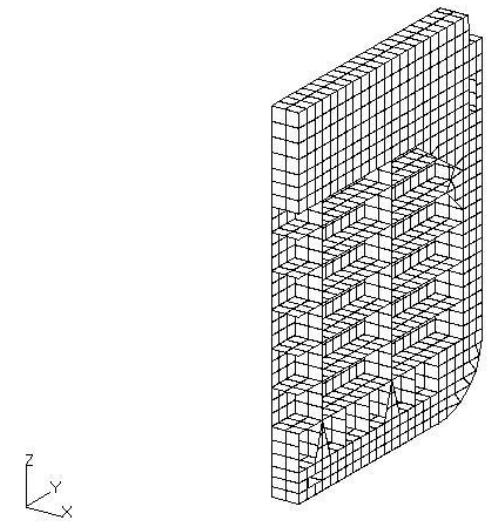


Figure 2.2.3(2) Typical finite element model of watertight transverse bulkhead (half-breadth)

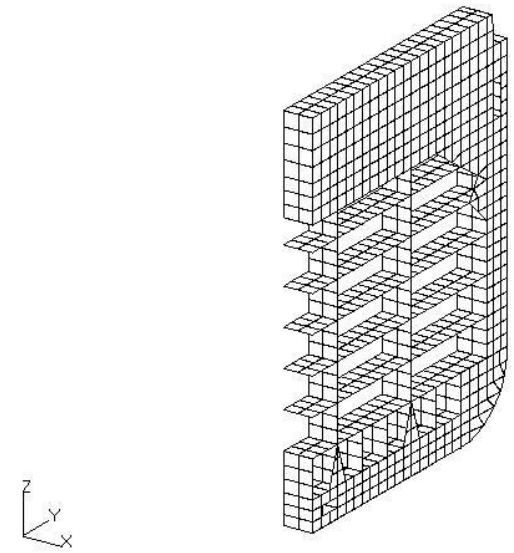


Figure 2.2.3(3) Typical finite element model of transverse support bulkhead (half-breadth)

2.3 Design loads

2.3.1 Unless stipulated otherwise in this Appendix, see Section 5, Chapter 1 of this PART for design loads.

2.3.2 The global loads include still water bending moment and wave bending moment. The still water bending moment M_S is to be taken as the permissible hogging moment $\overline{M}_{S-Hog}$ and permissible sagging moment $\overline{M}_{S-Sag}$ provided by the designer. Vertical wave bending moment M_W includes hogging wave bending moment M_{W-Hog} and sagging wave bending moment M_{W-Sag}, is to be calculated in accordance with 7.2.2.3 of Section 2 of this Chapter.

2.3.3 Local loads include:

(1) hydrostatic pressure;

(2) hydrodynamic wave pressure;

(3) self-weights of hull structure and containers;

(4) dynamic loads of hull structure and container induced by the ship's motions, see 2.3.5 for the acceleration of ship's motions.

2.3.4 External hydrodynamic wave pressure is an additional pressure induced by local wave loads,

consisting of hydrodynamic wave crest pressure and hydrodynamic wave trough pressure. See 1.5.3.3(4) and (5) of Chapter 1 of this PART for hydrodynamic wave crest pressure p_{hd}. The hydrodynamic wave trough pressure p_{hd1} is to be calculated as follows, the distribution is shown in Figure 2.3.4.

$$p_{hd1} = \max\left(-p_{hd}, \rho_w g\left(z - d_1\right)\right) \quad \text{KN/m}^2$$

where: p_{hd} — to be taken in accordance with 1.5.3.3(4) of Chapter 1 of this PART;

ρ_w — density of seawater, taken as 1.025 t/m^3;

g — acceleration due to gravity, g = 9.81 m/s^2;

z — vertical distance from calculation point to baseline, in m;

d_1 — draught in the considered load condition, in m.

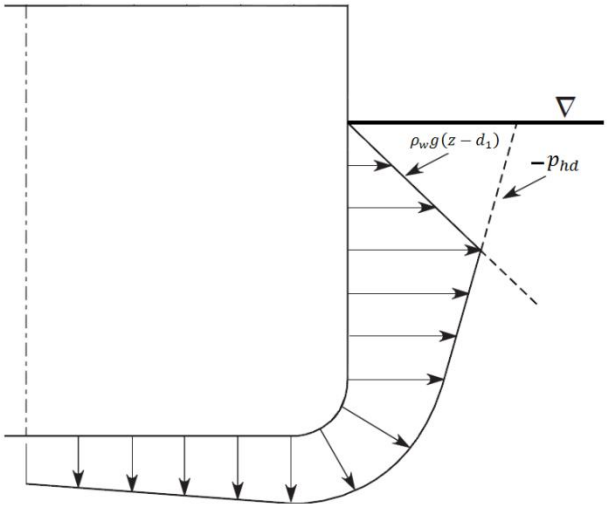


Figure 2.3.4 Distribution of hydrodynamic wave trough pressure on transverse section of the hull

2.3.5 The vertical acceleration a_v induced by the ship's motions is to be calculated as follows, positive downwards:

$$a_v = f_{LC}(C_{ZH}a_z - C_{ZP}a_p(x - 0.45L)) \quad \text{m/s}^2$$

where: f_{LC} — coefficient, to be taken as follows:

= -1.0 where the considered load condition is sagging condition;

= 1.0 where the considered load condition is hogging condition;

C_{ZH} — load combination factor of heave acceleration, C_{ZH} =0.15-0.5 f_T, $f_T = d_1/d$;

a_z — to be calculated in accordance with 1.5.2.1(3) of Chapter 1 of this PART;

C_{ZP} — load combination factor of pitch acceleration, taken as 0.7;

a_p — to be calculated in accordance with 1.5.2.1(5) of Chapter 1 of this PART;

x — X coordinate of the calculation point, in m;

L — length of the ship, in m.

The longitudinal acceleration a_1 induced by the ship's motions is to be calculated in accordance with 1.5.2.2(7) of Section 5, Chapter 1 of this PART and the speed is to be taken as half of the maximum service speed.

2.4 Loading conditions

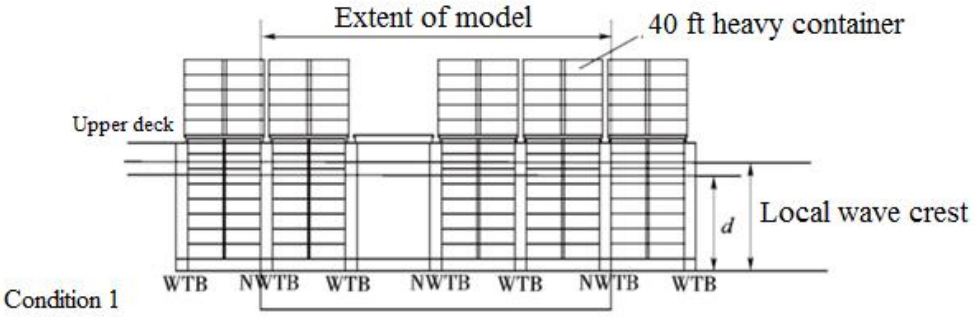
2.4.1 The applicable loading conditions are to be checked according to Table 2.4.1. For more severe loading conditions in the loading manual not covered by the Table, direct strength calculation is to be carried out. Figure 2.4.1 shows various loading conditions.

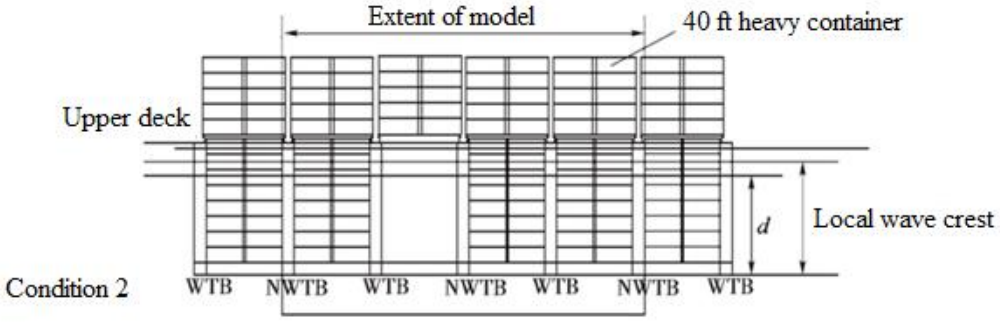
Loading Conditions **Table 2.4.1**

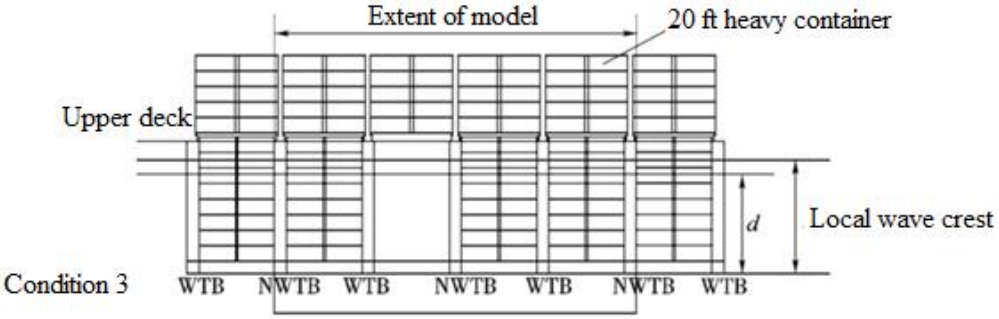
Loading condition	Condition description	Still water bending moment	Wave bending moment	Draught	hydrodynamic wave pressure	Container weight	dynamic acceleration of hull structure and containers
1	Empty within one 40 ft bay and hatch covers over the bay; full within other bays and hatch covers	$\overline{M}_{s-Hog}$	M_{w-Hog}	d	p_{hd}	40ft heavy container	a_v
2	Empty within one 40 ft bay and full on hatch covers over the bay; full within other bays and hatch covers	$\overline{M}_{s-Hog}$	M_{w-Hog}	d	p_{hd}	40ft heavy container	a_v
3	Empty within one 40 ft bay and full on hatch covers over the bay; full within other bays and hatch covers	$\overline{M}_{s-Hog}$	M_{w-Hog}	d	p_{hd}	20ft heavy container	a_v
4	Full within hold of all holds and on all hatch covers	$\overline{M}_{s-Sag}$	M_{w-Sag}	$0.9d$	p_{hd1}	20ft heavy container	a_v
5	Full within hold of all holds and on all hatch covers	$\overline{M}_{s-Hog}$	M_{w-Hog}	d	p_{hd}	40ft light container	a_v
6	Full within hold of all holds and on all hatch covers	$\overline{M}_{s-Hog}$	M_{w-Hog}	d	p_{hd}	40ft heavy container	a_v
7	Empty within one 40 ft bay and hatch covers over the bay; full within other bays and hatch covers (heeling of ship)	—	—	d	—	40ft heavy container	—
8	Full within hold of all holds and on all hatch covers (heeling of ship)	—	—	d	—	20ft heavy container	—
9	Full within hold of all holds and on all hatch covers (longitudinal motions of ship)	$\overline{M}_{s-Sag}$	M_{w-Sag}	d	p_{hd1}	40ft heavy container within holds, 20ft heavy container on hatch covers	a_l, a_v
10	Damage (heeling of ship)	$\overline{M}_{s-Sag}$	—	d_{dam}	—	40ft Heavy container (except the damaged tank in the middle)	—

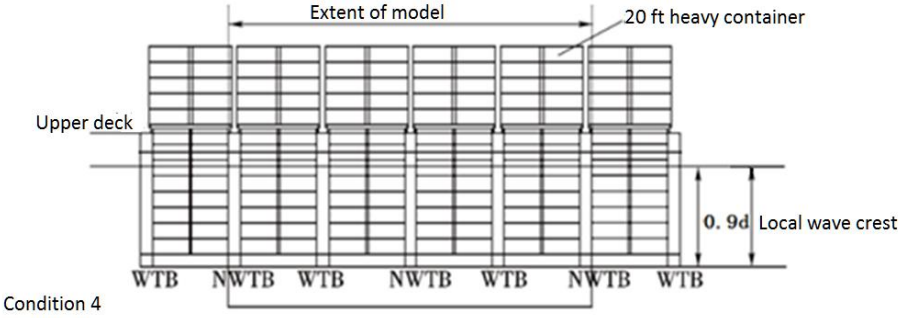
Notes:
(1) d — draught, in m;
(2) Heavy container — the weight of a container is to be taken as permissible stack weight divided by the maximum number of tiers;
(3) Light container — the weight of a container is not to be greater than the values taken as follows:
In hold: 55% of the weight of heavy container;

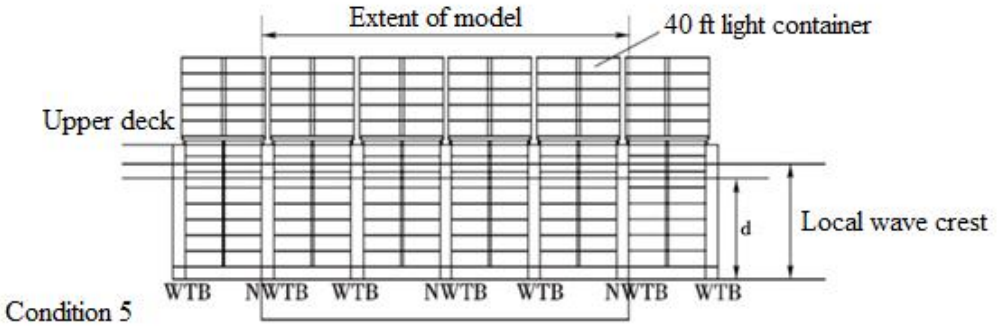
On hatch covers: to be taken as 90% of the permissible stack weight divided by the maximum number of tiers or 17 tons, whichever is the lesser;
(4) for condition 7 and 8, the heeling angle is to be calculated in accordance with Section 5, Chapter 1 of this PART; Where the direct calculation of wave load is available, the heeling angle predicted by direct calculation may be accepted, but not to be less than 18°;
(5) for condition 9, loads within hold and on hatch covers to be determined as specified in 2.4.3 and 2.4.4;
(6) where a hold consists of two or more 40 ft bays, then each bay is to be considered as entirely empty;
(7) definition for d_{dam} is defined in 2.4.5 of this appendix.



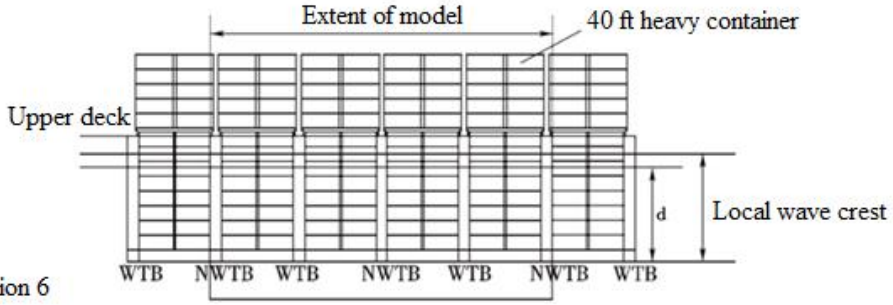




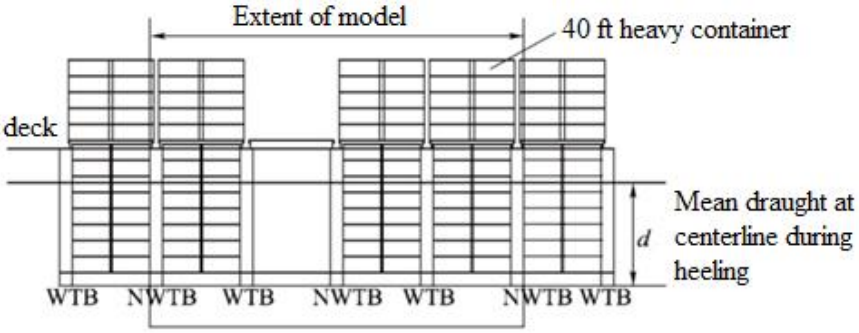




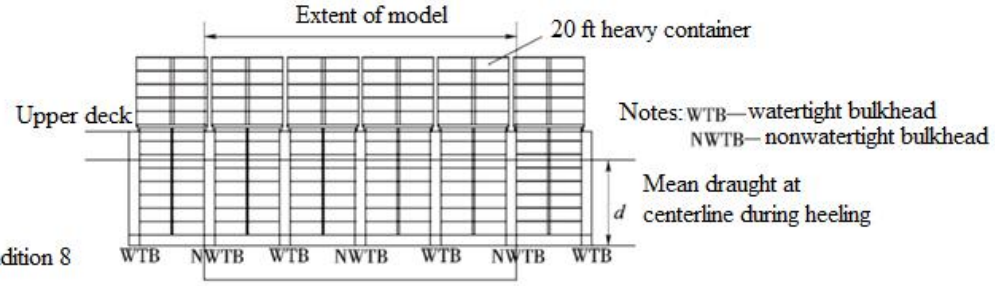
Condition 5



Condition 6



Condition 7



Condition 8

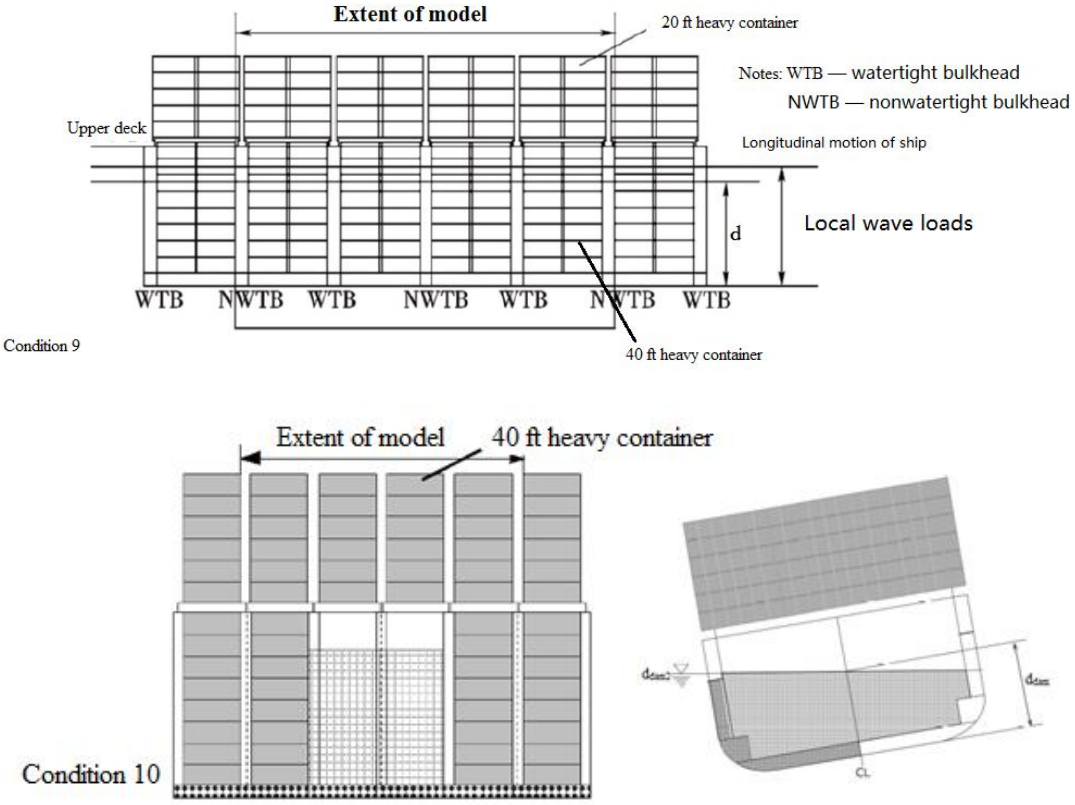


Figure 2.4.1 Loading conditions

2.4.2 For heeling conditions (conditions 7 and 8), the load components are to be calculated assuming that the ship heels to maximum heeling angle. The transverse load components of containers in holds are to act as a group of concentrated forces on transverse bulkheads, with the locations of container corners corresponding to transverse bulkheads as acting points. The load components from containers on deck are to act as a group of horizontally distributed shear forces on nodes of top elements of the transverse coaming.

2.4.3 Where deck is fitted with torsion box girders and the span of the cross deck box is not greater than 13.0 m, the condition 9 need not be considered.

2.4.4 For surging condition (condition 9), the forces arising from acceleration of the longitudinal motion of each container within hold is to be distributed from corresponding corners of the container to primary members of the transverse bulkhead (or the transverse support bulkhead) in way of cell guides. Determination of loads due to containers on hatch covers is as follows:

(1) The longitudinal forces from containers on each hatch cover are to be calculated at mid-height of the stack. The moment about the stack base caused by longitudinal forces may be ignored.

(2) The number of tiers of containers is the maximum one of loaded containers, and the maximum stack weight and the number of tiers are to be those permitted in the loading manual or the cargo handling manual.

(3) The longitudinal forces from containers sited between the ship's side and the longitudinal hatch coamings may be ignored.

(4) 15% of the total longitudinal force acting on hatch covers is to be distributed on nodes at top of longitudinal and transverse hatch coamings to simulate the friction force to which the bearing pads at hatch coamings are subjected due to longitudinal motion.

(5) The remaining 85% of the longitudinal forces on hatch covers are to act on nodes corresponding to the longitudinal stopper positions at one end of the hatch cover (top of the transverse hatch coaming). If the stopper positions are unknown, they are assumed to be located at the mid-breadth of the aft end of the hatch cover. Three covers are to be assumed if the number of hatch covers is unknown.

2.4.5 For damage condition (condition 10), it is assumed that any cargo hold of ship is flooded to the deepest equilibrium waterline. Only the damage of middle hold and the ballast tank on the same side is considered in the FE model. The loads are applied to the container in the same way of that specified in 2.4.2. The maximum height of damage point d_{dam2} and d_{dam} in way of longitudinal centerline is to be determined by the deepest equilibrium waterline.

2.5 Boundary conditions

2.5.1 Boundary conditions for local loads

2.5.1.1 For symmetric loading cases (conditions 1, 2, 3, 4, 5, 6, 9, 10), see Table 2.5.1.1(1) for boundary conditions; for asymmetric loading cases (conditions 7 and 8), see Table 2.5.1.1(2) for boundary conditions; nodes, intersection lines and end planes in the Table are shown in Figure 2.5.1.1.

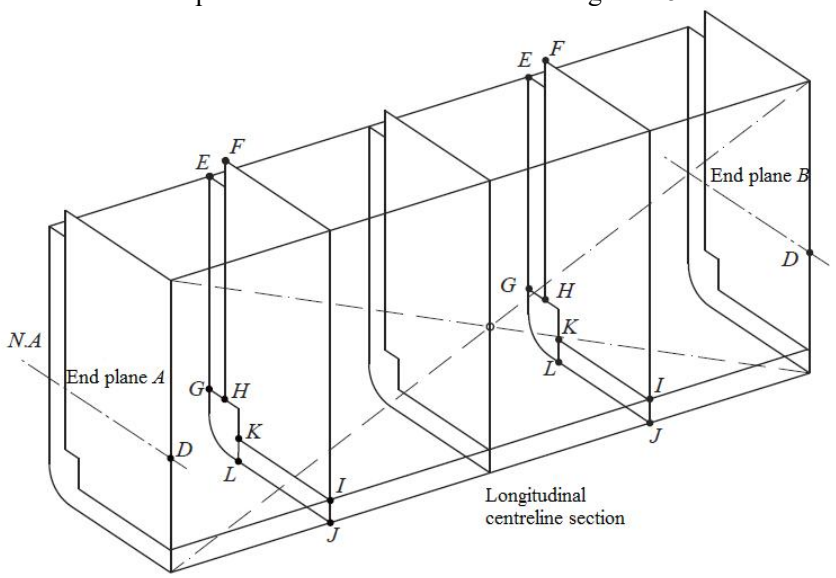


Figure 2.5.1.1 Boundary Conditions

2.5.1.2 For symmetric loading cases, vertical spring elements are to be provided at nodes on intersections of shell plating and inner hull plating with forward and aft transverse bulkheads. For asymmetric loading cases, Horizontal spring elements are to be provided at nodes on intersections of bottom plating and inner bottom plating with forward and aft transverse bulkheads in addition that vertical spring elements are to be provided at nodes on intersections of shell plating and inner hull plating with forward and aft transverse bulkheads. The coefficient of elasticity of spring elements is to be distributed evenly and calculated by the following formula:

$$K = \frac{5GA}{6l_H n} \quad \text{N/mm}$$

where: G — shear modulus of elasticity of material, $G = 0.792\times10^5$ N/mm^2 for steel;

A — shearing area of shell plating, inner hull plating, bottom plating and inner bottom plating in way of forward and aft bulkheads, in mm^2;

l_H — length of midship hold, in mm;

n — number of nodes on vertical intersections of shell plating and inner hull plating or number of nodes on horizontal intersections of bottom plating and inner bottom plating.

Boundary Conditions for Symmetric Loading Cases Table 2.5.1.1(1)

Position	Displacement constraint			Rotation constraint		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Node *J*	—	Constraint	—	—	—	—
End planes *A*, *B*	Constraint	—	—	—	Constraint	Constraint
Intersection lines *EG*, *FH*	—	—	Spring	—	—	—

Boundary Conditions for Asymmetric Loading Cases Table 2.5.1.1(2)

Position	Displacement constraint			Rotation constraint		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
End planes A, B	Constraint	—	—	—	Constraint	Constraint
Intersection lines EG, FH	—	—	Spring	—	—	—
Intersection lines IK, JL	—	Spring	—	—	—	—

2.5.2 Boundary conditions for global loads

2.5.2.1 See Table 2.5.2.1 for boundary conditions for global loads. The boundary conditions apply to the calculation of hull girder bending moments for Table 2.4.1 only.

2.5.2.2 An independent point *D* (see Figure 2.5.1.1) is to be set in way of intersection of the neutral axis with the longitudinal centerline section within end planes *A* and *B*, the overall longitudinal bending moment is to be applied on the point *D*, and the degree of freedom δ_x, δ_y and δ_z of each member node for end planes is linked to the independent point.

2.5.2.3 The displacements of the independent point *D* within end planes *A* and *B* in transverse direction, vertical direction, and the rotation around longitudinal axes are restrained, i.e.: $\delta_y = \delta_z = \theta_x = 0$; the displacement of the independent point *D* within end plane *A* in longitudinal direction is restrained, i.e.: $\delta_x = 0$.

Boundary conditions for global loads **Table 2.5.2.1**

Position	Displacement constraint			Rotation constraint		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Node *J*	—	Constraint	—	—	—	—
End planes A, B	Link	Link	Link	—	—	—
Independent point D (End plane A)	Constraint	Constraint	Constraint	Constraint	Bending moment	—
Independent point D (End plane B)	—	Constraint	Constraint	Constraint	Bending moment	—

2.6 Strength evaluation

2.6.1 Evaluation area

2.6.1.1 Evaluation is to be carried out for middle hold and the primary members with the scope of a transverse framing extending forward and afterward.

2.6.2 Yield strength evaluation

2.6.2.1 The strength check is to be carried out after the stresses due to local load case and global load case are combined. The in-plane stress of the element is to be taken for stress of plate element.

2.6.2.2 In all conditions, permissible stresses of primary members are shown in Table 2.6.2.2.

Permissible Stresses **Table 2.6.2.2**

Structural member	Loading condition	Permissible stress (N/mm^2)	
		$[\sigma_e]$	$[\tau]$
Deck plating	LC1, 2, 3, 4, 5, 6, 9	225/*K*	—
Bottom plate, inner bottom plate	LC1, 2, 3, 4, 5, 6, 9	225/*K*	—
Shell plating, longitudinal bulkhead	LC1, 2, 3, 4, 5, 6, 9	225/*K*	115/*K*
Bottom girders	LC1, 2, 3, 4, 5, 6, 9	235/*K*	115/*K*
Double bottom floors	LC1, 2, 3, 4, 5, 6, 7, 8, 9	175/*K*	90/*K*
Transverse web frames	LC1, 2, 3, 4, 5, 6, 7, 8, 9	195/*K*	95/*K*
Longitudinal stringers	LC1, 2, 3, 4, 5, 6, 9	225/*K*	—
	LC 7, 8	175/*K*	90/*K*
Transverse bulkhead plating	LC1, 2, 3, 4, 5, 6, 9	180/*K*	100/*K*
	LC10	235/*K*	—
Transverse bulkhead webs	LC1, 2, 3, 4, 5, 6, 7, 8, 9	175/*K*	—
	LC10	235/*K*	—
Connection of the double bottom and side platform to the watertight transverse bulkhead structure	LC10	235/*K*	—
Cross-deck torsion box	LC 7, 8	175/*K*	90/*K*
	LC9	175/*K*	—

Structural member	Loading condition	Permissible stress (N/mm^2)	
		$[\sigma_e]$	$[\tau]$
	LC10	235/K	—
Bracket toe end with local stress concentration	LC1, 2, 3, 4, 5, 6, 7, 8, 9, 10	220/K	—

Notes:
(1) K— material factor;
(2) The elements at king-pin area of hatch coaming are directly subjected to the load resulting from hatch cover under loading condition 9, so the permissible equivalent stress is $[\sigma_e]$=195/K N/mm^2.

2.6.3 Buckling strength evaluation

2.6.3.1 Finite element buckling strength evaluation is to be carried out for members such as shell plating, inner bottom plating, deck, bulkhead plating of hull structure of containership, web plates and pillars of primary and local supporting members, horizontal/vertical girders of supporting bulkhead.

2.6.3.2 See 2.6.1 for evaluation area.

2.6.3.3 In addition to the requirements of 2.6.3.4 to 2.6.3.8, buckling strength evaluation is to be carried out in accordance with the requirements for finite element buckling as specified in Chapter 8 of PART 9-1 of the Rules.

2.6.3.4 In buckling strength evaluation, the calculation of the buckling capacity of all panels and stiffeners is to be carried out based on the size after deduction of the standard thickness deduction t_r. The standard thickness deduction t_r is shown in Table 2.6.3.4.

Standard Thickness Deduction **Table 2.6.3.4**

Position	Standard thickness deduction (mm)
Deck, wing space plating (e.g. second deck, etc.)	1.0
Longitudinal bulkhead (inner hull plating)	1.0
Shell plating (including bottom plating), inner bottom	1.0
Inner structure (girder, floor) of double bottom and wing space	1.0
Transverse bulkhead structure (watertight, non-watertight)	0
Cross-deck torsion box	0

Note: If other thickness deduction method is used for buckling strength evaluation (e.g. based on corrosion allowance), the permissible utilization factor is to be considered otherwise.

2.6.3.5 For stresses obtained by calculation of finite element model (including stress components of direct stress and shear stress), if stress component is local stress or including components of local stress, the correction of stress is to be carried out for the stress calculation according to the following formula:

$$\sigma_A = \frac{\sigma t}{t - t_r} \qquad \text{N/mm}^2$$

where: σ_A — corrected buckling working stress (including components of axial compressive stress and shear stress), in N/mm^2;

σ — stress obtained by finite element calculation ((including components of axial compressive stress and shear stress), in N/mm^2;

t — plate thickness for finite element calculation, in mm;

t_r —standard thickness deduction, in mm, see Table 2.6.3.4.

2.6.3.6 For permissible buckling utilization factor η_{all} used for buckling strength evaluation, see Table 2.6.3.6.

Permissible buckling utilization factor η_{all} **Table 2.6.3.6**

Structural component	Permissible buckling utilization factor η_{all}
— Plating(including web plates in way of opening） — stiffener — stiffened panel	1.00
— strut, pillar — horizontal/vertical girder of supporting bulkhead checked by strut buckling mode	0.75

Structural component	Permissible buckling utilization factor η_{all}
— collision bulkhead (where necessary)	0.90

2.6.3.7 Definition of method for evaluating the stiffened/unstiffened panels of hull panel of containership is shown in Table 2.6.3.7 and Figures 2.6.3.7(1) to 2.6.3.7(6).

Types of panels and corresponding evaluation methods Table 2.6.3.7

Structural element	Evaluation method	Definition for regular panel
Longitudinal structure , see Figures 2.6.3.7(1), (4), (6)		
external shell plate (bottom plating, side shell plating） inner bottom plating inner hull/longitudinal bulkhead plating horizontal and longitudinal stringer of hopper tank and vertical side plating	SP-A	Length: between web frames Width: between primary supporting members (PSM)
Hatch coaming side plating	SP-A or UP-A	Length: between web frames Width: between primary supporting members (PSM)
Upper deck	SP-B[5]	Length: between web frames Width: between primary supporting members (PSM)
Double bottom longitudinal girders	SP-B[5]	Length: between web frames Width: height of the whole web plate
Transverse structure, see Figure 2.6.3.8(2)		
Transverse framing of deck/web plate of cross-deck torsion box, including bracket of regular mesh shape	SP-A[6]	Local stiffener / between face plate/PSM
Transverse framing of deck/ web plate of cross-deck torsion box, including bracket of irregular mesh shape	SP-B[5]	Local stiffener /between face plate/PSM
Transverse webs of double hull wing tank	SP-B[5]	Length: height of the whole web plate Width: between primary supporting members
Transverse webs of double hull wing tank (independent arrangement)	SP-B	Length: height of the whole web plate Width: between primary supporting members
Irregular stiffened panel, such as web plate panel in hopper tank and at bilge (continuous alignment arrangement)	UP-A	Local stiffener / between face plate/PSM
Irregular stiffened panel, such as web plate panel in hopper tank and at bilge (incontinuous alignment arrangement)	UP-B[5]	Local stiffener / between face plate/PSM
Double bottom floors	SP-A[6]	Length: height of the whole web plate Width: between primary supporting members
Watertight transverse bulkhead and transverse supporting bulkhead, see Figure 2.6.3.8(3),(4),(5)		
All regular bulkhead stiffened panels, including secondary buckling stiffeners vertical to the regular stiffeners (e.g. carling)	SP-A	Length: between primary supporting members Width: between primary supporting members
All irregular bulkhead stiffened panels, such as web plate panels in hopper tank and at bilge	UP-A	Local stiffener / between face plates
Bulkhead horizontal web plate, including bracket of regular mesh shape (three arrangement of panel and over)	SP-B[5]	Local stiffener / between face plates
Bulkhead horizontal web plate, including bracket of regular mesh shape (two arrangement of panel and less)	SP-B [5]	Local stiffener / between face plates
Bulkhead horizontal web plate, including bracket of irregular mesh shape	UP-B	Local stiffener / between face plates
Bulkhead vertical web plate, including bracket of regular mesh shape	SP-B [5]	Local stiffener / between face plates
Bulkhead vertical web plate, including bracket of irregular mesh shape	UP-B	Local stiffener / between face plates
Cross deck, see Figure 2.6.3.8(6)		
Longitudinal deck strips between hatchways	SP-B[5]	Local stiffener / between PSM
Cross deck strips between hatchways	SP-B	Local stiffener / between PSM
Notes: ① SP means stiffened panel;		

Structural element	Evaluation method	Definition for regular panel
② UP means unstiffened panel; ③ A means method A; ④ B means method B; ⑤ For a long side of the web plate panel of primary supporting member, if alongside the face plate, or alongside the attached plate without the property of "in-line support", e.g. property of "pull-in", method B (SP-B or UP-B) is to be selected. For other situations, method A (SP-A or UP-A) is to be selected. ⑥ In typical case that the short edge and sheathing (flange of attached plate) are connected with each other, method A (SP-A or UP-A) is to be selected. However, if a long side of the panel is without the property of "in-line support" and may be pulled in, method B (SP-B or UP-B) is to be selected. ⑦ In-line support means an edge of panel (always) subject to the structural support or restraint of adjacent panel and/or edge stiffener. ⑧ Pull-in means an edge of panel may be pulled freely toward the center of the plate. In this Table, "in-line support" and "pull-in" represent opposite mechanical properties.		

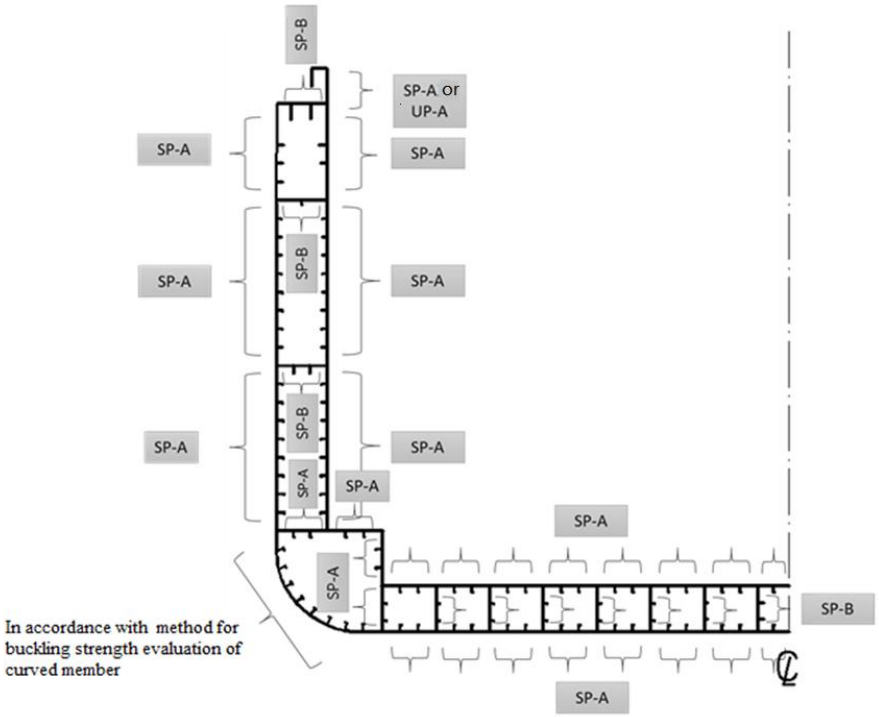


Figure 2.6.3.7(1) Typical longitudinal panels of containership

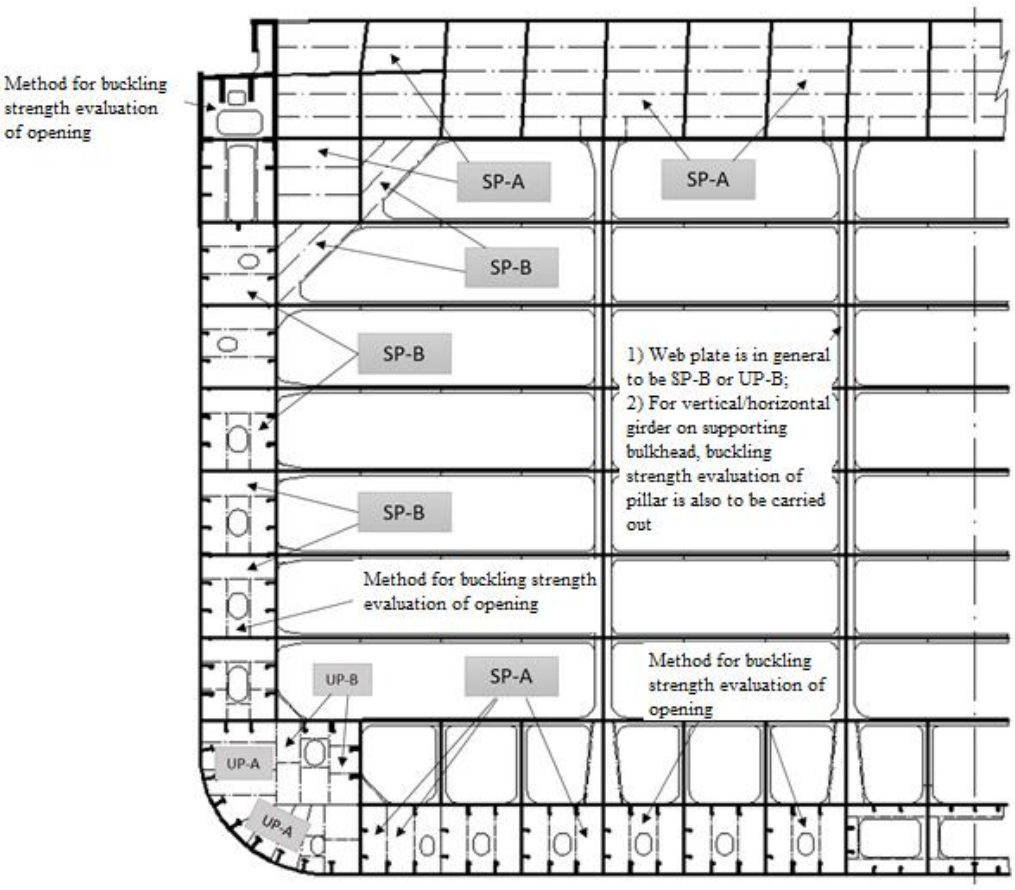


Figure 2.6.3.7(2) Typical transverse member in way of bulkhead (supporting) of containership

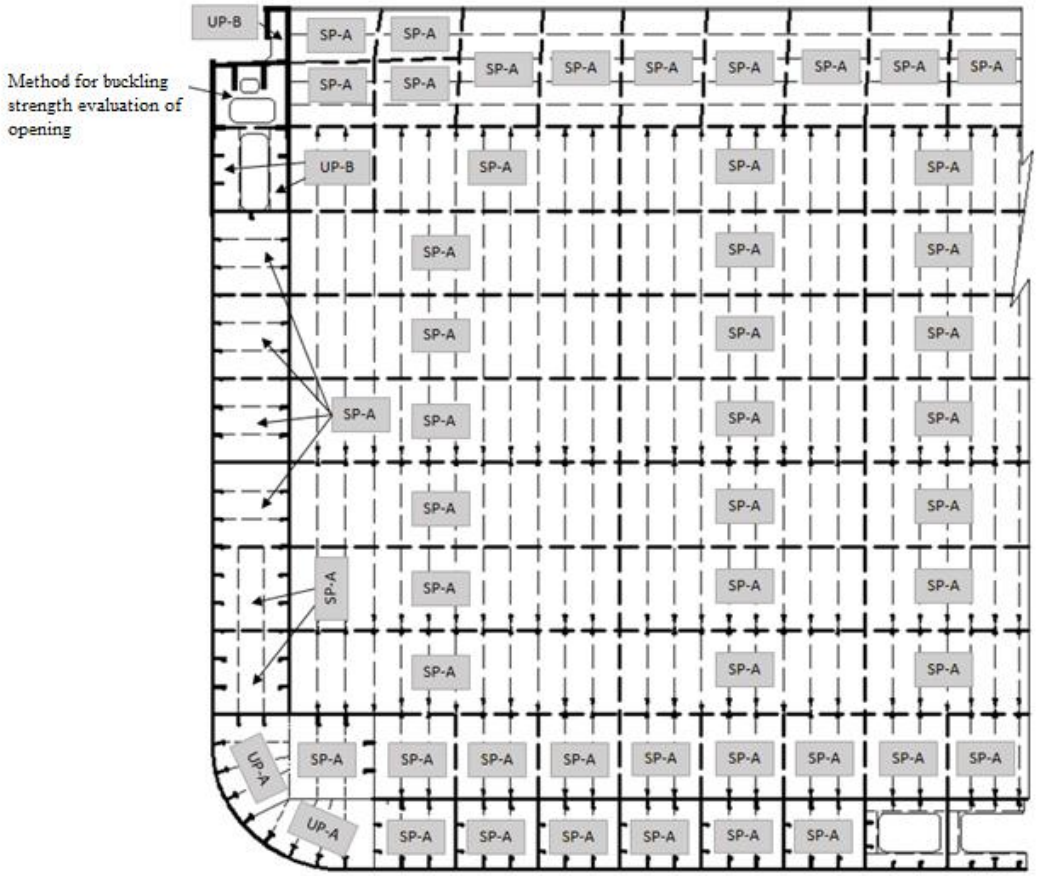


Figure 2.6.3.7(3) Typical watertight transverse bulkhead of containership

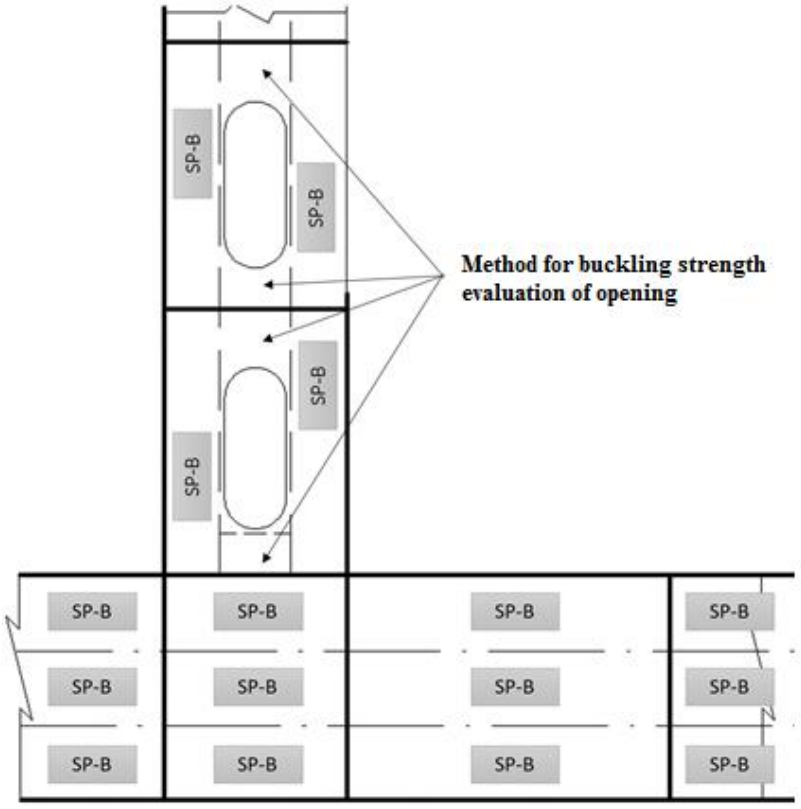


Figure 2.6.3.7(4) Transverse bulkhead vertical girder and double bottom girders

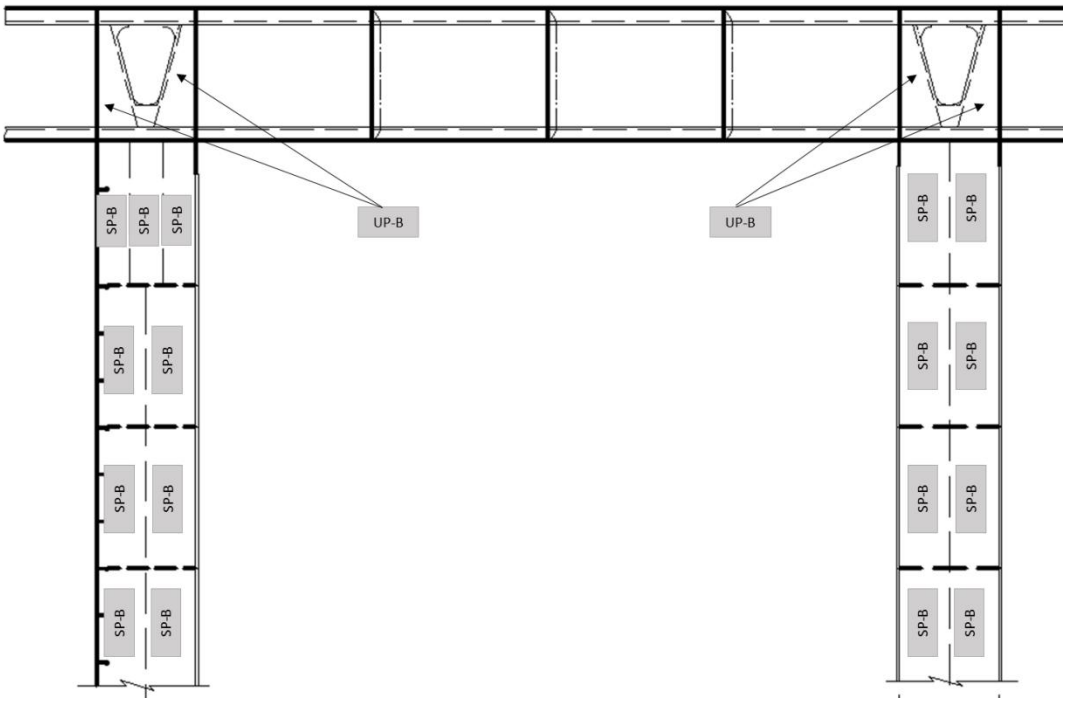


Figure 2.6.3.7(5) Horizontal girder of transverse bulkhead

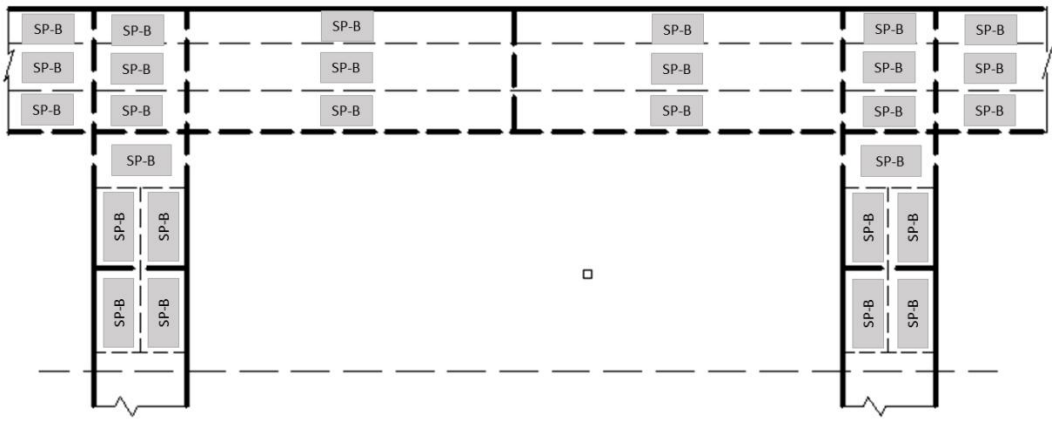


Figure 2.6.3.7(6) Deck strips between hatchways

2.6.3.8 For vertical and horizontal webs of supporting bulkhead, see Figure 2.6.3.8, the buckling utilization factor of its members is to be taken as the greater of the maximum buckling utilization factor of web plate panel (stiffened/unstiffened panel) and the maximum buckling utilization factor of pillars of web.

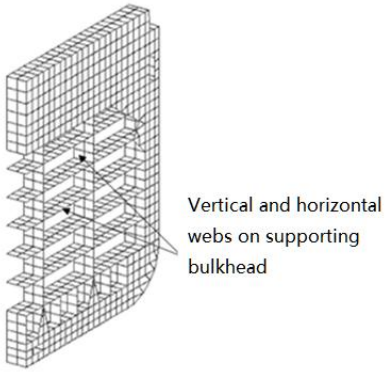


Figure 2.6.3.8 Vertical and horizontal webs on supporting bulkhead

2.7 Fine mesh analysis

2.7.1 In order to evaluate more accurately the stress level and distribution in way of the concentration of local structural stresses, fine mesh analysis and strength evaluation are at least to be carried out to the following critical parts in the evaluation area required by 2.6.1:
(1) in way of the steps of transverse web frames in the middle of supporting bulkhead and watertight transverse bulkhead (for cargo hold with two supporting transverse bulkheads, the location is the middle of the two supporting transverse bulkheads), see Figure 2.7.1(1).
(2) connection of bottom girder to inner bottom plate and bottom plating in watertight transverse bulkhead area, see Figure 2.7.1(2).
(3) large bracket toe near steps of the supporting bulkhead, see Figure 2.7.1(3).
Fine mesh analysis is also to be carried out if the stress in other critical areas exceeds the permissible criteria.

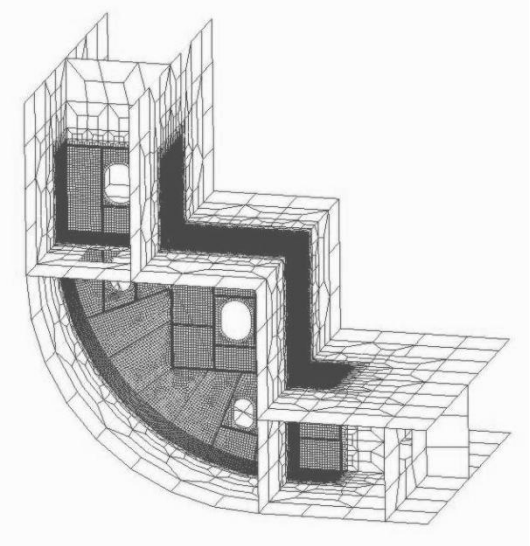


Figure 2.7.1(1) Refined transverse web frame

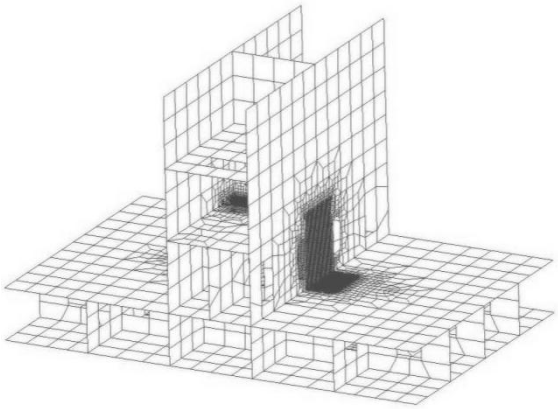


Figure 2.7.1(2) Refined structural connection of girder to inner bottom plating and bottom plating

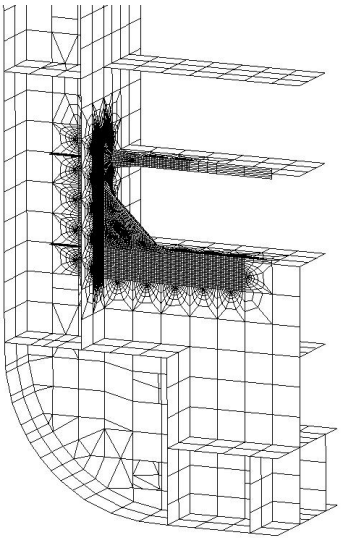


Figure 2.7.1(3) Refined large bracket toe of supporting bulkhead

2.7.2 The fine mesh analysis may be conducted by sub-modeling method and embedding method. The individual local finite element model in fine mesh areas is to be used for sub-modeling method, of which the boundary conditions and loads may be obtained from the finite element model of cargo hold blocks. The embedding method is to carry out analysis by embedding the fine mesh model into the finite element model of cargo hold block.

2.7.3 Where the local finite element model is used, its range is to be such that the stress of critical locations is not significantly affected by boundary conditions and applied loads. The boundaries of refined model are to be in consistent with the main support members (e.g. girders and floors) of finite element model o cargo hold blocks.

2.7.4 The mesh size of fine mesh area is not to be greater than 50 mm ×50 mm. In general, the range of fine mesh area is not to be less than 10 elements in all directions of critical positions.

2.7.5 Plate element simulation is to be used for all plating and stiffeners within fine mesh areas. The transition of mesh density is to be maintained stable. The aspect ratio of elements within fine mesh area is to be close to 1 as far as possible so as to avoid the change of mesh density and use of triangular element, as well as the distortion element of which the angle is less than 60° or greater than 120°. In any case, the aspect ratio of element is not to exceed 3. The stiffeners beyond the fine mesh area may be simulated by beam element.

2.7.6 For the transverse web frames, if finite element sub-model method is used, the longitudinal range of model is at least to be of the spacing of "1+1" web frames, i.e., one web frame spacing is extended both before and after the checked transverse web frames, and the web frames at forward and after ends may not be modeled. In addition, the model is to include the full molded breadth and full molded depth of ship.

2.7.7 The fine mesh analysis is to be carried out in accordance with the design conditions specified in this Appendix.

2.7.8 Where sub-model method is used for fine mesh analysis, node displacement obtained from finite element model calculation for cargo hold block is to be applied to the corresponding boundary node of individual local finite element model as a given displacement.

2.7.9 The stress criteria and check method for fine mesh analysis are shown in Table 2.7.9.

Maximum permissible membrane stress of fine mesh analysis Table 2.7.9

Element stress	Yield utilization factor (applicable to all conditions)
Element not adjacent to welds	$\lambda_y \leq 1.7$
Element adjacent to welds	$\lambda_y \leq 1.5$

where: (1) λ_y — yield utilization factor;

$$\lambda_y = \frac{\sigma_e}{[\sigma_e]}$$

(2) In the block finite element model, if the Von Mises stress of element located in the fine mesh check area exceeds the permissible values given in Table 2.7.9, the mean value of Von Mises stress calculation results obtained from fine mesh analysis with the area equivalent to the mesh size of block finite element model is not to exceed the permissible value specified in Table 2.7.9.

(3) The maximum permissible stress is to be based on the mesh size of 50 mm ×50 mm. If smaller size is used, the element mean Von Mises stress on the equivalent areas of above-mentioned mesh size may be compared with the permissible stress. The mean stress is to be calculated only when all the boundaries of element are within the range of above-mentioned mesh size.

Von Mises mean stress is to be weighted based on element area:

$$\sigma_{e-av} = \frac{\sum_1^n A_i \sigma_{e-i}}{\sum_1^n A_i}$$

Where: σ_{e-av} — Von Mises mean stress;

σ_{e-i} — Von Mises stress of the ith plate element within the area to be considered;

A_i — area of the ith plate element within the area to be considered;

n — number of elements within the area to be considered.

Note 1: The mean stress calculation is to be based on the stress at centroid of the element, and the value is not to be obtained by interpolation and/or extrapolation.

Note 2: Stress averaging method is not allowed to be used for evaluation in way of structural discontinuities and abutting members.

2.8 Strength evaluation of fuel oil tank areas

2.8.1 Where fuel oil tanks are provided within the cargo hold areas of container ships, structural strength evaluation is to be carried out for the primary members in the fuel oil tank areas:

(1) boundary structures of fuel oil tanks;

(2) deck and cross deck within fuel oil tank areas;

(3) internal grillage structures of fuel oil tanks, i.e., girders and web frame structures;

(4) double bottom structures below fuel oil tanks (bottom plating, inner bottom plating, girders and floors);

(5) side structures in way of fuel oil tank (side shell plating, inner shell plating, longitudinal stringers, side web frames).

2.8.2 Structural modeling

2.8.2.1 The longitudinal extent of block model is generally to cover the complete structures within the fuel oil tank area, with a cargo hold structure of 40 ft container bay extended both forward and afterward, i.e., “one 40 ft container bay + fuel oil tank + one 40 ft container bay”. The typical finite element model is shown in Figure 2.8.2.1.

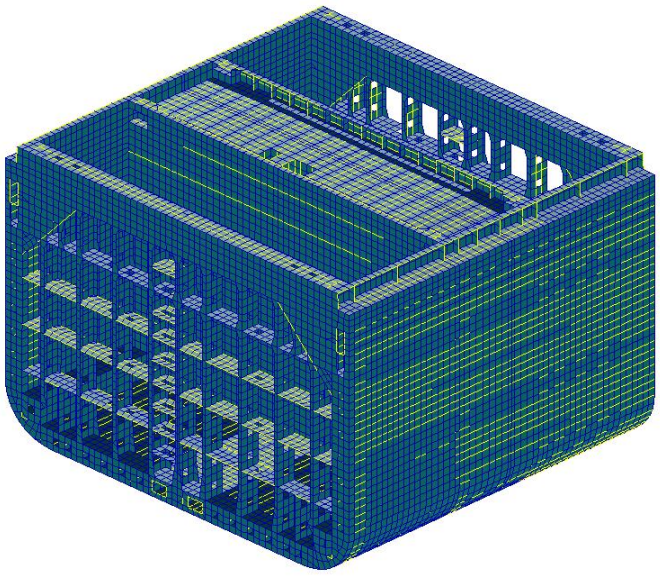


Figure 2.8.2.1 Finite Element Model of Fuel oil tank

2.8.2.2 Except the above-mentioned modelling requirements, the other structural modeling requirements are listed in 2.2 of this Appendix.

2.8.3 Design loads

2.8.3.1 Except the liquid pressure of tanks, the other loads are given in 2.3 of this Appendix.

2.8.3.2 Pressures of liquid in tank

The pressures of liquid in tank include the pressure in static load condition and the pressure in dynamic load condition.

(1) The pressure of ballast tanks under dynamic load condition p_{blast1} and the pressure of fuel oil tank under dynamic load condition p_{HD1} are to be calculated by:

$$p_{blast1} = \rho_w (a_v + g) h_1 + 10 p_v \quad \text{kN/m}^2$$

$$p_{HD1} = \rho_f (a_v + g) h_1 + 10 p_v \quad \text{kN/m}^2$$

where:

h_1 — distance from the load point to the top of tank, in m;

ρ_w — density of sea water, in 1.025 t/m^3;

ρ_f — density of oil fuel, in 1.0 t/m^3;

p_v — dynamic load coefficient, to be taken not less than 0, is to be calculated by:

$$p_v = \Delta z - 1.5$$

where: ΔZ — distance between the top of tank and the top of overflow pipe, in m.

(2) The pressure of ballast tanks under static load condition p_{blast} and The pressure of fuel oil tanks under static load condition p_{HO} are to be calculated by:

$$p_{blast} = \rho_w g h_2 \quad \text{kN/m}^2$$

$$p_{HO} = \rho_f g h_2 \quad \text{kN/m}^2$$

Where: h_2 — distance from the load point to the top of overflow pipe, in m.

ρ_w , ρ_f — the same as 2.8.3.2(1).

2.8.4 Loading conditions

2.8.4.1 In order to fully evaluate the structures of fuel oil tanks, the loading conditions are to be determined according to the arrangement type of fuel oil tanks. The basic principle is that strength analysis

is to be carried out for the structures within fuel oil tank area based on full load of fuel oil tank, alternate load and light ship conditions respectively. Figure 2.8.4.1 gives several typical arrangement types of fuel oil tanks, and the loading conditions of various typical fuel oil tank arrangement types are shown in Table 2.8.4.1(1) to Table 2.8.4.1(3).

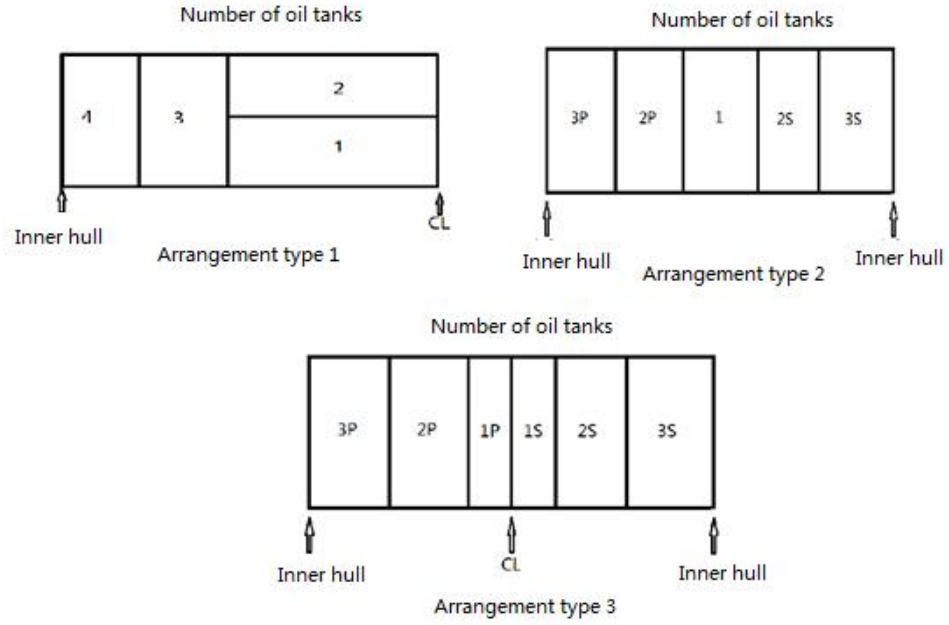


Figure 2.8.4.1 Diagram of Typical Fuel Oil Tank Arrangement Types (Vertical View)

Loading condition of Typical Fuel Oil Tank Arrangement Type 1 Table 2.8.4.1(1)

Loading condition	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Wave	Hogging	Hogging	Hogging	Hogging	Sagging	Sagging	Sagging	Sagging	Hogging	Hogging	Hogging	Hogging	Still water	Still water
Draught	d	d	d	d	0.9d	0.9d	0.9d	0.9d	d	d	d	d	d	d
Weight of container（TEU）	Light	Light	Light	Light	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
Side ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Bottom ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Oil tank	Empty	Full load	1，3，4 full load	2，3，4 full load	3 full load	1，2，4 full load	1，3 full load	2，4 full load	Empty	Full load	1，3，4 full load	2，3，4 full load	1,3 full load	2 full load
Remark									One bay empty	One bay empty	One bay empty	One bay empty		

Note 1: In the column of “According to loading manual”, it will be empty if there is no corresponding condition in the loading manual.

2: “One bay empty” means it is empty inside the tank and on the hatch cover of one 40 ft bay.

Loading condition of Typical Fuel Oil Tank Arrangement Type 2 Table 2.8.4.1(2)

Loading conditions	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Wave	Hogging	Hogging	Hogging	Hogging	Sagging	Sagging	Sagging	Sagging	Hogging	Hogging	Hogging	Hogging	Still water	Still water
Draught	d	d	d	d	0.9d	0.9d	0.9d	0.9d	d	d	d	d	d	d
Weight of container （teu）	Light	Light	Light	Light	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
Side ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Bottom ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Oil tank	Empty	Full load	1，3 full load	2 full load	Empty	Full load	1，3 full load	2 full load	Empty	Full load	1，3 full load	2 full load	1,3 full load	2 full load
Remark									One bay empty	One bay empty	One bay empty	One bay empty		

Note 1: In the column of “According to loading manual”, it will be empty if there is no corresponding condition in the loading manual.

2: “One bay empty” means it is empty inside the tank and on the hatch cover of one 40 ft bay.

Loading condition of Typical Fuel Oil Tank Arrangement Type 3 Table 2.8.4.1(3)

Loading conditions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Wave	Hogging	Hogging	Hogging	Hogging	Sagging	Sagging	Sagging	Sagging	Hogging	Hogging	Hogging	Hogging	Hogging	Hogging	Hogging	Hogging	Still water	Still water
Draught	d	d	d	d	0.9d	0.9d	0.9d	0.9d	d	d	d	d	d	d	d	d	d	d
Weight of container (TEU)	Light	Light	Light	Light	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
Side ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Bottom ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Oil tank	Empty	Full load	3P, 1P, 2S full load	2P, 1S, 3S full load	Empty	Full load	3P, 1P, 2S full load	2P, 1S, 3S full load	Empty	Full load	3P, 1P, 2S full load	2P, 1S, 3S full load	Empty	Full load	3P, 1P, 2S full load	2P, 1S, 3S full load	Full load	3P, 1P, 2S full load
Remark													One bay empty	One bay empty	One bay empty	One bay empty		

Note 1: In the column of “According to loading manual”, it will be empty if there is no corresponding condition in the loading manual.

2: “One bay empty” means it is empty inside the tank and on the hatch cover of one 40 ft bay.

2.8.5 Boundary conditions

2.8.5.1 The boundary conditions are to be in accordance with the relevant provisions of 2.5 in this Appendix.

2.8.6 Strength evaluation

2.8.6.1 Evaluated areas

2.8.6.1 The mid tank and primary structural members within the extent of one web frame extending forward and afterward are to be evaluated.

2.8.6.2 Yield strength evaluation

(1) The stresses generated by local load case and global load case are to be combined for strength check. The equivalent stress at midpoint of element is to be taken as the plate element stress.

(2) The permissible stress for each primary structural member is given in Table 2.8.6.2.

Permissible stress Table 2.8.6.2

Structural member	Permissible stress (N/mm^2)	
	$[\sigma_e]$	$[\tau]$
Bottom plating, inner bottom plating	225/K	–
Side shell plating, inner hull longitudinal bulkhead	225/K	115/K
Bottom girder	235/K	115/K
Intersection of oil fuel boundaries and bottom girders	235/K	115/K
Double bottom floor	175/*K*	90/*K*
Transverse web frame	195/*K*	95/*K*
Fuel oil tank bulkhead (excluding inner hull longitudinal bulkhead)	180/K	100/K
Stringers in fuel oil tank and girder webs between bulkheads	195/K	100/K

Note: *K*— material factor.

2.8.6.3 Buckling strength evaluation

(1) The buckling strength evaluation method is given in the provisions of 2.6 in this Appendix.

2.8.6.4 Fine mesh analysis

(1) If the yield stress exceeds the permissible criteria, fine mesh analysis may be carried out in the critical areas, such as the connection of fuel oil tank boundaries to bottom girders, platform corners within fuel oil tanks, etc. The fine mesh analysis method, element requirements and evaluation criteria are given in 2.7 of this Appendix.

3 Direct Calculation of Global Strength of Ship

3.1 General requirements

3.1.1 Direct strength calculation of whole ship is to be used to evaluate the global strength of primary hull members under combined bending and torsional moments. In calculation, the following two methods may be used:

Method 1: Analysis where hull girder loads (vertical bending moment, horizontal bending moment and torsional moment) are directly applied to the full ship finite element model.

Method 2: Analysis where direct loads transferred from wave load analysis are applied to the full ship finite element model.

3.2 Loading conditions

3.2.1 Still water condition

3.2.1.1 The still water condition is to be selected according to the loading manual, and generally the full load condition where maximum still water bending moment occurs and normal ballast condition where

maximum GM occurs are to be taken.

3.2.1.2 Under the maximum still water bending moment conditions, the ship is to be in or close to upright condition, at or near to the draught d, and the still water bending moment within $0.4L$ amidships is the maximum value. If one 40 ft bay in midship range is to be left empty, the maximum still water bending moment condition under this loading condition is required.

3.2.1.3 Consideration is also to be taken if more severe non-homogeneous loading conditions exist in the loading manual.

3.2.2 Wave load condition

3.2.2.1 The still water load condition as determined according to 3.2.1 is taken as the basic loading condition for wave load conditions.

3.2.2.2 Unless specified otherwise in the Appendix, the parameters of wave load conditions, such as length, height and phase of waves, are to be determined by the method and procedure used for equivalent design wave, see Section 5, Chapter 1 of this PART. The wave load conditions are to include head sea,oblique sea and beam sea conditions.

3.2.2.3 The dominant load parameters for direct calculation of wave loads include vertical wave bending moment, horizontal wave bending moment, torsional moment, acceleration and rolling angle. The prediction of the maximum wave load likely to be experienced during the service life covers mainly sea conditions to be encountered during navigation in sea areas around the world, expressed in the probability of waves occurring in various periods and heights. It is suggested that the wave scatter diagram recommended by IACS be adopted. The probability level of dominant load parameters is generally taken as 10^{-8}, and that of the prediction value of maximum vertical wave bending moment corresponding to the value as required in Section 2 of this Chapter may also be taken.

3.2.3 Loading conditions

3.2.3.1 Each calculation condition is based on different combination of still water condition and wave load condition. Generally, the global strength analysis of container ships is to be checked in accordance with the loading conditions in Table 3.2.3.1. For two-island container ship, the considered condition of the maximum torque at fore and aft ends of the fore island is also to be checked.

Loading Conditions **Table 3.2.3.1**

Loading conditions / Dominant load parameters	homogeneous full load	Normal ballast	Non-homogeneous loading（if any）
Maximum vertical wave bending moment	Applicable	Applicable	Applicable
Maximum horizontal wave bending moment	Applicable	Applicable	Applicable
Maximum torque in way of $L/2$	Applicable	Applicable	Applicable
Maximum torque in way of $L/4$	Applicable	Applicable	Applicable
Maximum torque in way of $3L/4$	Applicable	Applicable	Applicable
Maximum vertical bow acceleration	Applicable	Applicable	Applicable
Maximum rolling angle	-	Applicable	-

3.3 Finite element model for whole ship

3.3.1 Extent of finite element model

3.3.1.1 The ship's global three-dimensional finite element model covers all longitudinal stressed members in main hull within ship's complete length and full breadth, such as deck structure, side and longitudinal bulkhead structure and double bottom structure. The model covers also primary transverse structures such as transverse bulkhead, transverse web frame, transverse deck strip, etc. Local supporting members such as brackets may be omitted in the model. Requirements for openings of web plates of primary structural members are defined in Section 5, Chapter 1 of this PART and openings in brackets may be omitted. A global structural FE model of a typical container ship is shown in Figure 3.3.1.1.

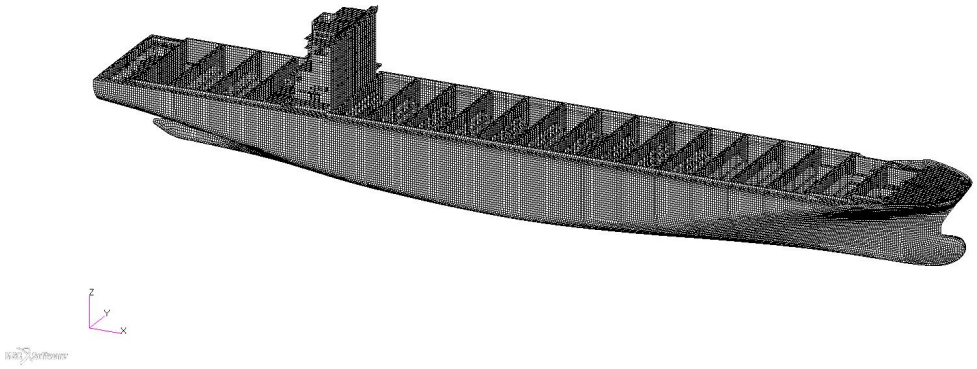


Figure 3.3.1.1 Global Structural FE Model of a Typical Container Ship

3.3.2 Selection of elements

3.3.2.1 All kinds of structures in the model are discretized into the following types of elements based on their structural responses:

(1) Shell element (four-node and three-node elements): such as deck, side shell, bottom plating, inner bottom plating, longitudinal and transverse bulkheads, bottom girder, floor, wing space horizontal girder, transverse web frame, etc.

(2) Beam element: such as girder, beam and watertight bulkhead stiffener, etc.

(3) Rod element: such as pillar, etc.

3.3.3 Meshing

3.3.3.1 Unless otherwise specified in this Appendix, the requirements for structural modeling are given in Section 5, Chapter 1 of this PART.

3.3.3.2 The aspect ratio of elements amidships is not to exceed 1:3 and is not to exceed 1:2 elsewhere. Warped quadrilateral elements are to be avoided for meshing.

3.3.4 Boundary conditions

3.3.4.1 In order to prevent rigid displacements, suitable linear displacement constraints are to be applied at corresponding nodes of hull as shown in Figure 3.3.4.1.

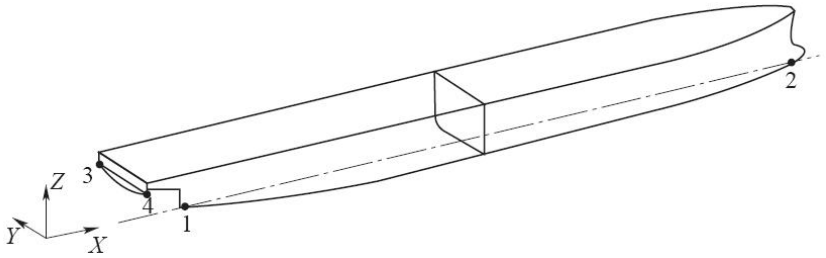


Figure 3.3.4.1 Diagram of Boundary Conditions

3.3.4.2 The displacement in transverse direction for bottom plate keel (in longitudinal centerline section) at aft end (node 1 in Figure 3.3.4.1 of this Appendix) is restrained, i.e.: $\delta_y = 0$; the displacements in longitudinal, transverse and vertical directions for bottom plate keel (in longitudinal centreline section) at fore end (node 2 in Figure 3.3.4.1 of this Appendix) are restrained, i.e.: $\delta_x = \delta_y = \delta_z = 0$.

3.3.4.3 The displacements in vertical direction for node 3 (port) and node 4 (starboard) respectively which are at an equal distance from the longitudinal centerline section on horizontal girder of stern transom plate are restrained, i.e.: $\delta_z = 0$.

3.3.5 Fine mesh analysis

3.3.5.1 Fine mesh analysis is to be carried out if the result of whole ship FE calculation of stresses in the following areas exceeds 90% of the permissible stress specified in 3.4.1 of this Appendix:

(1) in way of the steps of transverse web frames in cargo hold area;

(2) connection of double bottom girder and transverse bulkhead;

(3) face plate of horizontal girders and large bracket toe in way of the supporting transverse bulkhead;

(4) in way of the bracket toe of longitudinal hatch coaming;

(5) in way of hatch corners of hatch coamings top plates and deck plates;

(6) openings on inner shell, hatch coaming, deck and vertical girder and horizontal girder of transverse bulkheads.

3.3.5.2 Fine mesh analysis is to comply with the requirements of 2.7 of this Appendix.

3.4 Yield strength evaluation for global finite element structure of ship

3.4.1 The allowable stress of plates including girder web is as follows:

$$[\sigma_e] = 220/K \quad \text{N/mm}^2$$

where: K — material factor.

3.4.2 The beam element is taken as the axial stress and its allowable stress is as follows:

$$[\sigma] = 220/K \quad \text{N/mm}^2$$

where: K — material factor.

3.4.3 The stress criteria and checking method for fine mesh analysis are defined in 2.7.9 of this Appendix and $[\sigma_e]$ is to be calculated according to 3.4.1.

3.5 Buckling strength evaluation for global finite element structure of ship

3.5.1 The buckling strength evaluation for global finite element structure of ship is to be checked in accordance with 2.6.3 of this Appendix.

4 Fatigue Strength Evaluation

4.1 General requirements

4.1.1 This Section provides methods to evaluate fatigue strength of key positions of container ships under bending and torsional loads.

4.1.2 The wave load calculation for evaluation of fatigue strength of hatch corners is to be based on the equivalent design wave method used for structural analysis of the whole ship, as shown in Section 5 of Chapter 1.

4.1.3 Fatigue damage calculation is based on Palmgren-Miner linear cumulative damage principle, taking into account S-N curves and sea state parameters etc.

4.1.4 In addition to the evaluation method given in this Section, the fatigue evaluation may also be carried out in accordance with relevant requirements of CCS Guidelines for Spectrum-based Fatigue Assessment of Hull Structure.

4.1.5 Hull structures in way of key positions are to be screened based on the result of coarse mesh calculation to determine the fatigue evaluation spots. The evaluation spots are at least to include end bracket toes of longitudinal hatch coaming, hatch corners at the fore (aft) end of engine room, hatch corners at the end of No.1 cargo hold towards the fore end of the ship and a cargo hold hatch corner amidships.

4.2 Loads

4.2.1 The loads for fatigue evaluation are to be obtained from the corresponding loading conditions for global analysis of the ship.

4.2.2 The loading condition is to be taken as the full load condition in loading manual where maximum still water bending moment occurs.

4.2.3 Loading conditions

4.2.3.1 In general, the design wave loads to be calculated are as follows:

(1) LC1: maximum vertical wave bending moment in way of 1/2L from AP (hogging);
(2) LC2: minimum vertical wave bending moment in way of 1/2L from AP (sagging);
(3) LC3: maximum horizontal wave bending moment in way of 1/2L from AP;
(4) LC4: minimum horizontal wave bending moment in way of 1/2L from AP;
(5) LC5: maximum wave torque in way of 1/4L from AP;
(6) LC6: minimum wave torque in way of 1/4L from AP;
(7) LC7: maximum wave torque in way of 1/2L from AP;
(8) LC8: minimum wave torque in way of 1/2L from AP;
(9) LC9: maximum wave toque in way of 3/4L from AP;
(10) LC10: minimum wave torque in way of 3/4L from AP.

4.2.3.2 The displacements and stresses of the global structure are to be obtained by the loading conditions specified in 4.2.3.1 of this Appendix.

4.2.3.3 The range of dynamic stresses at the edge of hatch corners is to be based on the calculation results

of each loading condition specified in 4.2.3.1 of this Appendix and combined as follows:

$$\Delta\sigma_{12} = \sigma_{LC1} - \sigma_{LC2}$$

$$\Delta\sigma_{34} = \sigma_{LC3} - \sigma_{LC4}$$

$$\Delta\sigma_{56} = \sigma_{LC5} - \sigma_{LC6}$$

$$\Delta\sigma_{78} = \sigma_{LC7} - \sigma_{LC8}$$

$$\Delta\sigma_{910} = \sigma_{LC9} - \sigma_{LC10}$$

where: $\Delta\sigma_{ij}$ — range of stresses under the combined load cases *i* and *j*, taken as the range of tangential stresses at the free edge if the evaluation spot is the free edge of corners or openings, in N/mm^2;

σ_{LCi} — value of stress in load case *i*, taken as the value of tangential stresses at the free edge if the evaluation spot is the free edge of corners or openings, in N/mm^2.

4.3 Structural modeling

4.3.1 General requirements

4.3.1.1 The local fine mesh model is to be in accordance with the requirements of 4.3.2 to 4.3.7 of this Appendix .

4.3.1.2 For the fatigue analysis, the three-dimensional fine mesh model of the local structure may be separated for an individual analysis, applying the displacement results obtained from global three-dimensional coarse mesh finite element analysis to the corresponding boundary nodes as boundary conditions for forced displacements. Alternatively, the fine mesh model may be inserted directly into the global model for analysis. The boundary of fine mesh model is as far as practicable to be taken on the structure of primary supporting and web frames, provided that the following model extent is observed.

4.3.2 Fine mesh model of local structure of hatch corners in the midship region

4.3.2.1 For the local fine mesh model of the midship region, the deck openings where the maximum stress or maximum cross-deck strip warping displacement occurs are in general selected, see Figures 4.3.2.1(1) and (2), and the corresponding extent of model is as follows:

(1) for longitudinal extent, half length of a 40 ft container bay, extending forward and afterward of cross deck strip corner;

(2) for vertical extent, from No.2 deck to the top of hatch coaming;

(3) for transverse extent, from the centerline to ship side, covering hatch corners in way of upper deck and the transitional structure of corners in way of hatch coaming top plate.

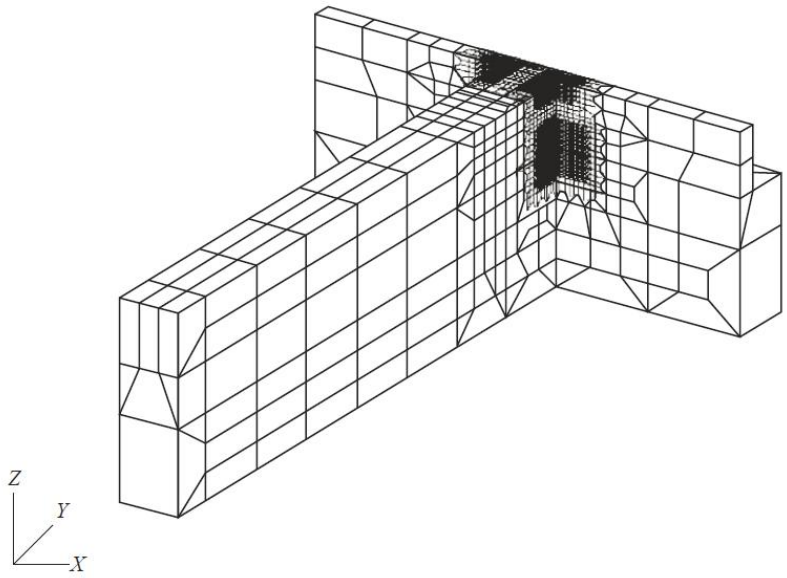


Figure 4.3.2.1(1) FE Model of Hatch Corners in Way of Cargo Hold Area

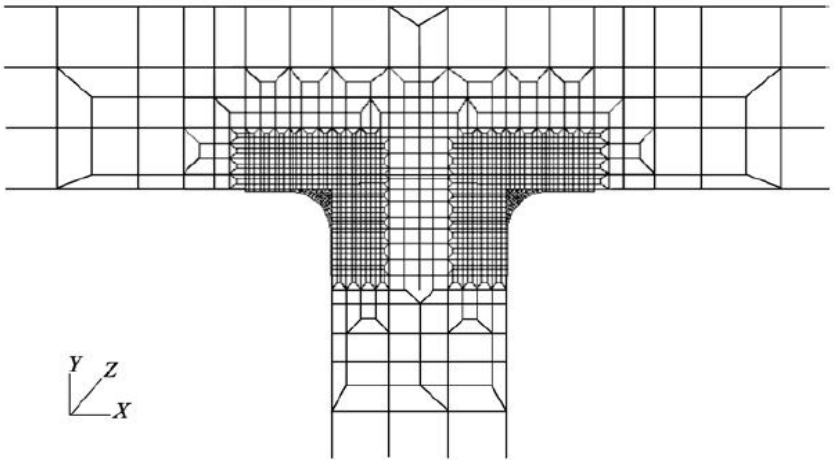


Figure 4.3.2.1(2) FE Model of Hatch Corners in Way of Cargo Hold Area
(Upper Deck Hatch Corners Amplified)

4.3.3 Fine mesh model of local structure of hatch corners at fore end of engine room

4.3.3.1 For the local fine mesh model at the fore end of the engine room, the hatch corners at the front bulkhead of the engine room at portside are to be selected, and the corresponding extent of model is as follows:

(1) for longitudinal extent, half length of a 40 ft container bay extending forward from the front transverse bulkhead of the engine room and a similar distance extending afterward to the transverse web frame (in general, at the mesh line of the transverse web frame of the global model);

(2) for vertical extent, from No.2 deck to hatch coaming (in general, up to the first-tier deck in way of superstructures);

(3) for transverse extent, from the centerline to ship side.

4.3.3.2 All the models are to include upper deck structures with openings, radiused transition structures in way of the hatch coaming top plate and the tapered bracket between the forward end of superstructures and hatch coaming, and their geometry is to be described accurately in the model, see Figures 4.3.3.2(1) to (3).

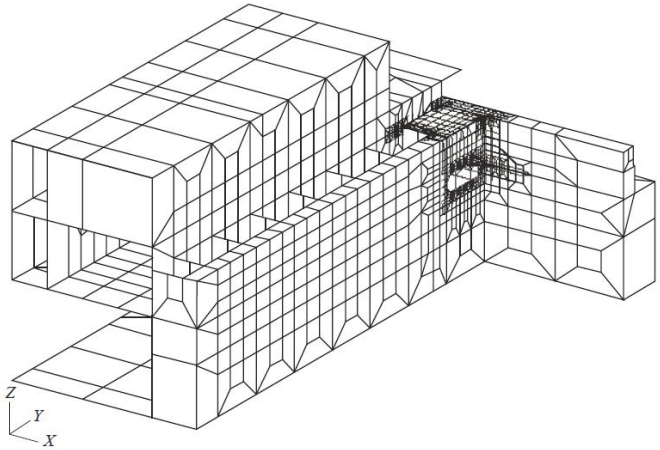


Figure 4.3.3.2(1) FE Model of Hatch Corners in Way of Engine Room Front Bulkhead

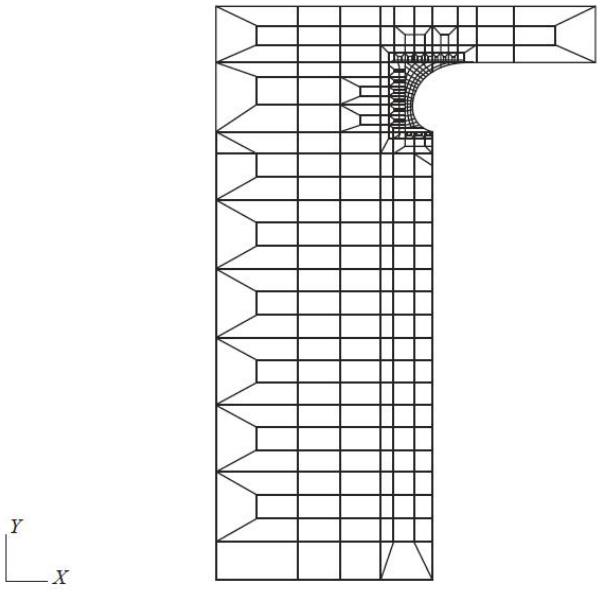


Figure 4.3.3.2(2) FE Model of Hatch Corners in Way of Engine Room Front Bulkhead
(Upper Deck Hatch Corners)

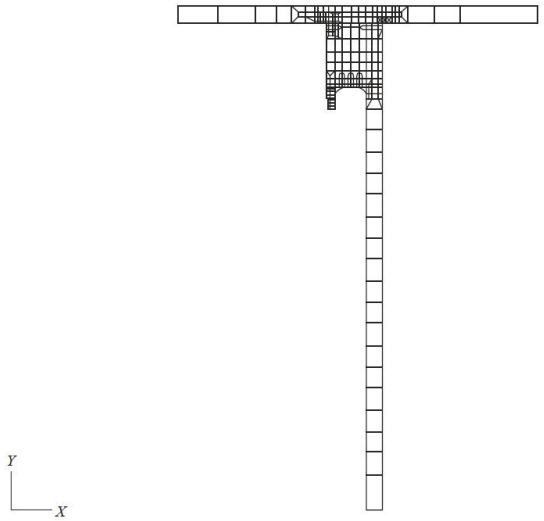


Figure 4.3.3.2(3) FE Model of Hatch Corner in Way of Engine Room Front Bulkhead
(Hatch Coaming Top Plate)

4.3.4 The requirements for the local fine mesh model of hatch corners at the aft end of the engine room and the forward end of No.1 cargo hold are the same as those in 4.3.3.1.

4.3.5 Selection of elements and meshing

4.3.5.1 Plate elements are used to simulate primary structural members such as upper deck, shell plate, longitudinal bulkhead and transverse plates, and beam elements are used to simulate longitudinals and stiffeners. Meshing of the positions where hot-spot stress is checked is shown in 4.3.5.4 of this Appendix.

4.3.5.2 The geometry of radiused corners in upper deck area, radiused top plates of hatch coamings, etc. are to be reflected accurately in the fine mesh model, and all openings (ventilators, access openings) are also to be described accurately in the model.

4.3.5.3 Where the tangential stress at the edge of hatch corners can not be obtained from the finite element analysis program, the method of providing virtual rod elements at the edge of hatch corners to obtain the axial stress of elements is to be used to get the tangential stress, and virtual rod elements may be applied to the following positions:

(1) along the radiused edge of hatch corners at the top level of upper deck and hatch coaming;

(2) along the superstructure to the upper edge of the radiused connecting bracket of longitudinal hatch coaming, if any.

4.3.5.4 The plate elements of areas of hot-spot stress evaluation are to be divided in accordance with the

mesh size of plate thickness × plate thickness ($t \times t$). This mesh density is to be maintained within the fine mesh zone, extending at least10t distance in all directions from the center of hot pot stress to provide a smooth transition to the model boundary.

4.3.6 Boundary conditions

4.3.6.1 The boundary conditions for the global three-dimensional coarse mesh FE model are given in 3.3.4 of this Appendix.

4.3.6.2 Where an independent sub-model is used for analysis, the nodal displacements in way of the boundary of a coarse mesh model, which are obtained from calculations of the above-mentioned loading conditions for the global model, are to be transmitted to corresponding nodes of the fine mesh model as forced displacement boundary conditions of the fine mesh model.

4.4 Fatigue strength evaluation

4.4.1 Assuming that the long-term distribution of the stress ranges of hull structures is a two-parameter Weibull distribution, the shape parameter ξ of Weibull distribution is to be calculated as follows:

$$\xi = 1.45 - 0.036 f\sqrt{L}$$

where: L— length of ship, in m;

$f = 1 - 0.08z/d_1$ for $z \le d_1$;

$f = 0.92+0.08(z - d_1)/(D - d_1)$ for $z > d_1$;

$f = 0.92$ for the calculated point on transverse bulkhead;

D — moulded depth, in m;

d_1— draught in the considered condition, in m;

z— vertical distance from calculation point to baseline, in m.

4.4.2 Design S-N curves are to be selected as follows:

For welding type joint, D curves are selected for fatigue strength evaluation;

For free edge of base metal, C curves are selected for fatigue strength evaluation.

4.4.3 Cumulative damage D_T is to be calculated as follows:

$$D_T = \frac{N_D \alpha}{K} \frac{S_D{}^m}{\left(\ln N_L\right)^{m/\xi}} \mu \Gamma\left(1 + \frac{m}{\xi}\right)$$

where: N_D — total cycles of loads within 20 years' service life of ships, normally taken as 0.65×10^8;

N_L — cycles of load spectrum response circle, taken as 10^8;

α — in-service coefficient of ship, taken as 0.85;

K — S-N curve parameter, see Table 4.4.3(1) of this Appendix;

S_D — design stress ranges, in N/mm^2, calculated as follows:

$$S_D = \max\left(f_c \cdot f_{mean} \cdot f_t \cdot \left|\Delta\sigma_{ij}\right|\right)$$

$\Delta\sigma_{ij}$ — design stress ranges of the combined load cases i and j, see 4.2.3.3 of this Appendix;

fc — corrosion correction factor, taken as 1.07;

f_{mean} — average stress correction factor, selected as follows:

for welding type joint:

$$f_{mean} = \begin{cases} \min\left(1.0, 0.85 + 0.3\sigma_{mean} / \Delta\sigma_{ij}\right), \sigma_{mean} \ge 0 \\ \max\left(0.7, 0.85 + 0.3\sigma_{mean} / \Delta\sigma_{ij}\right), \sigma_{mean} \le 0 \end{cases}$$

for free edge of base metal

$$f_{mean} = \begin{cases} \min\left(1.0, 0.8 + 0.4\sigma_{mean} / \Delta\sigma_{ij}\right), \sigma_{mean} \ge 0 \\ \max\left(0.6, 0.8 + 0.4\sigma_{mean} / \Delta\sigma_{ij}\right), \sigma_{mean} \le 0 \end{cases}$$

σ_{mean} — average stress of considered loading;

f_t — plating thickness correction coefficient, selected as follows:

$$f_t = 1.0 \quad \text{for} \quad t \le 22;$$

$$f_t = \left(\frac{t}{22}\right)^n \text{ for } t > 22;$$

n — coefficient, see Table 4.4.3(2) of this Appendix;

t — plating thickness at hot spot, in mm, taken as the thickness of plating of structure where cracks are easy to occur and extend;

ξ — parameter of Weibull distribution, see 4.4.1 of this Appendix;

m — inverse slope of the *S-N* curve, taken as 3;

Γ — complete GAMMA function values, to be calculated as follows:

$$\Gamma(x) = \int_0^\infty u^{x-1} e^{-u} du$$

$$\mu = 1.0 - \frac{\gamma\left(1+\frac{m}{\xi}, \nu\right) - \nu^{-\frac{\nabla m}{\xi}} \gamma\left(1+\frac{m+\nabla m}{\xi}, \nu\right)}{\Gamma\left(1+\frac{m}{\xi}\right)}$$

$$\nu = \left(\frac{S_q}{S_D}\right)^\xi \ln N_L$$

S_q — stress amplitude values at intersection point of two-slope S-N curves, see Table 4.4.3(1) of this Appendix;

∇m — difference of inverse slope of two-slope S-N curves, taken as 2;

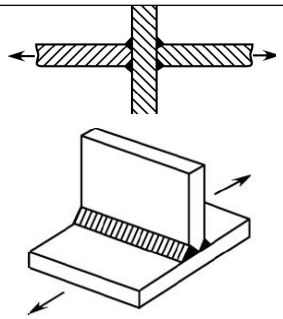
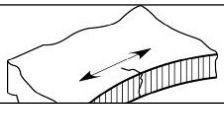
$\gamma(x, \nu)$ — incomplete GAMMA function values, to be calculated as follows:

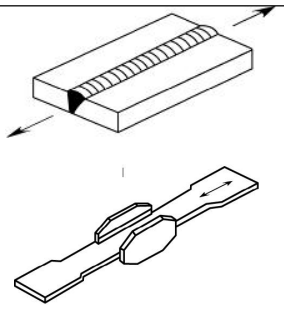
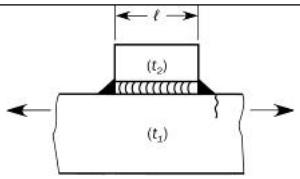
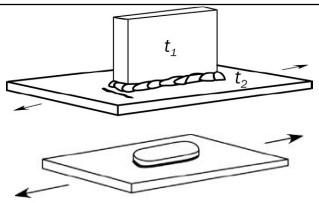
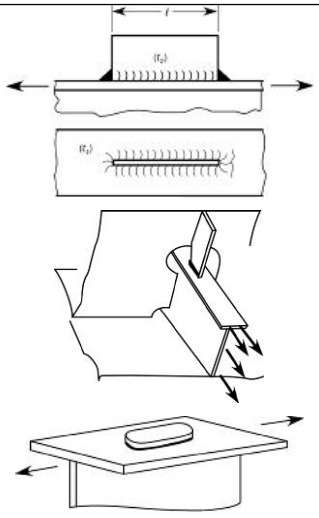
$$\gamma(x, v) = \int_0^v u^{x-1} e^{-u} du$$

Table 4.4.3(1)

S-N curves	K	S_q
C	3.464×10^{12}	70.2305
D	1.520×10^{12}	53.3680

Table 4.4.3(2)

Structural details	Sketches	Coefficient n
Cruciform joints or transverse T-joints, with weld perpendicular to the direction of load		0.25
Butt joints, with weld perpendicular to the direction of load		0.2
Machine controlled by program or plate with		0.1

Structural details	Sketches	Coefficient n
flame-cut edges, with plate edge parallel to the direction of load		
Plate edge which is ground smooth by machine or other means after cutting		0
Butt welds, attachments on plate edge, with weld parallel to the direction of load		0.1
Attachments on the flat bar or bulb profile, with weld parallel to the direction of load		0
Bracket welded on the plate, with weld parallel to the direction of load, doubling plate		0.2
T section face plate welded with bracket or doubling plates, with weld parallel to the direction of load		0.1

4.4.4 Structure fatigue life is to be calculated as follows:

$$T_F = \frac{20}{D_T}$$

4.4.5 Cumulative damage D_T for structure in its design service life is to meet the following requirement:

$$D_T \leq \frac{20}{T_D}$$

where: T_D — design fatigue life, in year.

Appendix 3 CALCULATION OF SHEAR FLOW

1 General Requirements

This Appendix describes the procedures of direct calculation of shear flow around a ship's cross section due to hull girder vertical shear force. The shear flow q_v at each location in the cross section, is calculated by considering the cross section is subjected to a unit vertical shear force of 1 N in the direction of Z coordinate.

The unit shear flow per mm, q_v, in N/mm, is to be taken as:

$$q_v = q_D + q_l$$

where: q_D — determinate shear flow, as defined in 2;

q_l — indeterminate shear flow which circulates around the closed cells, as defined in 3.

In the calculation of the unit shear flow, q_v, the longitudinal stiffeners are to be taken into account.

2 Determinate Shear Flow

The determinate shear flow, q_D, in N/mm at each location in the cross section is to be obtained from the following line integration:

$$q_D(\mathrm{s}) = -\frac{1}{10^6 I_{y-net}} \int_0^s (z - z_n) t_{net} d_s$$

where: s — coordinate value of running coordinate along the cross section, in m;

$I_{y\text{-}net}$ — net moment of inertia of the cross section, in m^4;

t_{net} — net thickness of plating, in mm;

z_n — Z coordinate of horizontal neutral axis from baseline, in m.

It is assumed that the cross section is composed of line segments as shown in Figure 1: where each line segment has a constant plate net thickness. The determinate shear flow is obtained by the following equation.

$$q_{Dk} = -\frac{t_{net}\ell}{2 \cdot 10^6 I_{Y-net}} (z_k + z_i - 2z_n) + q_{Di}$$

where: q_{Dk}, q_{Di} — determinate shear flow at node k and node i respectively , in N/mm;

l — length of line segments, in m;

y_k, y_i — Y coordinate of the end points k and i of line segment, in m, as defined in Figure 1;

z_k, z_i — Z coordinate of the end points k and i of line segment, in m, as defined in Figure 1.

Where the cross section includes closed cells, the closed cells are to be cut with virtual slits, as shown in Figure 2, in order to obtain the determinate shear flow.

These virtual slits must not be located in walls which form part of another closed cell.

Determinate shear flow at bifurcation points is to be calculated by water flow calculations, or similar, as shown in Figure 2.

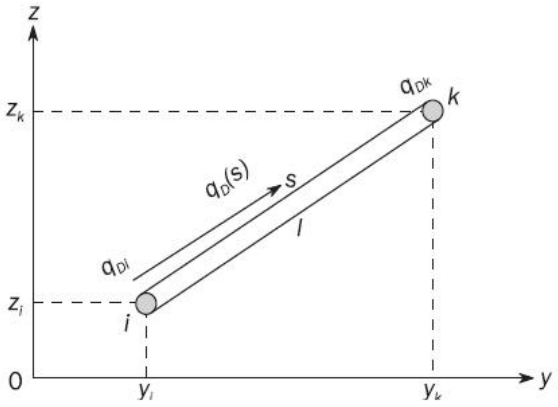


Figure 1 Definition of line segment

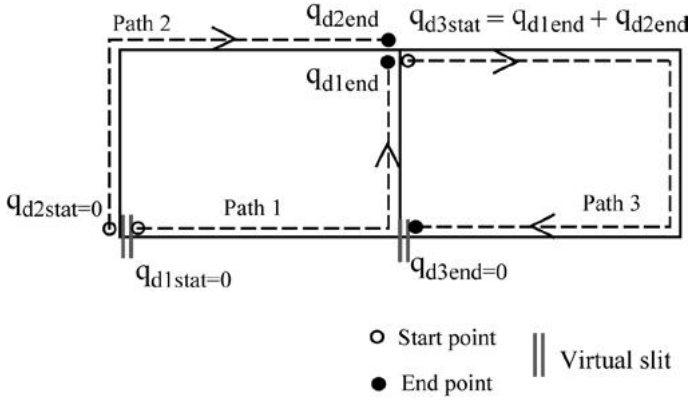


Figure 2 Calculation of determinate shear flow at bifurcation points

3 Indeterminate Shear Flow

The indeterminate shear flow around closed cells of a cross section is considered as a constant value within the same closed cell. The following system of equation for determination of indeterminate shear flows can be developed. In the equations, contour integrations of several parameters around all closed cells are performed.

$$q_{Ic} \oint_c \frac{1}{t_{net}} ds - \sum_{m=1}^{N_w} \left(q_{Im} \oint_{c\&m} \frac{1}{t_{net}} ds \right) = - \oint_c \frac{q_D}{t_{net}} ds$$

where: N_w — number of common walls shared by cell c and all other cells;
$c \,\&\, m$ — common wall shared by cells c and m;
q_{Ic}, q_{Im} — indeterminate shear flow around the closed cell c and m respectively, in N/mm.

Under the assumption of the assembly of line segments shown in Figure 1 and constant plate thickness of each line segment, the above equation can be expressed as follows:

$$q_{Ic} \sum_{j=1}^{N_c} \left(\frac{\ell}{t_{net}} \right)_j - \sum_{m=1}^{N_w} \left\{ q_{Im} \left[\sum_{j=1}^{N_m} \left(\frac{\ell}{t_{net}} \right)_j \right]_m \right\} = - \sum_{j=1}^{Nc} \phi_j$$

$$\phi_j = \left[- \frac{\ell^2}{6 \cdot 10^3 I_{Y-net}} (z_k + 2z_i - 3z_n) + \frac{\ell}{t_{net}} q_{Di} \right]_j$$

where: N_c — number of line segments in cell c;
N_m— number of line segments on the common wall shared by cells c and m;
q_{Di}— determinate shear flow, in N/mm, calculated according to 2.

The difference in the directions of running coordinates specified in 2 and in this section has to be considered.

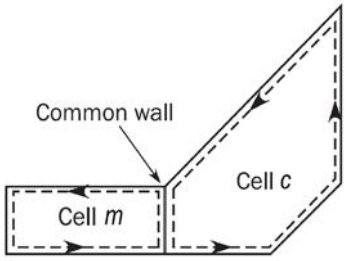


Figure 3 Closed cells and common wall

4 Computation of Sectional Properties

Properties of the cross section are to be obtained by the following formulae where the cross section is assumed as the assembly of line segments:

$$\ell = \sqrt{\left(y_k - y_i\right)^2 + \left(z_k - z_i\right)^2}$$

$$a_{net} = 10^{-3}\ell t_{net} \qquad A_{net} = \sum a_{net}$$

$$s_{y-net} = \frac{a_{net}}{2}(z_k + z_i) \qquad S_{y-net} = \sum s_{y-net}$$

$$i_{y0-net} = \frac{a_{net}}{3}\left(z_k^2 + z_k z_i + z_i^2\right) \qquad I_{y0-net} = \sum i_{y0-net}$$

where: a_{net}, A_{net} — area of the line segment and the cross section respectively, in m^2;

$s_{y\text{-}net}$, $S_{y\text{-}net}$ — first moment of the line segment and the cross section about the baseline, in m^3;

$i_{y0\text{-}net}$, $I_{y0\text{-}net}$ — moment of inertia of the line segment and the cross section about the baseline, in m^4.

The height of horizontal neutral axis, z_n, in m, is to be obtained as follows:

$$z_n = \frac{S_{y-net}}{A_{net}}$$

Inertia moment about the horizontal neutral axis, in m^4, is to be obtained as follows:

$$I_{y-net} = I_{y0-net} - z_n^2 A_{net}$$

Appendix 4 BUCKLING CAPACITY

Symbols

x axis : local axis of a rectangular buckling panel parallel to its long edge;
y axis : local axis of a rectangular buckling panel perpendicular to its long edge;
σ_x : membrane stress applied in *x* direction, in N/mm^2;
σ_y : membrane stress applied in *y* direction, in N/mm^2;
τ : membrane shear stress applied in *xy* plane, in N/mm^2;
σ_a : axial stress in the stiffener, in N/mm^2;
σ_b : bending stress in the stiffener, in N/mm^2;
σ_w : warping stress in the stiffener, in N/mm^2;
$\sigma_{cx}, \sigma_{cy}, \tau_c$: critical stress, in N/mm^2, defined in 2.1.1 of this Appendix for plates;
R_{eH_S} : specified minimum yield stress of the stiffener, in N/mm^2;
R_{eH_P} : specified minimum yield stress of the plate, in N/mm^2;
a : length of the longer side of the plate panel as shown in Table 2, in mm;
b : length of the shorter side of the plate panel as shown in Table 2, in mm;
d : length of the side parallel to the axis of the cylinder corresponding to the curved plate panel as shown in Table 3, in mm;
σ_E : elastic buckling reference stress, in N/mm^2, to be taken as:

(1) for the application of plate limit state according to 2.1.2 of this Appendix:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{b}\right)^2;$$

(2) for the application of curved plate panels according to 2.2 of this Appendix:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{d}\right)^2;$$

ν : Poisson's ratio to be taken equal to 0.3;
t_p: net thickness of plate panel, in mm;
t_w: net stiffener web thickness, in mm;
t_f: net flange thickness, in mm;
b_f: breadth of the stiffener flange, in mm;
h_w: stiffener web height, in mm;
e_f : Distance from attached plating to centre of flange, in mm, to be taken as:

(1) $e_f = h_w$ for flat bar profile;
(2) $e_f = h_w - 0.5\ t_f$ for bulb profile;
(3) $e_f = h_w + 0.5\ t_f$ for angle and Tee profiles;

α: aspect ratio of the plate panel, to be taken as:

$$\alpha = \frac{a}{b}$$

β: coefficient, to be taken as:

$$\beta = \frac{1-\psi}{\alpha}$$

ψ: edge stress ratio, to be taken as:

$$\psi = \frac{\sigma_2}{\sigma_1}$$

σ_1 : maximum stress, in N/mm^2;
σ_2 : minimum stress, in N/mm^2;
R : radius of curved plate panel, in mm;
ℓ : span, in mm, of stiffener equal to the spacing between primary supporting members;
S : spacing of stiffener, in mm;
ω: factor, to be taken as $\omega = \min(3; \alpha)$.

1 Elementary Plate Panel (EPP)

1.1 Definition

An Elementary Plate Panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary

supporting members.
All the edges of the elementary plate panel are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates (usually longitudinal stiffened panels in deck, bottom and inner-bottom plating, shell and longitudinal bulkheads).

1.2 EPP with different thicknesses

1.2.1 Longitudinally stiffened EPP with different thicknesses

In longitudinal stiffening arrangement, when the plate thickness varies over the width, b, in mm, of a plate panel, the buckling capacity is calculated on an equivalent plate panel width, having a thickness equal to the smaller plate thickness, t_1. The width of this equivalent plate panel, b_{eq}, in mm, is defined by the following formula:

$$b_{eq}=\ell_1+\ell_2\left(\frac{t_1}{t_2}\right)^{1.5}$$

where:

ℓ_1 : width of the part of the plate panel with the smaller plate thickness, t_1, in mm, as defined in Figure 1;

ℓ_2 : width of the part of the plate panel with the greater plate thickness, t_2, in mm, as defined in Figure 1.

Where a panel is consisted of different materials, the minimum yield strength is to be used in buckling assessment.

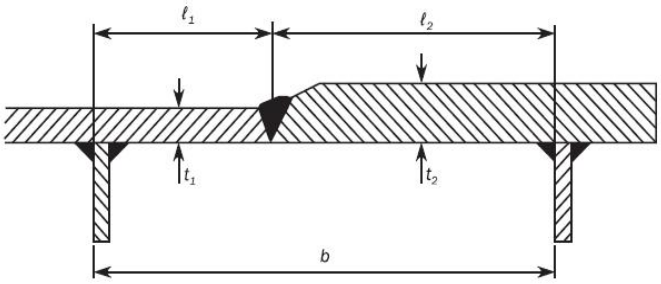


Figure 1 Plate thickness change over the width

1.2.2 Transversally stiffened EPP with different thicknesses

In transverse stiffening arrangement, when an EPP is made of different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the EPP. The applied stress and lateral pressure is to be measured from the load calculation point of the plate panel.

2 Buckling Capacity of Plates

2.1 Plate panel

2.1.1 Plate limit state

The plate limit state is based on the following interaction formulae. Buckling check under normal stress is for the compression stress, when the normal stress (σ_x, σ_y) is less than zero, the corresponding item is to be deleted and pure shear buckling is to be checked:

(a) longitudinal stiffening arrangement:

$$\left(\frac{\gamma_C\sigma_x}{\sigma_{cx}}\right)^{2/\beta_p^{0.25}}+\left(\frac{\gamma_C|\tau|}{\tau_c}\right)^{2/\beta_p^{0.25}}=1$$

(b) transverse stiffening arrangement:

$$\left(\frac{\gamma_C\sigma_y}{\sigma_{cy}}\right)^{2/\beta_p^{0.25}}+\left(\frac{\gamma_C|\tau|}{\tau_c}\right)^{2/\beta_p^{0.25}}=1$$

where:

σ_x, σ_y — applied normal stress to the plate panel, in N/mm², as defined in 7.2.4.4 of this Chapter;

τ — applied shear stress to the plate panel, in N/mm², as defined in 7.2.4.4 of this Chapter;

σ_{cx} — ultimate buckling stress, in N/mm², in direction parallel to the longer edge of buckling panel as defined in 2.1.3 of this Appendix;

σ_{cy} — ultimate buckling stress, in N/mm², in direction parallel to the shorter edge of buckling panel as defined in 2.1.3 of this Appendix;

τ_c — ultimate buckling shear stress, in N/mm², as defined in 2.1.3 of this Appendix;

β_p — plate slenderness parameter, to be taken as:

$$\beta_p = \frac{b}{t_p}\sqrt{\frac{R_{eH_P}}{E}}$$

2.1.2 Reference degree of slenderness

The reference degree of slenderness is to be taken as:

$$\lambda = \sqrt{\frac{R_{eH_P}}{K\sigma_E}}$$

where:

K — buckling factor, as defined in Table 2 and Table 3.

2.1.3 Ultimate buckling stresses

The ultimate buckling stress of plate panels, in N/mm², is to be taken as:

$$\sigma_{cx} = C_x R_{eH_P}$$

$$\sigma_{cy} = C_y R_{eH_P}$$

The ultimate buckling stress of plate panels subject to shear, in N/mm², is to be taken as:

$$\tau_c = C_\tau \frac{R_{eH_P}}{\sqrt{3}}$$

where:

C_x, C_y, C_τ — reduction factors, as defined in Table 2.

The boundary conditions for plates are to be considered as simply supported (see cases 1, 2 and 15 of Table 2). If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of Table 2 subject to the agreement of CCS.

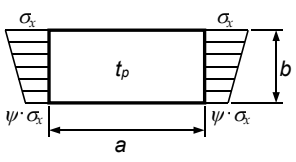
2.1.4 Correction factor F_{long}

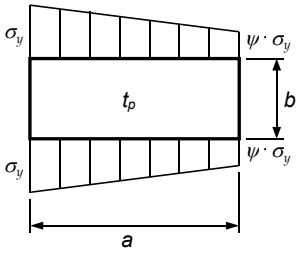
The correction factor F_{long} depending on the edge stiffener types on the longer side of the buckling panel is defined in Table 1. An average value of F_{long} is to be used for plate panels having different edge stiffeners. For stiffener types other than those mentioned in Table 1, the value of c is to be agreed by CCS. In such a case, value of c higher than those mentioned in Table 1 can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate by CCS.

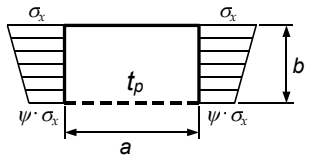
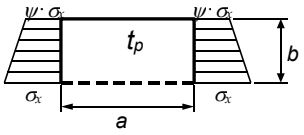
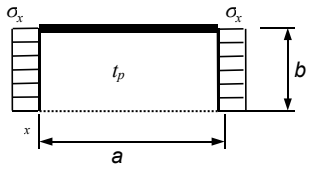
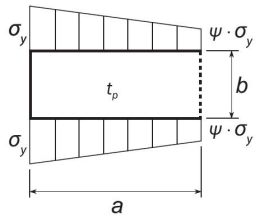
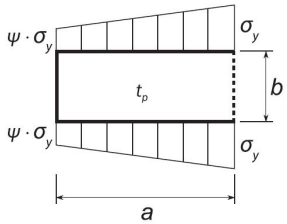
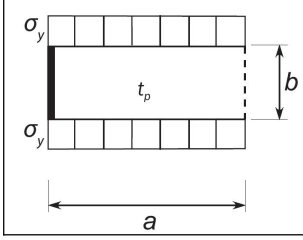
Correction factor F_{long} **Table 1**

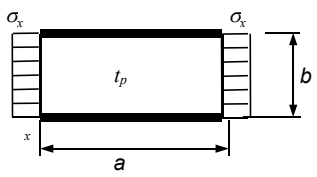
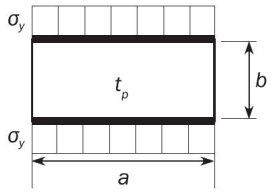
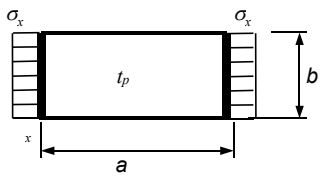
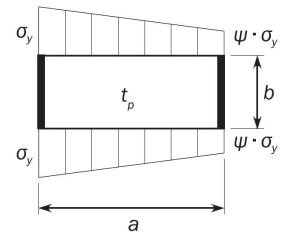
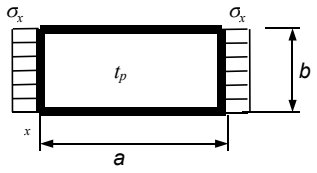
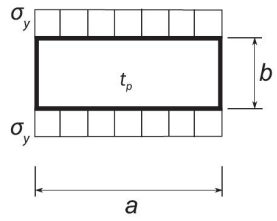
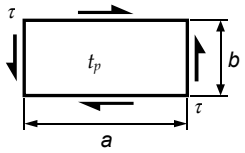
<table>
<tr><th colspan="3">Structural element types</th><th>F_{long}</th><th>c</th></tr>
<tr><td colspan="3">Unstiffened Panel</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="6">Stiffened panel</td><td colspan="2">Stiffener not fixed at both ends</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="4">Stiffener fixed at both ends</td><td>Flat bar (1)</td><td rowspan="3">$F_{long}=c+1$ for $\frac{t_w}{t_p}>1$</td><td>0.1</td></tr>
<tr><td>Bulb profile</td><td>0.3</td></tr>
<tr><td>Angle profile</td><td>0.4</td></tr>
<tr><td>T profile</td><td>$F_{long}=c\left(\frac{t_w}{t_p}\right)^3+1$ for $\frac{t_w}{t_p}\le 1$</td><td>0.3</td></tr>
<tr><td>Girder of high rigidity (e.g. bottom transverse)</td><td>1.4</td><td>N/A</td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="5">Note: (1) t_w is the net web thickness, in mm, without the correction defined in 4.3.5 of this Appendix.</td></tr>
</table>

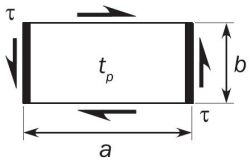
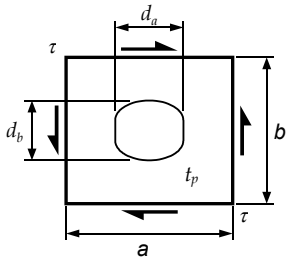
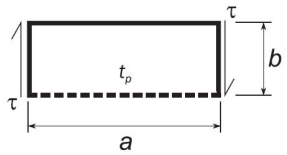
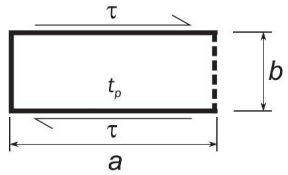
Buckling factor and reduction factor for plane plate panels **Table 2**

<table>
<tr><th>Case</th><th>Stress ratio ψ</th><th>Aspect ratio α</th><th>Buckling factor K</th><th>Reduction factor C</th></tr>
<tr><td rowspan="2">1
 
</td><td>$1 \ge \psi \ge 0$</td><td rowspan="2">α</td><td>$K_x = F_{long}\frac{8.4}{\psi+1.1}$</td><td rowspan="2">$C_x = 1$ for $\lambda \le \lambda_c$
$C_x = c\left(\frac{1}{\lambda}-\frac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$
where:
$c = (1.25 - 0.12\psi) \le 1.25$</td></tr>
<tr><td>$0 > \psi \ge -1$</td><td>$K_x = F_{long}\left[7.63 - \psi\,(6.26 - 10\,\psi)\right]$</td></tr>
</table>

Case	Stress ratio ψ	Aspect ratio α	Buckling factor $\boldsymbol{K}$	Reduction factor $\boldsymbol{C}$
	$\psi \le -1$	$K_x = F_{long}\left[5.975\ (1-\psi)^2\right]$		$\lambda_c = \frac{c}{2}\left(1+\sqrt{1-\frac{0.88}{c}}\right)$
2  	$1 \ge \psi \ge 0$		$K_y = \frac{2\left(1+\frac{1}{\alpha^2}\right)^2}{1+\psi+\frac{(1-\psi)}{100}\left(\frac{2.4}{\alpha^2}+6.9 f_1\right)}$	$C_y = c\left(\frac{1}{\lambda}-\frac{R+F^2(H-R)}{\lambda^2}\right)$ where: $c = (1.25 - 0.12\psi) \le 1.25$ $R = \lambda(1-\lambda/c)$ for $\lambda < \lambda_c$ $R = 0.22$ for $\lambda \ge \lambda_c$ $\lambda_c = 0.5\,c\,\left(1+\sqrt{1-0.88/c}\right)$ $F = \left(1-\left(\frac{K}{0.91}-1\right)/\lambda_p^2\right)c_1 \ge 0$ $\lambda_p^2 = \lambda^2 - 0.5$ for $1 \le \lambda_p^2 \le 3$ $c_1 = \left(1-\frac{1}{\alpha}\right) \ge 0$ $H = \lambda - \frac{2\lambda}{c(T+\sqrt{T^2-4})} \ge R$ $T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$
		$\alpha \le 6$	$f_1 = (1-\psi)(\alpha-1)$	
		$\alpha > 6$	$f_1 = 0.6\left(1-\frac{6\psi}{\alpha}\right)\left(\alpha+\frac{14}{\alpha}\right)$ but not greater than $14.5-\frac{0.35}{\alpha^2}$	
	$0 > \psi \ge 1-4\alpha/3$		$K_y = \frac{200(1+\beta^2)^2}{(1-f_3)(100+2.4\beta^2+6.9f_1+23f_2)}$	
		$\alpha > 6(1-\psi)$	$f_1 = 0.6\left(\frac{1}{\beta}+14\beta\right)$ but not greater than $14.5-0.35\beta^2$ $f_2 = f_3 = 0$	
		$3(1-\psi) \le \alpha \le 6(1-\psi)$	$f_1 = \frac{1}{\beta}-1$ $f_2 = f_3 = 0$	
		$1.5(1-\psi) \le \alpha < 3(1-\psi)$	$f_1 = \frac{1}{\beta}-(2-\omega\beta)^4-9(\omega\beta-1)\left(\frac{2}{3}-\beta\right)$ $f_2 = f_3 = 0$	
		$1-\psi \le \alpha < 1.5(1-\psi)$	For $\alpha > 1.5$: $f_1 = 2\left(\frac{1}{\beta}-16\left(1-\frac{\omega}{3}\right)^4\right)\left(\frac{1}{\beta}-1\right)$ $f_2 = 3\beta - 2$ $f_3 = 0$ For $\alpha \le 1.5$: $f_1 = 2\left(\frac{1.5}{1-\psi}-1\right)\left(\frac{1}{\beta}-1\right)$ $f_2 = \frac{\psi\left(1-16f_4^2\right)}{1-\alpha}$ $f_3 = 0$ $f_4 = (1.5\text{-}Min(1.5;\alpha))^2$	
		$0.75(1-\psi) \le \alpha < 1-\psi$	$f_1 = 0$ $f_2 = 1+2.31(\beta-1)-48\left(\frac{4}{3}-\beta\right)f_4^2$ $f_3 = 3f_4(\beta-1)\left(\frac{f_4}{1.81}-\frac{\alpha-1}{1.31}\right)$ $f_4 = (1.5\text{-}Min(1.5;\alpha))^2$	

Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
	$\psi < 1\text{-}4\alpha/3$		$K_y = 5.972\dfrac{\beta^2}{1-f_3}$ where: $f_3 = f_5\left(\dfrac{f_5}{1.81}+\dfrac{1+3\psi}{5.24}\right)$ $f_5 = \dfrac{9}{16}\left(1+Max(-1;\psi)\right)^2$	
3 	$1 \geq \psi \geq 0$		$K_x = \dfrac{4(0.425+1/\alpha^2)}{3\psi+1}$	$C_x = 1$ for $\lambda \leq 0.7$ $C_x = \dfrac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$
	$0 > \psi \geq -1$		$K_x = 4(0.425+1/\alpha^2)(1+\psi)$ $-5\psi(1-3.42\psi)$	
4 	$1 \geq \psi \geq -1$		$K_x = \left(0.425+\dfrac{1}{\alpha^2}\right)\dfrac{3-\psi}{2}$	
5 		$\alpha \geq 1.64$	$K_x = 1.28$	
		$\alpha < 1.64$	$K_x = \dfrac{1}{\alpha^2}+0.56+0.13\alpha^2$	
6 	$1 \geq \psi \geq 0$		$K_y = \dfrac{4(0.425+\alpha^2)}{(3\psi+1)\alpha^2}$	$C_y = 1$ for $\lambda \leq 0.7$ $C_y = \dfrac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$
	$0 > \psi \geq -1$		$K_y = 4(0.425+\alpha^2)(1+\psi)\dfrac{1}{\alpha^2}$ $-5\psi(1-3.42\psi)\dfrac{1}{\alpha^2}$	
7 	$1 \geq \psi \geq -1$		$K_y = (0.425+\alpha^2)\dfrac{(3-\psi)}{2\alpha^2}$	
8 	–		$K_y = 1+\dfrac{0.56}{\alpha^2}+\dfrac{0.13}{\alpha^4}$	

Case	Stress ratio ψ	Aspect ratio α	Buckling factor $\boldsymbol{K}$	Reduction factor $\boldsymbol{C}$
9 	–	$K_x = 6.97$		$C_x = 1$ for $\lambda \le 0.83$ $C_x = 1{,}13\left[\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right]$ for $\lambda > 0.83$
10 	–	$K_y = 4 + \frac{2.07}{\alpha^2} + \frac{0.67}{\alpha^4}$		
11 	–	$\alpha \ge 4$	$K_x = 4$	
		$\alpha < 4$	$K_x = 4 + 2.74\left(\frac{4-\alpha}{3}\right)^4$	
12 	–	K_y determined as per case 2		• For $\alpha < 2$: $C_y = C_{y2}$ • For $\alpha \ge 2$: $C_y = \left(1.06 + \frac{1}{10\alpha}\right) C_{y2}$ where: $C_{y2} = C_y$ (determined as per case 2)
13 	–	$\alpha \ge 4$	$K_x = 6.97$	$C_x = 1$ for $\lambda \le 0.83$ $C_x = 1{,}13\left[\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right]$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 6.97 + 3.1\left(\frac{4-\alpha}{3}\right)^4$	
14 	–	$K_y = \frac{6.97}{\alpha^2} + \frac{3.1}{\alpha^2}\left[\frac{4 - 1/\alpha}{3}\right]^4$		$C_y = 1$ for $\lambda \le 0.83$ $C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
15 	–	$K_\tau = \sqrt{3}\left[5.34 + \frac{4}{\alpha^2}\right]$		$C_\tau = 1$ for $\lambda \le 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$

Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
16 	–	$K_\tau = \sqrt{3}\left\{5.34 + Max\left[\frac{4}{\alpha^2};\frac{7.15}{\alpha^{2.5}}\right]\right\}$		
17 	–	$K = K'r$ K' = K according to case 15 r = opening reduction factor taken as: $r = \left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$ with $\frac{d_a}{a} \le 0.7$ and $\frac{d_b}{b} \le 0.7$		
18 	–	$K_\tau = 3^{0.5}\left(0.6 + 4/\alpha^2\right)$		$C_\tau = 1$ for $\lambda \le 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
19 	–	$K_\tau = 8$		
Edge boundary conditions: - - - - - - - - - Plate edge free ——————— Plate edge simply supported ▬▬▬▬▬▬ Plate edge clamped.				
Note: (1) Cases listed are general cases. Each stress component (σ_x, σ_y) is to be understood in local coordinates.				

2.2 Curved plate panels

This requirement for curved plate limit state is applicable when $R/t_p \le 2500$. Otherwise, the requirement for plate limit state given in 2.1.1 of this Appendix is applicable.

The curved plate limit state is based on the following interaction formula:

$$\left(\frac{\gamma_c \sigma_{ax}}{C_{ax} R_{eH_P}}\right)^{1.25} + \left(\frac{\gamma_c \tau\sqrt{3}}{C_\tau R_{eH_P}}\right)^2 = 1.0$$

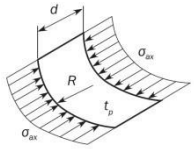
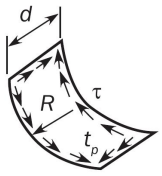
where:

σ_{ax} — applied axial stress to the cylinder corresponding to the curved plate panel, in N/mm². In case of tensile axial stresses, σ_{ax}= 0;

C_{ax}, C_τ — buckling reduction factor of the curved plate panel, as defined in Table 3.

The stress multiplier factor γ_c of the curved plate panel needs not be taken less than the stress multiplier factor γ_c for the expanded plane panel according to 2.1.1 of this Appendix.

Buckling Factor and reduction factor for curved plate panel with $R/t_p \le 2500$ Table 3

Case	Aspect ratio	Buckling factor K	Reduction factor C
1 	$\frac{d}{R} \le 0.5\sqrt{\frac{R}{t_p}}$	$K = 1 + \frac{2}{3}\frac{d^2}{Rt_p}$	For general application: $C_{ax} = 1$ for $\lambda \le 0.25$ $C_{ax} = 1.233\text{-}0.933\lambda$ for $0.25 < \lambda \le 1$ $C_{ax} = 0.3/\lambda^3$ for $1 < \lambda \le 1.5$ $C_{ax} = 0.2/\lambda^2$ for $\lambda > 1.5$ For curved single fields, e.g. bilge strake, which are bounded by plane panels: $C_{ax} = 0.65/\lambda^2 \le 1.0$
	$\frac{d}{R} > 0.5\sqrt{\frac{R}{t_p}}$	$K = 0.267\frac{d^2}{Rt_p}\left[3 - \frac{d}{R}\sqrt{\frac{t_p}{R}}\right] \ge 0.4\frac{d^2}{Rt_p}$	
2 	$\frac{d}{R} \le 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\sqrt{28.3 + \frac{0.67d^3}{R^{1.5}t_p^{1.5}}}$	$C_\tau = 1$ for $\lambda \le 0.4$ $C_\tau = 1.274 - 0.686\lambda$ for $0.4 < \lambda \le 1.2$ $C_\tau = 0.65/\lambda^2$ for $\lambda > 1.2$
	$\frac{d}{R} > 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\frac{0.28d^2}{R\sqrt{Rt_p}}$	
Explanations for boundary conditions: ——— Plate edge simply supported.			

3 Buckling Capacity of Overall Stiffened Panel

The elastic stiffened panel limit state is based on the following interaction formula:

$$\frac{P_Z}{c_f} = 1$$

where: P_z and c_f are defined in 4.4.3 of this Appendix.

4 Buckling Capacity of Longitudinal Stiffeners

4.1 Stiffeners limit states

The buckling capacity of longitudinal stiffeners is to be checked for the following limit states:
(1) stiffener induced failure (SI);
(2) associated plate induced failure (PI).

4.2 Lateral pressure

The lateral pressure is to be considered as constant in the buckling strength assessment of longitudinal stiffeners.

4.3 Stiffener idealization

4.3.1 Effective length of the stiffener ℓ_{eff}

The effective length of the stiffener ℓ_{eff}, in mm, is to be taken equal to:

(1) $\ell_{eff} = \frac{\ell}{\sqrt{3}}$ for stiffener fixed at both ends;

(2) $\ell_{eff} = 0.75\ell$ for stiffener simply supported at one end and fixed at the other;

(3) $\ell_{eff} = \ell$ for stiffener simply supported at both ends.

4.3.2 Effective width of the attached plating b_{eff1}

The effective width of the attached plating of a stiffener b_{eff1}, in mm, without the shear lag effect is to be taken equal to:

$$b_{eff1} = \frac{C_{x1}b_1 + C_{x2}b_2}{2}$$

where:

C_{x1}, C_{x2} — reduction factor defined in Table 2 calculated for each side of the considered stiffener according to case 1;

b_1, b_2 — width of plate panel on each side of the considered stiffener, in mm.

4.3.3 Effective width of attached plating b_{eff}

The effective width of attached plating of stiffeners, b_{eff}, in mm, is to be taken as:

$$b_{eff} = min\left(b_{eff1}, \chi_s s\right)$$

where:

χ_s — effective width coefficient to be taken as:

- $\chi_s = min\left[\frac{1.12}{1+\frac{1.75}{\left(\frac{\ell_{eff}}{s}\right)^{1.6}}}; 1\right]$ for $\frac{\ell_{eff}}{s} \geq 1$
- $\chi_s = 0.407\frac{\ell_{eff}}{s}$ for $\frac{\ell_{eff}}{s} < 1$

4.3.4 Net thickness of attached plating t_p

The net thickness of plate t_p, in mm, is to be taken as the mean thickness of the two attached plating panels.

4.3.5 Effective web thickness of flat bar

For accounting the decrease of stiffness due to local lateral deformation, the effective web thickness of flat bar stiffener, in mm, is to be used for the calculation of the net sectional area, A_s, the net section modulus, Z, and the moment of inertia, I, of the stiffener and is taken as:

$$t_{w_red} = t_w\left(1-\frac{2\pi^2}{3}\left(\frac{h_w}{s}\right)^2\left(1-\frac{b_{eff1}}{s}\right)\right)$$

4.3.6 Net section modulus Z of a stiffener

The net section modulus Z of a stiffener, in cm^3, including effective width of plating b_{eff} is to be taken equal to:

(1) the section modulus calculated at the top of stiffener flange for stiffener induced failure (SI).

(2) the section modulus calculated at the attached plating for plate induced failure (PI).

4.3.7 Net moment of inertia I of a stiffener

The net moment of inertia I, in cm^4, of a stiffener including effective width of attached plating b_{eff} is to comply with the following requirement:

$$I \geq \frac{s\, t_p^{\,3}}{12{\cdot}10^4}.$$

4.3.8 Idealisation of bulb profile

Bulb profiles may be considered as equivalent angle profiles. The net dimensions of the equivalent built-up section are to be obtained, in mm, from the following formulae:

$$h_w = h'_w - \frac{h'_w}{9.2} + 2$$

$$b_f = \alpha\left(t'_w + \frac{h'_w}{6.7} - 2\right)$$

$$t_f = \frac{h'_w}{9.2} - 2$$

$$t_w = t'_w$$

where: h'_w, t'_w — net height and thickness of a bulb section, in mm, as shown in Figure 2;

α — coefficient equal to:

$$\alpha = 1.1 + \frac{(120 - h'_w)^2}{3000} \quad \text{for} \quad h'_w \leq 120$$

$$\alpha = 1.0 \quad \text{for} \quad h'_w > 120$$

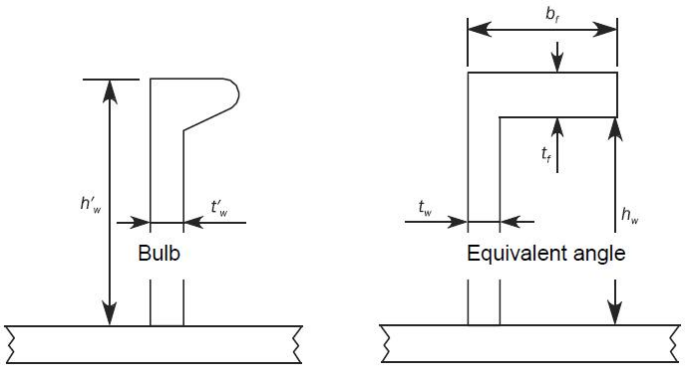


Figure 2 Idealisation of bulb stiffener

4.4 Ultimate buckling capacity

4.4.1 Longitudinal stiffener limit state

When $\sigma_a + \sigma_b + \sigma_w > 0$, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c \sigma_a + \sigma_b + \sigma_w}{R_{eH}} = 1$$

where:

σ_a — effective axial stress, in N/mm², at mid-span of the stiffener, defined in 4.4.2 of this Appendix;

σ_b — bending stress in the stiffener, in N/mm², defined in 4.4.3 of this Appendix;

σ_w — stress due to torsional deformation, in N/mm², defined in 4.4.4 of this Appendix;

R_{eH} — specified minimum yield stress of the material, in N/mm²:

(1) $R_{eH} = R_{eH_S}$ for stiffener induced failure (SI);

(2) $R_{eH} = R_{eH_P}$ for plate induced failure (PI).

4.4.2 Effective axial stress σ_a

The effective axial stress σ_a, in N/mm², at mid-span of the stiffener, acting on the stiffener with its attached plating is to be taken equal to:

$$\sigma_a = \sigma_x \frac{s t_p + A_s}{b_{eff1} t_p + A_s}$$

where:

σ_x — nominal axial stress, in N/mm², acting on the stiffener with its attached plating, calculated according to 7.2.4.4.1 a) of this Chapter;

A_s — net sectional area, in mm², of the considered stiffener.

4.4.3 Bending stress σ_b

The bending stress in the stiffener σ_b, in N/mm², is to be taken equal to:

$$\sigma_b = \frac{M_o + M_1}{1000\, Z}$$

where:

M_1 — bending moment, in Nmm, due to the lateral load P:

(1) $M_1 = C_i \frac{|P| s \ell^2}{24 \cdot 10^3}$ for continuous stiffener;

(2) $M_1 = C_i \frac{|P| s \ell^2}{8 \cdot 10^3}$ for sniped stiffener;

P — lateral load, in kN/m², to be equal to the static pressure at the load calculation point of the stiffener;

C_i — pressure coefficient;

(1) $C_i = C_{SI}$ for stiffener induced failure (SI);

(2) $C_i = C_{PI}$ for plate induced failure (PI);

C_{PI} — plate induced failure pressure coefficient:

(1) $C_{PI} = 1$ if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{PI}=-1$ if the lateral pressure is applied on the same side as the stiffener;

C_{SI} — stiffener induced failure pressure coefficient:

(1) $C_{SI}=-1$ if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{SI}=1$ if the lateral pressure is applied on the same side as the stiffener;

M_0 — bending moment, in Nmm, due to the lateral deformation w of stiffener:

$$M_0 = F_E\left(\frac{P_z w}{c_f - P_z}\right), \text{ with } c_f - P_z > 0;$$

F_E — ideal elastic buckling force of the stiffener, in N:

$$F_E=\left(\frac{\pi}{\ell}\right)^2 EI\cdot 10^4;$$

P_z — normal lateral load, in N/mm^2, acting on stiffeners due to stresses σ_x, σ_y and τ, in the attached plating in way of stiffener mid span:

$$P_z=\frac{t_p}{s}\left(\sigma_{xl}\left(\frac{\pi s}{\ell}\right)^2+\sqrt{2}\,\tau_1\right);$$

$$\sigma_{x\ell} = \gamma_c\sigma_x\left(1+\frac{A_s}{st_p}\right), \text{ but not less than 0;}$$

$$\tau_1=\gamma|\tau|-t_p\sqrt{R_{eH_P}\,E\left(\frac{m_1}{a^2}+\frac{m_2}{b^2}\right)}, \text{ but not less than 0;}$$

m_1, m_2 — coefficients, taken equal to:

(1) $m_1 = 1.47$, $m_2 = 0.49$ for $\alpha\geq 2$;

(2) $m_1 = 1.96$, $m_2 = 0.37$ for $\alpha<2$;

w — deformation of stiffener, in mm, taken equal to:

$$w = w_0 + w_1;$$

w_0 — assumed imperfection, in mm, taken equal to:

(1) $w_0=\ell/1000$ in general;

(2) $w_0=-w_{na}$ for stiffeners sniped at both ends, considering stiffener induced failure (SI);

(3) $w_0=w_{na}$ for stiffeners sniped at both ends, considering plate induced failure (PI);

w_{na} — distance, in mm, from the mid-point of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating;

w_1 — deformation of stiffener at midpoint of stiffener span due to lateral load P, in mm. In case of uniformly distributed load, w_1 is to be taken as:

(1) $w_1=C_i\frac{|P|\,s\,\ell^4}{384\cdot 10^7 E\,I}$ in general;

(2) $w_1=C_i\frac{5|P|\,s\,\ell^4}{384\cdot 10^7 E\,I}$ for stiffener sniped at both ends;

c_f — elastic support provided by the stiffener, in N/mm^2, to be taken equal to:

$$c_f=F_E\left(\frac{\pi}{\ell}\right)^2(1+c_p);$$

c_p — coefficient, to be taken as:

$$c_p=\frac{1}{1+\frac{0.91}{c_{xa}}\left(\frac{12I}{st_p^3}10^4-1\right)}$$

c_{xa} — coefficient, to be taken as:

(1) $c_{xa}=\left[\frac{\ell}{2s}+\frac{2s}{\ell}\right]^2$ for $\ell\geq 2s$;

(2) $c_{xa}=\left[1+\left(\frac{\ell}{2s}\right)^2\right]^2$ for $\ell<2s$.

4.4.4 Stress due to torsional deformation σ_w

The stress due to torsional deformation σ_w, in N/mm^2, is to be taken equal to:

(1) $\sigma_w = Ey_w\left(\frac{t_f}{2} + h_w\right)\Phi_0\left(\frac{\pi}{\ell}\right)^2\left(\frac{1}{1 - \frac{0.4R_{eH_S}}{\sigma_{ET}}} - 1\right)$ for stiffener induced failure (SI);

(2) $\sigma_w = 0$ for plate induced failure (PI).

where:

y_w — distance, in mm, from centroid of stiffener cross-section to the free edge of stiffener flange, to be taken as:

(1) $y_w = \frac{t_w}{2}$ for flat bar;

(2) $y_w = b_f - \frac{h_w t_w^2 + t_f b_f^2}{2A_s}$ for angle and bulb profiles;

(3) $y_w = \frac{b_f}{2}$ for Tee profile;

Φ_0 — coefficient, to be taken as:

$\Phi_0 = \frac{\ell}{h_w}10^{-3}$;

σ_{ET} — reference stress for torsional buckling, in N/mm^2:

$\sigma_{ET} = \frac{E}{I_p}\left(\frac{\varepsilon\pi^2 I_\omega 10^2}{\ell^2} + 0.385 I_T\right)$

I_p — net polar moment of inertia of the stiffener about point *C* as shown in Figure 3, as defined in Table 4, in cm^4;

I_T — net St. Venant's moment of inertia of the stiffener, as defined in Table 4, in cm^4;

I_ω — net sectional moment of inertia of the stiffener about point *C* as shown in Figure 3, as defined in Table 4, in cm^6;

ε — degree of fixation, to be taken as:

$$\varepsilon = 1 + \frac{\left(\frac{\ell}{\pi}\right)^2 10^{-3}}{\sqrt{I_\omega\left(\frac{0.75s}{t_p^3} + \frac{e_f - 0.5t_f}{t_w^3}\right)}}.$$

Moments of inertia **Table 4**

Characteristics of cross section	Flat bars	Bulb, angle and Tee profiles
I_P	$\frac{h_w^3 t_w}{3\cdot 10^4}$	$\left(\frac{A_w(e_f - 0.5t_f)^2}{3} + A_f e_f^2\right)10^{-4}$
I_T	$\frac{h_w t_w^3}{3\cdot 10^4}\left(1 - 0.63\frac{t_w}{h_w}\right)$	$\frac{(e_f - 0.5t_f)t_w^3}{3\cdot 10^4}\left(1 - 0.63\frac{t_w}{e_f - 0.5t_f}\right)$ + $\frac{b_f t_f^3}{3\cdot 10^4}\left(1 - 0.63\frac{t_f}{b_f}\right)$
I_ω	$\frac{h_w^3 t_w^3}{36\cdot 10^6}$	$\frac{A_f e_f^2 b_f^2}{12\cdot 10^6}\left(\frac{A_f + 2.6A_w}{A_f + A_w}\right)$ for bulb and angle profiles $\frac{b_f^3 t_f e_f^2}{12\cdot 10^6}$ for Tee profiles
A_w: net web area, in mm^2; A_f: net flange area, in mm^2.		

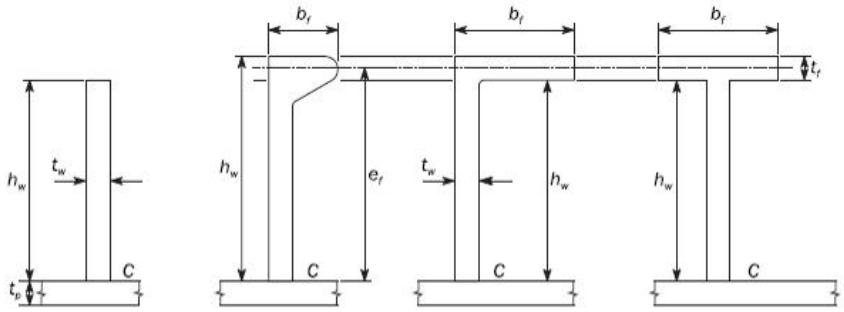


Figure 3 Stiffener cross sections

Appendix 5 HULL GIRDER ULTIMATE BENDING CAPACITY

Symbols

$I_{y\text{-}net}$: net moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis;

$Z_{B\text{-}net}$, $Z_{D\text{-}net}$: section moduli, in m^3, at bottom and deck, respectively;

R_{eH_S}: minimum yield stress, in N/mm^2, of the material of the considered stiffener;

R_{eH_P}: minimum yield stress, in N/mm^2, of the material of the considered plate;

$A_{s\text{-}net}$: net sectional area, in cm^2, of stiffener, without attached plating;

$A_{p\text{-}net}$: net sectional area, in cm^2, of attached plating.

1 General Assumptions

1.1 The method for calculating the ultimate hull girder capacity is to identify the critical failure modes of all main longitudinal structural elements.

1.2 Structures compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements, such as plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

2 Incremental-Iterative Method

2.1 Assumptions

In applying the incremental-iterative method, the following assumptions are generally to be made:

- The ultimate strength is calculated at hull transverse sections between two adjacent transverse webs.
- The hull girder transverse section remains plane during each curvature increment.
- The hull material has an elasto-plastic behaviour.
- The hull girder transverse section is divided into a set of elements, see 2.2.2 of this Appendix, which are considered to act independently.

According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ corresponding to the element strain, ε is to be obtained for each curvature increment from the non-linear load-end shortening curves σ-ε of the element.

These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in 2.3. The stress σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ-ε.

The procedure is to be repeated until the value of the imposed curvature reaches the value χ_F, in m^{-1}, in hogging and sagging conditions, obtained from the following formula:

$$\chi_F = \pm\, 0.003 \frac{M_y}{EI_{y-net}}$$

where: M_Y — lesser of the values M_{Y1} and M_{Y2}, in kN·m.;

$M_{Y1} = 10^3\, R_{eH}\, ZB\text{-}net.$

$M_{Y2} = 10^3\, R_{eH}\, ZD\text{-}net.$

If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

2.2 Procedure

2.2.1 General

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarized in the flow chart in Figure 1.

In this procedure, the ultimate hull girder bending moment capacity, M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature χ of the ship cross section as shown in Figure 1.

The curve is to be obtained through an incrementaliterative approach.
Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.
For each step, the value χ_i is to be obtained by summing an increment of curvature, $\Delta\chi$ to the value relevant to the previous step χ_{i-1}. This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.
This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened, and vice-versa in sagging condition.
The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ-ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.
The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position due to the nonlinear σ-ε, relationship. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements on the transverse section.
Once the position of the neutral axis is known and the relevant element stress distribution in the section is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.
The main steps of the incremental-iterative approach described above are summarised as follows (see also Figure 1):

Step 1: Divide the transverse section of hull into stiffened plate elements.

Step 2: Define stress-strain relationships for all elements as shown in Table 1.

Step 3: Initialise curvature χ_1 and neutral axis for the first incremental step with the value of incremental curvature (i.e. curvature that induces a stress equal to 1% of yield strength in strength deck) as:

$$\chi_1=\Delta\chi = 0.01\frac{R_{eH}}{E}\frac{1}{z_D - z_n}$$

where: z_D — Z coordinate, in m, of strength deck at side;
z_n — Z coordinate, in m, of horizontal neutral axis of the hull transverse section with respect to the reference coordinate system defined in 7.2.1.2, Section 2 of this Chapter.

Step 4: Calculate for each element the corresponding strain, $\varepsilon_i=\chi(z_i-z_n)$ and the corresponding stress σ_i.

Step 5: Determine the neutral axis z_{NA_cur} at each incremental step by establishing force equilibrium over the whole transverse section as:
$\Sigma A_{i\text{-}net}\,\sigma_i = \Sigma A_{j\text{-}net}\,\sigma_j$ (i-th element is under compression, j-th element under tension).

Step 6: Calculate the corresponding moment by summing the contributions of all elements as:

$$M_U = \sum \sigma_{Ui} A_{i-net}\left|\left(z_i - z_{NA_cur}\right)\right|.$$

Step 7: Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in M-χ relationship is less than a negative fixed value, terminate the process and define the peak value M_U. Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to Step 4.

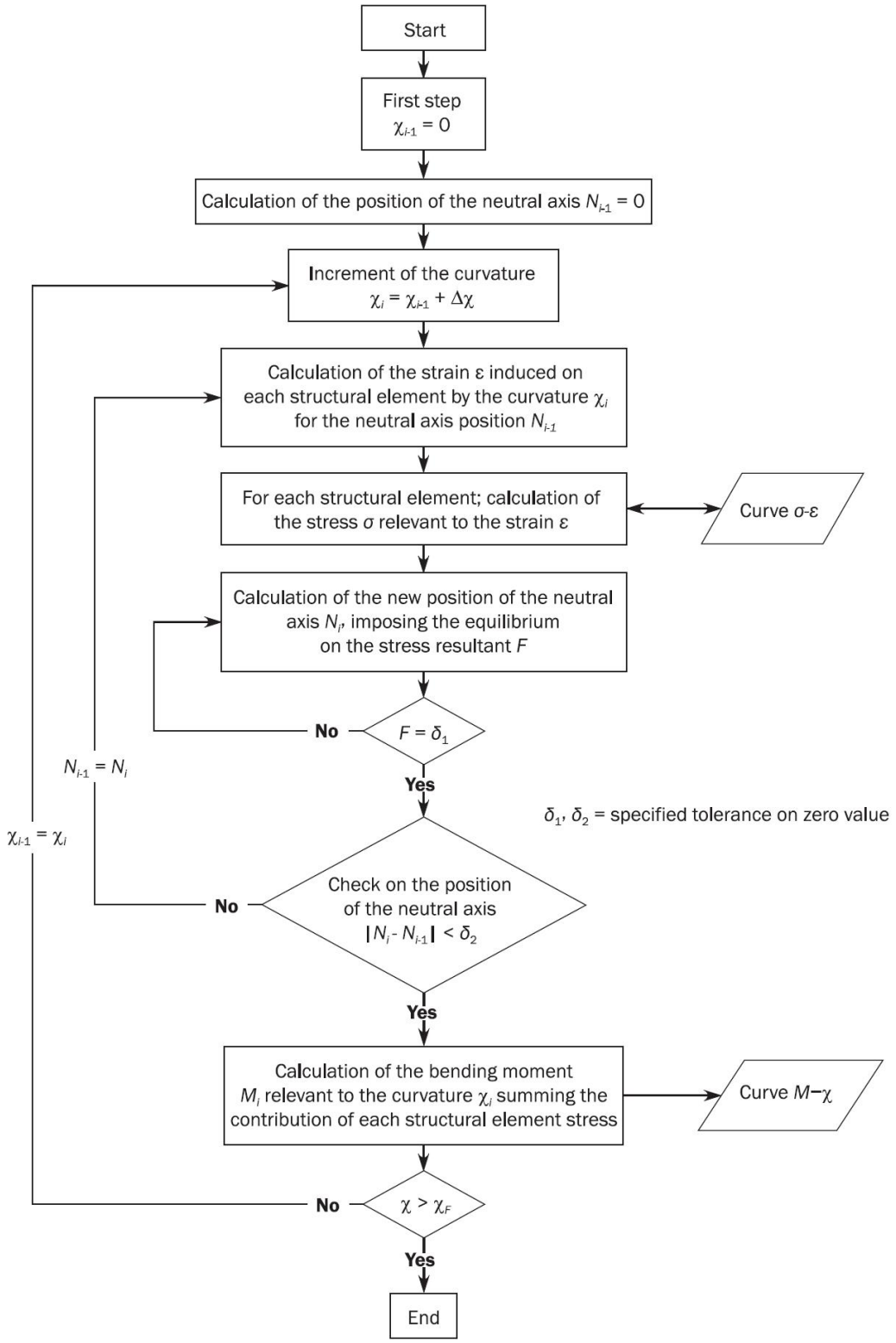


Figure 1 Flow chart of the procedure for the evaluation of the curve *M-χ*

2.2.2 Modelling of the hull girder cross section

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.

Sniped stiffeners are also to be modelled, taking account that they do not contribute to the hull girder strength.

The structural members are categorised into a stiffener element, a stiffened plate element or a hard corner element.

The plate panel including web plate of girder or side stringer is idealised into a stiffened plate element, an

attached plate of a stiffener element or a hard corner element.
The plate panel is categorised into the following two kinds:

— longitudinally stiffened panel of which the longer side is in ship's longitudinal direction, and
— transversely stiffened panel of which the longer side is in the perpendicular direction to ship's longitudinal direction.

• Hard corner element:
Hard corner elements are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding); they are generally constituted by two plates not lying in the same plane.
The extent of a hard corner element from the point of intersection of the plates is to be taken equal to 20 t_{net} on a transversely stiffened panel and to 0.5 s on a longitudinally stiffened panel, see Figure 2.
where:

t_{net} — net thickness of plate, in mm;
s — spacing of the adjacent longitudinal stiffener, in m.

Bilge, sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners.
• Stiffener element:
The stiffener constitutes a stiffener element together with the attached plate.
The attached plate width is in principle:

— equal to the mean spacing of the stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or
— equal to the width of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened, see Figure 2.

• Stiffened plate element:
The plate between stiffener elements, between a stiffener element and a hard corner element or between hard corner elements is to be treated as a stiffened plate element, see Figure 2.

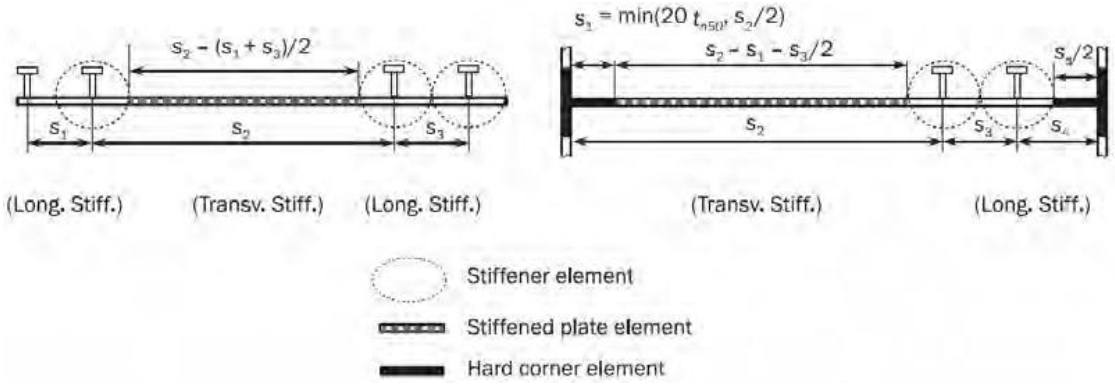


Figure 2 Extension of the breadth of the attached plating and hard corner element

The typical examples of modelling of hull girder section are illustrated in Figure 3.
Notwithstanding the foregoing principle, these figures are to be applied to the modelling in the vicinity of upper deck, sheer strake and hatch coaming.

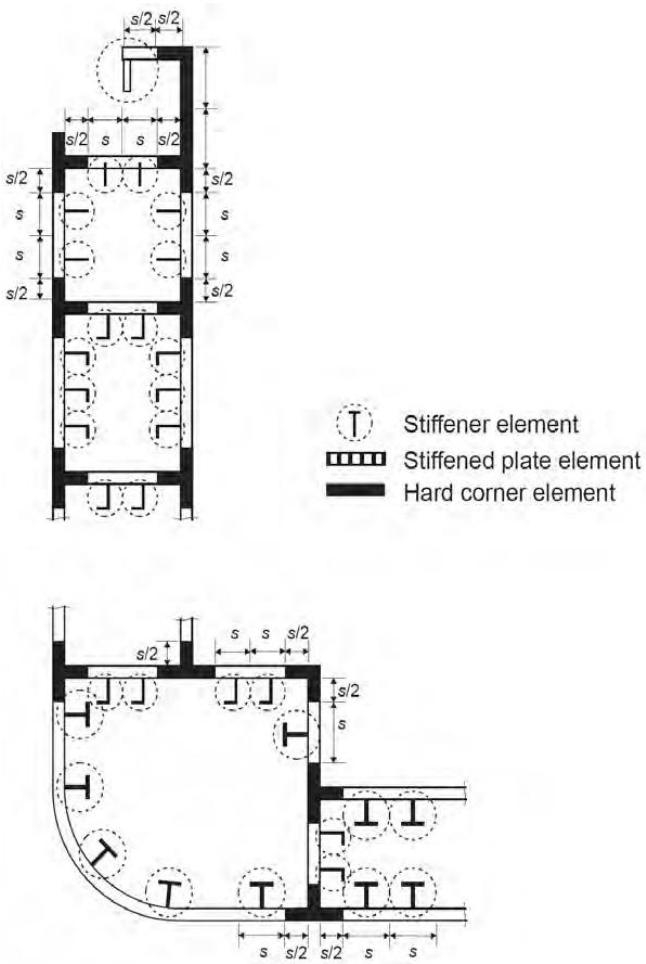


Figure 3 Examples of the configuration of stiffened plate elements, stiffener elements and hard corner elements on a hull section

Notes:

(1) In case of the knuckle point as shown in Figure 4, the plating area adjacent to knuckles in the plating with an angle greater than 30 degrees is defined as a hard corner. The extent of one side of the corner is taken equal to 20 t_{net} on transversely framed panels and to 0.5 s on longitudinally framed panels from the knuckle point.

(2) Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non- continuous stiffeners are considered only as dividing a plate into various elementary plate panels.

(3) Where the opening is provided in the stiffened plate element, the openings are to be considered in accordance with the requirements of Figure 2.2.4.7 of Section 2, Chapter 2 of this PART.

(4) Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress obtained from the following formula are to be used for the calculation:

$$t_{net} = \frac{t_{1-net}s_1 + t_{2-net}s_2}{s} \qquad R_{eH_P} = \frac{R_{eH_P1}t_{1-net}s_1 + R_{eH_P2}t_{2-net}s_2}{t_{net}s}$$

where: R_{eH_p1}, R_{eH_p2}, $t_{1\text{-}net}$, $t_{2\text{-}net}$, s_1, s_2 and s are shown in Figure 5.

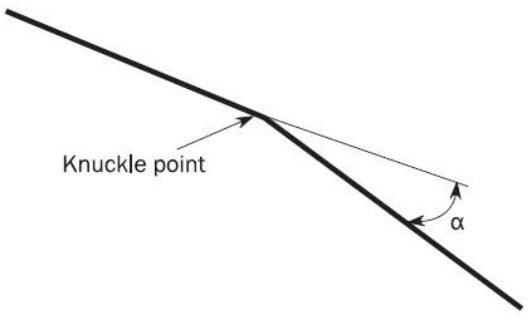


Figure 4 Plating with knuckle point

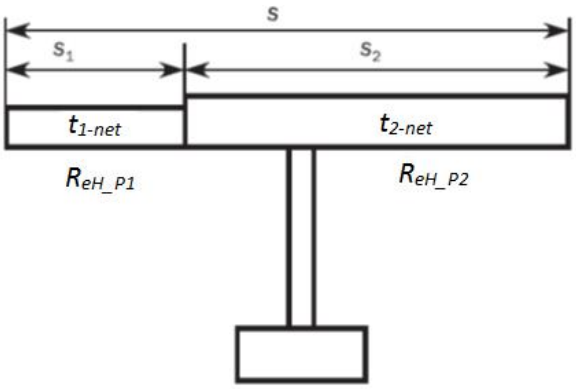


Figure 5 Element with different thickness and yield strength

2.3 Load-end shortening curves

2.3.1 Stiffened plate element and stiffener element

Stiffened plate element and stiffener element composing the hull girder transverse sections may collapse following one of the modes of failure specified in Table 1.

- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with 2.3.2 to 2.3.7 of this Appendix, taking into account the non-continuous longitudinal stiffener.

In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as zero.

- Where the opening is provided in the stiffened plate element, the considered area of the stiffened plate element is to be obtained by deducting the opening area from the plating in calculating the total forces for checking the hull girder ultimate strength.
- For stiffened plate element, the effective width of plate for the load shortening portion of the stress-strain curve is to be taken as full plate width, i.e. to the intersection of other plate or longitudinal stiffener – neither from the end of the hard corner element nor from the attached plating of stiffener element, if any. In calculating the total forces for checking the hull girder ultimate strength, the area of the stiffened plate element is to be taken between the hard corner element and the stiffener element or between the hard corner elements, as applicable.

Modes of failure of stiffened plate element and stiffener element Table 1

Element	Mode of failure	Curve σ-ε defined in
Lengthened stiffened plate element or stiffener element	Elasto-plastic collapse	2.3.2 of this Appendix
Shortened stiffener element	Beam column buckling	2.3.3 of this Appendix
	Torsional buckling	2.3.4 of this Appendix
	Web local buckling of flanged profiles	2.3.5 of this Appendix
	Web local buckling of flat bars	2.3.6 of this Appendix
Shortened stiffened plate element	Plate buckling	2.3.7 of this Appendix

2.3.2 Elasto-plastic collapse of structural elements (Hard corner element)

The equation describing the load-end shortening curve σ-ε for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula.

$$\sigma = \Phi R_{eHA}$$

where: R_{eHA} — equivalent minimum yield stress, in N/mm^2, of the considered element, obtained by the following formula:

$$R_{eHA} = \frac{R_{eH_P}A_{p-net} + R_{eH_S}A_{s-net}}{A_{p-net} + A_{s-net}};$$

Φ — edge function, equal to:

$\Phi = -1$ for $\varepsilon < -1$;

$\Phi = \varepsilon$ for $-1 \le \varepsilon \le 1$;

$\Phi = 1$ for $\varepsilon > 1$;

ε — relative strain, equal to:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y};$$

ε_E — element strain;

ε_Y — strain at yield stress in the element, equal to:

$$\varepsilon_Y = \frac{R_{eHA}}{E}.$$

2.3.3 Beam column buckling

The positive strain portion of the average stress – average strain curve σ_{CR1} - ε based on beam column buckling of plate-stiffener combinations is described according to the following:

$$\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_{s-net} + A_{pE-net}}{A_{s-net} + A_{p-net}}$$

where: Φ — edge function, as defined in 2.3.2 of this Appendix;

σ_{C1}— critical stress, in N/mm^2, equal to:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eHB}}{2}\varepsilon;$$

$$\sigma_{C1} = R_{eHB}\left(1 - \frac{R_{eHB}\varepsilon}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eHB}}{2}\varepsilon;$$

R_{eHB} — equivalent minimum yield stress, in N/mm^2, of the considered element, obtained by the following formula:

$$R_{eHB} = \frac{R_{eH_P}A_{pEI-net}\ell_{pE} + R_{eH_S}A_{s-net}\ell_{sE}}{A_{pEI-net}\ell_{pE} + A_{s-net}\ell_{sE}};$$

$A_{pEI\text{-}net}$ — effective area, in cm^2, equal to:

$$A_{pEI-net} = 10 b_{E1} t_{net};$$

l_{pE} — distance, in mm, measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the bottom of the attached plate;

l_{sE} — distance, in mm, measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the top of the stiffener;

ε — relative strain, as defined in 2.3.2 of this Appendix;

σ_{E1}— Euler column buckling stress, in N/mm^2, equal to:

$$\sigma_{E1} = \pi^2 E \frac{I_{E-net}}{A_{E-net}\ell^2} 10^{-4};$$

$I_{E\text{-}net}$ — net moment of inertia of stiffeners, in cm^4, with attached plate of width b_{E1};

$A_{E\text{-}net}$ — net area, in cm^2, of stiffeners with attached plating of width b_{E1};

b_{E1} — effective width corrected for relative strain, in m, of the attached plating, equal to:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for} \quad \beta_E > 1.0;$$

$$b_{E1} = s \quad \text{for} \quad \beta_E \le 1.0;$$

where: $\beta_E = 10^3 \frac{s}{t_{n50}} \sqrt{\frac{\varepsilon R_{eHp}}{E}}$;

$A_{pE\text{-net}}$ — net area, in cm^2, of attached plating of width b_E, equal to:

$$A_{pE-net} = 10 b_E t_{net};$$

b_E — effective width, in m, of the attached plating, equal to:

$$b_E = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right)s \quad \text{for} \quad \beta_E > 1.25;$$

$$b_E = s \quad \text{for} \quad \beta_E \le 1.25.$$

2.3.4 Torsional buckling

The load-end shortening curve σ_{CR2}-ε for the flexural-torsional buckling of stiffeners composing the hull girder transverse section is to be obtained according to the following formula:

$$\sigma_{CR2} = \Phi \frac{A_{s-net}\sigma_{C2} + A_{p-net}\sigma_{Cp}}{A_{s-net} + A_{p-net}}$$

where: Φ — edge function, as defined in 2.3.2 of this Appendix;

σ_{C2} — critical stress, in N/mm^2, equal to:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eH_S}}{2}\varepsilon;$$

$$\sigma_{C2} = R_{eH_S}\left(1 - \frac{R_{eH_S}\varepsilon}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH_S}}{2}\varepsilon;$$

ε— relative strain, as defined in 2.3.2 of this Appendix;

σ_{E2}— Euler column buckling stress, in N/mm^2, taken as σ_{ET} defined in 4.4.4 of Appendix 4 of this Chapter;

σ_{CP}— buckling stress of the attached plating, in N/mm^2, equal to:

$$\sigma_{CP} = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) R_{eH_P} \qquad \text{for } \beta_E > 1.25$$

$$\sigma_{CP} = R_{eH_P} \qquad \text{for } \beta_E \le 1.25$$

β_E— coefficient, as defined in 2.3.3 of this Appendix.

2.3.5 Web local buckling of stiffeners made of flanged profiles

The load-end shortening curve σ_{CR3} - ε for the web local buckling of flanged stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{10^3 b_E t_{net} R_{eH_P} + \left(h_{we} t_{w-net} + b_f t_{f-net}\right) R_{eH_S}}{10^3 s t_{net} + h_w t_{w-net} + b_f t_{f-net}}$$

where: Φ — edge function, as defined in 2.3.2 of this Appendix;

b_E — effective width, in m, of the attached plating, as defined in 2.3.3 of this Appendix;

h_{we} — effective height, in mm, of the web, equal to:

$$h_{we} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right) h_w \qquad \text{for } \beta_w \ge 1.25;$$

$$h_{we} = h_w \qquad \text{for } \beta_w < 1.25;$$

β_w — $\beta_w = \frac{h_w}{t_{w-net}} \sqrt{\frac{\varepsilon R_{eH_S}}{E}}$;

ε— relative strain, as defined in 2.3.2 of this Appendix.

2.3.6 Web local buckling of stiffeners made of flat bars

The load-end shortening curve σ_{CR4}-ε for the web local buckling of flat bar stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR4} = \Phi \frac{A_{p-net}\sigma_{CP} + A_{s-net}\sigma_{C4}}{A_{p-net} + A_{s-net}}$$

where: Φ — edge function, as defined in 2.3.2 of this Appendix;

σ_{CP} — buckling stress of the attached plating, in N/mm^2, as defined in 2.3.4 of this Appendix;

σ_{C4} — critical stress, in N/mm^2, equal to:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \qquad \text{for } \sigma_{E4} \le \frac{R_{eH_S}}{2}\varepsilon;$$

$$\sigma_{C4} = R_{eH_S}\left(1 - \frac{R_{eH_S}\varepsilon}{4\sigma_{E4}}\right) \qquad \text{for } \sigma_{E4} > \frac{R_{eH_S}}{2}\varepsilon;$$

σ_{E4} — local Euler buckling stress, in N/mm^2, equal to:

$$\sigma_{E4} = 160000\left(\frac{t_{w-net}}{h_w}\right)^2;$$

ε— relative strain, as defined in 2.3.2 of this Appendix.

2.3.7 Plate buckling

The load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = min\begin{Bmatrix} R_{eH_P}\Phi \\ \Phi R_{eH_P}\left[\frac{s}{\ell}\left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) + 0.1\left(1 - \frac{s}{\ell}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right] \end{Bmatrix}$$

where: Φ — edge function, as defined in 2.3.2 of this Appendix;

β_E — coefficient as defined in 2.3.3 of this Appendix;

s — plate breadth, in m, taken as the spacing between the stiffeners;

l— longer side of the plate, in m.

3 Alternative Methods

3.1 General

3.1.1 Application of alternative methods is to be agreed by CCS prior to commencement. Documentation of the analysis methodology and detailed comparison of its results are to be submitted for review and acceptance. The use of such methods may require the partial safety factors to be recalibrated.

3.1.2 The bending moment-curvature relationship, M-χ, may be established by alternative methods. Such models are to consider all the relevant effects important to the non-linear response with due considerations of:

(a) non-linear geometrical behavior;
(b) inelastic material behavior;
(c) geometrical imperfections and residual stresses (geometrical out-of-flatness of plate and stiffeners);
(d) simultaneously acting loads:
- bi-axial compression;
- bi-axial tension;
- shear and lateral pressure;

(e) boundary conditions;
(f) interactions between buckling modes;
(g) interactions between structural elements such as plates, stiffeners, girders, etc.;
(h) post-buckling capacity;
(i) overstressed elements on the compression side of hull girder cross section possibly leading to local permanent sets/buckle damages in plating, stiffeners, etc. (double bottom effects or similar).

3.2 Non-linear finite element analysis

3.2.1 Advanced non-linear finite element analyses models may be used for the assessment of the hull girder ultimate capacity. Such models are to consider the relevant effects important to the non-linear responses with due consideration of the items listed in 3.1.2.

3.2.2 Particular attention is to be given to modelling the shape and size of geometrical imperfections. It is to be ensured that the shape and size of geometrical imperfections trigger the most critical failure modes.

CHAPTER 8 BULK CARRIERS

Section 1 GENERAL PROVISIONS

8.1.1 Application

8.1.1.1 Bulk carriers are ships provided with single deck, double bottom, topside tank and hopper tank, and intended primarily to carry dry cargo in bulk, not including ore carriers.

8.1.1.2 This Chapter applies to bulk carriers as defined in 8.1.1.1 above, with the exception of those complying with 8.1.1.3 below.

8.1.1.3 CSR bulk carriers are to comply with the requirements in PART NINE of the Rules.

8.1.1.4 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

8.1.2 Class notations

8.1.2.1 Bulk carriers complying with the provisions of this Chapter are eligible for one of the following notations:

(1) “Bulk Carrier” for bulk carriers;

(2) “Bulk Carrier, Strengthened for Heavy Cargoes” for bulk carriers strengthened for heavy cargoes;

(3) “Bulk Carrier, Strengthened for Heavy Cargoes, Holds a,b,… may be empty” for bulk carriers strengthened for heavy cargoes with specified or alternate holds empty.

8.1.2.2 Bulk carriers complying with the provisions of this Chapter, of which all cargo holds are bounded by double side skin construction of not less than 1000 mm breadth between the inner shell and the outer shell, are to be assigned one of the following notations:

(1) “Bulk Carrier, Double Side Skin” for double side skin bulk carriers;

(2) “Bulk Carrier, Double Side Skin, Strengthened for Heavy Cargoes” for double side skin bulk carriers strengthened for heavy cargoes;

(3) “Bulk Carrier, Double Side Skin, Strengthened for Heavy Cargoes, Holds a,b,… may be empty” for double side skin bulk carriers strengthened for heavy cargoes with specified or alternate holds empty.

8.1.2.3 Typical bulk carriers of 150 m or over in length and constructed with single deck, double bottom, topside tanks and hopper tanks in the cargo hold region and of single side skin or double side skin construction are to be assigned one of the following harmonized notations: BC-A; BC-B; BC-C. The harmonized notations and relevant design loading conditions are to comply with the requirements of Section 12 of this Chapter.

8.1.2.4 Bulk carriers with self-unloading function complying with the requirements of this Chapter are assigned the class notation “Self-Unloading Bulk Carrier”.

8.1.3 Plans and documents

8.1.3.1 In addition to the plans and documents specified in Section 1, Chapter 2 of this PART, the following are to be submitted for information:

(1) the maximum pressure head in service on tanks and details of any double bottom tanks interconnected with hopper tanks, ballast tanks within double side skin and topside tanks;

(2) details of the proposed depths of any partial fillings where water ballast or liquid cargo is intended to be carried in the holds.

8.1.4 Direct strength calculation and fatigue strength assessment for hull structure

8.1.4.1 For bulk carriers of 150 m or over in length, direct calculation is to be carried out for the strength of primary structural members (both longitudinal and transverse) within cargo area in accordance with the requirements of Appendix 1 of this Chapter.

8.1.4.2 For bulk carriers of 150 m or over in length, the fatigue strength check is to be carried out for the following structural members in the cargo area in accordance with CCS Guidelines for Fatigue Strength of Ship Structure:

(1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;

(2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;

(3) connections of hopper tanks or inner shell to inner bottoms;

(4) connections of inner bottoms to lower stool side plates;

(5) connections of corrugated transverse bulkheads to lower stool top plates;

(6) connections of corrugated transverse bulkheads to upper stool sloping plates;

(7) connections of frames to top side tanks and hopper tanks of single hull bulk carriers.

8.1.5 Protection of cargo holds from loading/discharge equipment

8.1.5.1 In bulk carriers of 150 m in load line length L_L and upwards, carrying solid bulk cargoes having a density of 1,000 kg/m^3 and above, cargo holds are to be protected from loading/discharge equipment as follows:
(1) structural strengthening is to be provided and the Grab notation assigned in accordance with Section 23, Chapter 2 of this PART;
(2) wire rope grooving in way of cargo holds openings is to be prevented by fitting suitable protection such as half-round bar on the hatch side girders (i.e. upper portion of topside tank plates), hatch end beams or upper portion of hatch coamings.

Section 2 BOTTOM STRUCTURES

8.2.1 General requirements

8.2.1.1 For bulk carriers intended to be assigned the class notation of Bulk Carrier, Strengthened for Heavy Cargoes, the bottom structures are to comply with the provisions in Section 22, Chapter 2 of this PART.
8.2.1.2 Where the double bottom tanks are interconnected with hopper side tanks, the scantlings are to satisfy the requirements of Section 13, Chapter 2 of this PART for deep tanks.
8.2.1.3 For bulk carries of 150 m and over in length, the thickness of solid floors are determined by direction calculations, but the minimum thickness is not be less than that obtained from the following formula:

$$t_{\min} = \max\left(0.6\sqrt{L} + 3,\quad 12\right) \qquad \text{mm}$$

where: L—length of ship, in m, to be taken not greater than 300 m in calculation.
8.2.1.4 For bulk carries of 150 m and over in length, the thickness of watertight solid floors is also to comply with the requirements for deep tanks in Section 13, Chapter 2, in addition to complying with the requirements of 8.2.1.3.
8.2.1.5 For longitudinally framed double bottom, where it is verified by direct calculation, a maximum of 1.5 times frame spacing may be accepted for the spacing between bottom and inner bottom stiffening members within the duct keel.
8.2.1.6 For bulk carriers of less than 150 m in length intended to be assigned the class notation “Bulk Carrier, Strengthened for Heavy Cargoes, Hold Nos… may be Empty”, the bottom structures are to comply with the requirements of this Section and in addition, the direct calculation is to be carried out for the strength of primary members of double bottom (both longitudinal and transverse) in accordance with the requirements of Appendix 1 of this Chapter.

Section 3 SIDE FRAMING

8.3.1 Application

8.3.1.1 This Section applies to side structures of cargo holds bounded by the side shell only of bulk carriers constructed with single deck, topside tanks and hopper tanks in cargo spaces intended primarily to carry dry cargo in bulk.

8.3.2 Side shell plating

8.3.2.1 The thickness of the side shell plating is to be determined according to the requirements in Chapter 2 of this PART. The thickness t of the shell plating between hopper and topside tanks within the cargo area is not to be less than that obtained from the following formula:

$$t = \sqrt{L} \qquad \text{mm}$$

where: L — length of ship, in m.

8.3.3 Main Frames

8.3.3.1 For bulk carriers of 190 m and over in length, the main frames within the cargo area are to be integral with their upper and lower brackets and symmetrical in their transverse section.
8.3.3.2 In bulk carriers less than 190 m in length, mild steel main frames within the cargo area may be

fitted with separate brackets and asymmetric in their transverse section.

8.3.3.3 The minimum web thickness of main frames is to be obtained from the following formula:

$$t = 7.0 + 0.03L \quad \text{mm}$$

where: L — length of ship, in m, need not be taken greater than 200 m.

8.3.3.4 The section modulus W of the main frames in holds is not to be less than that obtained from the following formula:

$$W = 5.8\, sh_1 l^2 K \quad \text{cm}^3$$

where: s — spacing of frames, in m;

K — material factor;

h_1 — vertical distance, in m, measured between the midpoint of the span of frames and a point situated at $0.01L + 0.8$ above the load waterline, see Figure 8.3.3.4, where: L — the length of ship, in m;

l — span of frame, in m, i.e. the distance measured between the intersection of sloping plating with the side shell; for $l < 0.25D$, to be taken as $0.25D$ (D being moulded depth, in m).

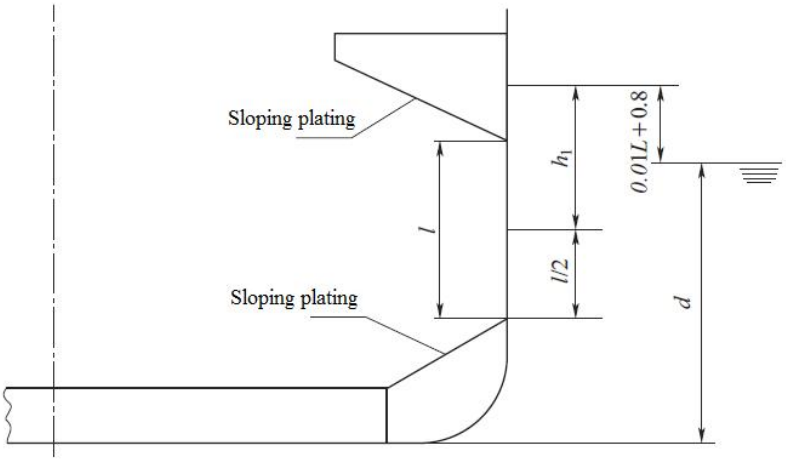


Figure 8.3.3.4

8.3.3.5 The web depth to thickness ratio of main frames is not to exceed the following values:

$60\sqrt{K}$ for symmetrically flanged frames

$50\sqrt{K}$ for unsymmetrically flanged frames

where: K — material factor.

8.3.3.6 The maximum breadth of the frame flange outstand is not to exceed $10\sqrt{K}$ times the thickness of the flange.

8.3.3.7 The frame flange is to be radiused at the connection with the end brackets (see Figure 8.3.3.7), with the radius of curvature being not less than that obtained by the following formula:

$$r = \frac{0.4 b_f^2}{t_f} \quad \text{mm}$$

where: b_f — face plate width of lower or upper bracket, in mm;

t_f — face plate thickness of lower or upper bracket, in mm.

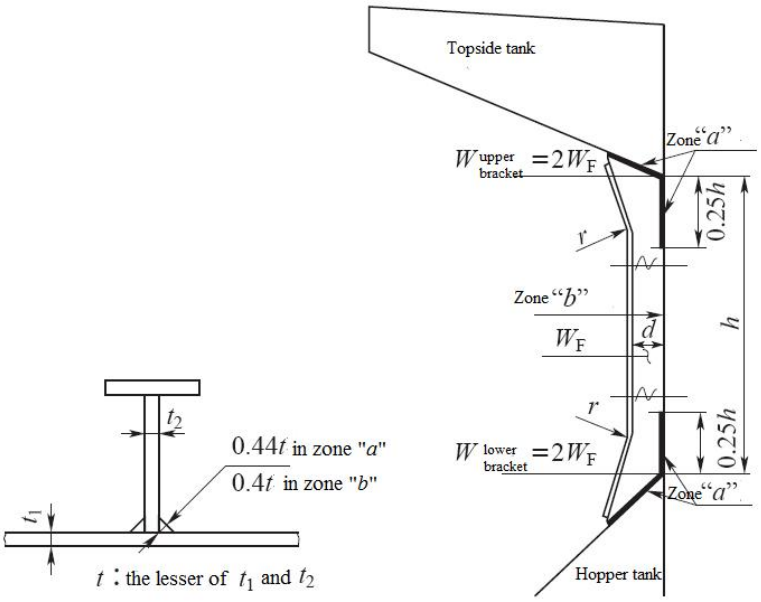


Figure 8.3.3.7

8.3.4 Lower and upper brackets of main frames

8.3.4.1 The thickness of the lower brackets is not to be less than that of the frame webs, nor to be less than that derived from 8.3.3.3 of this Section plus 2 mm.

8.3.4.2 The thickness of the upper brackets is not to be less than that of the frame webs.

8.3.4.3 The dimensions of the lower and upper brackets are not to be less than those shown in Figure 8.3.4.3.

8.3.4.4 The section modulus of the frame and the bracket or integral bracket, at the locations shown in Figure 8.3.3.7, is not to be less than twice the value obtained as per 8.3.3.4 of this Section.

8.3.4.5 The structural continuity of the upper and lower end connections of the frames is to be ensured by connecting brackets, as shown in Figure 8.3.4.5, within topside and hopper tanks. The brackets are in general to be stiffened against buckling in accordance with Figure 8.3.4.5.

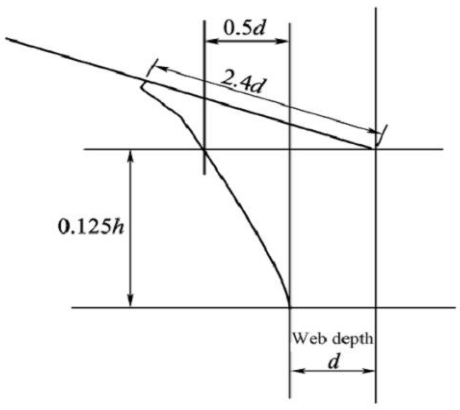


Figure 8.3.4.3

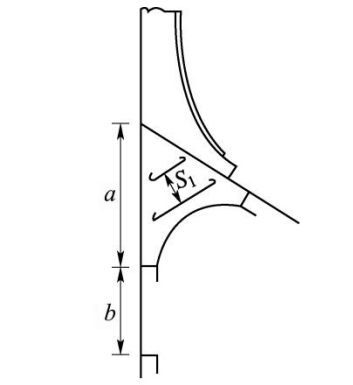


Figure 8.3.4.5

8.3.4.6 Upper and lower brackets are to be arranged at their ends with soft toes as shown in Figure 1.2.7.6 of Section 2, Chapter 1 of this PART.

8.3.4.7 The section moduli of the side longitudinals, topside tank sloping plate longitudinals and hopper tank sloping plate longitudinals which support the connecting brackets in 8.3.4.5 are to be determined with the span taken between transverses. When the arrangement of the upper and lower brackets of the frames and the connecting brackets is different from this Section, the side longitudinals, topside tank sloping plate longitudinals and hopper tank sloping plate longitudinals are to effectively support the connecting brackets, subject to agreement of CCS.

8.3.5 Strengthening of side structures in the foremost hold

8.3.5.1 The minimum web thickness of main frames is to be 1.15 times that required in 8.3.3.3 of this Section.
8.3.5.2 The scantlings of the main frames immediately adjacent to the collision bulkhead are to be properly increased in order to prevent deformation of the shell plating. As an alternative, side stingers or perforated platforms in the forepeak may be extended to the foremost frame of the foremost hold. The extension is to be provided with an adequate shear-resistant area for connection with the frame.
8.3.5.3 Where main frames of the foremost hold are asymmetrical in their transverse section, tripping brackets are to be fitted close to the mid-span of every second frame, as shown in Figure 8.3.5.3.

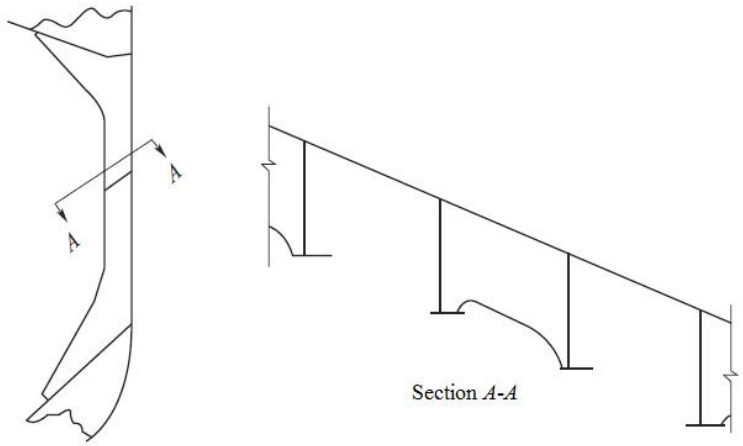


Figure 8.3.5.3

8.3.6 Weld connections of frames and brackets to side shell and sloping plating

8.3.6.1 Double continuous welding is to be adopted for the fillet-weld connections of frames and brackets to side shell, topside and hopper tank sloping plating and web to face plates. For this purpose, the weld throat is to be (see Figure 8.3.3.7):

0.44 t in zone “a”

0.4 t in zone “b”

where: t — the thinner of the two connected members, in mm.

8.3.6.2 Where the hull form is such that an effective fillet weld cannot be made, edge preparation of the web of the frame and bracket may be required, in order to ensure the required efficiency of the weld connection.

Section 4 WATERTIGHT BULKHEADS

8.4.1 General requirements

8.4.1.1 Watertight bulkheads are to comply with the requirements of Section 12, Chapter 2 of this PART. The transverse bulkheads forming boundaries of ballast holds are also to comply with the requirements of Section 13, Chapter 2 of this PART for deep tank bulkheads.
8.4.1.2 Stools, if fitted at the top and bottom of the corrugated watertight bulkhead, are to comply with the following requirements:
(1) The sloping plating of lower stools is to be fitted on solid floors. The thickness of the sloping plating is not to be less than that of the bulkhead plating required in Section 12, Chapter 2 of this PART and in addition, is not to be less than that required in 8.5.2.1 of this Chapter for the sloping plating of hopper tanks.
(2) Where stiffeners are fitted on the sloping plating of lower stools, their section modulus is not to be less than that required in 8.5.3.1 of this Chapter for the longitudinals on the sloping plating of hopper tanks.
(3) Diaphragms are to be fitted in lower stools in way of bottom girders, having the same thickness as that of the inner bottom longitudinal girders.
(4) The scantlings of upper stools are not to be less than those required in Section 12, Chapter 2 of this PART.
(5) Stool structures situated in liquid tanks are also to comply with the requirements of Section 13, Chapter 2 of this PART for deep tanks.

Section 5 HOPPER TANKS

8.5.1 General requirements

8.5.1.1 Watertight bulkheads are to be fitted, as far as practicable, in the hopper tanks in way of the watertight bulkheads in holds. Otherwise wash bulkheads are to be fitted.

8.5.1.2 Consideration is to be given to the structural continuity of both ends of hopper tanks.

8.5.1.3 For the calculation of scantlings of hopper tank structural members, the tank top is the highest point of the topside tank where hopper tanks are interconnected with topside tanks, or the highest point of the ballast tank within double side skin where hopper tanks are interconnected with such ballast tanks.

8.5.1.4 The requirements of this Section apply to hopper tanks framed longitudinally.

8.5.2 Sloping plating

8.5.2.1 The thickness of the sloping plating is not to be less than that of inner bottom plating as required in Section 6, Chapter 2 of this PART. For ships intended to be assigned the class notation of Bulk Carrier, Strengthened for Heavy Cargoes, the sloping plating is to be increased in thickness in accordance with the requirements of 2.22.3.4 of this PART, but this increase may be gradually tapered from the intersection of sloping plating and inner bottom plating to nil at the top corner of the tank. Where hopper tanks are interconnected with topside tanks or form boundaries of ballast holds, the thickness of the sloping plating is not to be less than that required in Section 13, Chapter 2 of this PART for deep tanks.

8.5.2.2 Where the hopper tanks are fitted with watertight side bulkheads, the thickness t of the side bulkhead plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of strake to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater;

K — material factor.

8.5.3 Longitudinals

8.5.3.1 The section modulus W of the sloping plating longitudinals is not to be less than that of the inner bottom longitudinals as required in Section 6, Chapter 2 of this PART.

If the class notation of Strengthened for Heavy Cargoes is intended, the section modulus is nor to be less than that obtained from the following formula:

$$W = 8.5Hsl^2K/\gamma \quad \text{cm}^3$$

where: γ — see Section 22, Chapter 2 of this PART;

H — vertical distance, in m, measured from longitudinal to the lower edge of the sloping plating of topside tanks; where no topside tank is provided, measured from longitudinal to upper deck;

s — spacing of longitudinals, in m;

l — span of longitudinal, in m;

K — material factor.

Where hopper tanks are interconnected with topside tanks or form boundaries of ballast holds, the section modulus W of the sloping plating longitudinals is not to be less than:

$$W = 9shl^2K \quad \text{cm}^3$$

where: s, l, K— same as defined above;

h — vertical distance, in m, measured from the longitudinal to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater.

8.5.3.2 The section modulus W of side and bilge longitudinals in hopper tanks is not to be less than that required in Section 7, Chapter 2 of this PART.

8.5.3.3 The section modulus W of bottom longitudinals in hopper tanks is not to be less than that required in Section 6, Chapter 2 of this PART.

8.5.4 Transverse supporting structural members

8.5.4.1 Transverse structural members supporting the longitudinals of the hopper tanks are to be fitted in way of the floors within holds.

8.5.4.2 The section modulus W and the section moment of inertia I of bottom transverses and side shell transverses are not to be less than those obtained from the following formulae:

$$W = 12Shl^2K \quad \text{cm}^3$$

$$I = 2.5Wl/K \quad \text{cm}^4$$

where: S — spacing of bottom or side shell transverses, in m;
l — span of bottom or side shell transverse, in m;
h — vertical distance, in m, from the mid-point of span to the upper deck at side;
K — material factor.

8.5.4.3 The section modulus W and the section moment of inertial I of sloping plating transverses are not to be less than those obtained from the following formulae:

$$W = 12Shl^2K \quad \text{cm}^3$$
$$I = 2.5Wl/K \quad \text{cm}^4$$

where: S — spacing of transverses, in m;
l — span of transverse, in m;
h — vertical distance, in m, measured from the mid-point of span to the tank top of or half of the vertical distance to the top of the overflow, whichever is the greater;
K — material factor.

If the class notation of Strengthened for Heavy Cargoes is intended, the section modulus W and the section moment of inertial I of sloping plating transverses are not to be less than those obtained from the following formulae:

$$W = 6.6HSl^2K/\gamma \quad \text{cm}^3$$
$$I = 1.8Wl/K \quad \text{cm}^4$$

where: γ — see Section 22, Chapter 2 of this PART;
H — vertical distance, in m, measured from the mid-point of span to the lower edge of the sloping plating of the topside tank;
S — spacing of transverses, in m;
l — span of transverse, in m;
K — material factor.

8.5.4.4 Bottom transverses, side shell transverses and sloping plating transverses are to be effectively connected one another. Longitudinals are to be continuous through the bottom and side shell transverses and the sloping plating transverses, and are to be welded to their web plates. The web depth of primary supporting members is not to be less than 2.5 times the depth of the slot for the passage of longitudinals, and the web is to be suitably fitted with stiffeners between sloping plating longitudinals and bottom longitudinals or side longitudinals in compliance with the same requirements in 2.6.11.2 of Section 6, Chapter 2 of this PART. Brackets connecting the face plate of primary supporting members and the longitudinals are to be fitted at least at alternate longitudinals, and the thickness of brackets is to be the same as that of the web of the primary supporting members.

8.5.4.5 Where non-watertight transverse webs are provided in lieu of the above-mentioned bottom transverses, side shell transverses and slopping plating transverses, the thickness and stiffeners of such webs are to meet the requirements of 8.5.6.

8.5.4.6 Where the side shell in way of cargo holds is framed transversely, brackets are to be fitted above the hopper tank at every frame. The thickness of the brackets is to be the same as the web depth in way of the side shell transverse ring in the hopper tank, and the length of the brackets, measured along the sloping plating and the side shell, is not to be less than that of the free edge of the lower brackets of the hold main frames. These brackets are to be welded to the adjacent longitudinals. Buckling-restrained stiffeners are to be fitted to the brackets. The direction of stiffeners is shown in Figure 8.3.4.5 of this Chapter and their sectional scantlings are to be the same as that of the stiffeners on bottom transverses.

8.5.5 Watertight bulkheads

8.5.5.1 The thickness t of watertight bulkhead plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;
K — material factor;
h — vertical distance, in m, measured from the lower edge of strake to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater.

8.5.5.2 The section modulus W of stiffeners on the watertight bulkheads is not to be less than that obtained from the following formula:

$$W = 8.2shl^2K \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;
h — vertical distance, in m, measured from the mid-point of span of the stiffeners to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater;
l — span of stiffener, in m;

K — material factor.

Stiffeners are to be bracketed at both ends.

8.5.6 Non-watertight bulkheads and wash bulkheads

8.5.6.1 The plating thickness t of non-watertight or wash bulkheads is not to be less than that obtained from the following formula and not to be less than 8 mm:

$$t = 12s \quad \text{mm}$$

where: s — spacing of stiffeners, in m.

8.5.6.2 The section modulus of the stiffeners on the non-watertight or wash bulkheads is not to be less than 50% of that derived from 8.5.5.2 of this Section. Stiffeners are to be bracketed at both ends.

Section 6 TOPSIDE TANKS

8.6.1 General requirements

8.6.1.1 Watertight bulkheads are to be fitted, as far as practicable, in the topside tanks in way of the watertight bulkheads in holds. Otherwise, wash bulkheads are to be fitted.

8.6.1.2 Consideration is to be given to the structural continuity of both ends of topside tanks.

8.6.2 Sloping plating and vertical side plating

8.6.2.1 The thickness t of the sloping plating is not to be less than that obtained from the following formula, and not to be less than 8 mm:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

$$t = 12s/\sqrt{K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m;

K — material factor;

h = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the lower edge of strake to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater;

h_1 — vertical distance, in m, measured from the lower edge of strake to the highest point of the topside tank;

b_1 — horizontal distance, in m, measured from the lower edge of strake to the highest point of the topside tank at either side, whichever is the greater;

θ = 30°.

The thickness of the lowest strake is to be increased by 1 mm above that obtained from the above formula.

8.6.2.2 The thickness of the vertical side plating fitted in line with hatch side coamings and of the top strake of the topside tank sloping plating is not to be less than 60% of that of the deck plate outside the line of openings, nor to be less than 18s (s being the spacing of longitudinals, in m). Brackets, spaced not more than 2 frame spaces apart, are to be fitted at the vertical side plating, and extended to deck and sloping plating longitudinals and welded to them.

8.6.3 Longitudinals

8.6.3.1 The section modulus W of deck, sloping plating and side longitudinals are not to be less than that of the following formula:

$$W = 10shl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinal, in m;

K — material factor;

h = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the longitudinal to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater, and not to be less than 1.5 m;

h_1 — vertical distance, in m, measured from the longitudinal to the highest point of the topside tank;

b_1 — horizontal distance, in m, measured from the longitudinal to the highest point of the topside tank at either side, whichever is the greater;

θ = 30°.

8.6.3.2 The scantlings of deck and side longitudinals are also to comply with the relevant requirements of Chapter 2 of this PART.

8.6.4 Transverse supporting structural members

8.6.4.1 The section modulus W and the section moment of inertia I of the deck, sloping plating and side shell transverses supporting the longitudinals are not to be less than those obtained from the following formulae:

$$W = 7.5Shl^2K \quad \text{cm}^3$$
$$I = 2.5Wl/K \quad \text{cm}^4$$

where: S — spacing of deck or side shell transverses, in m;
l — span of deck or side shell transverse, in m;
K — material factor;
h = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the mid-point of span to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater, and not to be less than 1.5 m;
h_1 — vertical distance, in m, measured from the mid-point of span to the highest point of the topside tank;
b_1 — horizontal distance, in m, measured from the mid-point of span to the highest point of the topside tank at either side, whichever is the greater;
θ = 30°.

8.6.4.2 The scantlings of deck or side shell transverses are not to be less than as required in Chapter 2 of this PART. Their web depth is not to be less than twice the depth of the slot for the passage of longitudinals. The web thickness is not to be less than 1% of its depth plus 4 mm.

8.6.4.3 The deck, sloping plating and side shell transverses are to be connected one another by brackets.

8.6.4.4 The longitudinals are to be continuous through the deck, sloping plating and side shell transverses, and are to be welded to their web plates. Brackets connecting the face plate of primary supporting members and the longitudinals are to be fitted at least at alternate longitudinals, and the thickness of brackets is to be the same as that of the web of the primary supporting members.

8.6.4.5 Primary transverse members supporting the longitudinals in topside tanks are, in general, to be spaced not more than 3.6 m apart for ships equal to or less than 100 m in length, and not more than $0.006L$ + 3.0 m apart for ships more than 100 m in length. Larger spacing may be accepted where the evaluation is carried out by means of direct strength calculation in accordance with the requirements of Appendix 1 of this Chapter.

8.6.4.6 Where non-watertight transverse webs are provided in lieu of the above-mentioned deck transverses, side shell transverses and slopping plating transverses, the thickness and stiffeners of such webs are to meet the requirements of 8.6.7.

8.6.4.7 Where the side shell in way of cargo holds is framed transversely, brackets are to be fitted below the topside tank at every frame. The thickness of the brackets is to be the same as the web depth in way of the side shell transverse ring in the topside tank, and these brackets are to be extended and welded to the adjacent longitudinals along the side shell and sloping plating. The brackets are to be in line with the upper brackets of the hold main frames.

8.6.4.8 Where a rounded gunwale is adopted, a bracket is to be fitted in way of the rounded gunwale approximately halfway between transverses, extending and welded to the adjacent deck and shell longitudinals.

8.6.4.9 Transverse supporting members are to be arranged in topside tanks in line with hatch end coamings.

8.6.5 Shell framing

8.6.5.1 Where the side shell is framed transversely, the section modulus W of the frames is not to be less than that obtained from the following formula:

$$W = 10shl^2K \quad \text{cm}^3$$

where: s — spacing of frames, in m;
l — span of frame, in m;
K — material factor;
h = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the mid-point of span to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater;
h_1 — vertical distance, in m, measured from the mid-point of span to the highest point of the topside tank;
b_1 — horizontal distance, in m, measured from the mid-point of span to the highest point of the topside tank at either side, whichever is the greater;
θ = 30°.

Frames are also to comply with the requirements of 2.13.6.1 of this PART.
8.6.5.2 Bracket are to be fitted at both ends of frames, extended and welded to the adjacent deck and sloping plating longitudinals. The thickness of brackets is to be the same as that of the upper brackets of hold main frames.

8.6.6 Watertight bulkheads

8.6.6.1 The thickness t of the watertight bulkheads is not to be less than that obtained from the following formula, and not to be less than 8 mm:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

$$t = 12s/\sqrt{K} \quad \text{mm}$$

where: s — spacing of stiffeners, in m;
K — material factor;
h = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the lower edge of strake to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater;
h_1 — vertical distance, in m, measured from the lower edge of strake to the highest point of the topside tank;
b_1 — horizontal distance, in m, measured from the lower edge of strake to the highest point of the topside tank at either side, whichever is the greater;
θ = 30°.
The thickness of the lowest strake is to be increased by 1 mm above that derived from above.
8.6.6.2 The section modulus W of stiffeners on the watertight bulkheads is not to be less than that obtained from the following formula:

$$W = 10shl^2K \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;
l — span of stiffener, in m;
K — material factor;
h = $h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the mid-point of span to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater;
h_1 — the vertical distance, in m, measured from the mid-point of span to the highest point of the topside tank;
b_1 — horizontal distance, in m, measured from the mid-point of span to the highest point of the topside tank at either side, whichever is the greater;
θ = 30°.
The stiffeners are to be bracketed at both ends.

8.6.7 Non-watertight and wash bulkheads

8.6.7.1 The plating thickness t of non-watertight or wash bulkheads is to be in compliance with 8.5.6.1 of this Chapter.
8.6.7.2 The section modulus of the stiffeners on the non-watertight or wash bulkheads is not to be less than 50% of that derived from 8.6.6.2 of this Section. The stiffeners are to be bracketed at both ends.

Section 7 ADDITIONAL REQUIREMENTS FOR LOADING MANUALS AND LOADING INSTRUMENTS

8.7.1 Application

8.7.1.1 This Section applies to bulk carriers, ore carriers and combination carriers of 150 m and over in length.
8.7.1.2 Hold mass curves are calculated and drawn in accordance with Appendix 2 of this Chapter.

8.7.2 Loading manuals

8.7.2.1 The loading manual is to describe:
(1) the loading condition on which the design of the ship has been based, including still water bending moments and shear forces and where applicable, the results of the calculations of torsional loads;
(2) permissible limits of still water bending moments and shear forces;
(3) envelope results and still water bending moments and shear forces in the hold flooded condition according to Section 8 of this Chapter as applicable;

(4) the cargo hold(s) or combination of cargo holds that may be empty at full draught. If no cargo hold is allowed to be empty at full draught, this is to be clearly stated in the loading manual;
(5) maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of the draught at mid-hold position;
(6) maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught is to be calculated by averaging the draught at the two mid-hold positions;
(7) maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes;
(8) maximum allowable load on deck and hatch covers. If the vessel is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual;
(9) the maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the achievable rates of change of ballast.

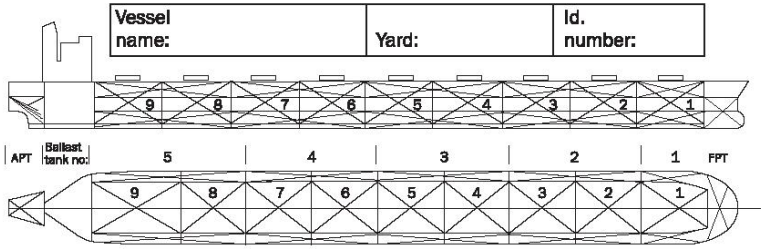
8.7.2.2 Conditions of approval of loading manuals

In addition to the requirements given in 2.2.8.11 of this PART, the following conditions, subdivided into departure and arrival conditions as appropriate, are to be included in the loading manual:
(1) Alternate light and heavy cargo loading conditions at maximum draught, where applicable;
(2) Homogeneous light and heavy cargo loading conditions at maximum draught;
(3) Ballast conditions. For bulk carriers having ballast holds adjacent to topside wing, hopper and double bottom tanks, it is to be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty;
(4) Short voyage conditions where the ship is to be loaded to maximum draught but with limited amount of bunkers, where applicable;
(5) Multiple port loading/unloading conditions, where applicable;
(6) Deck cargo conditions, where applicable;
(7) Typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions are also to be included. The typical loading/unloading sequences are to be developed not to exceed applicable strength limitations. These sequences are to be developed paying due attention to loading/unloading rate and deballasting capacity. Table 8.7.2.2 shows an example of the Sheet of Loading Sequences for guidance;
(8) Typical sequences for exchange of ballast water at sea, where applicable.

Typical Sheet of Loading Sequences for Guidance

Table 8.7.2.2

Vessel name:	Yard:	Id. number:



Port (specific or typical):	Condition at commencement of loading/discharging:	
Total mass of cargo to be loaded/discharged:	Condition at end of loading/discharging:	
Dock water density (t/m³):	Maximum loading/discharging rate:	Average loading/discharging rate:
Number of loaders/dischargers:	Maximum ballasting/deballasting rate:	Average ballasting/deballasting rate:

Volume of Hold, Vh (m³)									
Height of hold, h (m)									

Note: During each pour it it has to be controlled that allowable limits for hull girder shear forces, bending moments and mass in holds are not exceeded. Loading/discharging operations may have to be paused to allow fo ballasting/deballasting in order to keep actual values within limits.

	Hold content at commencement of loading/discharging								
Cargo mass									
Density (t/m³)									
Grade									

Wings or peaks	APT	Ball. no. 5	Ball. no. 4	Hold. no. 6	Ball. no. 3	Hold. no. 4	Ball. no. 2	Ball. no. 1	FPT
Upper									
Lower/Peaks									

Commencement of loading/discharging (sea)				
T aft (m)	T rim (m)	T fwd (m)	Maximum	
			S.F. (%)	B.M. (%)

	CARGO OPERATIONS								
Pour no. /grade	Hold 9	Hold 8	Hold 7	Hold 6	Hold 5	Hold 4	Hold 3	Hold 2	Hold 1
1									
2									
3									
4									
5									
6									
7									
8									
Draft Survey (for loading):	Total cargo onboard (t):				Remaining cargo to be loaded (t):				
n-1									
n									

Upper Lower/Peaks	BALLAST OPERATIONS								
	APT	Ballast tank no. 5	Ballast tank no. 4	No.5 Ballast hold	Ballast tank no.3	No.4 Ballast hold	Balalst tank no. 2	Ballast tank no.1	FPT
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									
Total amount of bunkers onboard (t):									
Upper									
Lower/Peaks									
Upper									
Lower/Peaks									

Values at end of pour (from harbour to sea)				
T aft (m)	T rim (m)	T fwd (m)	Maximum	
			S.F. (%)	B.M. (%)

	Hold content at end of loading/discharging								
Cargo mass:									
Total mass loaded/discharge (t):									

Wings or peaks	APT	Ball. no. 5	Ball. no. 4	No. 6 hold	Ball. no. 3	No. 4 hold	Ball. no. 2	Ball. no. 1	FPT
Upper									
Lower/Peaks									

Values at end of loading/discharging (sea)				
T aft (m)	T rim (m)	T fwd (m)	Maximum	
			S.F. (%)	B.M. (%)

	Maximum occuring values among all conditions above									
Net load on Double Bottom:										tons/m²
Net load in two adjacent holds:										tons

Net load on double bottom = (Mh/V) h-T (t/m²)
- where: Mh = Mass in hold + mass in DB (t)
V = Total volume of hold (m³)
h = height of hold from inner bottom to top of coaming (m)
T = draught (m)

Approved by:

Place, date, stamp and sign

8.7.3 Loading instrument

8.7.3.1 A loading instrument with the display function is an approved digital system as defined in 2.2.8.4 of this PART. In addition to the requirements in 2.2.8.4 of this PART, it is to ascertain as appropriate that:

(1) the mass of cargo and double bottom contents in way of each hold as a function of the draught at mid-hold position;

(2) the mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds;

(3) the still water bending moment and shear forces in the hold flooded conditions according to Section 8 of this Chapter are permissible.

8.7.3.2 Conditions of approval of loading instruments

The loading instrument is subject to approval. In addition to the requirements given in 2.2.8.12 of this PART, the approval is to include as applicable:

(1) acceptance of hull girder bending moment limits for all read-out points;

(2) acceptance of hull girder shear force limits for all read-out points;

(3) acceptance of limits for mass of cargo and double bottom contents of each hold as a function of draught;

(4) acceptance of limits for mass of cargo and double bottom contents in any two adjacent holds as a function of draught.

8.7.4 Guidance for loading/unloading sequences

8.7.4.1 Where a typical loading/unloading sequences manual is prepared, due attention is to be given to the loading/unloading rate, ballasting/deballasting capacity and applicable strength limitations.

8.7.4.2 The typical loading/unloading sequence is to be prepared and submitted for approval by shipyard.

8.7.4.3 The relevant contents of typical loading/unloading sequences are to include:

(1) alternate light and heavy cargo loading conditions;

(2) homogeneous light and heavy cargo loading conditions;

(3) short voyage conditions where the ship is to be loaded to maximum draught but with limited amount of bunkers;

(4) multi-port loading/unloading conditions;

(5) deck cargo condition;

(6) alt-block loading condition.

8.7.4.4 The loading/unloading sequences may be for a specific port or a typical sequence.

8.7.4.5 The loading/unloading sequences of the selected loading condition are to be compiled one step by one step from commencement of cargo loading to reaching full deadweight capacity. A step is finished when the loading equipment is moved to another cargo hold. File is to be submitted to CCS for each step. In addition to the longitudinal strength, the local strength of each cargo hold is to be taken into consideration.

8.7.4.6 Each loading condition is to include the summary of all steps. It is to focus on the key information of each step, such as:

(1) the capacity of cargoes in each cargo hold for different steps;

(2) the volume of discharged ballast water for each ballast tank in different steps;

(3) the maximum still water bending moment and shear force when each step is finished;

(4) the trim and draught of ship when each step is finished.

Section 8 OVERALL LONGITUDINAL STRENGTH IN FLOODED CONDITION

8.8.1 General requirements

8.8.1.1 This Section applies to non-CSR bulk carriers of 150 m and over in length, intending to carry solid bulk cargoes having a density of 1.0 t/m^3 and above, and

(1) single hull, or

(2) double side skin construction in which any part of longitudinal bulkhead is located within $B/5$ or 11.5 m, whichever is less, inboard from the ship's side at right angle to the centreline at the assigned summer load line.

8.8.1.2 Such ships are to have their hull girder strength checked for conditions as specified in Section 2, Chapter 2 and Section 7, Chapter 8 of this PART and in every other condition considered in the intact longitudinal strength calculations, except the following conditions:

(1) harbor conditions;
(2) docking condition afloat;
(3) loading and unloading transitory conditions in port;
(4) loading conditions encountered during ballast water exchange.
8.8.1.3 The hull girder is to be considered intact for checking its overall longitudinal strength.

8.8.2 Flooding criteria
8.8.2.1 The permeability of empty cargo spaces and volume left in loaded cargo spaces above any cargo is to be taken as 0.95.
8.8.2.2 Appropriate permeability and bulk density are to be determined for any cargo carried. "Permeability" for solid bulk cargo means the ratio of the floodable volume between the particles, granules or any larger pieces of cargo, to the gross volume of the bulk cargo. For iron ore, a minimum permeability of 0.3 with a corresponding bulk density of 3.0 t/m³ is to be used. For cement, a minimum permeability of 0.3 with a corresponding bulk density of 1.3 t/m³ is to be used.
8.8.2.3 For packed cargo (such as steel mill products), the actual density of the cargo is to be used with a permeability of zero.

8.8.3 Flooding conditions
8.8.3.1 Each cargo hold is to be considered individually flooded up to the equilibrium waterline. This application is to be applied to self-unloading bulk carriers (SUBC) where the unloading system maintains the watertightness during seagoing operations. In SUBCs with unloading systems that do not maintain watertightness, the longitudinal strength in the flooded conditions is to be considered using the extent to which the flooding may occur.
8.8.3.2 The wave loads in the flooded conditions are assumed to be equal to 80% of those given in Section 2 of Chapter 2.

8.8.4 Stress calculations
8.8.4.1 The overall longitudinal bending stress σ of hull girders at deck and bottom is to be obtained according to 2.2.5.5 of Chapter 2 of this PART, but the wave bending moment is to be determined according to 8.8.3.2 of this Section, with permissible still water bending moment being taken as that in flooding conditions.
8.8.4.2 The shear stress τ of hull girders at any point on the side shell is to be obtained according to 2.2.6.4 of Chapter 2 of this PART, but the wave shear force is to be determined according to 8.8.3.2 of this Section, with permissible still water shear force being taken as that in flooding conditions.

8.8.5 Strength criteria
8.8.5.1 The permissible hull girder bending and shear stresses are to comply with the requirements of Section 2, Chapter 2 of this PART.
8.8.5.2 The buckling strength is to be checked according to 2.2.7 of this PART.

Section 9 STRENGTH OF CORRUGATED TRANSVERSE WATERTIGHT BULKHEADS IN HOLD-FLOODED CONDITIONS

8.9.1 General requirements
8.9.1.1 This Section applies to non-CSR bulk carriers of 150 m and over in length, intending to carry solid bulk cargoes having a density of 1.0 t/m^3, or above, and
(1) single hull, or
(2) double side skin construction in which any part of longitudinal bulkhead is located within $B/5$ or 11.5 m, whichever is less, inboard from the ship's side at right angle to the centreline at the assigned summer load line.
8.9.1.2 The thickness obtained according to the strength criteria given in 8.9.4 of this Section is the net thickness t_{net} required for the strength.
8.9.1.3 The required actual thickness is obtained by adding the corrosion addition given in 8.9.5 of this Section to the net thickness t_{net}.
8.9.1.4 The homogeneous loading condition stated in this Section means a loading condition in which the ratio between the highest and lowest filling ratios, evaluated for any hold, does not exceed 1.20, to be corrected for different cargo densities.

8.9.1.5 The scantlings of corrugated transverse watertight bulkheads determined according to this Section need not be checked again according to 8.4.1 of this Chapter.

8.9.2 Load model

8.9.2.1 General requirements

The loads to be considered as acting on the bulkheads are those given by the combination of the cargo loads with those induced by the flooding of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooding water alone is to be considered. This application is to be applied to self-unloading bulk carriers (SUBC) where the unloading system maintains the watertightness during seagoing operations. In SUBCs with unloading systems that do not maintain watertightness, the combination loads acting on the bulkheads in the flooded conditions are to be considered using the extent to which the flooding may occur.

The most severe combinations of cargo induced loads and flooding loads are to be used for the check of strength of each bulkhead, depending on the loading conditions included in the loading manual:

— homogeneous loading conditions;

— non-homogeneous loading conditions;

considering the individual flooding of both loaded and empty holds.

The specified design load limits for the cargo holds are to be represented by loading conditions defined by the Designer in the loading manual.

Non-homogeneous part loading conditions associated with multi-port loading and unloading operations for homogeneous loading conditions need not to be considered according to these requirements.

Holds carrying packed cargoes are to be considered as empty holds for this application.

Unless the ship is intended to carry, in non-homogeneous conditions, only iron ore or cargo having bulk density equal to or greater than 1.78 t/m³, the maximum mass of cargo which may be carried in the hold is to be the mass that fills the hold up to the upper deck level at centreline.

8.9.2.2 The bulkhead flooding head h_f (see Figure 8.9.2.3(1)) is the distance, in m, measured vertically with the ship in the upright position, from the calculation point to a level located at a distance d_f, in m, from the baseline equal to (D being moulded depth):

(1) in general:

— D, for the foremost transverse corrugated bulkhead;

— 0.9 D, for the other corrugated bulkheads.

Where the ship is to carry cargoes having bulk density less than 1.78 t/m³ in non-homogeneous loading conditions, the following values are to be taken:

— 0.95 D, for the foremost transverse corrugated bulkhead;

— 0.85 D, for the other corrugated bulkheads;

(2) for ships less than 50,000 tons deadweight with type B freeboard:

— 0.95 D, for the foremost transverse corrugated bulkhead;

— 0.85 D, for the other corrugated bulkheads.

Where the ship is to carry cargoes having bulk density less than 1.78 t/m³ in non-homogeneous loading conditions, the following values are to be taken:

— 0.9 D, for the foremost transverse corrugated bulkhead;

— 0.8 D, for the other corrugated bulkheads.

8.9.2.3 The pressure P_c exerted by bulk cargo on bulkheads and the force F_c acting on a corrugation in the non-flooded holds are to be obtained from the following formulae:

$$P_c = 9.81 \rho_c h_1 \tan^2 \gamma \quad \text{kN/m}^2$$

$$F_c = 4.91 \rho_c s_1 (d_1 - h_{DB} - h_{LS})^2 \tan^2 \gamma \quad \text{kN}$$

where: ρ_c — bulk cargo density, in t/m³;

h_1 — vertical distance, in m, from the calculation point to horizontal plane corresponding to the level height of the cargo, located at a distance d_1, in m, from the baseline (see Figure 8.9.2.3(1));

γ — 45°− (φ/2), in degrees;

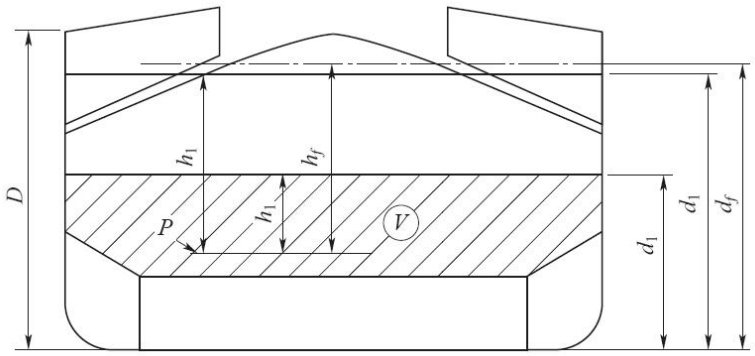
φ — angle of repose of the cargo, in degrees, that may be taken as 35° for iron ore and 25° for cement;

d_1 — see Figure 8.9.2.3 (1), in m;

s_1 — spacing of corrugations, in m (see Figure 8.9.2.3 (2));

h_{LS} — mean height of the lower stool, in m, from the inner bottom;

h_{DB} — height of the double bottom, in m.



V = Volume of cargo *P* = Calculation point

Figure 8.9.2.3(1)

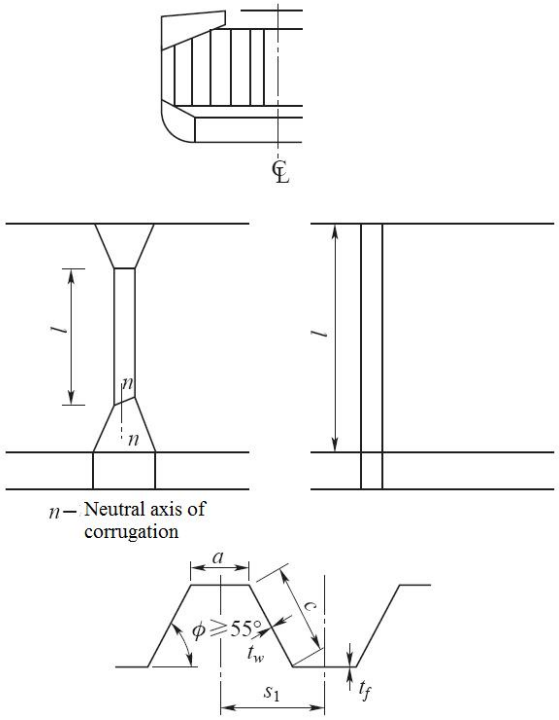


Figure 8.9.2.3(2)

8.9.2.4 Pressure in the flooded holds

(1) The pressure P_{cf} acting on bulkheads and the force F_{cf} acting on a corrugation in the flooded loaded holds are to be obtained from the following formulae:

In the case of $d_f \geq d_1$ (the distance d_f from horizontal plane to the baseline is equal to or greater than the distance d_1 from the level height of the cargo to the baseline in flooded conditions):

$P_{cf} = 10h_f$ kN / m², calculation point between d_f and d_1

$P_{cf} = 10\left\{h_f + \left[\rho_c - (1 - perm)\right]h_1 \tan^2\gamma\right\}$ kN/m², calculation point below d_1

$$F_{cf} = 5s_1\left[\left(d_f - d_1\right)^2 + \left(d_f - d_1 + 0.1P_{le}\right)\left(d_1 - h_{DB} - h_{Ls}\right)\right] \quad \text{kN}$$

In the case of $d_f < d_1$ (the distance from horizontal plane to the baseline is less than the distance from the height of the cargo to the baseline in flooded conditions):

$P_{cf} = 9.81\rho_c h_1 \tan^2\gamma$ kN/m², calculation point between d_f and d_1

$P_{cf} = 10\left\{h_f + \left[\rho_c h_1 - (1 - perm)h_f\right]\tan^2\gamma\right\}$ kN/m², calculation point below d_f

$$F_{cf} = 4.91s_1\left\{\rho_c\left(d_1 - d_f\right)^2\tan^2\gamma + \left[\rho_c\left(d_1 - d_f\right)^2\tan^2\gamma + 0.1P_{le}\right]\left(d_f - h_{DB} - h_{Ls}\right)\right\} \quad \text{kN}$$

where: ρ_c, h_1, γ, s_1, d_1, h_{DB} and h_{Ls} are as given in 8.9.2.3 of this Section;

h_f — flooding head, see 8.9.2.2 of this Section;
perm — permeability of cargo, see 8.8.2.2 of this Chapter;
P_{le} — pressure, in kN/m², at the lower end of the corrugation.

(2) The pressure P_f acting on bulkheads and the force F_f acting on a corrugation in the flooded empty holds are to be obtained as follows:

For the pressure acting on bulkheads, the hydrostatic pressure is to be calculated according to the flooding head h_f.

The force, induced by hydrostatic pressure and acting on a corrugation, is to be obtained from the following formula:

$$F_f = 5 s_1 (d_f - h_{DB} - h_{LS})^2 \quad \text{kN}$$

where: s_1, h_{DB}, h_{Ls} and d_f are as given in 8.9.2.3 of this Section

8.9.2.5 The resultant pressure P acting on any point of bulkheads and the resultant force F acting on a corrugation are to be obtained from the following formulae:

For homogeneous loading conditions: $P = P_{cf} - 0.8\, P_c$ kN / m²

$F = F_{cf} - 0.8\, F_c$ kN

where: P_c, F_c — see 8.9.2.3 of this Section;
P_{cf}, F_{cf} — see 8.9.2.4(1) of this Section.

For non-homogeneous loading conditions: $P = P_{cf}$ kN / m²

$F = F_{cf}$ kN

where: P_c, F_c — see 8.9.2.3 of this Section;
P_{cf}, F_{cf} — whichever is the greatest as given in 8.9.2.4(1) and (2) of this Section.

8.9.3 Bending moment and shear force in bulkhead corrugations

8.9.3.1 The bending moment in bulkhead corrugations is to be obtained from the following formula:

$$M = Fl/8 \quad \text{kN} \cdot \text{m}$$

where: F — see 8.9.2.5 of this Section;
l — span of corrugation, in m, to be taken according to Figure 8.9.2.3(2) and 8.9.3.1. For the definition of l, the internal end of the upper stool is not to be taken more than a distance from the deck at the center line equal to: 3 times the depth of corrugations, in general; 2 times the depth of corrugations, for rectangular stool.

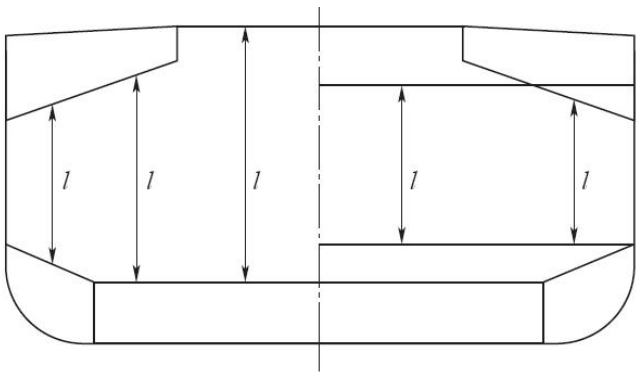


Figure 8.9.3.1

8.9.3.2 The shear force Q at the lower end of bulkhead corrugations is to be obtained from the following formula:

$$Q = 0.8F \quad \text{kN}$$

where: F — see 8.9.2.5 of this Section.

8.9.4 Strength criteria for corrugated bulkheads

8.9.4.1 General requirements

The following criteria are applicable to transverse bulkheads with vertical corrugations (see Figure 8.9.2.3(2)).

For ships of 190 m or over in length, the bulkheads are to be fitted with a lower stool, and generally with an upper stool below deck. For small bulk carriers, both lower and upper stools may not be fitted and corrugations may extend from inner bottom to deck, and if these stools are fitted, they are to comply with the requirements of 8.9.4.1.

The corrugation angle φ shown in Figure 8.9.2.3 (2) is not to be less than 55°.

The net plate thickness of corrugated transverse bulkheads is to comply with 8.9.4.7 of this Section and in addition, corrugated transverse bulkheads are to comply with 8.9.4.2 and 8.9.4.5 of this Section.
The thickness of the lower part of corrugations complying with 8.9.4.2 and 8.9.4.3 is to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than 0.15*l*.
The thickness of the middle part of corrugations complying with 8.9.4.2 and 8.9.4.4 is to be maintained for a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than 0.3*l*.
The section modulus of the corrugation in the remaining upper part of the bulkhead is not to be less than 75% of that required for the middle part, corrected for different yield stresses.
Excessive stress concentration is, as far as practicable, to be avoided for transferring the corrugated bulkhead forces and moments to the boundary structures, in particular to the double bottom and cross-deck structures.
In particular, the thickness and stiffening of effective gusset and shedder plates, as defined in 8.9.4.2 of this Section, is to comply with CCS requirements, on the basis of the load model in 8.9.2 of this Section.
Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the relevant requirements of CCS.
(1) Lower stool
The height of the lower stool is generally not to be less than 3 times the depth of the corrugations. The thickness and material properties of the stool top plate are not to be less than those required for the bulkhead plating above. The thickness and material properties of the upper portion of vertical or sloping stool side plating within the depth equal to the corrugation flange width from the top are not to be less than the required flange plate thickness and material properties to meet the bulkhead stiffness requirement at lower end of corrugation. The structural scantlings of the lower stool are to comply with the relevant requirements of 8.4.1.2 of this Chapter. The section modulus of the stool side vertical stiffeners is not to be less than 85% of that of the corresponding inner bottom longitudinals, and the ends of the stiffeners are to be attached to brackets at the upper and lower ends of the stool.
The distance *d* from the edge of the stool top plate to the surface of the corrugation flange is to be determined in accordance with Figure 8.9.4.1(1). The stool bottom is to be installed in line with double floors and is to have a width not less than 2.5 times the mean depth of the corrugation. The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders for effective support of the corrugated bulkhead. The thickness of the diaphragms is to be the same as that of the longitudinal double bottom girders. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.
Where corrugations are cut at the lower stool, corrugated bulkhead plating is to be connected to the stool top plate by full penetration welds. The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or deep penetration welds (see Figure 8.9.4.1(2)). The supporting floors are to be connected to the inner bottom by either full penetration or deep penetration welds (see Figure 8.9.4.1(2)).

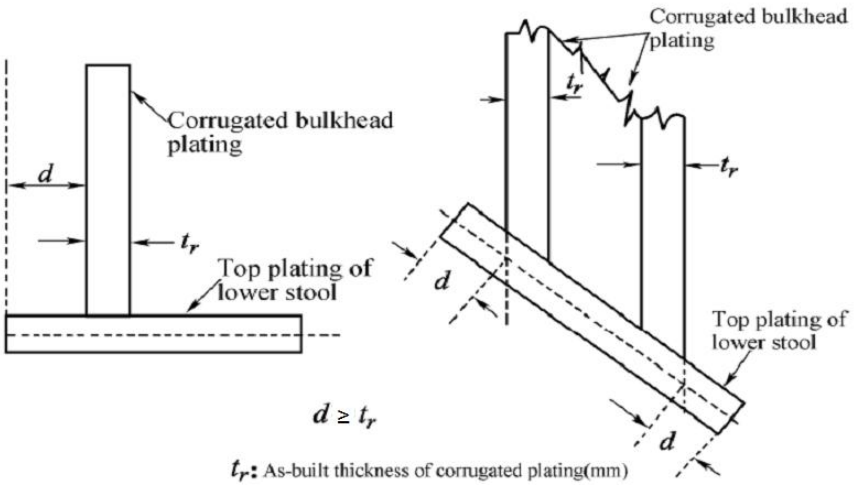
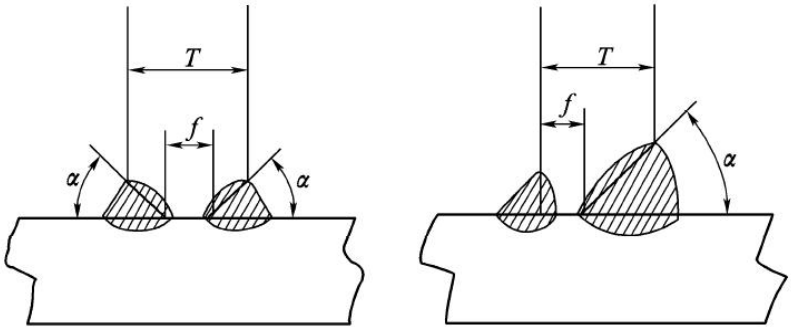


Figure 8.9.4.1(1)



Root face (f) 3 ~ T/3mm
Groove angle (α) 40° ~ 60°

Figure 8.9.4.1(2)

(2) Upper stool

The upper stool, where fitted, is to have a height generally between 2 and 3 times the depth of corrugations. Rectangular stools are to have a height generally equal to twice the depth of corrugations, measured from the depth level and at hatch side girder. The upper stool is to be supported by girders or deep brackets or between the adjacent hatch-end beams.

The width of the stool bottom plate is generally to be the same as that of the lower stool top plate. The top of non-rectangular stools is to have a width not less than twice the depth of corrugations. The thickness and material properties of the stool bottom plate are to be the same as those of the bulkhead plating below. The thickness of stool side plating is not to be less than 80% of that required for the upper part of the bulkhead plating where the same material is used. The structural scantlings of the upper stool are to comply with the relevant requirements of 8.4.1.2 of this Chapter. The section modulus of the stool side vertical stiffeners is not to be less than 85 % of that of the corresponding deck longitudinals. The ends of the stool side vertical stiffeners are to be attached to brackets at upper and lower ends of the stool. Diaphragms are to be fitted inside the stool in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connections to the stool bottom plate are to be avoided.

(3) Structural arrangement

At deck, if no stool is fitted, two transverse reinforced beams are to be fitted in line with the corrugation flanges.

At bottom, if no stool is fitted, the corrugated flanges are to be in line with the supporting floors. Corrugated bulkhead plating is to be connected to the inner bottom plating by full penetration welds. The plating of supporting floors is to be connected to the inner bottom by either full penetration or deep penetration welds (see Figure 8.9.4.1(2)). The thickness and material properties of the supporting floors are to be at least equal to those provided for the corrugation flanges. Moreover, the cut-outs for connections of the inner bottom longitudinals to double bottom floors are to be closed by collar plates. The supporting floors are to be connected to each other by shear plates.

Stool side plating is to align with the corrugation flanges and stool side vertical stiffeners and their brackets in lower stool are to align with the inner bottom longitudinals to provide appropriate load transmission between these stiffening members. Stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top.

8.9.4.2 Bending capacity and shear stress of corrugations

The bending capacity is to comply with the following relationship:

$$\frac{M}{0.5Z_{le}\sigma_{a,le} + Z_m\sigma_{a,m}} \times 10^3 \leq 0.95$$

where: M — bending moment, in kN · m, as given in 8.9.3.1 of this Section;

Z_{le} — section modulus, in cm³, at the lower end of corrugations, calculated according to 8.9.4.3;

Z_m — section modulus, in cm³, at the mid-span of corrugations, calculated according to 8.9.4.4;

$\sigma_{a,le}$ — allowable bending stress, in N/mm², as given in 8.9.4.5, for the lower end of corrugations;

$\sigma_{a,m}$ — allowable bending stress, in N/mm², as given in 8.9.4.5, for the mid-span of corrugations.

In no case Z_m is to be taken greater than the lesser of 1.15 Z_{le} and 1.15 Z'_{le} for calculation of the bending capacity, Z'_{le} being defined below.

In case shedder plates are fitted which:

— are not knuckled;

— are welded to the corrugations and the top of the lower stool by one side penetration welds or equivalent;
— are fitted with a minimum slope of 45° (angle to horizontal plane) and their lower edge is in line with the stool side plating;
— have thickness not less than 75% of that provided by the corrugation flanges;
— and material properties at least equal to those provided by the flanges.

Or gusset plates are fitted which:

— are in combination with shedder plates having thickness, material properties and welded connections in accordance with the above requirements;
— have a height not less than half of the flange width;
— are fitted in line with the stool side plating;
— are generally welded to the top of the lower stool by full penetration welds, and to the corrugations and shedder plates by one side penetration welds or equivalent;
— have thickness and material properties at least equal to those provided by the flanges;

the section modulus Z_{le}, in cm³, is to be taken not larger than the value Z'_{le}, in cm³, given by:

$$Z'_{le} = Z_g + 10^3 \frac{Q \cdot h_g - 0.5 h_g^2 s_1 P_g}{\sigma_a} \quad \text{cm}^3$$

where: Z_g — section modulus, in cm³, of the corrugations calculated according to 8.9.4.4 of this Section, in way of the upper end of shedder or gusset plates, as applicable;
Q — shear force, in kN, as given in 8.9.3.2 of this Section;
h_g — height, in m, of shedder or gusset plates, as applicable, see Figures 8.9.4.2(1) and 8.9.4.2(2);
s_1 — see 8.9.2.3 of this Section;
P_g — resultant pressure, in kN/m², as defined in 8.9.2.5 of this Section, calculated in way of the middle of the shedder or gusset plates, as applicable;
σ_a — allowable bending stress of material, in N/mm², as given in 8.9.4.5.

The shear stress τ is obtained by dividing the shear force Q by the shear area. In general, the shear area may be obtained by multiplying the web sectional area by sin φ, φ being the angle between the web and the flange, in order to account for possible non-perpendicularity between the corrugation webs and flanges.

When calculating the section modulus and the shear area, the net plate thicknesses are to be used.

The section modulus of corrugations is to be calculated on the basis of the following requirements given in 8.9.4.3 and 8.9.4.4.

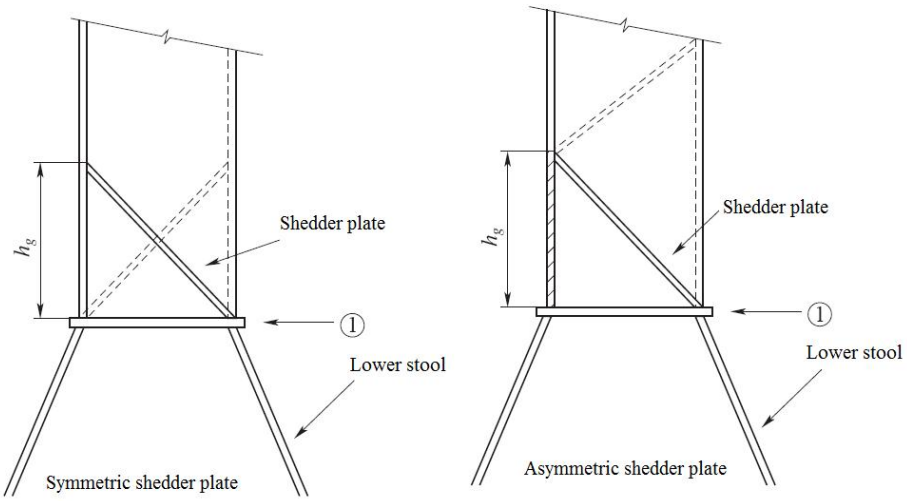


Figure 8.9.4.2(1)

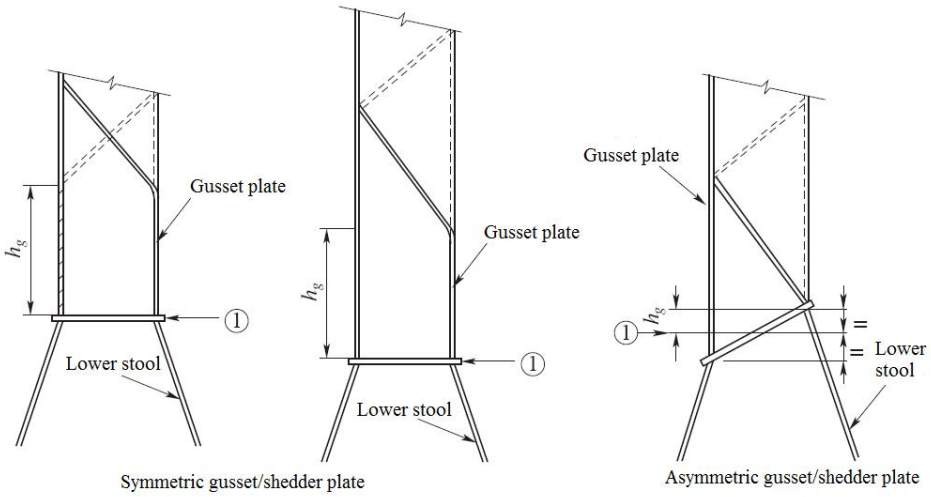


Figure 8.9.4.2(2)

8.9.4.3 Section modulus Z_{le} at the lower end of corrugations

The section modulus is to be calculated with the compression flange having an effective flange width, b_{ef}, not larger than as given in 8.9.4.6(1).

If the corrugation webs are not supported by local brackets below the stool top (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

(1) Provided that effective shedder plates are fitted (see Figure 8.9.4.2(1)), when calculating the section modulus of corrugations at the lower end (cross-section ① in Figure 8.9.4.2(1)), the area of flange plates, in cm^2, may be increased by:

$$2.5a\sqrt{t_f t_{sh}} \text{ , but not greater than } 2.5at_f \quad \text{cm}^2$$

where: a — width of the corrugation flange, in m, see Figure 8.9.2.3(2);

t_{sh} — net thickness of shedder plate, in mm;

t_f — net thickness of corrugation flange, in mm.

(2) Provided that effective gusset plates are fitted (see Figure 8.9.4.2(2)), when calculating the section modulus of corrugations at the lower end (cross-section ① in Figure 8.9.4.2(2)), the area of flange plates, in cm^2, may be increased by:

$$7h_g t_f \quad \text{cm}^2$$

where: h_g — height of gusset plate, in m (see Figure 8.9.4.2(2)), not to be taken greater than 10 S_{gu}/7;

S_{gu} — width of gusset plate, in m;

t_f — net thickness of corrugation flange, in m, based on the as-built condition.

The lower stool top plate is assumed to be at 0° angle to horizontal plane for (1) and (2) above.

(3) If the lower stool top plate is sloped and at an angle not less than 45° to the horizontal plane, the corrugation webs are to be considered fully effective when calculating the section modulus of corrugations at the lower end. In case effective gusset plates are fitted, when calculating the section modulus of corrugations the area of flange plates may be increased as specified in (2) above. However, no increase may be permitted in the case where shedder plates are fitted without gussets.

If the lower stool top plate is sloped and at an angle less than 45° to the horizontal plane, the effectiveness of corrugation webs is to be obtained by linear interpolation between 30% for 0° and 100% for 45°.

8.9.4.4 Section modulus of corrugations at cross sections other than the lower end

The section modulus is to be calculated with the corrugation webs being considered fully effective and the compression flange having an effective flange width b_{ef} not larger than as given in 8.9.4.6(1).

8.9.4.5 Allowable stress

The normal and shear stresses are not to exceed the allowable values σ_a and τ_a. The allowable stress is given by:

$$\sigma_a = R_{eH}$$
$$\tau_a = 0.5R_{eH}$$

where: R_{eH} — yield stress, in N/mm^2, of the material.

8.9.4.6 Effective compression flange width and shear buckling check

(1) Effective width of the compression flange of corrugations

The effective width b_{ef}, in m, of the corrugation flange is given by:

$$b_{ef} = C_e a$$

where: C_e = $\frac{2.25}{\beta} - \frac{1.25}{\beta^2}$ for $\beta > 1.25$

C_e = 1.0 for $\beta \leq 1.25$

β = $10^3 \frac{a}{t_f}\sqrt{\frac{R_{eH}}{E}}$;

t_f — net flange thickness, in mm;

a — width of the corrugation flange, in m;

R_{eH} — yield stress, in N/mm^2, of the material;

E — modulus of elasticity of the material, in N/mm^2, to be assumed equal to 2.06×10^5 N/mm^2 for steel.

(2) Shear

The buckling check is to be performed for the web plates at the corrugation ends.

The shear stress τ is not to exceed the critical value τ_c, in N/mm^2, obtained by the following:

$$\tau_c = \tau_E \quad \text{for} \quad \tau_E \leqslant \frac{\tau_s}{2}$$

$$\tau_c = \tau_s \left(1 - \frac{\tau_s}{4\tau_E}\right) \quad \text{for} \quad \tau_E > \frac{\tau_s}{2}$$

where: τ_s = $\frac{R_{eH}}{\sqrt{3}}$

R_{eH} — yield stress, in N/mm^2, of the material;

τ_E = $0.9 k_t E \left(\frac{t}{1000c}\right)^2$, N/mm^2;

k_t = 6.34;

E — modulus of elasticity of the material, in N/mm^2;

t — net thickness, in mm, of corrugation web;

c — width, in m, of corrugation web (See Figure 8.9.2.3(2)).

8.9.4.7 Net plate thickness

When the thickness of the flange is the same as that of the web, the bulkhead net plate thickness t is given by:

$$t = 15.27\, s_w \sqrt{\frac{P}{R_{eH}}} \quad \text{mm}$$

where: s_w — plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is the greater (see Figure 8.9.2.3(2));

P — resultant pressure, in kN/mm^2, as defined in 8.9.2.5, at the bottom of each strake of plating; in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, or at the inner bottom, if no lower stool is fitted or at the top of shedders, if shedder or gusset/shedder plates are fitted;

R_{eH} — yield stress, in N/mm^2, of the material.

For built-up corrugation bulkheads, when the thickness of the flange is different from that of the web, the net thickness of the narrow plating is not to be less than t_n, in mm, given by:

$$t_n = 15.27\, s_n \sqrt{\frac{P}{R_{eH}}} \quad \text{mm}$$

where: s_n — width of the narrower plating, in m;

R_{eH} — yield stress, in N/mm^2, of the material.

The net thickness of the wider plating, in mm, is not to be taken less than the maximum of the following:

$$t_{w1} = 15.27\, s_w \sqrt{\frac{P}{R_{eH}}} \quad \text{mm}$$

and

$$t_{w2} = \sqrt{462\, S_w^2 \frac{P}{R_{eH}} - t_{np}^2} \quad \text{mm}$$

where: t_{np} — less or equal to actual net thickness of the narrower plating and not to be greater than:

$15.27\, s_w \sqrt{\frac{P}{R_{eH}}}$ mm

R_{eH} — yield stress, in N/mm^2, of the material.

8.9.5 Corrosion addition and steel renewal

8.9.5.1 The corrosion addition is to be taken equal to 3.5 mm.

8.9.5.2 Steel renewal is required where the gauged thickness is less than t_{net} + 0.5 mm. Where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, coating or annual gauging may be adopted as an alternative to steel renewal.

Section 10 ALLOWABLE HOLD LOADING CONSIDERING HOLD FLOODING

8.10.1 General requirements

8.10.1.1 This Section applies to non-CSR bulk carriers of 150 m and over in length, intending to carry solid bulk cargoes having a density of 1.0 t/m^3, or above, and

(1) single hull, or

(2) double side skin construction in which any part of longitudinal bulkhead is located within B/5 or 11.5 m, whichever is less, inboard from the ship's side at right angle to the centreline at the assigned summer load line.

8.10.1.2 The loading in each hold is not to exceed the allowable hold loading in flooded condition, calculated according to 8.10.4 of this Section, using the shear capacity of the double bottom given in 8.10.3 of this Section.

8.10.1.3 In no case is the allowable hold loading, considering flooding, to be taken greater than the design hold loading in intact condition.

8.10.2 Loading model

8.10.2.1 General requirements

(1) The loads to be considered as acting on the double bottom are those given by the external sea pressure and the combination of the cargo loads with those induced by the flooding of the hold which the double bottom belongs to.

(2) The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual:

— homogeneous loading conditions;

— non-homogeneous loading conditions;

— packed cargo conditions (such as steel products).

(3) For each loading condition, the maximum bulk cargo density to be carried is to be considered in calculation of the allowable hold loading limit.

8.10.2.2 The flooding head h_f (see Figure 8.10.2.2) is the distance, in m, measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance d_f, in m, from the baseline equal to (D being moulded depth):

(1) In general:

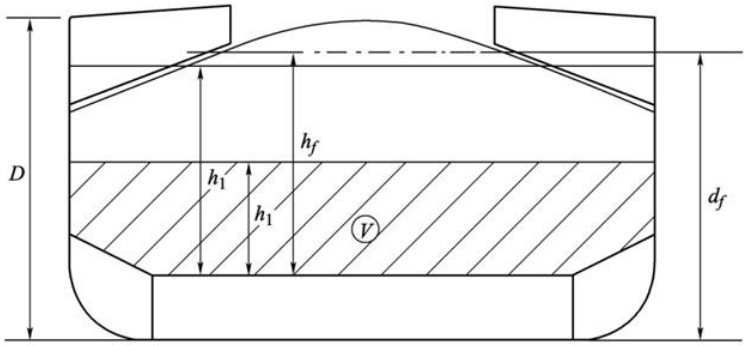
— D, for the foremost hold;

— 0.9D, for the other holds.

(2) For ships less than 50,000 tons deadweight with Type B freeboard:

— 0.95D, for the foremost hold;

— 0.85D, for the other holds.



V = Volume of cargo

Figure 8.10.2.2

8.10.3 Shear capacity of double bottom

8.10.3.1 The shear capacity C of the double bottom is defined as the sum of the shear strength at each end of:

— all floors adjacent to both hopper tanks, less one half of the strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted (see Figures 8.10.3.1(1) and 8.10.3.1(2));

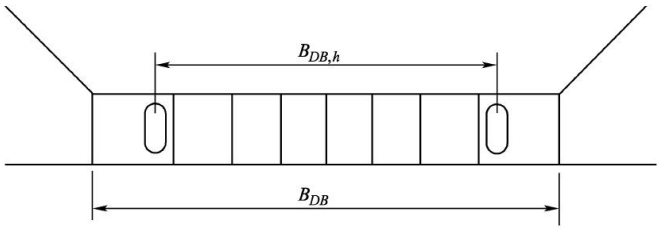


Figure 8.10.3.1(1)

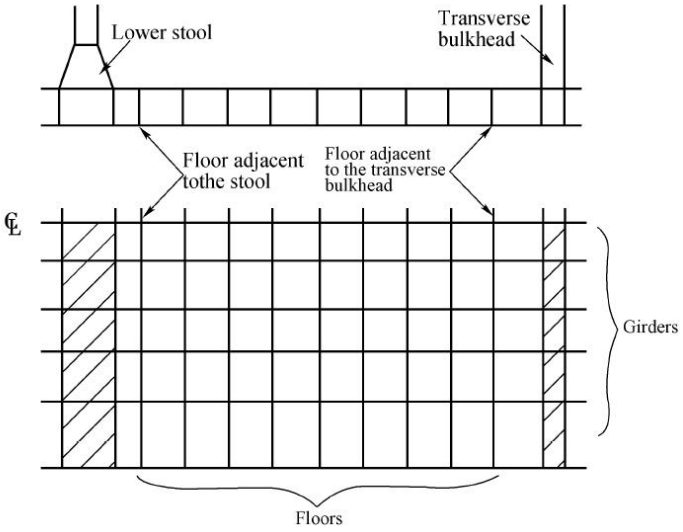


Figure 8.10.3.1(2)

— all double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted.

Where in the end holds, girders or floors run out or are not directly attached to the boundary stool, their strength is to be evaluated for the end only.

Note that the floors and girders to be considered are those inside the hold boundaries formed by the hopper tanks and stools (or transverse bulkheads if no stool is fitted). The hopper tank girders and the floors below the lower stools (or transverse bulkheads if no stool is fitted) are not to be included.

Where the geometry and or/the structural arrangement of the double bottom are different from those stated above, special consideration is to be given.

In calculation of the shear strength, the net thickness of floors and girders is to be used. The net thickness t_{net} is given by:

$$t_{net} = t - 2.5 \quad \text{mm}$$

where: t — actual thickness of floors or girders, in mm.

8.10.3.2 The floor shear strength S_{f1} in way of the floor panel adjacent to hoper tanks, in kN, and the floor shear strength S_{f2} in way of the openings in the outmost bay (i.e. that bay which is closer to hopper tank), in kN, are given by the following formulae:

$$S_{f1} = A_f \frac{[\tau]}{\eta_1} \times 10^{-3} \quad \text{kN}$$

$$S_{f2} = A_{fh} \frac{[\tau]}{\eta_2} \times 10^{-3} \quad \text{kN}$$

where: A_f — sectional area, in mm², of the floor panel adjacent to hopper tanks;

A_{fh} — net sectional area, in mm², of the floor panels in way of the openings in the outmost bay (i.e.

that bay which is closer to hopper tank);

$[\tau]$ — allowable shear stress, in N/mm^2, to be taken equal to the lesser of

$$[\tau] = \frac{162R_{eH}^{0.6}}{(s/t_{net})^{0.8}} \quad \text{and} \quad \frac{R_{eH}}{\sqrt{3}}$$

For floors adjacent to the stools or transverse bulkheads, $[\tau]$ may be given by

$$[\tau] = \frac{R_{eH}}{\sqrt{3}}$$

where: R_{eH} — yield stress, in N/mm^2, of the material;

s — spacing of stiffening members, in mm, of panel under consideration;

t_{net} — net thickness, in mm, of floor;

η_1 = 1.10;

η_2 = 1.20.

Where appropriate reinforcements are fitted around openings, η_2 may be reduced down to 1.10.

8.10.3.3 The girder shear strength S_{g1} in way of the girder panel adjacent to stools (or transverse bulkheads, if not stool is fitted), in kN, and the girder shear strength S_{g2} in way of the largest opening in the outmost bay (i.e. that bay which is closer to hopper tank), in kN, are given by:

$$S_{g1} = A_g \frac{[\tau]}{\eta_1} \times 10^{-3} \quad \text{kN}$$

$$S_{g2} = A_{gh} \frac{[\tau]}{\eta_2} \times 10^{-3} \quad \text{kN}$$

where: A_g — sectional area, in mm², of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted);

A_{gh} — net sectional area, in mm², of the girder panel in way of the largest opening in the outmost bay (i.e. that bay which is closer to stool, or transverse bulkhead, if no stool is fitted);

$[\tau]$ — the same as in 8.10.3.2 of this Section, t_{net} being net thickness of girder in mm;

η_1 = 1.10;

η_2 = 1.15, may be reduced down to 1.10 where appropriate reinforcements are fitted around openings.

8.10.4 Allowable hold loading

8.10.4.1 The allowable hold loading is given by:

$$W = \frac{\rho_c V}{F} \quad t$$

where: F — coefficient, 1.1 in general and 1.05 for steel products;

ρ_c — cargo density, in t/m³, for steel products, ρ_c is to be taken as the density of steel;

V — volume, in m³, occupied by cargo at a level h_1, to be obtained by the following formula:

$$h_1 = \frac{X}{9.81\rho_c}$$

X = for bulk cargoes, the lesser of X_1 and X_2 given by:

$$X_1 = \frac{Z + 10(E - h_f)}{1 + \frac{1}{\rho_c}(perm - 1)}$$

$$X_2 = Z + 10\,(E - h_f\, perm)$$

for steel products, X may be taken as X_1, using $perm = 0$;

E — ship immersion, in m, for flooded hold condition, to be obtained by:

$$d_f - 0.1D$$

d_f,D — determined according to Figure 8.10.2.2;

h_f — flooding head, in m;

$perm$— cargo permeability; it need not be taken as greater than 0.3;

Z — the lesser of Z_1 and Z_2 given by:

$$Z_1 = \frac{C_h}{A_{DBh}}$$

$$Z_2 = \frac{C_e}{A_{DBe}}$$

C_h — shear capacity of the double bottom, in kN, considering, for each floor, the lesser of the shear

strength S_{f1} and S_{f2} and, for each girder, the lesser of the shear strength S_{g1} and S_{g2};

C_e — shear capacity of the double bottom, in kN, considering, for each floor, the shear strength S_{f1} and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2};

$$A_{DBh} = \sum_{i+1}^{n} S_i B_{DBi} ;$$

$$A_{DBe} = \sum_{i+1}^{n} S_i (B_{DB} - s_l) ;$$

n — number of floors between stools (for transverse bulkheads, if no stool is fitted);

S_i — space of ith-floor, in m;

$B_{DBi} = B_{DB} - s_l$, for floors whose shear strength is given by S_{f1};

$B_{DBi} = B_{DBh}$, for floors whose shear strength is given by S_{f2};

B_{DB} — breadth of double bottom, in m, between hopper tanks (see Figure 8.10.3.1(1));

B_{DBh} — distance, in m, between the two considered openings (see Figure 8.10.3.1(1));

s_l — spacing, in m, of double bottom longitudinals adjacent to hopper tanks.

Section 11 HATCH COVERS OF CARGO HOLDS

8.11.1 General requirements

8.11.1.1 This Section applies to bulk carriers, ore carriers and combination carriers. The hatch covers of cargo holds are to comply with the relevant requirements of Section 20, Chapter 2 of this PART.

Section 12 HARMONIZED NOTATIONS AND CORRESPONDING DESIGN LOADING CONDITIONS FOR BULK CARRIERS

8.12.1 General requirements

8.12.1.1 This Section is not intended to prevent any other loading conditions to be included in the loading manual for which calculations are to be submitted as required, nor is it intended to replace in any way the required loading manual/instrument.

8.12.1.2 A bulk carrier may in actual operation be loaded differently from the design loading conditions specified in the loading manual, provided limitations for longitudinal and local strength as defined in the loading manual and loading instrument onboard and applicable stability requirements are not exceeded.

8.12.2 Application

8.12.2.1 Typical bulk carriers of 150 m or over in length and constructed with single deck, double bottom, topside tanks and hopper tanks in the cargo hold region and of single side skin or double side skin construction are to comply with relevant requirements of this Section. General dry cargo ships intended to carry cargoes in bulk may also be assigned relevant notations provided that relevant requirements of this Section are satisfied.

8.12.2.2 The loading conditions listed in 8.12.4 are to be used for the checking of rules criteria regarding longitudinal strength, local strength, capacity and disposition of ballast tanks and stability. The longitudinal strength is to comply with the requirements of Section 2, Chapter 2 and Section 8, Chapter 8 of this PART. The loading conditions listed in 8.12.5 are to be used for the checking of local strength. Direct calculations are to be carried out for the strength of primary structural members within the cargo area in accordance with the requirements of 8.1.4 of this Chapter.

8.12.2.3 Maximum draught mentioned in this Section is to be taken as moulded summer load line draught.

8.12.2.4 Filling rate mentioned in this Section is the rate of cargo mass to hold cubic capacity. The hold cubic capacity is to be taken up to the top of the hatch coaming in calculation.

8.12.3 Harmonized notations and annotations

8.12.3.1 Bulk carriers complying with this Section are to be assigned one of the following notations:

(1) BC–A: for bulk carriers:

— designed to carry dry bulk cargoes of cargo density 1.0 t/m^3 and above,

— with specified holds empty at maximum draught, and

— in addition to BC–B conditions.

(2) BC–B: for bulk carriers:

— designed to carry dry bulk cargoes of cargo density of 1.0 t/m^3 and above,
— with all cargo holds loaded, and
— in addition to BC–C conditions.

(3) BC–C: for bulk carriers:
— designed to carry dry bulk cargoes of cargo density less than 1.0 t/m^3.

8.12.3.2 Additional notations:

(1) {Maximum cargo density x.y t/m^3}: When the maximum design cargo density is less than 3.0 t/m^3, for bulk carriers, the limitation is to be given after the harmonized notation, indicating the maximum cargo density allowed to be loaded. This additional notation is only applicable to notations BC–A and BC–B. For general dry cargo ships intended to carry cargoes in bulk, when the maximum density of the bulk cargo designed under the bulk cargo loading condition is less than 3.0 t/m^3, this notation is assigned to indicate the limitation and the maximum density value of the bulk cargo allowed to be loaded.

(2) {No MP}: When requirements for loading and unloading in multiple ports have not been raised in accordance with 8.12.5.3 in the design of bulk carrier, the limitation is to be given after the harmonized notation. This additional notation is applicable to all harmonized notations (BC-A, BC-B, BC-C). For general dry cargo ships intended to carry cargoes in bulk, this notation is assigned to show the limitation when the bulk cargo loading condition has not been designed for loading and unloading in multiple ports in accordance with the Rules.

(3) {Holds a, b, …may be empty}: When specified empty holds are allowed in the design of bulk carriers, this additional notation is to be given after the harmonized notation. This notation is only applicable to notation BC-A. For general dry cargo ships intended to carry cargoes in bulk, this notation is assigned to specify the empty hold No. when specified empty holds are allowed in the design of bulk cargo loading condition.

8.12.4 Design loading conditions (General)

8.12.4.1 Harmonized notation BC–C is to cover:

Homogeneous cargo loaded condition where the cargo density corresponds to all cargo holds, including hatchways, being 100% full at maximum draught with all ballast tanks empty.

8.12.4.2 Harmonized notation BC–B is to cover:

The condition as required by 8.12.4.1, plus: homogeneous cargo loaded condition with cargo density 3.0 t/m^3, and the same filling rate in all cargo holds at maximum draught with all ballast tanks empty.

In cases where the cargo density applied for this design loading condition is less than 3.0 t/m^3, the maximum density of the cargo that the vessel is allowed to carry is to be indicated with the additional notation (Maximum cargo density x.y t/m^3) as specified in 8.12.3.2(1).

8.12.4.3 Harmonized notation BC–A is to cover:

The condition as required by 8.12.4.1 and 8.12.4.2, plus: at least one cargo loaded condition with specified holds empty, with cargo density 3.0 t/m^3, and the same filling rate in all loaded cargo holds at maximum draught with all ballast tanks empty.

The combination of specified empty holds is to be indicated with the annotation (Holds a, b, ... may be empty). In such cases where the design cargo density applied is less than 3.0 t/m^3, the maximum density of the cargo that the vessel is allowed to carry is to be indicated within the annotation, e.g. (Maximum cargo density x.y t/m^3, Holds a, b, ... may be empty).

8.12.4.4 Ballast conditions (applicable to all notations)

(1) Ballast tank capacity and disposition

All bulk carriers are to have ballast tanks of sufficient capacity and so disposed to at least fulfill the following requirements:

① Normal ballast condition for the purpose of this Section is a ballast (no cargo) condition where:
— all cargo holds or holds adapted for the carriage of water ballast at sea are to be empty;
— the ballast tanks may be full, partially full or empty. Where partially full option is exercised, the conditions in 2.2.2.5 of Section 2, Chapter 2 of this PART are to be complied with;
— the propeller is to be fully immersed; and
— the trim is to be by the stern and is not to exceed 0.015L, where L is the length between perpendiculars of the ship. In the assessment of the propeller immersion and trim, the draughts at the forward and after perpendiculars may be used.

② Heavy ballast condition for the purpose of this Section is a ballast (no cargo) condition where:
— at least one cargo hold adapted for carriage of water ballast at sea, where required or provided, is to be full;
— the ballast tanks may be full, partially full or empty. Where partially full option is exercised, the conditions in 2.2.2.5 of Section 2, Chapter 2 of this PART are to be complied with;

— the propeller immersion I/D is to be at least 0.60 where I = the distance from propeller centerline to the waterline, in m, D = propeller diameter, in m;
— the trim is to be by the stern and is not to exceed 0.015L, where L is the length, in m, between perpendiculars of the ship; and
— the moulded forward draught in the heavy ballast condition is not to be less than the smaller of 0.03L or 8 m.

(2) Strength requirements

① Normal ballast condition:

— the structures of bottom forward are to be strengthened in accordance with the relevant requirements of 2.15.3 of Section 15, Chapter 2 of this PART against slamming for the condition of 8.12.4.4(1)① where the lightest forward draught is less than 0.04L;
— the longitudinal strength requirements are to be met for the condition of 8.12.4.4(1)①; and
— in addition, the longitudinal strength requirements are to be met with all ballast tanks 100% full for the condition of 8.12.4.4(1)① where the ballast tanks may be partially full or empty.

② Heavy ballast condition:

— the longitudinal strength requirements are to be met for the condition of 8.12.4.4(1)②;
— in addition, the longitudinal strength requirements are to be met with all ballast tanks 100% full for the condition of 8.12.4.4(1)② where the ballast tanks may be partially full or empty; and
— where more than one hold is adapted and designated for the carriage of water ballast at sea, it will not be required that two or more holds be assumed 100% full simultaneously in the longitudinal strength assessment, unless such conditions are expected in the heavy ballast condition. Unless each hold is individually investigated, the designated heavy ballast hold and any/all restrictions for the use of other ballast hold(s) are to be indicated in the loading manual.

8.12.4.5 Unless otherwise specified, each of the design loading conditions defined in 8.12.4 is to be investigated for the arrival and departure conditions as defined below.

(1) Departure condition: with bunker tanks not less than 95% full and other consumables 100%;

(2) Arrival condition: with 10% of consumables.

8.12.5 Design loading conditions (for local strength)

8.12.5.1 The maximum allowable or minimum required cargo mass in a cargo hold, or in two adjacently loaded holds, is related to the net load on the double bottom. The net load on the double bottom is a function of draft, cargo mass in the cargo hold, as well as the mass of fuel oil and ballast water contained in double bottom tanks. For the purpose of the conditions in 8.12.5.2 to 8.12.5.6, the following definitions apply:

(1) M_H: the actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught;

(2) M_{Full}: the cargo mass in a cargo hold corresponding to cargo with virtual density (homogeneous mass/hold cubic capacity, minimum 1.0 t/m^3) filled to the top of the hatch coaming. M_{Full} is in no case to be less than M_H;

(3) M_{HD}: the maximum cargo mass allowed to be carried in a cargo hold according to design loading condition(s) with specified holds empty at maximum draft.

8.12.5.2 For all ships within the scope of application, the cargo hold is to be checked in accordance with the following loading conditions.

(1) Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught (see Figure 8.12.5.2(1)).

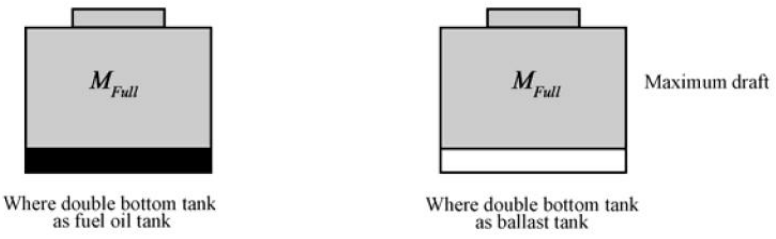


Figure 8.12.5.2(1)

(2) Any cargo hold is to be capable of carrying minimum 50% of M_H, with all double bottom tanks in way

of the cargo hold being empty, at maximum draught (see Figure 8.12.5.2(2)).

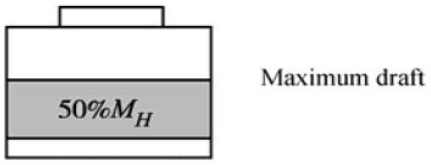


Figure 8.12.5.2(2)

(3) Any cargo hold is to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at the deepest ballast draught (see Figure 8.12.5.2(3)).

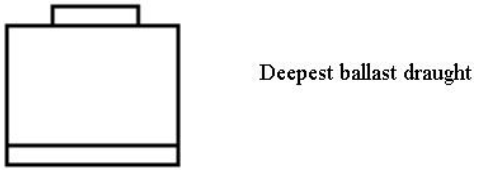


Figure 8.12.5.2(3)

8.12.5.3 For all ships within the scope of application, the cargo hold is to be checked in accordance with the following loading conditions, except when notation (No MP) is assigned

(1) Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of maximum draught (see Figure 8.12.5.3(1)).

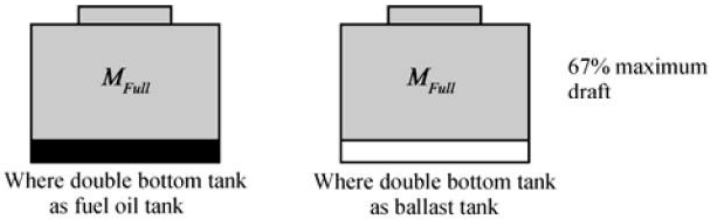


Figure 8.12.5.3(1)

(2) Any cargo hold is to be capable of being empty with all double bottom tanks in way of the cargo hold being empty, at 83% of maximum draught (see Figure 8.12.5.3(2)).

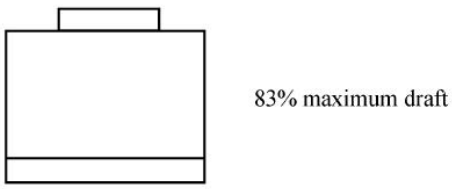


Figure 8.12.5.3(2)

(3) Any two adjacent cargo holds are to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of the maximum draught. This requirement to the mass of cargo and fuel oil in double bottom tanks in way of the cargo hold applies also to the condition where the adjacent hold is filled with ballast, if applicable (see Figure 8.12.5.3(3)).

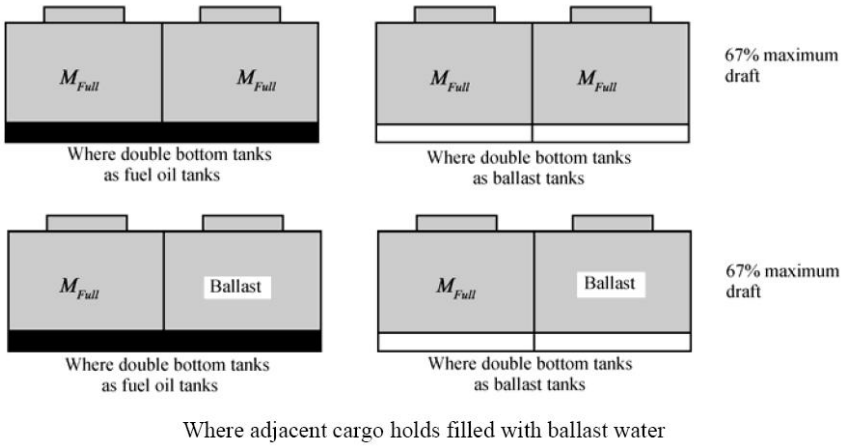


Figure 8.12.5.3(3)

(4) Any two adjacent cargo holds are to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at 75% of maximum draught (see Figure 8.12.5.3 (4)).

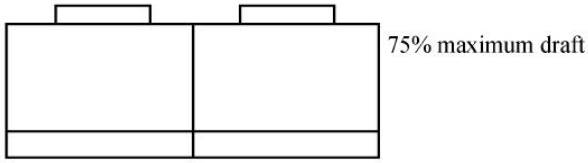


Figure 8.12.5.3(4)

8.12.5.4 Additional requirements for ships where empty holds are allowed in the bulk cargo loading condition

(1) Cargo holds, which are intended to be empty at maximum draught, are to be capable of being empty with all double bottom tanks in way of the cargo hold also being empty (see Figure 8.12.5.4 (1)).

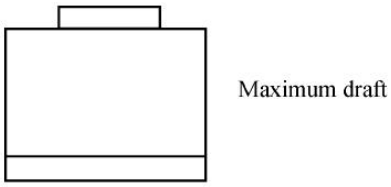


Figure 8.12.5.4(1)

(2) Cargo holds, which are intended to be loaded with high density cargo, are to be capable of carrying M_{HD} plus 10% of M_H, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty in way of the cargo hold, at maximum draught. In operation the maximum allowable cargo mass is to be limited to M_{HD} (see Figure 8.12.5.4 (2)).

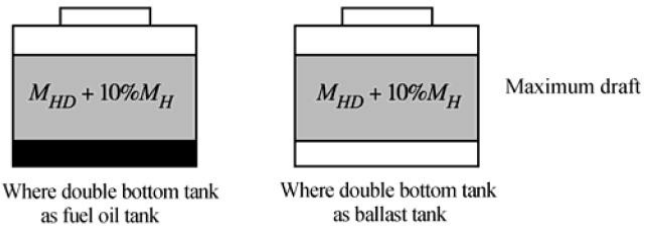


Figure 8.12.5.4(2)

(3) Any two adjacent cargo holds which according to a design loading condition may be loaded with the next holds being empty, are to be capable of carrying 10% of M_H in each hold in addition to the maximum cargo load M'_{HD} according to that design loading condition, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught. In operation the maximum allowable mass is to be limited to the

maximum cargo load according to the design loading conditions (see Figure 8.12.5.4 (3)).

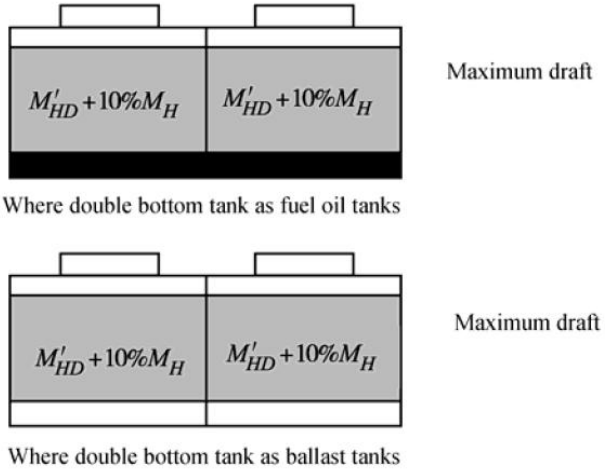


Figure 8.12.5.4(3)

8.12.5.5 Additional conditions applicable for ballast hold(s) only

(1) Cargo holds, which are designed as ballast water holds, are to be capable of being 100% full of ballast water including hatchways, with all double bottom tanks in way of the cargo hold being 100% full, at any heavy ballast draught. For ballast holds adjacent to topside wing, hopper and double bottom tanks, it is to be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty (see Figure 8.12.5.5 (1)).

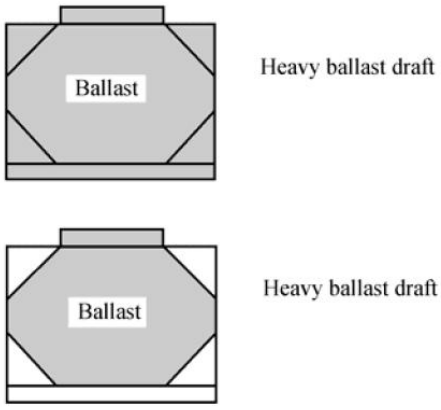


Figure 8.12.5.5(1)

8.12.5.6 Additional conditions applicable during loading and unloading in harbor only

(1) Any single cargo hold is to be capable of holding the maximum allowable seagoing mass at 67% of maximum draught, in harbor condition (see Figure 8.12.5.6 (1)).

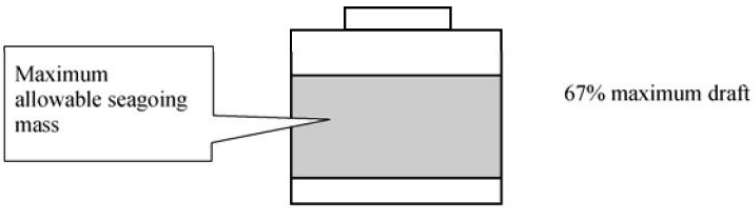


Figure 8.12.5.6(1)

(2) Any two adjacent cargo holds are to be capable of carrying M_{Full} ,with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of maximum draught, in harbor condition (see Figure 8.12.5.6(2)).

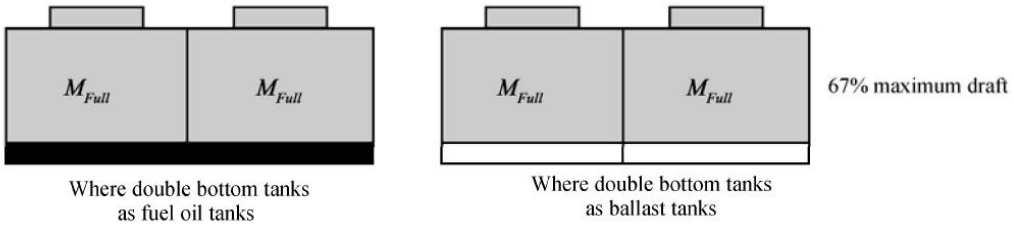


Figure 8.12.5.6(2)

(3) At reduced draught during loading and unloading in harbor, the maximum allowable mass in a cargo hold may be increased by 15% of the maximum mass allowed at the maximum draught in sea-going condition, but is not to exceed the mass allowed at maximum draught in the sea-going condition. The minimum required mass may be reduced by the same amount.

8.12.5.7 Hold mass curves

(1) Based on the design loading criteria for local strength, as given in 8.12.5.2 to 8.12.5.6 above, hold mass curves are to be included in the loading manual and the loading instrument, showing maximum allowable and minimum required mass as a function of draught, in sea-going condition as well as during loading and unloading in harbor (see Section 7, Chapter 8 of this PART).

(2) At other draughts than those specified in the design loading conditions above, the maximum allowable and minimum required mass is to be adjusted for the change in buoyancy acting on the bottom. Change in buoyancy is to be calculated using water plane area at each draught.

Section 13 REQUIREMENTS FOR THE FITTING OF A FORECASTLE

8.13.1 General requirements

8.13.1.1 This Section applies to bulk carriers, ore carriers and combination carriers.

8.13.1.2 Ships to which this Section applies are to be fitted with an enclosed forecastle on the freeboard deck.

8.13.1.3 In addition, structural arrangement and scantlings of the forecastle are to comply with the applicable requirements of Section 17, Chapter 2 of this PART.

8.13.2 Arrangement

8.13.2.1 The forecastle is to be located on the freeboard deck with its aft bulkhead fitted in way or aft of the forward bulkhead of the foremost hold, as shown in Figure 8.13.2.1. However, if this requirement hinders hatch cover operation, the aft bulkhead of the forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 0.07 L_L of ship's length abaft the forward perpendicular, where the ship's length and forward perpendicular are defined in Regulation 3 of Annex I of the International Convention on Load Lines, 1966 and its 1988 amendments.

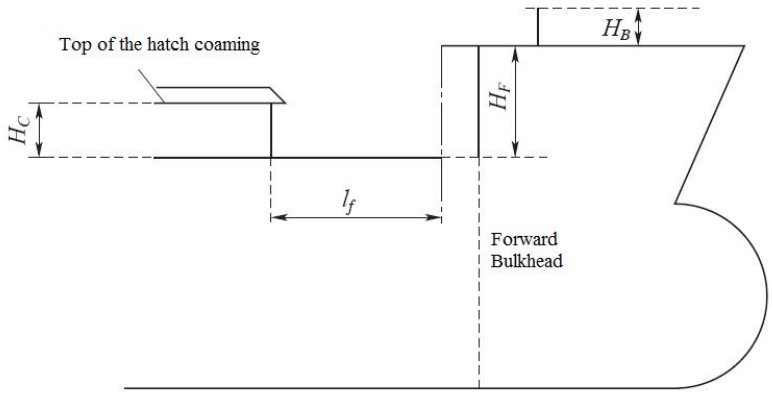


Figure 8.13.2.1

8.13.2.2 The forecastle height H_F above the main deck is not to be less than:

$$H_{F1} = H_{sh} \quad \text{m}$$

$$H_{F2} = H_C + 0.5 \quad \text{m}$$

where: H_{sh} — the standard height of a superstructure as specified in the International Convention on Load Lines, 1966 and its 1988 amendments;

H_C — the height, in m, of the forward transverse hatch coaming of cargo hold No.1,

whichever is the greater.

8.13.2.3 All points of the aft edge of the forecastle deck are to be located at a distance l_f:

$$l_f \le 5\sqrt{H_F - H_C} \quad \text{m}$$

from the hatch coaming plate in order to apply the reduced loading to the No.1 forward transverse hatch coaming and No.1 hatch cover in applying 2.20.2.2(2)② and 2.20.2.9(2)③, respectively, of Chapter 2 of this PART.

8.13.2.4 A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centre line is not less than H_B/tan 20° forward of the aft edge of the forecastle deck, where H_B is the height of the breakwater above the forecastle (see Figure 8.13.2.1).

Section 14 DOUBLE SIDE STRUCTURE

8.14.1 General requirements

8.14.1.1 This Section applies to the double side skin construction within the cargo area of bulk carriers.

8.14.1.2 Manholes are to be provided in transverse webs and horizontal girders. The manholes may either be round or elliptical. The long axis of an elliptical manhole is to be vertical to or along the length of the ship. Except access openings, the holes in upper and lower adjacent horizontal girders are not to be on the same vertical line. The manhole edges are to be strengthened.

8.14.2 Structural arrangements of double side skin

8.14.2.1 Where double side skin is provided in the cargo area, the inner shell is to extend as far forward and aft as practicable at the fore and aft ends of the cargo hold and is to be effectively connected and tapered to the structures there. Supporting members within the inner shell are to be provided in double side skin instead of one side of the cargo hold.

8.14.2.2 Cargo loading is not permitted inside double side skin, and the inner shell is to be so arranged that all cargo holds are inboard of double side skin.

8.14.2.3 Where the load line length L_L is 150 m and upwards, the width of double side skin at any transverse section of the hull is not to be less than 1 m. Such width is the distance between the outer shell and the inner shell, measured perpendicular to the side shell.

8.14.2.4 Where the load line length L_L is 150 m and upwards, the structural arrangement of double side skin is to comply with the following:

(1) the minimum width of the clear passage through the double-side skin space in way of obstructions such as piping or vertical ladders is not to be less than 0.6 m;

(2) where the inner and outer skins are transversely framed, the minimum clearance between the inner surfaces of the frames is not to be less than 0.6 m;

(3) where the inner and outer skins are longitudinally framed, the minimum clearance between the inner surfaces of the frames is not to be less than 0.8 m. Outside the parallel part of the cargo hold length, this clearance may be reduced where necessitated by the structural configuration, but not less than 0.6 m.

Consideration over end brackets of frames is not necessary when measuring the clearance, see Figure 8.14.2.4 for the measurement.

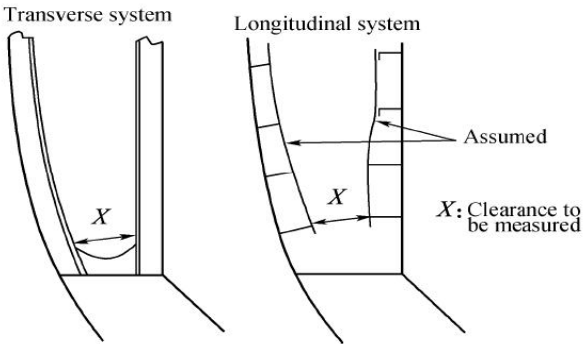


Figure 8.14.2.4

8.14.2.5 Transverse webs are to be provided within double side skin in line with the transverse watertight bulkheads of cargo holds. Otherwise, transverse framing is to be provided and ballast tanks are to be provided with swash bulkheads.

8.14.2.6 Transverse framing or transverse webs, which are to be provided or alternately provided within double side skin in line with double bottom transverses, together with transverse supporting members in topside tanks and hopper tanks and double bottom transverses, form transverse strength framing.

8.14.2.7 Horizontal girders must be provided at bottom of topside tanks and at top of hopper tanks. Manholes may not be provided for the sake of subdivision and stability.

8.14.3 Minimum thickness

8.14.3.1 The minimum thickness t of webs and face plates of primary members, horizontal girders, transverse webs and inner shell plating in double side skin is not to be less than that obtained from the following formula:

$$t = 7.5 + 0.015L, \text{ but need not be greater than 11 mm}$$

8.14.3.2 Where specified empty spaces are within double side skin, the minimum thickness as required in 8.14.3.1 may be reduced by 1 mm.

8.14.4 Inner shell plating

8.14.4.1 Where specified empty spaces are within double side skin, in addition to complying with the requirement in 8.14.3 of this Section, the thickness t of inner shell plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of the inner shell plating strake to bulkhead deck;

K — material factor.

Where no hopper tank is provided, the thickness obtained of strake at the bottom of the inner shell plating is to be increased by 1 mm, the width is not to be less than 900 mm. Where the thickness of inner shell plating is much less than that of the girder web to which the shell plating is connected, the thickness of the inner shell plating in way of the connecting area is in general to be increased.

8.14.4.2 Where ballast tanks are within double side skin, in addition to complying with the requirement in 8.14.3 of this Section, the thickness t of inner shell plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of the inner shell plating strake to the top of the ballast tank, or half the distance to the top of the overflow, whichever is the greater;

K — material factor.

Where no hopper tank is provided, the thickness obtained of the lowest strake of inner shell plating is to be increased by 1 mm.

8.14.4.3 Where no topside tank is provided, the thickness of inner shell plating within $0.1D$ of strength deck is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{DK} \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

D — molded depth, in m;

K — material factor.

However, the thickness of inner shell plating is not to be necessarily greater than that of sheer strakes with same frame spacing.

8.14.4.4 Stiffener spacing of inner shell plating is to be the same as that of side frames or side longitudinals.

8.14.4.5 In specified empty spaces, the section modulus W of inner shell plating stiffeners is not to be less than that obtained from the following formula:

$$W = 3shl^2K \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the mid-span of the stiffener to upper deck,

but not less than 2 m;

l — span of stiffener, in m;

K — material factor.

8.14.4.6 In the ballast tank, the section modulus W and the moment of inertia I of inner shell stiffeners are not to be less than those obtained from the following formulae respectively:

$$W = 8.2shl^2K \quad \text{cm}^3$$

$$I = 2.3Wl/K \quad \text{cm}^4$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the mid-span of the stiffener to tank top, or half the distance to the top of the overflow, whichever is the greater;

l — span of stiffener, in m;

K — material factor.

8.14.4.7 In ships over 150 m in length or where higher tensile steel is used for horizontal stiffeners, horizontal stiffeners of inner shell plating within $0.1D$ from bottom and strength deck are to pass continuously through watertight transverse webs. Where horizontal stiffeners are cut at watertight transverse webs, they are to be bracketed to transverse webs.

8.14.4.8 Tripping brackets are to be provided at both ends of vertical stiffeners.

8.14.4.9 Scantlings of tripping brackets are to comply with the requirements in 1.2.6 of Chapter 1 of this PART.

8.14.5 Transverse webs

8.14.5.1 Where watertight transverse webs in double side skin constitute boundaries of specified empty spaces, their scantlings are to comply with the requirements in 8.14.4.1 and 8.14.4.5 of this Section.

8.14.5.2 Where watertight transverse webs in double side skin constitute boundaries of ballast tanks, their scantlings are to comply with the requirements in 8.14.4.2 and 8.14.4.6 of this Section.

8.14.5.3 Stiffeners are to be provided in between side longitudinals and inner shell horizontal stiffeners in way of transverse webs.

8.14.5.4 Where longitudinal framing is provided inside double side skin, non-watertight transverse webs supporting side longitudinals and inner shell horizontal stiffeners are to be provided or alternately provided at the same frame of bottom transverse in double side skin. The thickness of non-watertight transverse webs is to comply with the requirements in 8.14.3 of this Section. The side longitudinals and inner shell horizontal stiffeners are to pass through the non-watertight transverse webs.

8.14.6 Platform in deep tanks

8.14.6.1 The platform in deep tanks is to comply with the relevant requirements of Section 13, Chapter 2 of this PART.

Section 15 ADDITIONAL REQUIREMENTS FOR STIFFENING STRUCTURAL MEMBERS

8.15.1 General requirements

8.15.1.1 This Section applies to bulk carriers of 150 m in load line length and upwards, carrying solid bulk cargoes having a density of 1 t/m^3 and above, as defined in SOLAS Regulation XII/1.

8.15.2 Materials

8.15.2.1 For ships with single side structures, the steel grade is not to be less than grade D or DH for:

(1) the lower bracket of side frames;

(2) side shell plate between two points located to $0.125l$ above and $0.125l$ below the intersection of side shell and bilge hopper sloping plate or inner bottom plate, l being the span of the side frame.

(3) In case of side frames built with multiple spans, the above requirements are to apply to the lower part only, see Figure 8.15.2.1.

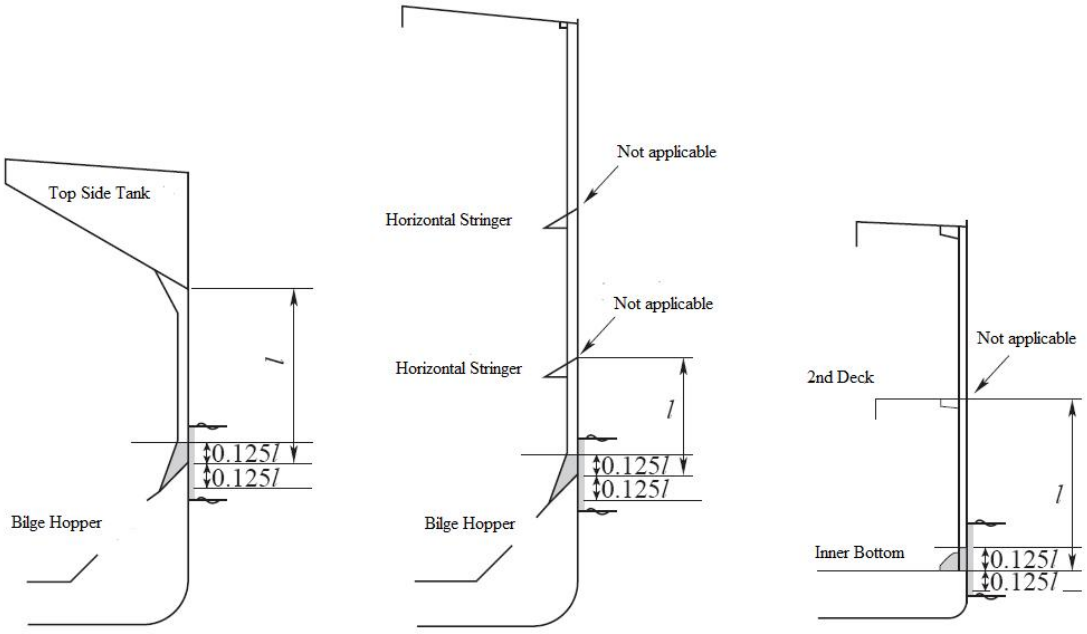


Figure 8.15.2.1

8.15.3 Lateral buckling of stiffeners

8.15.3.1 Scope of check

The lateral buckling of longitudinal and transverse stiffeners in the following areas within cargo areas are to be checked:

(1) hatchway coaming;
(2) inner bottom;
(3) sloped stiffened panel of topside tanks and hopper tanks (if any);
(4) inner side (if any);
(5) top stool and bottom stool of transverse bulkhead (if any);
(6) stiffened transverse bulkhead (if any);
(7) side shell (if directly bounding the cargo hold).

8.15.3.2 Design loads

(1) Design loads are to be based on the loading conditions under intact stability as specified in the loading manual. The loads and loading conditions, for which the strength requirements in 8.15.3.1 are applicable, are given in 8.15.3.2(2).

(2) Loads and load cases

① The following types of loads, if applicable, are to be considered:

(a) normal stress σ_n due to bending of hull girder, see ② below;

(b) shear stress τ_{SF}, see ③ below;

(c) lateral pressure applied to the member in loading conditions under intact stability as specified in the loading manual, see ④ below.

② Normal stress σ_n — the normal stress σ_n considered for each of the mutually exclusive load cases is the maximum compressive stress in the sagging or hogging condition as calculated according to 2.2.5.5 of Chapter 2 of this PART.

③ Shear stress τ_{SF} — the shear stress τ_{SF} considered for each of the mutually exclusive load cases is the shear stress calculated according to 2.2.6.4 of Chapter 2 of this PART.

If the value of the permissible still water shear force is not available at the preliminary design stage, the following value, in kN, may be used:

$$F_s = 0.3CLB(C_B + 0.7)$$

④ Lateral pressure p — the lateral pressure for each of the mutually exclusive load cases is to be selected according to 1.5.3, 1.5.4 and 1.5.5 of Section 5 of Chapter 1 of this PART. The lateral pressure of hatch coaming stiffeners is to be calculated according to 2.20.2.2 of Chapter 2 of this PART.

⑤ The load calculation point for normal stress, shear stress and lateral pressure of stiffener and its

attached plating is defined in Section 7, Chapter 3 of PART 9-1 of the Rules.

⑥ The lateral buckling strength is to be checked for the following two stress combinations:

(a) stress combination 1: 100% of the normal stress as defined in 8.15.3.2(2)② and 70% of the shear stress as defined in 8.15.3.2(2)③;

(b) stress combination 2: 70% of the normal stress as defined in 8.15.3.2(2)② and 100% of the shear stress as defined in 8.15.3.2(2)③.

8.15.3.3 Methods and criteria for check of buckling strength

The lateral buckling capacity of stiffeners is to be calculated according to 2.1 and 2.3 of Section 5, Chapter 8 of Part 9-1 of the Rules, with the safety factor S being taken as 1.15 (i.e. the allowable utilization factor being 0.87). The standard thickness deduction specified in Table 2.2.7.4 of Chapter 2 of this PART is to be deducted in calculation. The buckling strength of stiffeners is to be checked according to the criteria specified in 3.3.1 of Section 3, Chapter 8 of Part 9-1.

Appendix 1 DIRECT STRENGTH CALCULATION OF BULK CARRIERS

1 General

1.1 General requirements

1.1.1 This Appendix applies to the direct strength calculation of bulk carriers as required by this Chapter.

1.1.2 For those not covered in this Appendix, the relevant requirements of Section 5, Chapter 1 of this PART are to be complied with.

2 Design Loads

2.1 General requirements

2.1.1 Unless otherwise specified in this Appendix, the design loads are to be referred to in Section 5, Chapter 1 of this PART.

2.1.2 Unless otherwise specified in this Appendix, the still water bending moment in the global load condition is to be taken as the permissible value $\overline{M}_s$ provided by the designer, and the wave bending moment M_w is to be calculated according to 1.5.6.1(2) of Section 5, Chapter 1 of this PART.

2.1.3 For harbour conditions, the effect of wave loads (pressure and bending moment) is not considered; the allowable still water bending moment $\overline{M}_{sp}$ is determined by the designer, but it is to envelop the design still water bending moment under the loading and unloading conditions in harbour given in the loading manual. The sequence of loading and unloading is to be indicated in the loading manual.

3 Loading Conditions

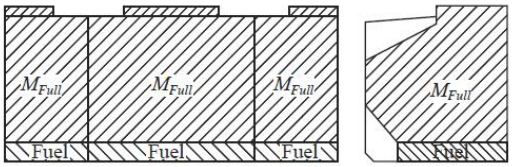
3.1 General requirements

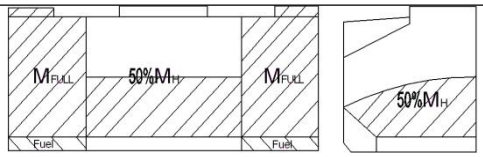
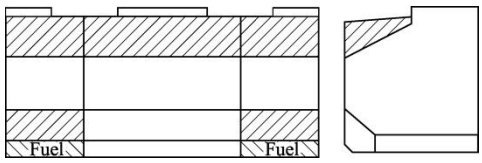
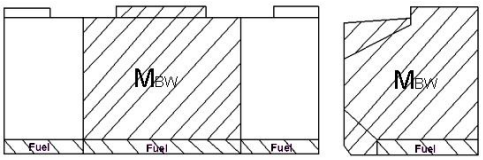
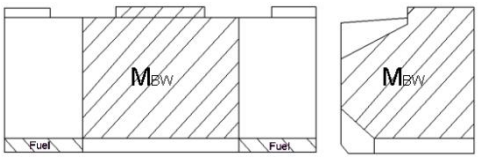
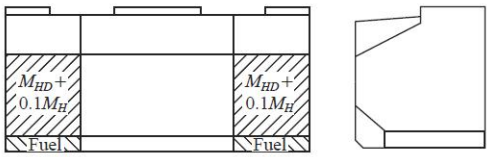
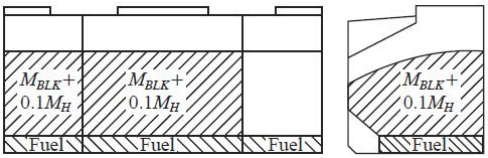
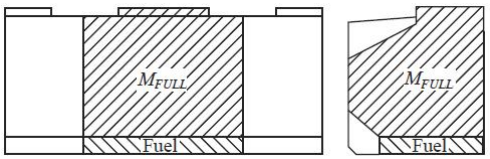
3.1.1 Normally, the loading conditions under consideration are to cover the most severe condition in ship design. The corresponding loading conditions are to be selected from Table 3.2.1 of this Appendix for check. For more severe loading conditions in the loading manual which are not covered by the Table, direct strength analysis is also to be carried out.

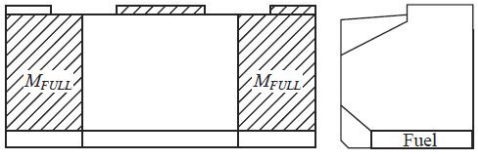
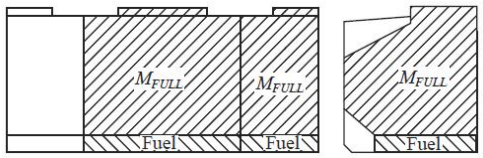
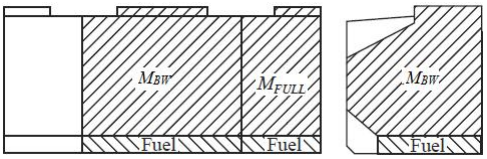
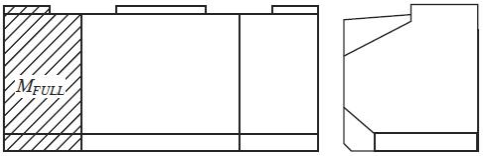
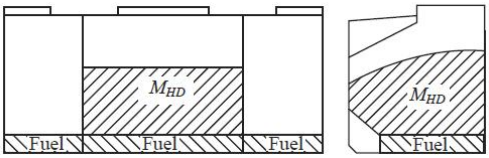
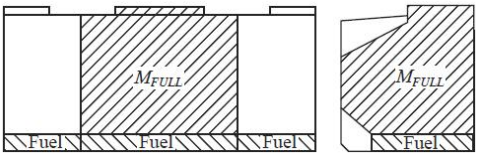
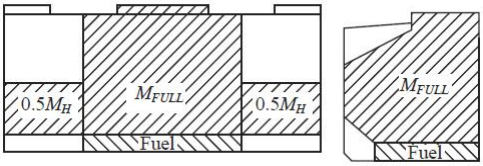
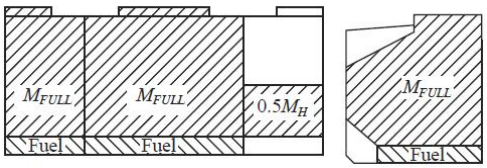
3.2 Loading conditions

3.2.1 The finite element analysis for holds is to be carried out in accordance with the applicable loading conditions in Table 3.2.1.

Loading Conditions **Table 3.2.1**

Type of loading condition	Loading condition no.	Condition considered	Mode of loading	Still water bending moment	Wave bending moment
Full load	1	Full load	Draught = d	$\overline{M}_s$	M_w
	2	Full load	 Draught = d	$\overline{M}_s$	M_w
	3	Non-homogeneous full load		1.1 M_a, but need not be greater than $\overline{M}_s$, taken as $\overline{M}_s$ if there is no such loading	M_w

Type of loading condition	Loading condition no.	Condition considered	Mode of loading	Still water bending moment	Wave bending moment
			 Draught = d	condition	
Ballast	4	Normal ballast	 Draught = deepest ballast draught	$\overline{M}_s$	M_w
	5	Heavy ballast	 Draught = heavy draught	$\overline{M}_s$	M_w
	6	Heavy ballast	 Draught = heavy draught	$\overline{M}_s$	M_w
Alternate load	7	Alternate load	 Draught = d	$\overline{M}_s$	M_w
	8	Alternate load	Draught = d	$\overline{M}_s$	M_w
	9	Alt-block load	 Draught = d	$\overline{M}_s$	M_w
Loading/ Unloading in multiple ports	10	Multi port - 1	 Draught = 0.67d	$\overline{M}_s$	M_w
	11	Multi port - 2		$\overline{M}_s$	M_w

Type of loading condition	Loading condition no.	Condition considered	Mode of loading	Still water bending moment	Wave bending moment
			 Draught = 0.83d		
	12	Multi port – 3a	 Draught = 0.67d	$\overline{M}_s$	M_w
	13	Multi port – 3b	 Draught = 0.67d	$\overline{M}_s$	M_w
	14	Multi port - 4	 Draught = 0.75d	$\overline{M}_s$	M_w
Loading/ Unloading in harbour	15	Harbour condition -1a	 Draught = 0.67d	$\overline{M}_{sp}$	—
	16	Harbour condition - 1b	 Draught = 0.67d	$\overline{M}_{sp}$	—
	17	Harbour condition - 1c	 Draught = 0.67d	$\overline{M}_{sp}$	—
	18	Harbour condition - 2	 draught=0.67d	$\overline{M}_{sp}$	—

Notes:

M_a — actual still water bending moment in the corresponding condition, in kN·m;

M_H — actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught, in t;

M_{FULL} — cargo mass in a cargo hold corresponding to cargo with virtual density filled to the top of the hatch coaming, in t, i.e.:

$$M_{FULL} = V_{FULL} \bullet \max(M_H / V_{FULL}, 1.0)$$

M_{HD} — maximum cargo mass allowed to be carried in a cargo hold according to design loading condition with specified holds empty at maximum draught, in t;

M_{BW} — maximum ballast water mass in cargo holds, in t;

M_{BLK} — maximum cargo mass under packed cargo conditions, in t;

V_H — volume, in m^3, of cargo hold excluding the volume enclosed by hatch coaming;

V_{FULL} — volume, in m^3, of cargo hold including the volume enclosed by hatch coaming;

ρ_w — density of sea water, to be taken as 1.025 t/m^3.

4 Structural Modeling

4.1 General requirements

4.1.1 Unless otherwise specified in this Appendix, the requirements for structural modeling are to be referred to in Section 5, Chapter 1 of this PART (for typical finite element model, see Figure 4.1.1).

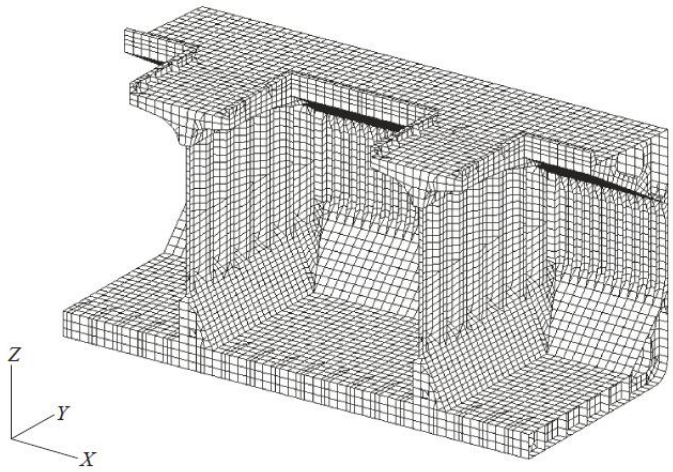


Figure 4.1.1 Finite Element Model

4.2 Boundary conditions

4.2.1 Boundary condition with the structures symmetrical to longitudinal centerline section

4.2.1.1 If a half-breadth FE model is used, the displacements in transverse direction of nodes on the longitudinal centerline section and the rotation around the two coordinate axes on the longitudinal centerline section are restrained, i.e.: $\delta_y = \theta_x = \theta_z = 0$.

4.2.1.2 If a full-breadth FE model is used, the displacements in transverse direction of intersection G of the longitudinal centerline section in way of forward and aft bulkheads of midship cargo holds and bottom plating are restrained, i.e.: $\delta_y = 0$.

4.2.2 Boundary conditions for local loads (see Table 4.2.2)

4.2.2.1 Symmetrical boundary conditions are applied respectively to end planes *A* and *B*, and the displacements in longitudinal direction of nodes within the end plane and the rotations around the two coordinate axes within the end plane are restrained, i.e.: $\delta_x = \theta_y = \theta_z = 0$.

4.2.2.2 Vertical spring elements are to be provided at intersections of side shell plating and inner hull plating with forward and aft transverse bulkheads in midship holds. The coefficient of elasticity of spring elements is to be distributed evenly and calculated by the following formula:

$$K = \frac{5GA}{6l_H n} \quad \text{N/mm}$$

where: G — shear modulus of elasticity of material, $G = 0.792 \times 10^5$ N/mm^2 for steel;

A — shearing area of side shell plating and inner hull plating in way of forward and aft bulkheads, in mm^2;

l_H — length of midship hold, in mm;
n — number of nodes on vertical intersections of side shell plating and inner hull plating.

Boundary Conditions for Local Loads **Table 4.2.2**

Position	Displacement constraint			Rotation constraint		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Longitudinal centerline section (half-breadth model)	–	Constraint	–	Constraint	–	Constraint
Node *G* (full-breadth model)	–	Constraint	–	–	–	–
End planes *A*, *B*	Constraint	–	–	–	Constraint	Constraint
Intersection line *C*	–	–	Spring	–	–	–

4.2.3 Boundary conditions for global load (see Table 4.2.3)
4.2.3.1 An independent point *H* is to be set in way of intersection of the neutral axis with the longitudinal centerline section within end planes *A* and *B*, the longitudinal bending moment is to be applied on the point *H*, and the degrees of freedom δ_x, δ_y and δ_z of each member node for end planes is linked to independent point.
4.2.3.2 The displacements of the independent point *H* within end planes *A* and *B* in transverse direction, vertical direction, and the rotation around longitudinal axes are restrained, i.e.: $\delta_y = \delta_z = \theta_x = 0$; the displacement of the independent point *H* within the end plane *A* in longitudinal direction are restrained, i.e.: $\delta_x = 0$.

Boundary Conditions for Global Load **Table 4.2.3**

Position	Displacement constraint			Rotation constraint		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Longitudinal centerline section (half-breadth model)	–	Constraint	–	Constraint	–	Constraint
Node *G* (full-breadth model)	–	Constraint	–	–	–	–
End planes *A*, *B*	Link	Link	Link	–	–	–
Independent point *H* (end plane *A*)	Constraint	Constraint	Constraint	Constraint	Bending moment	–
Independent point *H* (end plane *B*)	–	Constraint	Constraint	Constraint	Bending moment	–

4.2.4 For boundary conditions of the model, see Figure 4.2.4.

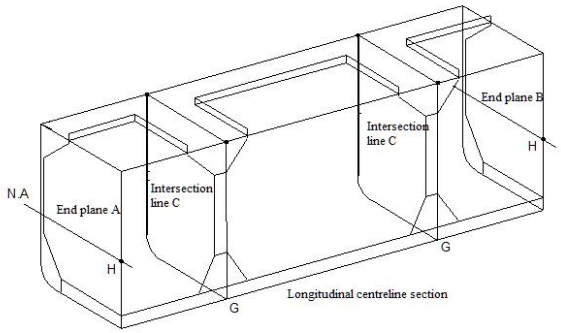


Figure 4.2.4 Boundary Conditions

5 Yield Strength Evaluation

5.1 Allowable stresses

5.1.1 Strength evaluation is to be carried out for all primary members in the cargo holds amidships (including bulkheads) within the longitudinal extent. The stress evaluated is to be the combined one due to local load case and global load case in accordance with 1.5.1.9(2) of Chapter 1 of this PART.

5.1.2 The allowable stresses for each primary structural member are given in Table 5.1.2.

Allowable Stresses **Table 5.1.2**

Type of structures	Allowable stress (N/mm^2)	
	$[\sigma_e]$	$[\tau]$
Deck	220/K	–
Bottom shell plating, inner bottom plating	220/K	–
Side shell plating, inner skin plating, horizontal girder in double hulls	220/K	115/K
Hopper and topside tank sloping plating	220/K	115/K
Bottom girder	235/K	115/K
Double bottom floor	175/K	95/K
Transverse bulkhead	175/K	95/K
Side plating of lower and upper stools	195/K	95/K
Transverse web frame	195/K	95/K
Deck between hatchways	175/K	–
Other	195/K	–

Note: *K*— material factor.

6 Buckling Strength Evaluation

6.1 Buckling safety factors

6.1.1 The standard thickness deduction of members is given in Table 6.1.1.

Standard Thickness Deduction **Table 6.1.1**

Position		Standard thickness deduction (mm)
Within 1.5 m below weather deck	One side connected to ballast water	1.0
	Two sides connected to ballast water	2.0
Elsewhere		1.0

6.1.2 The safety factor λ against plate panel buckling is not to be less than the minimum one in Table 6.1.2.

Minimum Buckling Safety Factor **Table 6.1.2**

Structural member	Minimum buckling safety factors	Structural member	Minimum buckling safety factors
Deck, deck between hatchways	0.8	Double bottom girder, horizontal girder in double hulls	1.0
Bottom shell plating, inner bottom plating	0.8	Double bottom floor, transverse web frame	1.0
Side shell plating, inner skin plating	0.8	Transverse bulkhead, lower stool, upper stool	0.8
Hopper and topside tank sloping plating	0.8		

Appendix 2 HOLD MASS CURVES

Symbols

h : vertical distance from the top of inner bottom plating to upper deck plating at the ship's centerline section, in m;

h_a : vertical distance from the top of inner bottom plating to upper deck plating at the ship's centerline section of aft cargo holds under the alt-block loading condition, in m;

h_f : vertical distance from the top of inner bottom plating to upper deck plating at the ship's centerline section of forward cargo holds under the alt-block loading condition, in m;

M_H : see Appendix 1 of this Chapter;

M_{FULL} : see Appendix 1 of this Chapter;

M_{HD} : see Appendix 1 of this Chapter;

M_D : maximum cargo mass given for each cargo hold, in t;

M_{BLK} : see Appendix 1 of this Chapter;

T_{HB} : maximum ballast draught, in m;

T_i : draught in loading condition No. i at mid-hold position of cargo hold length l_H, in m;

d : draught, in m;

V_H : volume, in m^3, of cargo hold excluding the volume enclosed by hatch coaming;

V_f, V_a : volume, in m^3, of forward or aft cargo hold excluding the volume enclosed by hatch coaming;

T_{min} : 0.75 d or draught in ballast conditions with the two adjacent cargo holds empty, whichever is greater, in m;

Σ : sum of mass of two adjacent cargo holds.

1 General Requirements

1.1 Application

1.1.1 This Appendix applies to ships of 150 m or over in length.

1.1.2 This Appendix describes the procedure to be used for determination of:

(1) the maximum and minimum masses of cargo in each cargo hold as a function of the draught at mid-hold position of cargo hold;

(2) the maximum and minimum mass of cargo in any two adjacent holds as a function of the mean draught in way of these holds.

1.1.3 The calculation results are to be included in the loading manual.

2 Maximum and Minimum Masses of Cargo in Each Hold

2.1 Maximum permissible mass and minimum required mass of single cargo hold in sea-going condition

2.1.1 The cargo mass curves of single cargo hold in sea-going condition are defined in 2.1.2 to 2.1.5 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

2.1.2 Ships with alternate load under multi-port condition

For loaded holds, the maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \frac{(d - T_i)}{h}$$

$W_{max}(T_i)$ in no case to be greater than M_{HD}.

For loaded holds, the minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \le 0.83d$$

$$W_{\min}(T_i) = 1.025V_H \frac{(T_i - 0.83d)}{h} \qquad \text{for } d \ge T_i > 0.83d$$

For empty holds which may be empty at the maximum draught, the maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

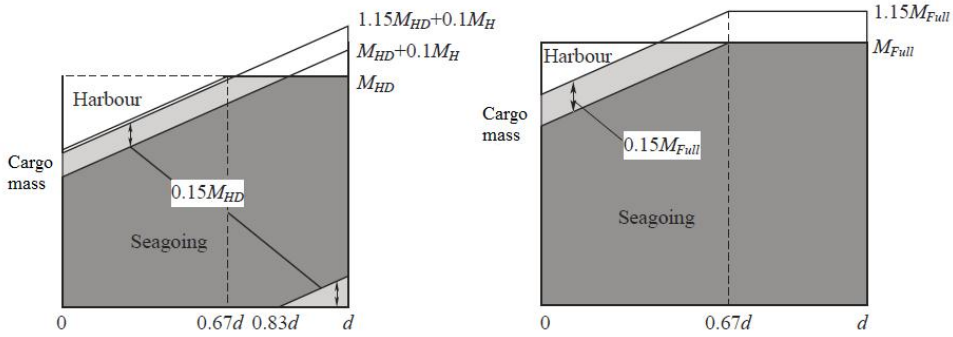
$$W_{\max}(T_i) = M_{Full} \qquad \text{for } d \ge T_i \ge 0.67d$$

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(0.67d - T_i)}{h} \quad \text{for } T_i < 0.67d$$

For loaded holds, the minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formula:

$$W_{\min}(T_i) = 0 \quad \text{for } T_i \le d$$

Mass curves of loaded cargo hold and cargo hold which may be empty at the maximum draught for ships with alternate load under multi-port condition are shown in Figure 2.1.2.



(a) Loaded hold (b) Cargo hold which may be empty at the maximum draught

Figure 2.1.2 Mass Curve for Ships with Alternate Load under Multi-port Condition

2.1.3 Ships with alternate load under no multi-port condition

For cargo holds, the maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts (T_i), in t, is the same as specified in 2.1.2.

For cargo holds, the minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \quad \text{for } T_i \le T_{HB}$$

$$W_{\min}(T_i) = \min \begin{cases} 1.025V_H \dfrac{(T_i - T_{HB})}{h} & \text{for } d \ge T_i > T_{HB} \\ 0.5M_{\mathrm{H}} - 1.025V_{\mathrm{H}} \dfrac{(d - T_{\mathrm{i}})}{h} \geqslant 0 & \text{for } d \ge T_i \end{cases}$$

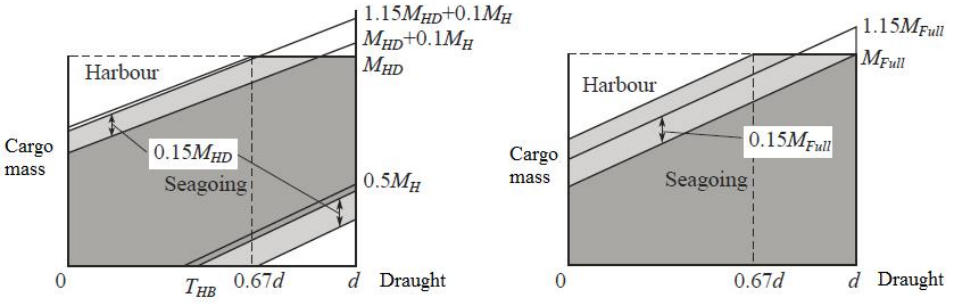
For empty hold which may be empty at the maximum draught, the maximum permissible cargo mass ($W_{max}(T_i)$) at various draught (T_i) is obtained, in t, by the following formula:

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(d - T_i)}{h}$$

For empty hold which may be empty at the maximum draught, the minimum required cargo mass ($W_{min}(T_i)$) at various draught (T_i) is obtained, in t, by the following formula:

$$W_{\min}(T_i) = 0 \quad \text{for } T_i \le d$$

Mass curves of loaded cargo hold and cargo hold which may be empty at the maximum draught for ships with alternate load under no multi-port condition are shown in Figure 2.1.3.



(a) Loaded hold (b) Cargo hold which may be empty at the maximum draught

Figure 2.1.3 Mass Curve for Ships with Alternate Load under no Multi-port Condition

2.1.4 Ships with homogeneous load under multi-port condition

The maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following

formulae:

$$W_{\max}(T_i) = M_{Full} \qquad \text{for } d \geq T_i \geq 0.67d$$

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(0.67d - T_i)}{h} \qquad \text{for } T_i < 0.67d$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq 0.83d$$

$$W_{\min}(T_i) = 1.025V_H \frac{(T_i - 0.83d)}{h} \qquad \text{for } d \geq T_i > 0.83d$$

Mass curves of loaded cargo hold for ships with homogeneous load under multi-port condition are shown in Figure 2.1.4.

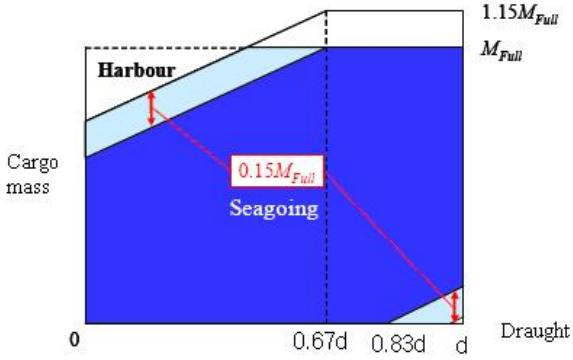


Figure 2.1.4 Mass Curve for Ships with Homogeneous Load under Multi-port Condition

2.1.5 Ships with homogeneous load under no multi-port condition

The maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formula:

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(d - T_i)}{h}$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq T_{HB}$$

$$W_{\min}(T_i) = \min \begin{cases} 1.025V_H \dfrac{(T_i - T_{HB})}{h} \geqslant 0 & \text{for } d \geq T_i > T_{HB} \\ 0.5M_{\mathrm{H}} - 1.025V_{\mathrm{H}} \dfrac{(d - T_{\mathrm{i}})}{h} \geqslant 0 & \text{for } d \geq T_i \end{cases}$$

Mass curves of loaded cargo hold for ships with homogeneous load under no multi-port condition are shown in Figure 2.1.5.

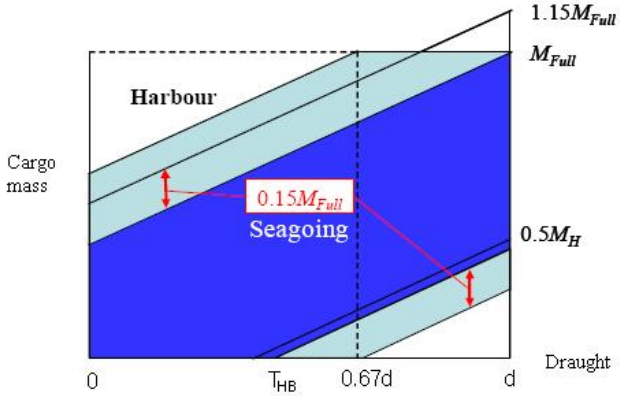


Figure 2.1.5 Mass Curve for Ships with Homogeneous Load under No Multi-port Condition

2.2 Maximum permissible mass and minimum required mass of single cargo hold in harbour

condition

2.2.1 The cargo mass curves of single cargo hold in harbour condition are defined in 2.2.2 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

2.2.2 For all ships, the maximum permissible cargo mass and the minimum required cargo mass corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in sea-going condition. Maximum permissible cargo mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

2.2.3 Ships with alternate load under multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts (T_i) is to be checked by the following formulae, in addition to the requirements of 2.1.2 of this Appendix:

For cargo hold,

$$W_{\max}(T_i) = M_{HD} \qquad \text{for } T_i \geq 0.67d$$

$$W_{\max}(T_i) = M_{HD} - 1.025V_H \frac{(0.67d - T_i)}{h} \qquad \text{for } T_i < 0.67d$$

2.2.4 Ships with alternate load under no multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts (T_i) is to be checked by the following formulae, in addition to the requirements of 2.1.3 of this Appendix:

For empty hold which may be empty at the maximum draught,

$$W_{\max}(T_i) = M_{FULL} \qquad \text{for } T_i \geq 0.67d$$

$$W_{\max}(T_i) = M_{FULL} - 1.025V_H \frac{(0.67d - T_i)}{h} \qquad \text{for } T_i < 0.67d$$

2.2.5 Ships with homogeneous load under no multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts (T_i) is to be checked by the following formulae, in addition to the requirements of 2.2.2 of this Appendix:

$$W_{\max}(T_i) = M_{FULL} \qquad \text{for } d \geq T_i > 0.67d$$

$$W_{\max}(T_i) = M_{FULL} - 1.025V_H \frac{(0.67d - T_i)}{h} \qquad \text{for } T_i < 0.67d$$

3 Maximum and Minimum Cargo Masses of Two Adjacent Holds

3.1 Maximum permissible cargo mass and minimum required cargo mass of two adjacent holds in sea-going condition

3.1.1 The cargo mass curves of two adjacent cargo holds in sea-going condition are defined in 3.1.2 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

3.1.2 Ships with alternate load of bulk goods under multi-port condition

The maximum permissible mass cargo ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = \sum (M_{BLK} + 0.1M_H) - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(d - T_i)$$

or

$$W_{\max}(T_i) = \sum M_{FULL} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67d - T_i)$$

$W_{\max}(T_i)$ is not greater than $\sum M_{BLK}$.

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq 0.75d$$

$$W_{\min}(T_i) = 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(T_i - 0.75\mathrm{d}) \quad \text{for } d \geq T_i > 0.75d.$$

3.1.3 Ships with alternate load of packed cargo under no multi-port condition

The maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = \sum(M_{BLK} + 0.1M_H) - 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(d - T_i)$$

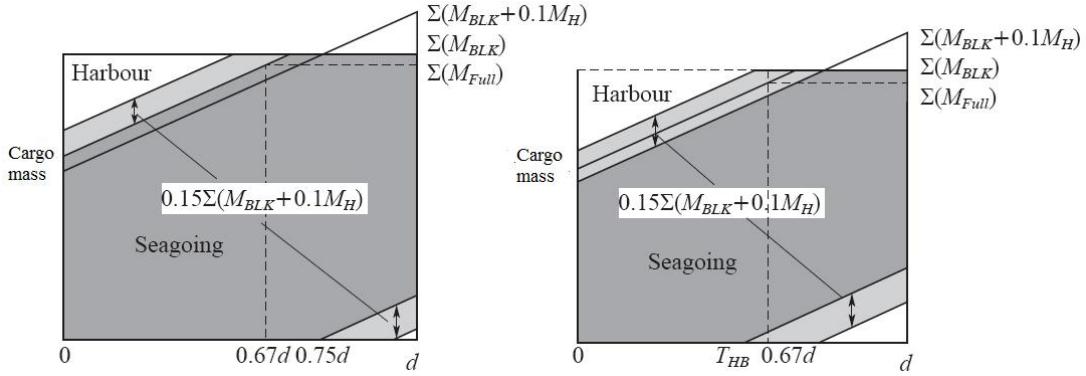
$W_{\max}(T_i)$ is not greater than $\sum M_{BLK}$.

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq T_{HB}$$

$$W_{\min}(T_i) = 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(T_i - T_{HB}) \quad \text{for } d \geq T_i > T_{HB}.$$

Mass curves of loaded cargo hold for ships with alternate load of packed cargo are shown in Figure 3.1.3.



(a) Under multi-port condition (b) Under no multi-port condition

Figure 3.1.3 Mass Curve of Loaded Cargo Hold for Ships with Alternate Load of Packed Cargo

3.1.4 Ships with alternate load without packed cargo under multi-port condition and ships with homogeneous load

The maximum permissible mass cargo ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = \sum M_{FULL} \qquad \text{for } d \geq T_i \geq 0.67d$$

$$W_{\max}(T_i) = \sum M_{FULL} - 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(0.67d - T_i) \qquad \text{for } T_i < 0.67d$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq 0.75d$$

$$W_{\min}(T_i) = 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(T_i - 0.75\mathrm{d}) \qquad \text{for } d \geq T_i > 0.75d$$

3.1.5 Ships with alternate load without packed cargo under no multi-port condition and ships with homogeneous load

The maximum permissible mass cargo ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formula:

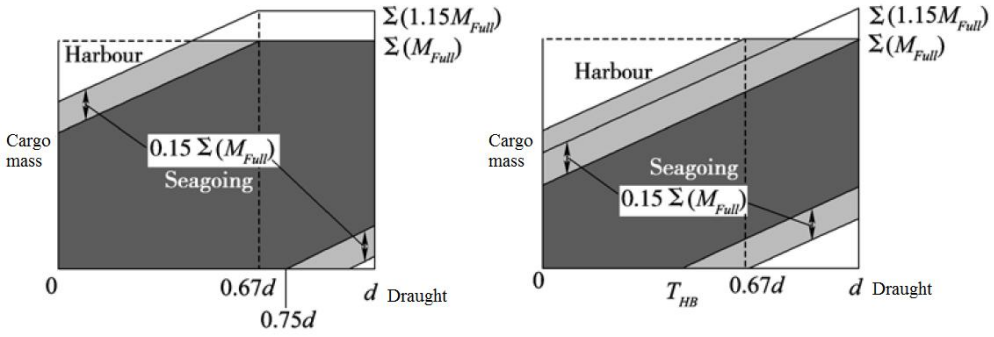
$$W_{\max}(T_i) = \sum M_{FULL} - 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(d - T_i) \qquad \text{for } T_i < d$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \qquad \text{for } T_i \leq T_{HB}$$

$$W_{\min}(T_i) = 1.025(\frac{V_f}{h_f} + \frac{V_a}{h_a})(T_i - T_{HB}) \quad \text{for } d \geq T_i > T_{HB}$$

Mass curves of loaded cargo hold for ships with alternate load without packed cargo are shown in Figure 3.1.5.



(a) Under multi port condition (b) Under no multi port condition

Figure 3.1.5 Mass Curve of Loaded Cargo Hold for Ships with Alternate Load without Packed Cargo and Ships with Homogeneous Load

3.2 Maximum permissible cargo mass and minimum required cargo mass in two adjacent holds in harbour condition

3.2.1 The cargo mass curves of two adjacent cargo holds in harbour condition are defined in 3.2.2 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

3.2.2 For all ships, the maximum permissible cargo mass and the minimum required cargo mass corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in sea-going condition. Maximum permissible cargo mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

3.2.3 Ships with alternate load of packed cargo under no multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts (T_i) is to be checked by the following formulae, in addition to the requirements of 3.1.3 of this Appendix:

$$W_{\max}(T_i) = \sum M_{FULL} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67d - T_i)$$

$$W_{\max}(T_i) \le M_{BLK}$$

3.2.4 Ships with alternate load without packed cargo under no multi-port condition and ships with homogeneous load

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts (T_i) is to be checked by the following formulae, in addition to the requirements of 3.1.5 of this Appendix:

$$W_{\max}(T_i) = M_{FULL} \qquad \text{for } d \ge T_i \ge 0.67d$$

$$W_{\max}(T_i) = \sum M_{FULL} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67d - T_i) \qquad \text{for } T_i < 0.67d$$

CHAPTER 9 ROLL ON-ROLL OFF SHIPS, PASSENGER SHIPS, RO-RO PASSENGER SHIPS AND FERRIES

Section 1 GENERAL PROVISIONS

9.1.1 Application

9.1.1.1 This Chapter applies to roll on-roll off ships, passenger ships, ro-ro passenger ships and ferries defined as follows:

(1) A roll on-roll off ship is a ship specially designed and constructed for the carriage of vehicles, and cargo in pallet form or in containers, and loaded/unloaded by wheeled vehicles;

(2) A passenger ship is a ship which carries more than twelve passengers;

(3) Ro-ro passenger ship means a passenger ship with ro-ro cargo spaces or special category spaces;

(4) Ferries are the ships specially designed for the carriage of passengers (without sleeping berths) and/or vehicles engaged on regular voyages between two sides of straits or islands. Ferries carrying more than 12 passengers are ferry passenger ships.

9.1.1.2 Ro-ro spaces are spaces not normally subdivided in any way and normally extending to either a substantial length or the entire length of the ship, in which motor vehicles with fuel in their tanks for their own propulsion or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction.

9.1.1.3 Special category spaces are those enclosed vehicle spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

9.1.1.4 Those not specified in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

9.1.2 Class notations

9.1.2.1 Ships complying with the requirements of this Chapter will be eligible to be assigned one of the following class notations:

(1) Roll on-roll off ships: RO-RO Ship;

(2) Passenger ships: Passenger Ship;

(3) Ro-ro passenger ships carrying only road vehicles: RO-RO Passenger Ship;

(4) Ro-ro passenger ships carrying railway vehicles: Train/RO-RO Passenger Ship;

(5) Ferries: Ferry;

(6) Ferry Passenger Ship.

9.1.3 Plans and documents

9.1.3.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, the following plans and documents are to be submitted for approval:

(1) Structural arrangement of ramps (appropriate strength calculations are submitted for information);

(2) Structural arrangements of bow doors, inner doors, stern doors and side doors and their operating and maintenance manual (appropriate strength calculations are submitted for information);

(3) Structural arrangement of movable platforms (appropriate strength calculations are submitted for information);

(4) Structural arrangement of sloping vehicle ramps (appropriate strength calculations are submitted for information).

9.1.3.2 Direct strength calculations for vehicle deck (where available), direct calculations of transverse strength for hull (where applicable), the arrangement of wheel prints for the carriage of vehicles and the data related to design loading, e.g. loads and axle loads, are to be provided for information.

Section 2 HULL STRUCTURE

9.2.1 General requirements

9.2.1.1 The structural arrangements of the hull are to comply with the relevant requirements of Section 12,

Chapter 1 of this PART.

9.2.1.2 The basic structural configuration is to be a single deck or multi-deck hull, and in some cases wing tanks up to the freeboard deck or bulkhead deck may be fitted.

9.2.1.3 Where the number of transverse bulkheads is not in accordance with the requirements in Section 12, Chapter 2 of this PART, partial transverse bulkheads, or web frames and deck transverses are to be fitted to provide equivalent transverse strength.

9.2.1.4 Longitudinal framing is, in general, to be adopted at the strength deck and at the bottom for ships greater than 65 m in length.

9.2.1.5 Web frames and deck transverses within vehicle spaces above the bulkhead deck may be connected with continuous rounded corners or by cross joints without brackets, see Figure 9.2.1.5(1) and (2). The radius R of the rounded corners is not to be less than the web depth of web frame or deck transverse, whichever is greater. The web thickness t_3 of the joint of cross connection without brackets (between web frame and deck transverse) is not to be less than the greater of the values obtained by the following formulas, nor less than the web thickness of web frame or deck transverse, whichever is greater.

$$t_3 = \frac{1}{K}\left(\frac{\sigma_1 A_1}{d_{w_2}} - \frac{t_2\tau_2}{100}\right) \quad \text{mm}$$

$$t_3 = \frac{1}{K}\left(\frac{\sigma_2 A_2}{d_{w_1}} - \frac{t_1\tau_1}{100}\right) \quad \text{mm}$$

where: A_1, A_2 — sectional area of faceplate respectively of web frame and deck transverse, in cm^2;

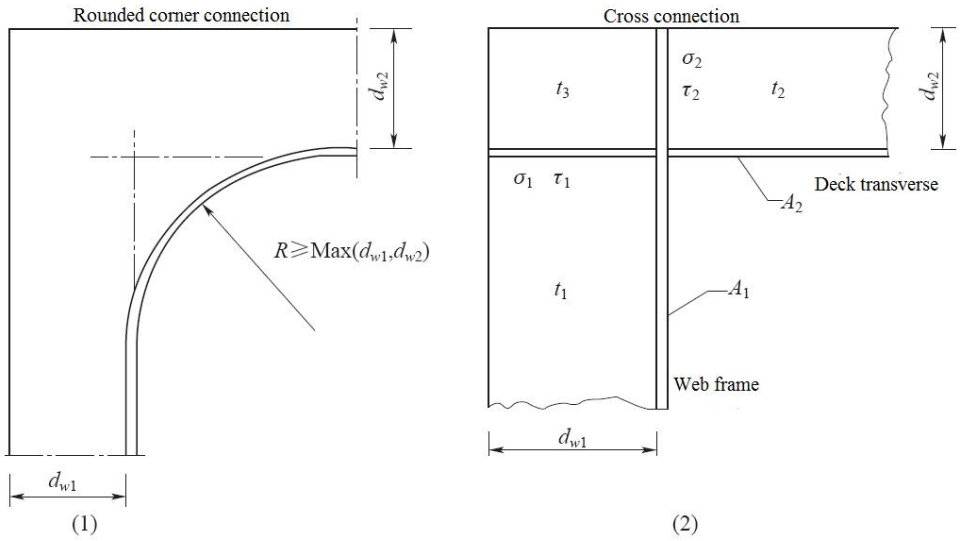
d_{w1}, d_{w2} — web depth respectively of web frame and deck transverse, in mm;

t_1, t_2 — web thickness respectively of web frame and deck transverse adjacent to cross connection joint, in mm;

σ_1, σ_2 — bending stress respectively of web frame and deck transverse adjacent to cross connection joint, in N/mm^2;

τ_1, τ_2 — shear stress respectively of web frame and deck transverse adjacent to cross connection joint, in N/mm^2;

K — material factor.



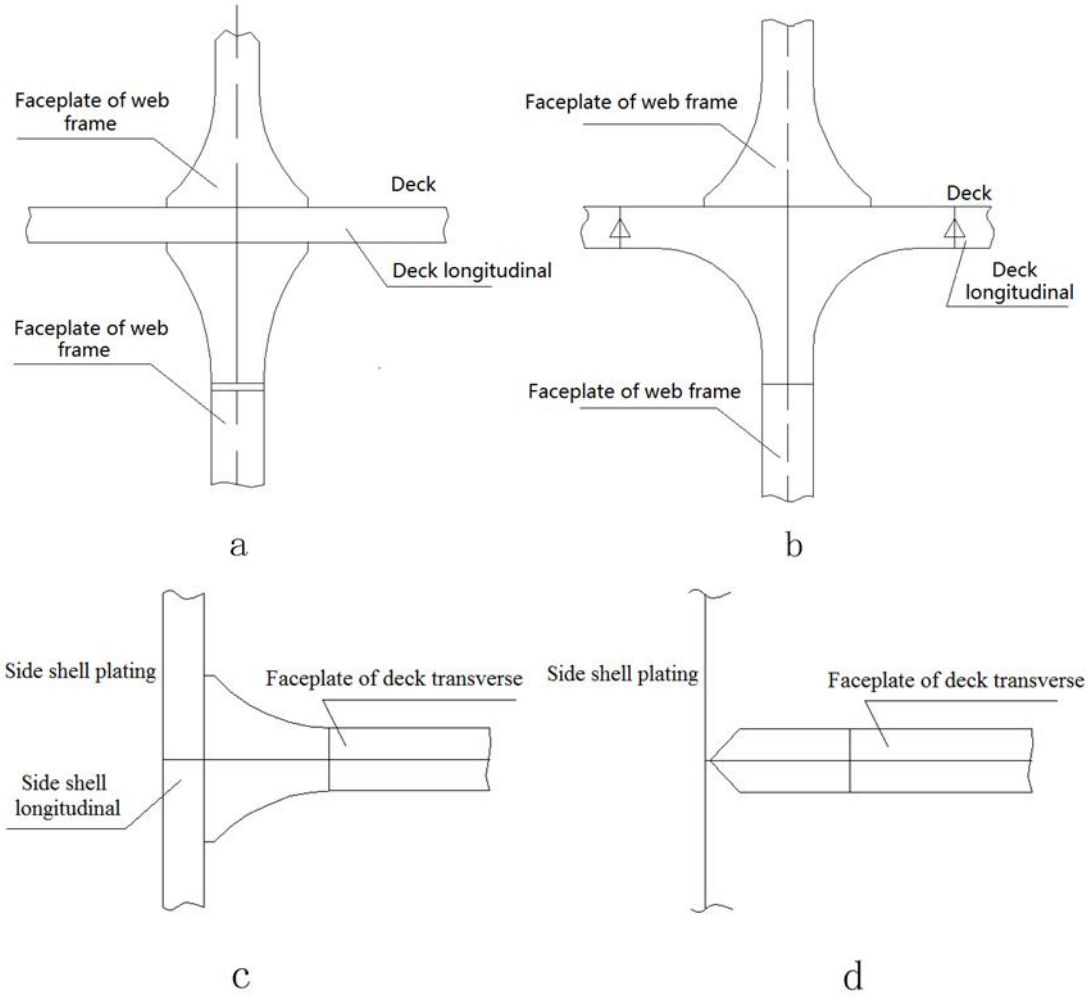


Figure 9.2.1.5

The faceplate of web frames and deck transverses, which are cross-connected without brackets, is to be continuous to deck plating and side shell and to be well transitioned, see Figure 9.2.1.5(3) for typical types of joints.

9.2.1.6 Where necessary, the structures in way of securing devices of vehicles and securing points of the hull are to be locally strengthened as appropriate.

9.2.1.7 The scantlings of stabilizing tanks and balancing tanks are to comply with the requirements of Section 13, Chapter 2 of this PART for deep tanks. The scantlings of those members, which may be subject to sloshing loads, are to be increased by 10%.

9.2.2 Longitudinal strength

9.2.2.1 The longitudinal strength is to comply with the requirements of Section 2, Chapter 2 of this PART. Where large openings are cut in side shell below strength deck and this significantly reduces shear force transmission from side shell to strength deck, the contribution of longitudinal continuous members within the area of strength deck and openings below to the longitudinal strength may be determined by finite element direct calculations.

9.2.3 Transverse strength

9.2.3.1 For roll on-roll off ships, ro-ro passenger ships and ferries carrying vehicles, the transverse strength of the hull is to be checked in accordance with the relevant requirements of Section 7 of this Chapter.

9.2.4 Superstructure deck

9.2.4.1 Where superstructure deck is strength deck, the thickness of deck plating, excluding that of the forecastle, is to comply with the requirements of 2.17.5.4 in Section 17, Chapter 2 of this PART and the buckling strength requirements in respect to longitudinal strength in Section 2 of the same Chapter, but not

less than 6 mm.
9.2.4.2 Where superstructure deck is strength deck, the framing of superstructure deck is to comply with the relevant requirements in Section 8, Chapter 2 of this PART and the buckling strength requirements in respect to longitudinal strength in Section 2 of the same Chapter.

9.2.5 Side framing

9.2.5.1 Side framing is to comply with the relevant requirements of Section 7, Chapter 2 of this PART. When calculating the scantlings of primary members of side framing below freeboard deck, however, the design pressure head may be measured to freeboard deck at side.

9.2.6 Vehicle deck

9.2.6.1 The structure of vehicle deck is to comply with the requirements of Section 21, Chapter 2 of this PART.
9.2.6.2 The strength of primary supporting members of vehicle deck is to comply with relevant requirements in Section 7 of this Chapter.

9.2.7 Train deck

9.2.7.1 Rails on the deck are to be fitted in way of deck girders or longitudinals. The effects of rails on the structural strength are not to be considered.
9.2.7.2 The thickness of deck plating is to be in accordance with the relevant requirements in Section 4, Chapter 2 of this PART.
9.2.7.3 The longitudinals or beams of deck framing are to be in accordance with the relevant requirements in Section 8, Chapter 2 of this PART, and the design head h is to be taken as $0.14p$, p being design cargo load, in kPa. Deck longitudinals supporting rails are to comply with the relevant requirements of Section 21, Chapter 2 of this PART.
9.2.7.4 The girders and transverses of deck framing are to be in accordance with 2.21.2.3 in Section 21, Chapter 2 of this PART. Where the deck framing is fitted with transverses and girders, their scantlings may be determined by direct calculations in accordance with the relevant requirements in Section 7 of this Chapter. The load of train wheels and the concentrated static load at supporting points of lifting jacks are to be taken into account respectively.
9.2.7.5 Where the train deck is intended to carry road vehicles, the relevant requirements in this Chapter for vehicle decks are to be complied with.
9.2.7.6 Where jacks are used to secure trains, the supporting points of the jacks are to be arranged as far as practicable in way of primary supporting members of the deck structure, otherwise the structure in this area is to be locally strengthened as appropriate.

9.2.8 Deck framing within area of deckhouses in accommodation spaces

9.2.8.1 The section modulus W of deck longitudinals or beams within the area of deckhouses is not to be less than the value obtained as follows:

$$W = 5shl^2K \quad \text{cm}^3, \text{ and not less than } 25s$$

where: s — spacing of deck longitudinals or beams, in m;
l — span of deck longitudinals or beams, in m;
h — design head, in m, taken as 0.45 m and for portions exposed to weather, increased by $h_0 - 1.2$ m, where h_0 is to be calculated according to 2.8.1.1 of Chapter 2 of this PART;
K — material factor.

The scantlings of deck girders and transverses within the area of deckhouses are to be calculated in accordance with the relevant requirements in Section 8, Chapter 2 of this PART, while the design head is to be taken as 0.45 m and the web thickness of deckhouse girders is not to be less than 1% of web depth plus 2 mm, nor less than 4 mm.

9.2.9 Deck framing within area of deckhouses in baggage and storage spaces

9.2.9.1 For deck framing within the area of deckhouses, calculations are to be in accordance with the requirements in Section 8, Chapter 2 of this PART for cargo decks not exposed to weather.

Section 3 MOVABLE PLATFORMS AND SLOPING VEHICLE RAMPS

9.3.1 Movable platforms

9.3.1.1 Movable platforms are generally to be constructed as pontoons comprising a web structure with

top decking.

9.3.1.2 Positive means of control are to be provided to secure the platform in the lowered position.

9.3.1.3 The supporting members of movable platforms are to have sufficient strength. For the design of movable platform, the strength of the fittings or members at the following supports is to be checked on the basis of the imposed loads (including the weight of the platform):

(1) Flexible supports: the permissible load for fittings such as chains and steel hawsers is to be taken as 1/5 of the breaking strength;

(2) Rigid supports: the allowable stresses are to be as follows:

Allowable bending stress $[\sigma] \leq 85/K$ N/mm²;

Allowable shear stress $[\tau] \leq 43/K$ N/mm²;

Allowable equivalent stress $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} \leq 108/K$ N/mm²

where: K — material factor.

(3) Buckling is to be checked for the pressured members.

9.3.1.4 The thickness of the movable platform plating is to be calculated as that of the vehicle decks.

9.3.1.5 Where the movable platforms are intended for handling cargo with forklifts, the scantlings of the stiffeners are to comply with the requirements for deck beams or longitudinals in Section 21, Chapter 2 of this PART.

9.3.1.6 The section modulus W of the stiffeners of movable platforms designed exclusively for the carriage of vehicles is not to be less than that obtained from the following formula:

$$W = 1.39 J_1 P l K \quad \text{cm}^3$$

where: J_1, P and l — see 2.21.2.2(2) of Chapter 2 of this PART;

K— material factor.

9.3.1.7 The scantlings of girders of movable platforms may be determined by a direct calculation on the basis of the following criteria:

Allowable bending stress: $[\sigma] \leq 128/K$ N/mm²;

Allowable shear stress: $[\tau] \leq 64/K$ N/mm²;

Allowable equivalent stress: $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} \leq 160/K$ N/mm²;

Deflection: $f \leq l/400$ mm.

where: K — material factor;

l — distance between the supporting points of stiffeners, in mm.

9.3.2 Sloping vehicle ramps

9.3.2.1 Fixed sloping vehicle ramps are to comply with the requirements for vehicle decks in Section 21, Chapter 2 of this PART.

9.3.2.2 Movable sloping vehicle ramps are to comply with the requirements for vehicle ramps in Section 6 of this Chapter, and their rigid supports are to comply with 9.3.1.3(2) of this Section.

Section 4 BOW DOORS AND INNER DOORS

9.4.1 General requirements

9.4.1.1 Application

(1) This Section applies to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure, or to a long non-enclosed superstructure which is fitted to attain minimum bow height equivalence.

(2) This Section is applicable to the following two types of bow doors:

① Visor doors opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms;

② Side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.

Other types of bow door will be specially considered.

9.4.1.2 Arrangement

(1) Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline, fitted for arrangement of ramps

or other related mechanical devices, may be regarded as a part of the freeboard deck for the purpose of this requirement.
(2) An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead, provided it is located within the limits specified for the position of the collision bulkhead (1.12.3.1 or 1.12.3.2 of Section 12, Chapter 1 of this PART). A vehicle ramp may be arranged for this purpose at the position specified in 1.12.3.1 or 1.12.3.2 of Section 12, Chapter 1 of this PART. If this is not possible, a separate inner weathertight door is to be installed, as far as practicable, within the limits specified for the position of the collision bulkhead.
(3) Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.
(4) Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 9.4.1.2(2) of this Section.
(5) The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in stowed position.
9.4.1.3 Definitions
(1) **Securing device**: a device used to keep the door closed by preventing it from rotating about its hinges;
(2) **Supporting device**: a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure;
(3) **Locking device**: a device that locks a securing device in the closed position;
(4) **Ro-ro passenger ship**: see 9.1.1.1(3) of Section 1 of this Chapter;
(5) **Ro-ro spaces**: see 9.1.1.2 of Section 1 of this Chapter;
(6) **Special category spaces**: see 9.1.1.3 of Section 1 of this Chapter.

9.4.2 Strength criteria of primary structures and securing and supporting devices

9.4.2.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be determined to withstand the design loads defined in 9.4.3 of this Section, using the following permissible stresses:

Permissible bending stress $[\sigma] = 120/K$ N/mm^2

Permissible shear stress $[\tau] = 80/K$ N/mm^2

Permissible equivalent stress $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 150/K$ N/mm^2

where: K − material factor, but not to be taken less than 0.72 (unless a fatigue analysis is carried out).
9.4.2.2 The buckling strength of primary members is to be verified as being adequate.
9.4.2.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed $0.8R_{eH}$, where R_{eH} is the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.
9.4.2.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of bolts not carrying support forces is not to exceed $125/K$, in N/mm^2.

9.4.3 Design loads

9.4.3.1 Bow doors
(1) The design external pressure P_e, in kN/m^2, which is to be considered for the scantlings of primary members, securing and supporting devices of bow doors, is not to be less than that obtained from the following formula:

$$P_e = 2.75\lambda C_H (0.22 + 0.15\tan\alpha)(0.4V\sin\beta + 0.6\sqrt{L})^2 \quad \text{kN/m}^2$$

where: V — contractual ship's speed, in kn;
L — ship's length, in m, but need not be taken greater than 200 m;
λ — coefficient depending on the intended service of the ship:
$\lambda = 1$ for ships intended for unrestricted service;
C_H — coefficient, to be determined as follows:
$C_H = 0.0125L$ for $L < 80$ m;
$C_H = 1$ for $L \geq 80$ m;
α — flare angle at the point considered, defined as the angle between a vertical line and the

tangent to the side shell, measured in a vertical plane normal to the horizontal tangent to the outer shell of the door, with the considered point being on the bow door, $l/2$ aft of the stem line on the plane $h/2$ above the bottom of the door, see Figure 9.4.3.1(1);

l — length of the door on the plane $h/2$ above the bottom of the door, in m, see Figure 9.4.3.1(1);

β — entry angle at the point considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, with the considered point being the same as that of angle α, see Figure 9.4.3.1(1);

h — height, in m, of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser.

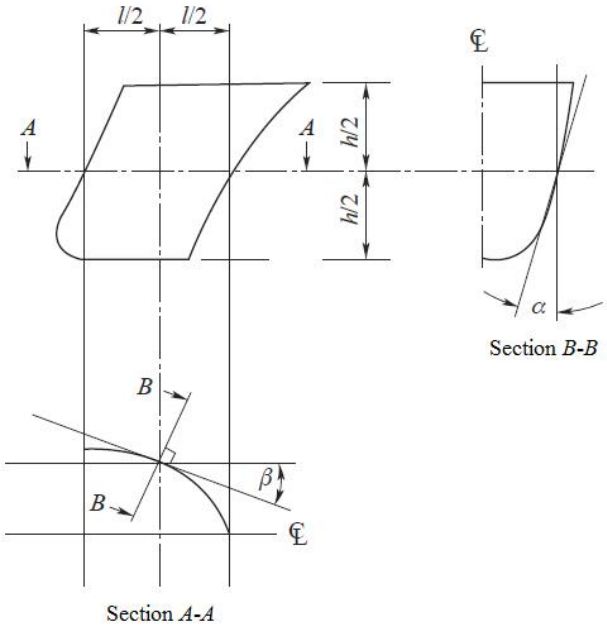


Figure 9.4.3.1(1)

(2) The design external forces, in kN, considered for the scantlings of securing and supporting devices of bow doors are to be determined by the following formulae:

$$F_x = P_e A_x \text{ kN}$$
$$F_y = P_e A_y \text{ kN}$$
$$F_z = P_e A_z \text{ kN}$$

where: A_x — area, in m^2, of the transverse vertical projection of the bow door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded. See Figure 9.4.3.1(2);

A_y — area, in m^2, of the longitudinal vertical projection of the bow door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. See Figure 9.4.3.1(2);

A_z — area, in m^2, of the horizontal projection of the bow door between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. See Figure 9.4.3.1(2).

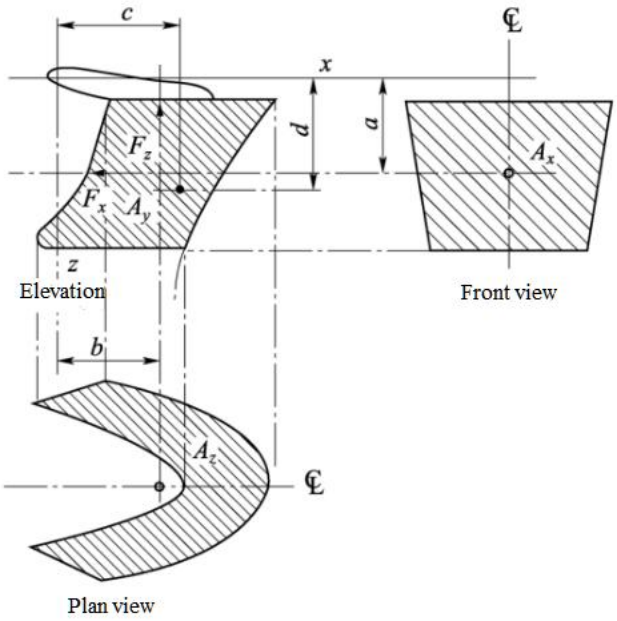


Figure 9.4.3.1(2)

For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces are to be specially considered.

(3) For visor doors the closing moment M_y under external loads, in kN · m, is to be taken as:

$$M_y = F_x a + 10Wc - F_z b \quad \text{kN·m}$$

where: F_x, F_z — to be obtained in accordance with 9.4.3.1(2);

W — mass of the visor door, in t;

a — vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Figure 9.4.3.1(2);

b — horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Figure 9.4.3.1(2);

c — horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Figure 9.4.3.1(2).

(4) Moreover, the lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1.5 kN/m^2 is to be taken into account.

9.4.3.2 Inner doors

(1) The design external pressure considered for the scantlings of primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of p_e, external pressure and p_h, hydrostatic pressure:

$$p_e = 0.45L \quad \text{kN/m}^2$$
$$p_h = 10h \quad \text{kN/m}^2$$

where: L — the ship's length, in m, need not be taken as greater than 200 m;

h — the distance, in m, from the load point under consideration to the top of the cargo space.

(2) The design internal pressure p_i considered for the scantlings of securing devices of inner doors is not to be less than 25 kN/m^2.

9.4.4 Scantlings of bow doors

9.4.4.1 General requirements

(1) The strength of bow doors is to be commensurate with that of the surrounding structure.

(2) Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors, adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship structure.

9.4.4.2 Plating and stiffeners

(1) The thickness of the bow door plating is not to be less than that required for the side shell plating, using

bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.
(2) The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and bow door stiffeners.
(3) The stiffener webs are to have a net sectional area A not less than:

$$A = \frac{QK}{10} \quad \text{cm}^2$$

where: Q — shear force, in kN, in the stiffener, calculated by using uniformly distributed external pressure p_e as given in 9.4.3.1(1);
K — material factor.

9.4.4.3 Primary structure
(1) The bow door stiffeners are to be supported by primary members constituting the main stiffening elements of the door.
(2) The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure the integrity of the boundary support of the door.
(3) Scantlings of the primary members are generally to be supported by direct strength calculations in association with the external pressure given in 9.4.3.1(1) of this Section and permissible stresses given in 9.4.2.1 of this Section. Normally, formulae for simple beam theory may be applied to determine the bending stress, with members being considered to have simply supported end connections.

9.4.5 Scantlings of inner doors

9.4.5.1 General requirements
(1) Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 9.4.3.2(1) and permissible stresses given in 9.4.2.1 of this Section. Normally, formulae for simple beam theory may be applied.
(2) Where inner doors also serve as vehicle ramps, the scantlings are to comply with Section 6 of this Chapter.
(3) The distribution of the forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

9.4.6 Securing and supporting of bow doors

9.4.6.1 General requirements
(1) Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.
A means is to be provided for mechanically fixing the door in the open position.
(2) Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small or flexible devices, such as cleats, intended to provide load compression of the packing material are generally not to be included in the calculations called for in 9.4.6.2(5) of this Section. The number of securing and supporting devices are generally to be the minimum practical whilst taking into account the requirements for redundant provision given in 9.4.6.2(6) and 9.4.6.2(7) of this Section and the available space for adequate support in the hull structure.
(3) For visor doors opening outwards, the pivot arrangement is generally to be such that the visor is self-closing under external loads, that is $M_y > 0$. Moreover, the closing moment M_y as given in 9.4.3.1(3) is not to be less than:

$$M_y = 10Wc + 0.1\sqrt{(a^2 + b^2)(F_x^2 + F_z^2)} \quad \text{kN} \cdot \text{m}$$

where: F_x, F_z — to be obtained in accordance with 9.4.3.1(2);
W — mass of the visor door, in t;
a — vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Figure 9.4.3.1(2);
b — horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Figure 9.4.3.1(2);

c — horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Figure 9.4.3.1(2).

9.4.6.2 Scantlings

(1) Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 9.4.2.1.

(2) For visor doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self-weight of the door:

Case 1: F_x and F_z;

Case 2: $0.7F_y$ acting on each side separately together with $0.7F_x$ and $0.7F_z$.

(3) For side-opening doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self-weight of the door:

Case 1: F_x, F_y and F_z acting on both doors;

Case 2: $0.7F_x$ and $0.7F_z$ acting on both doors and $0.7F_y$ acting on each door separately.

F_x, F_y and F_z in (2) and (3) above are determined as indicated in 9.4.3.1(2) and applied at the centroid of projected areas.

(4) The support forces as determined according to 9.4.6.2(2) and (3) (Case 1) are generally to give rise to a zero moment about the transverse axis through the centroid of the area A_x (see Figure 9.4.3.1(2)). For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

(5) The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

(6) The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the permissible stresses as given in 9.4.2.

(7) For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 9.4.2.1 of this Section. The opening moment M_0 to be balanced by this reaction force is not to be taken less than:

$$M_0 = 10Wd + 5A_x a \quad \text{kN} \cdot \text{m}$$

where: A_x — to be obtained from 9.4.3.1(2) of this Section;

W — mass of the visor door, in t;

a — vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Figure 9.4.3.1(2);

d — vertical distance, in m, from the hinge axis to the centre of gravity of the door, as shown in Figure 9.4.3.1(2).

(8) For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force:

$F_z - 10W$, in kN, within the permissible stresses given in 9.4.2.1

where: F_z — to be obtained from 9.4.3.1(2);

W — mass of the visor door, in t.

(9) All load transmitting elements in the design load path, from door through securing and supporting devices into the ship structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

(10) For side-opening doors, a thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under the effect of unsymmetrical pressure (see example of Figure 9.4.6.2). Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangement serving the same purpose may be proposed.

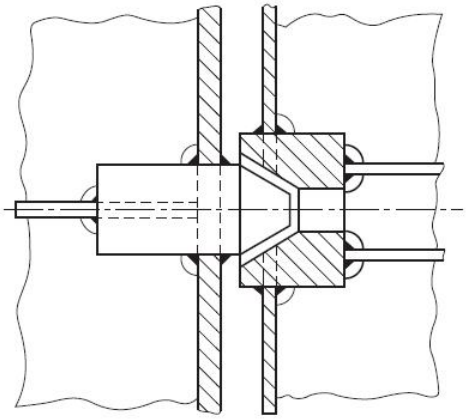


Figure 9.4.6.2

9.4.7 Securing and locking arrangements

9.4.7.1 Systems for operation

(1) Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

(2) Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

① the closing and opening of the doors; and

② associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorized persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

(3) Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

9.4.7.2 For indication/monitoring systems of doors, refer to the relevant requirements in Section 9, Chapter 2 of PART FOUR of the Rules.

9.4.8 Operating and maintenance manual

9.4.8.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and is to contain necessary information on:

(1) Main particulars and design drawings:

Special safety precautions;

Details of ship;

Equipment and design loading (for ramps);

Key plan of equipment (doors and ramps);

Manufacturer's recommended testing for equipment;

Description of equipment: bow doors, inner bow doors, bow ramp/doors, side doors, stern doors, central power pack, bridge panel, engine control room panel.

(2) Service conditions:

Limiting heel and trim of ship for loading/unloading;

Limiting heel and trim for door operations;

Doors/ramps operating instructions;

Doors/ramps emergency operating instructions.

(3) Maintenance:

Schedule and extent of maintenance;

Trouble shooting and acceptable clearances;

Manufacturer's maintenance procedures.

(4) Register of inspections, including inspection of locking, securing and supporting devices, repairs and

renewals.

It is to be ensured that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, troubleshooting and acceptance/rejection criteria①.

9.4.8.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at appropriate place.

Section 5 SIDE SHELL AND STERN DOORS

9.5.1 General requirements for side and stern doors

9.5.1.1 This Section applies to the arrangement, strength and securing of side shell doors, abaft the collision bulkhead, and of stern doors leading to enclosed spaces.

9.5.1.2 Stern doors for passenger ships are to be situated above the freeboard deck. Stern doors for ro-ro cargo ships and side shell doors may be either below or above the freeboard deck.

9.5.1.3 Side shell doors and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.

9.5.1.4 Where the sill of any side shell door is below the uppermost load line, the arrangement is to be specially considered, i.e. an inner door of equivalent strength and watertightness is to be fitted in the place. In that case a leakage detection device is to be provided in the compartment between the two doors. Further, drainage of this compartment to the bilges controlled by an easily accessible screw-down valve is to be arranged.

9.5.1.5 The doors are to preferably open outwards.

9.5.1.6 Definitions

(1) Securing device means a device used to keep the door closed by preventing it from rotating about its hinges or about pivoted attachments to the ship.

(2) Supporting device and locking device, ro-ro passenger ship, ro-ro space and special category space are as defined in 9.4.1.3, Section 4 of this Chapter.

9.5.2 Strength criteria of side shell doors and stern doors

9.5.2.1 Scantlings of the primary members, securing and supporting devices of side shell doors and stern doors are to be determined to withstand the design loads defined in 9.5.3, using the following permissible stresses:

Permissible bending stress $[\sigma] = 120/K$ N/mm^2

Permissible shear stress $[\tau] = 80/K$ N/mm^2

Permissible equivalent stress $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 150/K$ N/mm^2

where: K — material factor, not to be taken less than 0.72 unless a direct strength analysis with regard to relevant modes of failures is carried out.

9.5.2.2 The buckling strength of primary members is to be verified as being adequate.

9.5.2.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed $0.8R_{eH}$, where R_{eH} is the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

9.5.2.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of bolts not carrying support forces is not to exceed $125/K$, in N/mm^2, with K defined in 9.5.2.1 above.

9.5.3 Design loads of side shell doors and stern doors

9.5.3.1 The design forces, considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are not to be less than:

(1) Design forces for securing or supporting devices of doors opening inwards:

External force: $F_e = AP_e + F_p$ kN

Internal force: $F_i = F_o + 10W$ kN

(2) Design forces for securing or supporting devices of doors opening outwards:

---

① It is recommended that recorded inspections of the door supporting and securing devices be carried out by the ship's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the shell doors. Any damages recorded during such inspections are to be reported to CCS.

External force: $F_e = AP_e$ kN

Internal force: $F_i = F_o + 10W + F_p$ kN

(3) Design forces for primary members:

External force: $F_e = AP_e$ kN

Internal force: $F_i = F_o + 10W$ kN

where: A — area, in m^2, of the door opening;

W — mass of door, in t;

F_p — total packing force in kN; packing line pressure is normally not to be taken less than 5 N/mm;

F_o — the greater of F_c and $5A$, in kN;

F_c — accidental force, in kN, due to loosening of cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of F_c may be appropriately reduced. However, the value of F_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes, etc.;

P_e — external design pressure, in kN/m^2, determined at the centre of gravity of the door opening and not taken less than:

$$P_e = 10(T - Z_G) + 25 \quad kN/m^2, \text{ for } Z_G < d$$

$$P_e = 25 \quad kN/m^2, \text{ for } Z_G \geq d$$

Moreover, for stern doors of ships fitted with bow doors, P_e is not to be taken less than:

$$P_e = 0.6\lambda C_H(0.8 + 0.6\sqrt{L})^2 \quad kN/m^2$$

where: d — draught, in m, at the highest subdivision load line, in m;

Z_G — height of the centre of area of the door, in m, above the baseline;

λ — coefficient depending on the area where the ship is intended to be operated:

$\lambda = 1$ for ships intended for unrestricted service;

C_H — coefficient, to be determined as follows:

$C_H = 0.0125L$ for $L < 80$ m;

$C_H = 1$ for $L \geq 80$ m;

L — the ship's length, in m, need not be taken as greater than 200 m.

9.5.4 Scantlings of side shell doors and stern doors

9.5.4.1 The strength of side shell doors and stern doors is to be commensurate with that of the surrounding structure.

9.5.4.2 Side shell doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship's structure.

9.5.4.3 Where doors also serve as vehicle ramps, the design of the hinges should take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

9.5.4.4 Shell door openings are to have well-rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below and they are to comply with the relevant requirements in 2.3.7 of Section 3, Chapter 2 of this PART.

9.5.4.5 The thickness of the door plating is not to be less than the required thickness for the side shell plating, using the door stiffener spacing, but in no case less than the minimum required thickness of shell plating. Where doors serve as vehicle ramps, the plating thickness is to comply with Section 6 of this Chapter.

9.5.4.6 The section modulus of horizontal or vertical stiffeners is not to be less than that required for side framing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and door stiffeners. Where doors serve as vehicle ramps, the stiffener scantlings are to comply with Section 6 of this Chapter.

9.5.4.7 The secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

9.5.4.8 The primary members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the door.

9.5.4.9 Scantlings of the primary members are generally to be supported by direct strength calculations in association with the design forces given in 9.5.3.1 of this Section and permissible stresses given in 9.5.2.1 of this Section. Normally, formulae for simple beam theory may be applied to determine the bending stresses. Members are to be considered to have simply supported end connections.

9.5.5 Securing and supporting of doors

9.5.5.1 Side shell doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.
Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered.
Maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.
A means is to be provided for mechanically fixing the door in the open position.
9.5.5.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material are generally not to be included in the calculations called for in 9.5.5.4. The number of securing and supporting devices are generally to be the minimum practical whilst taking into account the requirement for redundant provision given in 9.5.5.5 and the available space for adequate support in the hull structure.
9.5.5.3 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 9.5.2.1.
9.5.5.4 The distribution of the reaction forces acting on the securing devices and supporting devices may be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.
9.5.5.5 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the permissible stresses as given in 9.5.2.1.
9.5.5.6 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, support brackets and back-up brackets.

9.5.6 Securing and locking arrangement and systems for operation

9.5.6.1 Securing devices are to be simple to operate and easily accessible.
Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or are to be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.
9.5.6.2 Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control, from a position above the freeboard deck, of the closing and opening of the doors and associated securing and locking devices. For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorized persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.
9.5.6.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.
9.5.6.4 For the indicating/monitoring systems of doors, see the relevant requirements in Section 9, Chapter 2 of PART FOUR of the Rules.

9.5.7 Operating and Maintenance Manual

9.5.7.1 An Operating and Maintenance Manual for the side shell and stern doors is to be provided on board and is to contain the necessary information on:
(1) Main particulars and design drawings
Special safety precautions;
Details of ship;
Equipment and design loading (for ramps);
Key plan of equipment (doors and ramps);
Manufacturer's recommended testing for equipment;
Description of equipment: bow doors, inner bow doors, bow ramp/doors, side doors, stern doors, central power pack, bridge panel, engine control room panel.

(2) Service conditions
Limiting heel and trim of ship for loading/unloading;
Limiting heel and trim for door operations;
Doors/ramps operating instructions;
Doors/ramps emergency operating instructions.
(3) Maintenance
Schedule and extent of maintenance;
Trouble shooting and acceptable clearances;
Manufacturer's maintenance procedures.
(4) Register of inspections and repairs
Including inspection of locking, securing and supporting devices, repairs and renewals.
It is to be ensured that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, troubleshooting and acceptance/rejection criteria①.
9.5.7.2 Documented operating procedures for closing and securing side shell and stern doors are to be kept on board and posted at the appropriate places.

Section 6 VEHICLE RAMPS

9.6.1 Structural strength of vehicle ramps
9.6.1.1 The relevant requirements of Section 21, Chapter 2 of this PART are to be complied with.

9.6.2 Framing of vehicle ramps
9.6.2.1 The strength is to be checked in accordance with the following requirements:
(1) the ramp is in a lowered position;
(2) the design vehicle load multiplied by coefficient 1.1 is the load acting on the ramp at its worst position and the mass of the ramp is also to be considered;
(3) allowable bending stress $[\sigma] = 141/K$, in N/mm^2, with K being the material factor; allowable deflection $[f] = l/200$ mm, with l being the distance between the supporting points of primary structures of vehicle ramps, in mm.

9.6.3 Connecting hinges of vehicle ramps
9.6.3.1 The following requirements are to be complied with:
(1) The diameter d of the axial pin is to comply with the following:

$$d \geq d_0$$

(2) The size of the central eye plate of hinges is to comply with the following:

$$\frac{F}{2b_0t_0} \leq [\tau], \quad b_0 \geq d_0$$

(3) The size of the eye plates on both sides of hinges is to comply with the following:

$$\frac{F}{4t_1t_2} \leq [\tau], \quad t_1 \geq d_0 / 2$$

where: d_0 — minimum required diameter of the axial pin, $d_0 = 0.92\sqrt{\frac{F}{[\tau]}}$ mm;

F— maximum force transmitted by the hinge, in N;
t_1, t_2, b_0, t_0, d — size of hinge parts, in mm, see Figure 9.6.3;
$[\tau]$ — allowable shear stress, to be taken as $[\tau] = 81.6/K$, in N/mm^2, K being the material factor.

① It is recommended that recorded inspections of the door supporting and securing devices be carried out by the ship's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the shell doors or stern doors. Any damage recorded during such inspections is to be reported to CCS.

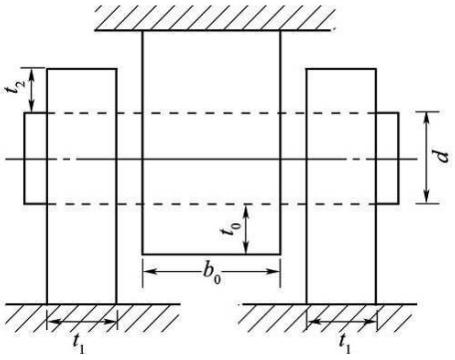


Figure 9.6.3

Section 7 DIRECT CALCULATIONS

9.7.1 General requirements

9.7.1.1 This Section specifies the methods to be used in direct calculations for the strength of transverses and girders of vehicle deck framing and for the transverse strength of hull structure.

9.7.2 Design loads and loading conditions

9.7.2.1 For the acceleration of ship motions, see the relevant requirements of Section 5, Chapter 1 of this PART

9.7.2.2 For direct strength calculation of vehicle deck structure, the deck load is to be calculated as follows:

Vehicle load $P_h = (g + 0.5a_v)M$ kN

Uniformly distributed load $p_{d_h} = (g + 0.5a_v)p$ kN/m^2

Deck weight load $p_{s_h} = (g + 0.5a_v)m_s$ kN/m^2

where: g — acceleration due to gravity, to be taken as 9.81 m/s^2;

a_v — vertical composite acceleration, in m/s^2, see 9.7.2.1 of this Section;

M — design vehicle mass, in t;

p — design uniformly distributed load of vehicle deck, in t/m^2, not to be less than 0.25 t/m^2;

m_s —deck weight, in t/m^2.

9.7.2.3 For direct calculation of transverse strength, the ship is assumed to heel to maximum heeling angle (if hull structures are not symmetrical to the longitudinal centerline, rolling towards portside and rolling towards starboard are to be considered separately) and the design load is to be calculated as follows:

(1) Vertical load and transverse load of vehicle deck are to be respectively calculated as follows:

Vertical load of vehicle $P_{r_v} = (g\cos\varphi_m + 0.5a_v)M$ kN

Transverse load of vehicle $P_{r_t} = (g\sin\varphi_m + 0.5a_t)M$ kN

Uniformly distributed vertical load $p_{d_r_v} = (g\cos\varphi_m + 0.5a_v)p$ kN/m^2

Uniformly distributed transverse load $p_{d_r_t} = (g\sin\varphi_m + 0.5a_t)p$ kN/m^2

Deck weight vertical load $p_{s_r_v} = (g\cos\varphi_m + 0.5a_v)m_s$ kN/m^2

Deck weight transverse load $p_{s_r_t} = (g\sin\varphi_m + 0.5a_t)m_s$ kN/m^2

where: g— acceleration due to gravity, to be taken as 9.81 m/s^2;

φ_m —maximum heeling angle, in rad, see 9.7.2.1 of this Section, to be taken not less than 0.35 rad;

a_v —vertical composite acceleration, in m/s^2, see 9.7.2.1 of this Section;

a_t —transverse composite acceleration, in m/s^2, see 9.7.2.1 of this Section;

M — design vehicle mass, in t;

p — design uniformly distributed load of vehicle deck, in t/m^2, not to be less than 0.25 t/m^2;

m_s — deck weight, in t/m^2.

(2) Vertical load and transverse load of superstructure deck and deckhouse deck are to be respectively calculated as follows:

Vertical load $p_{u_r_v} = (g\cos\varphi_m + 0.5a_v)m_0$ kN/m^2

Transverse load $p_{u_r_t} = (g\sin\varphi_m + 0.5a_t)m_0$ kN/m^2

where: g — acceleration due to gravity, to be taken as 9.81 m/s^2;

φ_m —maximum heeling angle, in rad, see 9.7.2.1 of this Section, to be taken not less than 0.35 rad;

a_v —vertical composite acceleration, in m/s^2, see 9.7.2.1 of this Section;

a_t —transverse composite acceleration, in m/s^2, see 9.7.2.1 of this Section;

m_0 — design load including deck weight, in t/m^2, not to be less than 0.25 t/m^2.

(3) The hydrostatic pressure p_{hs}, which is to be calculated in accordance with 1.5.3.2 of Section 5 of Chapter 1, is to be taken as the external sea pressure.

9.7.2.4 Calculation conditions are given in Tables 9.7.2.4.

Calculations conditions **Table 9.7.2.4**

Condition	Load area	Direction calculations of vehicle deck strength	Direction calculations of transverse strength
1	Vehicle deck	Vehicle load P_h Deck weight load p_{s_h}	Vehicle vertical load P_{r_v} Vehicle transverse load P_{r_t} Deck weight vertical load $p_{s_r_v}$ Deck weight transverse load $p_{s_r_t}$
	Superstructure and deckhouse	-	Vertical load $p_{u_r_v}$ Transverse load $p_{u_r_t}$
	External	-	Hydrostatic pressure p_{hs}
2	Vehicle deck	Uniformly distributed load P_{d_h} Deck weight load p_{s_h}	Uniformly distributed vertical load $p_{d_r_v}$ Uniformly distributed transverse load $p_{d_r_t}$ Deck weight vertical load $p_{s_r_v}$ Deck weight transverse load $p_{s_r_t}$
	Superstructure and deckhouse	-	Vertical load $p_{u_r_v}$ Transverse load $p_{u_r_t}$
	External	-	Hydrostatic pressure p_{hs}

9.7.3 Model and boundary conditions for strength calculation of vehicle deck structure

9.7.3.1 A 2- or 3-dimensional beam or plate/beam model may be used for direct strength calculations of vehicle deck structure, and the extent of the model is usually based on the following principles: Girders and transverses of the vehicle deck are to be taken as main objects of analysis, covering at least half the longitudinal length of the deck. Alternatively, a typical portion of the deck structure may be taken for modelling according to specific conditions of load distribution, deck structure and its supporting structures (e.g. pillars, bulkheads). Regardless of the length of the model, the whole tier of deck is to be considered for the selection of loads.

9.7.3.2 To minimize the effects of boundary constraints on the results of vehicle deck structure strength calculations, the boundary conditions are preferably to be applied at a suitable distance above and/or below the vehicle deck plane. For the fore and aft end planes of the model, the displacement in the longitudinal direction and the rotation about the coordinate axis perpendicular to the longitudinal direction are to be taken as zero.

9.7.4 Model and boundary conditions for transverse strength calculation

9.7.4.1 A 2- or 3-dimensional beam or plate/beam model may be used for direct transverse strength calculations, and the extent of the model is usually based on the following principles: Primary members of the deck and their supporting structures (e.g. pillars, bulkheads, side structures and transverse webs) are to be taken as main objects of analysis, covering at least in the vertical direction all tiers of decks and their supporting structures starting from baseline to the uppermost deck, in the transverse direction the entire breadth of the ship, and in the longitudinal direction at least the length of 5 strength frame rings or one design length of a vehicle amidships, whichever is the greater.

9.7.4.2 For the fore and aft end planes of the model, the displacement in the longitudinal direction and the rotation about the coordinate axis perpendicular to the longitudinal direction are to be taken as zero; For intersection lines AA', BB', CC', DD' of side ring frame or web frame and side shell plating, the displacement in vertical direction is to be taken as zero. For the intersection line $A'B'$ of inner bottom and portside shell plating, the displacement in transverse direction is to be taken as zero. Where inner bottom is not provided, the constraint of displacement in transverse direction may be applied to the intersection line EF of centre keelson and bottom plating (or similar position), see Figure 9.7.4.2.

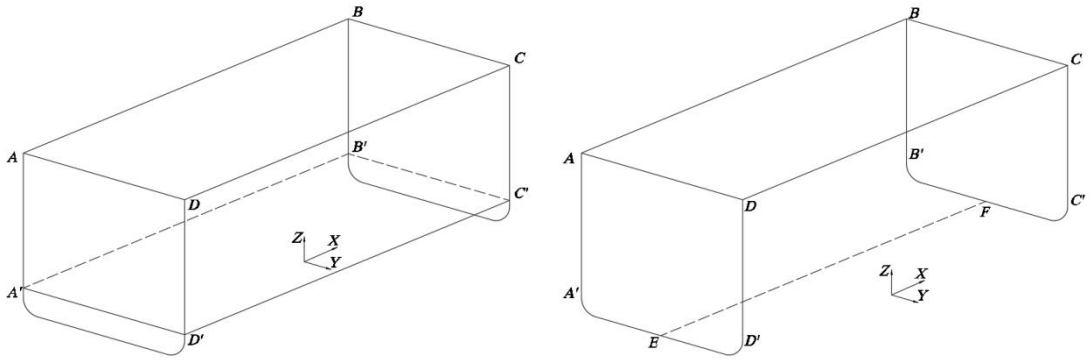


Figure 9.7.4.2

9.7.5 Permissible stresses

9.7.5.1 Permissible stresses for the 2- or 3-dimensional beam model:

Permissible bending stress $[\sigma]$ is to be:

$$[\sigma] = 165/K, \text{ in N/mm}^2$$

but $[\sigma]$ may be taken as $180/K$, in N/mm^2, for primary transverse members;

Permissible shear stress $[\tau]$ is to be:

$$[\tau] = 94/K, \text{ in N/mm}^2$$

where: K — material factor;

σ — bending stress, in N/mm^2;

τ — shear stress, in N/mm^2.

9.7.5.2 Permissible stress for plate/beam model

Permissible shear stress $[\tau]$ is to be:

$$[\tau] = 94/K, \text{ in N/mm}^2;$$

Permissible equivalent stress $[\sigma_e]$ is to be:

$$[\sigma_e] = \sqrt{\sigma_x^{\,2} + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2} = 180/K, \quad \text{N/mm}^2$$

where: K — material factor;

σ_x — normal stress of the element in X direction under plane stress, in N/mm^2;

σ_y — normal stress of the element in Y direction under plane stress, in N/mm^2;

τ_{xy} — shear stress of the element in X direction under plane stress, in N/mm^2.

Section 8 EXTERNAL GLASS BALUSTRADES

9.8.1 General

9.8.1.1 The requirements of this Section apply solely to external glass balustrades. External glass balustrades are barriers constructed with glass that are used on exposed decks.

9.8.1.2 Glass balustrades, in lieu of bulwark or guard rails (see Section 19, Chapter 2 of this PART), may be accepted on exposed decks above position 2 specified in 1.1.2.22, Section 1, Chapter 1 of this PART, except on mooring deck and in way of lifeboats and life rafts and embarkation stations.

9.8.1.3 Glass is to be manufactured in accordance with a recognised National or International Standard.

9.8.1.4 The detailed arrangement, applicable loads and structural strength calculations are to be submitted to CCS.

9.8.2 Arrangement requirements

9.8.2.1 External glass balustrades are to be not less than 1 m in height.

9.8.2.2 In general, openings (e.g. the gaps between panels or the gap between the deck and the bottom of a panel) are not to be greater than 76 mm unless required for water freeing.

9.8.2.3 If a well is formed, the necessary drainage port is to be provided. Openings for water freeing are not to be greater than 230 mm.

9.8.3 Design pressure

9.8.3.1 For the lowest weather deck, the minimum design pressure P_w of glass balustrades is to be calculated as follows:

$$P_w = 9.81h, \quad \text{kN/m}^2$$

where: h——head in 2.17.2, Section 17, Chapter 2 of this PART.

9.8.3.2 For higher exposed decks, the minimum design pressure P_w of glass balustrades is to be calculated as follows:

(1) Below $1.7C$ m above the scantling draught, P_w=5kN/m^2, where C is the coefficient as specified in 2.2.3.1, Section 2, Chapter 2 of this PART;

(2) For other locations, P_w=2.5kN/m^2.

9.8.4 Minimum scantling requirements

9.8.4.1 External glass balustrades using monolithic glass are to comply with the following requirements:

(1) Minimum thickness of glass is not to be less than 6.0 mm;

(2) Top rail is required, with a minimum section modulus of 17 cm^3;

(3) Stanchions is to be fitted, not more than 1.5 m apart, with minimum section modulus of 20 cm^3.

9.8.4.2 External glass balustrades using laminated glass are to comply with the following requirements:

(1) Minimum thickness for each glass pane is not to be less than 4 mm;

(2) Top rail is required, with a minimum section modulus of 17 cm^3;

(3) Stanchions is to be fitted, not more than 1.5 m apart, with minimum section modulus of 20 cm^3.

9.8.4.3 The section modulus requirements in 9.8.4.1 and 9.8.4.2 above are based on steel. For other metallic materials, equivalent section modulus is to be calculated.

9.8.4.4 The glass panes are to be supported at minimum two opposite sides by metallic mounting frames. The glass panes can be fixed to the metal frame by mechanical means or adhesive. If the metal mounting frames are connected to the stanchion by bolts, there is to be no less than two force bolts on one side.

9.8.4.5 The overlap between the glass panes and metallic frames is not to be less than 10 mm or b/75 mm, whichever is greater, but not more than 20 mm, b is the breadth of the glass pane, in mm.

9.8.4.6 In public areas, laminated glass panes are required for external glass balustrades.

9.8.5 Glass thickness

9.8.5.1 For monolithic toughened glass, the thickness is to be less than the value obtained from the following formula:

$$t = b\sqrt{\beta P} / 200 \quad \text{mm}$$

where: b ——length of the shorter side of the glass, in mm;

P ——load for calculation, $P = 0.5Pw$, in kN/m^2;

P_w——design pressure, in kN/m^2, see 9.8.3 of this Section;

β ——coefficient, to be taken as follows:

1) glass with firm support on all sides:

$$\beta = 0.54A_R - 0.078A_R^2 - 0.17 \quad \text{for} \quad A_R \le 3.6$$

$$\beta = 0.7645 \quad \text{for} \quad A_R > 3.6$$

2) glass with firm support on two sides only:

$$\beta = 0.7645$$

where: A_R ——aspect ratio of rectangle window, to be taken as follows

$$A_R = a / b$$

a ——length of the longer side of the glass, in mm;

b ——length of the shorter side of the glass, in mm.

9.8.5.2 For laminated toughened glass, the equivalent thickness is to be less than the value obtained from 9.8.5.1. The equivalent thickness is calculated according to the following formula:

$$t_e = \sqrt{\sum_{i=1}^{n} t_i^2} \quad \text{mm}$$

where: n —number of glass layers;

t_i —thickness of the ith layer glass.

9.8.6 Balustrade stanchions

9.8.6.1 For balustrade stanchions below 1.7C m above the scantling draught, the section modulus W at the bottom is not to be less than:

$$W = 655 \frac{\mathrm{P\,Sl^2}}{\mathrm{R_{eH}}} \quad \text{cm}^3$$

where: S ——distance between stanchions, in m;

l ——height of the stanchion, in m;

P ——load for calculation, $P = Pw$, in kN/m^2;

P_w——design pressure, in kN/m^2, see 9.8.3 of this Section;

R_{eH}——yield stress of material, in N/mm^2.

9.8.6.2 For balustrade stanchions below 1.7C m above the scantling draught, the shear area A at the bottom is not to be less than:

$$A = 22.7 \frac{\mathrm{P\,Sl}}{\mathrm{R_{eH}}} \quad \text{cm}^2$$

where: S ——distance between stanchions, in m;

l ——height of the stanchion, in m;

P ——load for calculation, $P = Pw$, in kN/m^2;

R_{eH}——yield stress of material, in N/mm^2.

CHAPTER 10 TUGS

Section 1 GENERAL PROVISIONS

10.1.1 Application

10.1.1.1 The provisions of this Chapter apply to ships intended exclusively for towing.

10.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

10.1.1.3 For the determination of scantlings of tugs, the draught d used is not to be less than 85% of the mounded depth.

10.1.1.4 For the calculation of rudder force, the design speed V of the ship is not to be taken as less than 10 kn.

10.1.2 Class notation

10.1.2.1 Tugs complying with the requirements of this Chapter are eligible to be assigned the class notation of Tug.

10.1.3 Plans and documents

10.1.3.1 In addition to those specified in Section 1, Chapter 2 of this PART, the following plan is to be submitted for approval:

(1) Supporting structure of towing equipment (appropriate strength calculations are submitted for information).

(2) Towing arrangement.

(3) Fender (structure) arrangement.

Section 2 HULL FRAMING

10.2.1 Web beam

10.2.1.1 A web beam is to be arranged throughout in way of the mid-portion of the long opening for the machinery space.

10.2.2 Side strengthening outside the fore peak

10.2.2.1 Where the side is framed transversely, the side framing outside the fore peak is to be strengthened in compliance with the requirements of 2.15.2, Chapter 2 of this PART, and the strengthened region is to be extended to 0.3L from the F.P. Within the region of strengthening, the section moduli of the main and 'tween deck frames are to be 20% greater than those required in Section 7, Chapter 2 of this PART.

Section 3 MACHINERY CASINGS

10.3.1 Machinery casings

10.3.1.1 The height of exposed machinery casings is not to be less than 900 mm. The stiffeners of the casings are to be spaced not more than 750 mm apart. The thickness of casing wall is to be increased by 20 % over that required in 2.17.9.3, Chapter 2 of this PART, while the section modulus of the stiffeners is to be increased by 50 % over that required in 2.17.9.3, Chapter 2 of this PART.

Section 4 BULWARKS AND FENDERS

10.4.1 Bulwarks

10.4.1.1 Tugs are to be provided with tumble-home bulwarks and the thickness t of bulwark plating is to comply with the following requirements:

t = 5 mm for $L \leq 30$ m;

t = 6 mm for $30 < L < 50$ m;

t = 7 mm for $L \geq 50$ m.

where: L — length of ship, in m.

10.4.1.2 The bulwarks are to be supported by stays with a flange or face plate. The stays are to be spaced not more than two frame spaces apart and are to be in line with the beams.

10.4.2 Fenders

10.4.2.1 Fenders are to be fitted along the deck line at side over the full length of the tug and are to have a thickness equal to that of side shell plating at 0.4L amidships. Stiffeners are to be arranged inside the fenders.

Section 5 TOWING ARRANGEMENTS AND SUPPORTING STRUCTURE

10.5.1 Towing hooks and towing winches

10.5.1.1 Towing hooks or the position of fixed towing guide point are normally to be situated at 5% to 10% of the ship's length abaft amidships, but in no case are they to be sited forward of the longitudinal centre of gravity of the tug in any anticipated condition of loading. In addition, they are to be located as low as practicable in order to minimize heeling moments arising in normal working conditions.

10.5.1.2 Towing winches and its members are to undertake the breaking loads of the towline selected by the tug and without permanent deformation. Towing hooks are to undertake the testing loads and without permanent deformation. The breaking loads of towlines and the testing loads of towing hooks may be determined according to CCS Guidelines for Towage at Sea.

10.5.2 Releasing arrangements

10.5.2.1 Towing hooks are to have reliable slip arrangements which facilitate towline releasing regardless of the direction of the towing line or the angle of heel and can avoid any inadvertent slipping.

10.5.2.2 The operating position of the slip arrangements is to be such as to ensure free visibility of the towing hook. It is recommended that the slip arrangements also be operable from the bridge.

10.5.3 Supporting structure

10.5.3.1 Pillars or pillar bulkheads are to be provided as far as possible under towing arrangements.

10.5.3.2 The design load for the supporting structure in way of towing arrangements is not to be less than the breaking loads of the towline selected by the tug.

10.5.3.3 The scantlings of primary members of the supporting structure are to be determined by direct calculations using the following allowable stresses:

Allowable shear stress: $[\tau] = 87/K$ N/mm²;

Allowable bending stress: $[\sigma] = 150/K$ N/mm²;

Allowable equivalent stress: $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 213/K$ N/mm².

where: K — material factor.

Section 6 TOWING WINCH EMERGENCY RELEASE SYSTEMS

10.6.1 Scope and definitions

10.6.1.1 This Section defines minimum safety standards for winch emergency release systems provided on towing winches that are used on towing ships within close quarters, ports or terminals, including those ships normally not intended for towing operation in transverse direction.

10.6.1.2 This Section is not intended to cover towing winches on board ships used solely for long distance ocean towage, anchor handling or similar offshore activities.

10.6.1.3 This Section applies to ships contracted for construction on or after 1 January 2020.

10.6.1.4 The purpose of this section is to provide requirements to prevent the capsize of a tug when in the act of towage as a result of the towline force acting transversely to the tug (in beam direction) as a consequence of an unexpected event (could be loss of propulsion/steering or otherwise), whereby the resulting couple generated by offset and opposing transverse forces (towline force is opposed by thrust or hull resistance force) causes the tug to heel and, ultimately, to capsize, see Figure 10.6.1.4.

10.6.1.5 For the purposes of this Section, definitions are as follows:

(1) Emergency release system refers to the mechanism and associated control arrangements that are used to release the load on the towline in a controlled manner under both normal and black out conditions.
(2) Maximum design load is the maximum load that can be held by the winch as defined by the manufacturer (the manufacturer's rating).
(3) Fleet angle is the angle between the applied load (towline force) and the towline as it is wound onto the winch drum, see Figure 10.6.1.5.

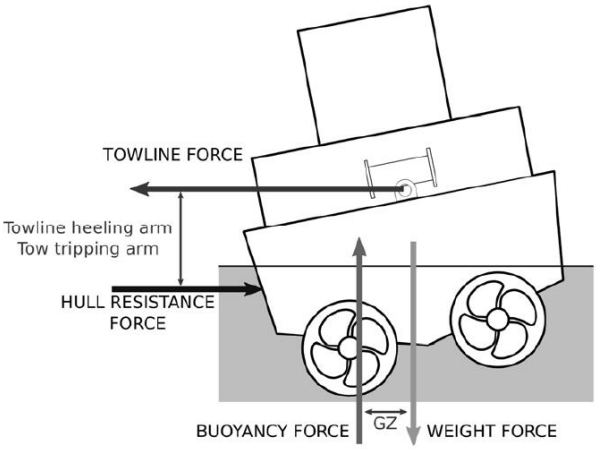


Figure 10.6.1.4 Forces during towing

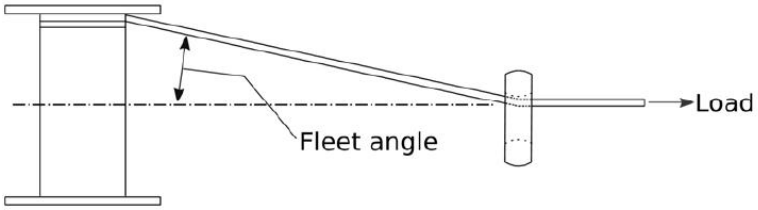


Figure 10.6.1.5 Towline fleet angle

10.6.2 General requirements

10.6.2.1 The in-board end of the towline is to be attached to the winch drum with a weak link or similar arrangement that is designed to release the towline at low load.
10.6.2.2 All towing winches are to be fitted with an emergency release system.

10.6.3 Performance requirements for emergency release system

10.6.3.1 The emergency release system is to operate across the full range of towline load, fleet angle and ship heel angle under all normal and reasonably foreseeable abnormal conditions (these may include, but are not limited to, the following: vessel electrical failure, variable towline load (for example due to heavy weather), etc.).
10.6.3.2 The emergency release system shall be capable of operating with towline loads up to at least 100 per cent of the maximum design load.
10.6.3.3 The emergency release system is to function as quickly as is reasonably practicable and within a maximum of three seconds after activation.
10.6.3.4 The emergency release system is to allow the winch drum to rotate and the towline to pay out in a controlled manner such that, when the emergency release system is activated, there is sufficient resistance to rotation to avoid uncontrolled unwinding of the towline from the drum. Spinning (free, uncontrolled rotation) of the winch drum is to be avoided, as this could cause the towline to get stuck and disable the release function of the winch.
10.6.3.5 Once the emergency release is activated, the towline load required to rotate the winch drum is to be no greater than:
(1) the lesser of five tonnes or five per cent of the maximum design load when two layers of towline are on the drum, or
(2) 15 per cent of the maximum design load where it is demonstrated that this resistance to rotation does not exceed 25 per cent of the force that will result in listing sufficient for the immersion of the lowest unprotected opening.

10.6.3.6 Emergency release of the towline is to be possible in the event of a blackout. For this purpose, where additional sources of energy are required, such sources are to comply with 10.6.3.7.
10.6.3.7 The alternative source of energy required by 10.6.3.6 of this Section is to be sufficient to achieve the most onerous of the following conditions (as applicable):
(1) sufficient for at least three attempts to release the towline (i.e. three activations of the emergency release system). Where the system provides energy for more than one winch it is to be sufficient for three activations of the most demanding winch connected to it.
(2) Where the winch design is such that the drum release mechanism requires continuous application of power (e.g. where the brake is applied by spring tension and released using hydraulic or pneumatic power) sufficient power is to be provided to operate the emergency release system (e.g. hold the brake open and allow release of the towline) in the event of a blackout for a minimum of five minutes. This may be reduced to the time required for the full length of the towline to feed off the winch drum at the load specified in 10.6.3.5 if this is less than five minutes.

10.6.4 Operational requirements for emergency release system
10.6.4.1 Emergency release operation must be possible from the bridge and from the winch control station on deck. The winch control station on deck is to be in a safe location. A position in close proximity to the winch is not regarded as safe location, unless it is documented that the position is at least protected against towline break or winch failure.
10.6.4.2 The emergency release control is to be located close to an emergency stop button for winch operation, if provided, and shall be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.
10.6.4.3 The emergency release function is to take priority over any emergency stop function. Activation of the winch emergency stop from any location is not to inhibit operation of the emergency release system from any location.
10.6.4.4 Emergency release system control buttons are to require positive action to cancel, the positive action may be made at a different control position from the one where the emergency release was activated. It must always be possible to cancel the emergency release from the bridge regardless of the activation location and without manual intervention on the working deck.
10.6.4.5 Controls for emergency use are to be protected against accidental use.
10.6.4.6 Indications are to be provided on the bridge for all power supply and/or pressure levels related to the normal operation of the emergency release system. Alarms are to activate automatically if any level falls outside of the limits within which the emergency release system is fully operational.
10.6.4.7 Wherever practicable, control of the emergency release system is to be provided by a hard-wired system, fully independent of programmable electronic systems.
10.6.4.8 Computer based systems that operate or may affect the control of emergency release systems are to meet the requirements for Category III systems of Section 6, Chapter 2 of PART SEVEN of the Rules.
10.6.4.9 Components critical for the safe operation of the emergency release system are to be identified by the manufacturer.

10.6.5 Test requirements for emergency release system
10.6.5.1 General requirements
(1) All testing defined within this Section is to be witnessed by a CCS surveyor.
(2) For each emergency release system or type thereof, the performance requirements of 10.6.3 of this Section are to be verified either at the manufacturer's works or as part of the commissioning of the towing winch when it is installed on board. Where verification solely through testing is impracticable (e.g. due to health and safety), testing may be combined with inspection, analysis or demonstration in agreement with CCS.
(3) The performance capabilities, as well as instructions for operation of the emergency release system are to be documented by the manufacturer and made available on board the ship on which the winch has been installed.
(4) Instructions for surveys of the emergency release system are to be documented by the manufacturer, when agreed, and made available on board the ship on which the winch has been installed.
(5) Where necessary for conducting the annual and special surveys of the winch, adequately sized strong points are to be provided on deck.
10.6.5.2 Installation trials
(1) The full functionality of the emergency release system is to be tested as part of the shipboard commissioning trials to the satisfaction of the surveyor. Testing may be conducted either during a bollard pull test or by applying the towline load against a strong point on the deck of the tug that is certified to the

appropriate load.
(2) Where the performance of the winch in accordance with 10.6.3 of this Section has previously been verified, the load applied for the installation trials is to be at least the lesser of 30% of the maximum design load or 80% of vessel bollard pull.

CHAPTER 11 OFFSHORE SUPPLY SHIPS

Section 1 GENERAL PROVISIONS

11.1.1 Application

11.1.1.1 This Chapter applies to offshore supply ships specially designed and constructed for the carriage of specialized stores and cargoes to mobile or fixed offshore installations, and also to offshore tug/supply ships and offshore anchoring handling/tug/supply ships.

11.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

11.1.1.3 This Chapter applies to supply ships having the accommodation and bridge erections in the forward part of the vessel and an exposed deck in the after part for the handling of cargo at sea.

11.1.1.4 In addition to the requirements of this Chapter, tug/supply ships are to comply with the relevant requirements as specified in Section 5, Chapter 10 of this PART. A tug/supply ship, when engaged in towing operations, is in general not to carry deck cargo.

11.1.2 Class notations

11.1.2.1 Ships complying with the requirements of this Chapter are eligible to be assigned one of the following class notations:

(1) Offshore Supply Ship for offshore supply ships; or

(2) Offshore Tug/Supply Ship for offshore tug/supply ships.

11.1.3 Plans and documents

11.1.3.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, plans covering the following items are to be submitted for approval:

(1) Independent cargo tanks and their foundations and securing arrangements;

(2) Drawing of the deck(s) showing the details of loads, the points where they apply and lashing arrangement;

(3) Towing arrangement;

(4) Supports and foundations for towing winches, stern towing bollards and for stern rollers of anchor handling/supply ships (appropriate strength calculations are submitted for information);

(5) Movable decks, including the stowing arrangements for portable components;

(6) Freeing arrangement;

(7) Fender arrangement (structure).

Section 2 CARGO CONTAINMENT AND OTHER FITTINGS

11.2.1 Cargo containment

11.2.1.1 Means are to be provided to enable deck cargoes to be adequately secured and protected. In general, suitable inner bulwarks, rails, bins or storage racks of substantial construction are to be provided and properly secured to adequately strengthened parts of the hull structure.

11.2.1.2 Properly designed locking equipment or efficient means for lashing the deck cargoes are to be fitted where appropriate.

11.2.1.3 Small hatches (including escape hatches), control valves, ventilators, air pipes, etc., are to be situated clear of the cargo containment areas and fitted in protected positions.

11.2.2 Doors and accesses

11.2.2.1 If possible, the accesses to machinery spaces are to be arranged in forecastle. Any accesses to machinery spaces from weather cargo decks are to be provided with two weathertight closing appliances. The accesses to spaces below the weather cargo decks are to be preferably from a position on or above the superstructure deck as far as possible.

11.2.2.2 Doors leading directly to and hatches on the open cargo deck are to be kept closed during navigation. These doors are to be clearly marked to indicate that they are to be kept closed except for access.

11.2.3 Side scuttles, windows and skylights

11.2.3.1 Side scuttles, windows and skylights are to comply with the relevant requirements of Section 12, Chapter 1 of this PART.

11.2.3.2 Windows are only allowed to be fitted in the following locations and side scuttles are to be fitted in other positions.

(1) Second tier and higher above the freeboard deck:

① in the aft end bulkheads of deckhouses and superstructures;

② in the sides of deckhouses and superstructures which are not part of the shell plating;

(2) Third tier and higher above the freeboard deck:

① in the forward facing bulkheads of deckhouse and superstructures, except that in the first tier of the front bulkhead above the weather deck, only side scuttles will be accepted.

11.2.3.3 Permanently attached deadlights are to be provided as follows:

(1) Side scuttles:

① in the side shell plating;

② in the forward facing bulkheads of superstructures and deckhouses;

③ in the sides of deckhouses and superstructures up to and including the third tier above the freeboard deck;

④ in the after end bulkheads of superstructures, deckhouses, casings and companionways in the first and second tiers above the freeboard deck.

(2) Windows:

① in the sides of deckhouses and superstructures in the second and third tiers above the freeboard deck;

② in the after end bulkheads of superstructures, deckhouses, casings and companionways in the second tier above the freeboard deck.

11.2.3.4 On windows in the second tier and higher above the freeboard deck, hinged storm covers may be fitted in lieu of deadlights, provided there is safe access for closing.

11.2.3.5 Windows in the wheelhouse front are to have deadlights or storm covers. For storm covers, an arrangement for easy and safe access is to be provided, (e.g. gangway with railing). However, for practical purposes, the deadlights or storm covers may be portable if stowed adjacent to the window for quick fitting. At least two of the deadlights or storm covers are to have the means of providing a clear view.

11.2.3.6 Deadlights for side scuttles, and for windows not mentioned in 11.2.3.4 and 11.2.3.5, are to be internally hinged.

11.2.3.7 The thickness of toughened glass for windows is not to be less than the value calculated by the following formula, and the minimum is not to be less than 10 mm.

$$t = b\sqrt{\varphi\beta\eta h} \qquad \text{mm}$$

where:

φ — coefficient, taken as 2 for fronts, 1.2 for sides and aft ends;

η — coefficient, taken as 223 for fronts and sides on the forth tier or above, 125 for aft ends on the forth tier or above, 500 for other cases;

h — design head of window, calculated according to 2.17.2, Chapter 2 of this PART;

β — coefficient, to be calculated by the following:

$$\beta = 0.54A_R - 0.078A_R^2 - 0.17 \quad \text{for} \quad A_R \le 3.6$$

$$\beta = 0.7645, \quad \text{for} \quad A_R > 3.6$$

where: A_R —aspect ratio factor of window, calculated by the following equation:

$$A_R = a/b$$

a — length of long edge of window, in m;

b — length of short edge of window, in m.

11.2.3.8 Skylights, where fitted, are to be of substantial construction. The height of coamings of skylights is not to be less than 600 mm when situated on open freeboard decks, and raised quarter decks and open superstructure decks forward of 1/4L from F.P., and 450 mm when situated on open superstructure decks abaft of 1/4L from F.P. The thickness of glass in skylights is to be equal to that required for side scuttles or windows at the same position. Skylights are to be provided with strong storm covers.

11.2.3.9 For laminated toughened glass, the equivalent thickness is not to be less than that calculated according to 11.2.3.7. The equivalent thickness is to be calculated by the following formula and the thickness of single layer of glass is not to be less than 4 mm.

$$t_e = \sqrt{\sum_{i=1}^{n} t_i^2}$$

where: n — the number of layer of glass;
t_i — the thickness of the i[th] layer of glass.

11.2.4 Air pipes, ventilators and freeing ports

11.2.4.1 Air pipes situated on the exposed cargo and forecastle decks are to be provided with automatic closing devices.

11.2.4.2 Machinery space ventilators are to be arranged above the superstructure deck, or above an equivalent level if no superstructure deck is fitted.

11.2.4.3 The area of the freeing ports in the side bulwarks on the cargo deck is to be suitably increased above that required in 1.12.6.2, Chapter 1 of this PART. The disposition of the freeing ports is to be carefully considered to ensure the most effective drainage of water trapped in deck cargoes or in recesses in the after end bulkhead of the forecastle.

In ships operating in areas where icing is likely to occur, no shutters are to be fitted in the freeing ports.

11.2.4.4 Engine exhaust outlets are to be located as high as practicable above the deck and are to be fitted with spark arresters.

Section 3 SHELL AND DECK PLATING

11.3.1 Shell plating

11.3.1.1 The thickness of side shell is to be in accordance with the relevant requirements of Section 3, Chapter 2 of this PART, but is in no case to be less than 9 mm.

11.3.1.2 The side shell in way of the stern rollers immediately adjacent to high duty mooring bollards and in other high load areas of anchor handling/supply ships is to be suitably reinforced.

11.3.2 Decks

11.3.2.1 The minimum thickness t of deck plating is not to be less than that obtained from the following formula:

$$t = 0.025L + 7 \quad \text{mm}$$

where: L — length of ship, in m.

In the deck cargo area, the thickness t of deck plating is, in addition, in no case to be less than that obtained from the following formula:

$$t = 4.8s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of beams or longitudinals, in m;
h — design head, in m, to be determined from $h = 0.14p$ (p being the load of deck, in kPa), but not to be less than 3.5 m;
K — material factor.

11.3.2.2 The deck plating near the stern and that subject to concentrated loads are to be suitably increased in thickness.

Section 4 HULL ENVELOPE FRAMING

11.4.1 Deck framing

11.4.1.1 The scantlings of cargo decks are to be suitable for the specified loadings, but in no case is a head less than 3.5 m to be used.

11.4.1.2 Additional local increases in scantlings is to be required where specific cargoes are likely to induce concentrated loads.

11.4.2 Side framing

11.4.2.1 Efficient fenders are to be fitted to the ship's side above the waterline, and are to have a thickness equal to that of side shell. Stiffeners are to be arranged inside the fenders. If fenders are not provided, the thickness of the shell plating at least 600 mm below the deck is to be increased by 5 mm.

11.4.2.2 The section moduli of the main and 'tween deck frames are to be 25% greater than those required in Section 7 of Chapter 2 of this PART. Frames are not to be scalloped.

11.4.3 Bottom framing

11.4.3.1 The flat bottom in way of stern is to be suitably strengthened.

Section 5 SUPERSTRUCTURES AND DECKHOUSES

11.5.1 Scantlings

11.5.1.1 The section modulus of the frames in superstructures is to be 25% greater than that required in Section 7, Chapter 2 of this PART. The scantlings of the end bulkheads of superstructures are not to be less than those as specified in Table 11.5.1.2 of this Section.

11.5.1.2 The scantlings of deckhouses situated on the forecastle deck and above are to comply with the requirements of Table 11.5.1.2.

Plate thickness, Stiffener Modulus and Depth of Deckhouses Table 11.5.1.2

Position	Thickness t of plating (mm)	Section modulus W of stiffeners (cm^3)	Depth of stiffeners (mm)
Fronts	The greater of 12s or 8.0	34sl^2	Not less than 100
Sides	The greater of 10s or 6.5	27sl^2	Not less than 75
Aft ends	The greater of 8s or 6.5	27sl^2	Not less than 65

Note: s and l are respectively spacing and span of stiffeners, in m.

11.5.2 End connection

11.5.2.1 Both ends of the stiffeners in superstructures and deckhouses are to be bracketed or connected by other effective means on all tiers.

CHAPTER 12 BARGES

Section 1 GENERAL PROVISIONS

12.1.1 Application

12.1.1.1 The barges defined in this Chapter are non-self-propelled ships pushed or towed by other ships and divided into the following types:

(1) Barges carrying general dry cargo in cargo holds;

(2) Barges carrying cargo oil in cargo tanks;

(3) Shipborne barges carrying general dry cargo in cargo holds and carried on board a barge carrier;

(4) Specially designed pontoons for the carriage of cargo on deck;

(5) Barges dedicated to transporting marine engineering jacket structure and landing jacket into water by the stern for launching of jacket;

(6) Barges carrying chemicals in cargo tanks;

(7) Barges carrying liquefied gas in cargo tanks.

12.1.1.2 Where not covered by this Chapter, barges carrying cargo oil in bulk in cargo tanks are to comply with the relevant requirements of Chapter 5 or 6 of this PART according to its structural configuration; barges carrying chemicals in cargo tanks are to comply with the relevant requirements of Chapter A4, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk; barges carrying liquefied gas in cargo tanks are to comply with the relevant requirements of Appendices 1 and 2, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gas in Bulk and other barges are to comply with the relevant requirements of Chapter 2 of this PART.

12.1.1.3 For pontoons regarded as one of offshore floating facilities, the structure may be in accordance with the requirements of this Chapter for pontoon barges.

12.1.2 Class notations

12.1.2.1 Barges complying with the requirements of this Chapter are eligible to be assigned one of the following class notations:

(1) Barges: the notation Barge is to be assigned to the barges as defined in 12.1.1.1(1);

(2) Oil barges: the notation Oil Barge is to be assigned to the barges as defined in 12.1.1.1(2);

(3) Shipborne barges: the notation Shipborne Barge is to be assigned to the barges as defined in 12.1.1.1(3);

(4) Pontoon barges: the notation Pontoon Barge is to be assigned to the barges as defined in 12.1.1.1(4);

(5) Launch Barge: the notation Launch Barge is to be assigned to the barges as defined in 12.1.1.1(5);

(6) Chemical Barge: the notation Chemical Barge is to be assigned to the barges as defined in 12.1.1.1(6);

(7) Gas Barge: the notation Gas Barge is to be assigned to the barges as defined in 12.1.1.1(7).

12.1.3 Plans and documents

12.1.3.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, plans and documents covering the following are to be submitted for approval:

(1) Details of structure and fittings to which deck cargo securing lashings, etc. are attached;

(2) Details of bollards and their supporting structure;

(3) Where pusher tugs or integral tug/barge systems are proposed, full details and data of the attachment and support arrangements;

(4) Longitudinal strength (appropriate strength calculations are submitted for information) and lifting arrangements for shipborne barges.

12.1.4 Structural configuration

12.1.4.1 For barges with large deck openings, deck and bottom are in general to be longitudinally framed.

12.1.4.2 Barges are to be fitted with a collision bulkhead extending intact to the strength/weather deck and, in general, this is to be located in accordance with Table 12.1.4.2. Greater distance between the collision bulkhead and the forward perpendicular may be accepted if assessed by damage stability calculation.

Table 12.1.4.2

Length L of ship (m)	Distance between collision bulkhead and forward perpendicular (m)	
	Minimum	Maximum
≤ 150	0.05L	0.05L + 4.5
> 150	0.05L or 10, whichever is the lesser	0.08L

12.1.4.3 Where the ends of the barge are identical both in structural arrangement and in shape so that its fore and after ends are not distinguishable, collision bulkheads are to be fitted at both ends.

12.1.4.4 Pusher barges are in general to be fitted with a collision bulkhead at the aft end.

12.1.4.5 The total number of watertight bulkheads is in general not to be less than required in Table 12.1.4.5. For ships of over 190 m in length, this is to be determined by direct calculation. Attention is to be paid to reasonable and even arrangement of transverse watertight bulkheads.

Total Number of Transverse Watertight Bulkheads **Table 12.1.4.5**

Length L (m)	$L \leq 60$	$60 < L \leq 85$	$85 < L \leq 105$	$105 < L \leq 145$	$145 < L \leq 165$	$165 < L \leq 190$
Total number of watertight bulkheads	3	4	5	6	7	8

12.1.4.6 Pontoon barges are in general to be fitted with longitudinal bulkheads extending fore and aft in accordance with Table 12.1.4.6, the scantlings of which are to be calculated as required for watertight longitudinal bulkheads. Attention is to be paid to reasonable arrangement of longitudinal bulkheads. For pontoon barges with B/D greater than 6, this is to be determined by direct calculation.

Total Number of Longitudinal Bulkheads **Table 12.1.4.6**

B/D	$B/D \leq 2.5$	$2.5 < B/D \leq 3$	$3 < B/D \leq 4$	$4 < B/D \leq 5$	$5 < B/D \leq 6$
Total number of longitudinal bulkheads	0	1	2	3①	3

Note: ① Centre longitudinal bulkheads may be replaced by longitudinal trusses.

12.1.4.7 For pontoon barges with B/D equal to or greater than 3, the transverse strength is to be checked by direct calculation (see Appendix 1 of this Chapter).

Section 2 LONGITUDINAL STRENGTH

12.2.1 General requirements

12.2.1.1 The longitudinal strength of barges is to comply with the relevant requirements of Section 2, Chapter 2 of this PART, with the exception of the requirements for loading instruments.

12.2.1.2 For shipborne barges intended to be lifted on board by crane, longitudinal strength calculations for a condition "fully loaded barge suspended by crane" are to be made with the following permissible stresses:

Permissible bending stress $[\sigma] = 150/K$ N/mm²

Permissible shear stress $[\tau] = 100/K$ N/mm²

where: K — material factor.

12.2.1.3 For barges having large deck openings, torsional strength is to be checked in accordance with Chapter 7 of this PART.

12.2.1.4 Where the transverse watertight bulkheads and longitudinal bulkheads of pontoon barges are fitted in compliance with the requirements for structural arrangement in Section 1 of this Chapter, their proportions may exceed those specified in 2.2.1.2 of Section 2, Chapter 2 of this PART when the requirements for longitudinal strength in Section 2, Chapter 2 of this PART are applied, provided that the following condition is met:

$$L/B > 3$$

$$B/D \leq 6.0$$

12.2.1.5 For pontoon barges not meeting the condition in 12.2.1.4 above, this is generally to be determined by direct calculation. See 2.2.9 of Chapter 2 for direct calculation of wave loads.

Section 3 SHELL AND DECK PLATING

12.3.1 General requirements

12.3.1.1 In addition to the requirements of this Section, the shell and deck plating of barges carrying cargo oil in cargo tanks are to comply with the relevant requirements of Chapter 6 of this PART and those of other barges are to comply with the relevant requirements of Chapter 2 of this PART.

12.3.2 Shell plating Decks

12.3.2.1 On barges with two chines each side, the thickness of bilge plating is to be calculated from the bottom plating formulae. On hard chine barges, flanged chines will not, in general, be approved, but where a chine is formed by knuckling the shell plating, the radius of curvature, measured on the inside of the plate, is not to be less than 10 times the plate thickness. Where a solid round chine bar is fitted, the bar diameter is not to be less than 3 times the thickness of the thickest abutting plate. Where welded chines are used, the welding is to be built up as necessary to ensure that the shell plating thickness is maintained across the weld.

12.3.2.2 For barges of less than 100 m in length and without dead rise, the thickness of plate keel is to be calculated from the bottom plating formulae.

12.3.3 Decks

12.3.3.1 For barges with large deck openings, the half sectional area a of the strength deck within $0.4L$ amidships is not to be less than that obtained from the following formula:

$$a = \frac{1}{4.3} B(L + 30) \quad \text{cm}^2$$

where: L — length of ship, in m;
B — breadth of ship, in m.

The half sectional area of deck means the sum of sectional areas of the continuous longitudinal members outside the line of openings and on one side of the longitudinal centreline, such as deck plating, deck longitudinals and deck girders.

12.3.3.2 For pontoons, the thickness of deck plating in the deck cargo area is, in addition, not to be less than that obtained from the following formula:

$$t = 4.5s\sqrt{hK} \quad \text{mm, but not less than 6 mm}$$

where: s — spacing of beams or longitudinals, in m;
h — design head, in m, to be taken as $0.14p + 0.3$, p being the design load, in kPa;
K — material factor.

12.3.3.3 Where vehicles are to be carried on deck, the deck plating is also to comply with the relevant requirements of Section 21, Chapter 2 of this PART.

Section 4 HULL ENVELOPE FRAMING

12.4.1 General requirements

12.4.1.1 The hull envelope framing of barges carrying dry cargo in cargo holds are to comply with the relevant requirements of Chapter 2 of this PART. The hull envelope framing of barges carrying cargo oil in cargo tanks are to comply with the relevant requirements of Chapter 6 of this PART. The hull envelope framing of pontoon barges are to comply with the relevant requirements of this Section.

12.4.1.2 In way of deck and bottom primary transverse members, a web frame is to be fitted so that the bottom, side and deck transverses are connected into a transverse ring system to ensure sufficient transverse strength.

12.4.1.3 Pontoon barges are in general longitudinally framed. If they are framed transversely, transverse ring systems or transverse trusses are to be suitably fitted to ensure sufficient transverse strength.

12.4.1.4 Figure 12.4.1.4 shows the longitudinally framed structure of pontoon barges.

12.4.1.5 Figure 12.4.1.5 shows the transversely framed structure of pontoon barges.

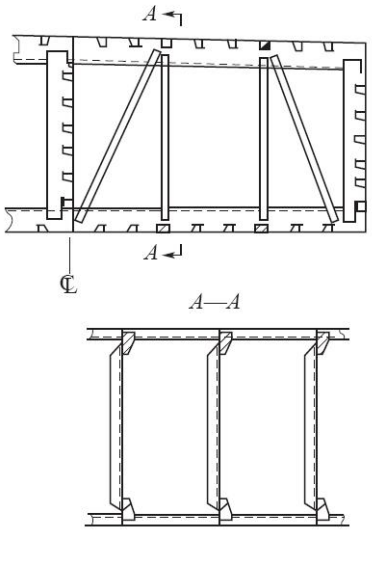


Figure 12.4.1.4

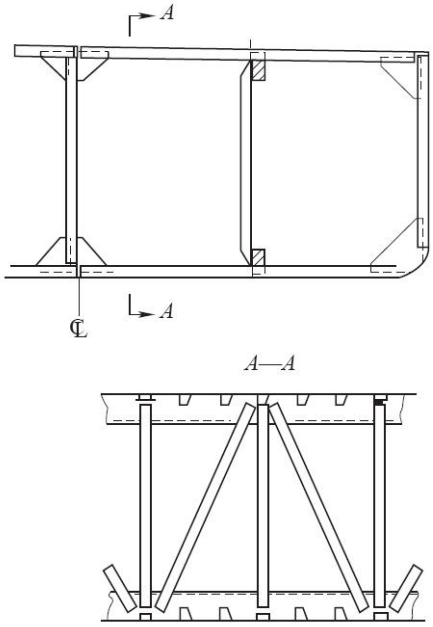


Figure 12.4.1.5

12.4.2 Bottom framing of pontoons

12.4.2.1 Where transversely framed, bottom frames are to be fitted at every frame, and their section modulus W is not to be less than that obtained from the following formula:

$$W = 9.5sDl^2K \quad \text{cm}^3$$

where: s — spacing of bottom frames, in m;

D — moulded depth, in m;

l — span of bottom frames, in m; supporting structures of bottom frames are to be ship side, longitudinal bulkheads or bottom stringers;

K — material factor.

12.4.2.2 Where longitudinally framed, the section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = CsDl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

D — moulded depth, in m;

l — span of longitudinal, in m; supporting structures of bottom longitudinals are to be transverse bulkheads or bottom webs;

C — coefficient, taken as:

$C = 12$, for rake-ended bow of pontoon barges;

$C = 10.5$, for others;

K — material factor.

12.4.2.3 The section modulus W of bottom stringers (including bottom chords of longitudinal trusses) is not to be less than that obtained from the following formula:

$$W = 9.5SDl^2K \quad \text{cm}^3$$

where: S — average width of areas supported by bottom stringers, in m;

D — moulded depth, in m;

l — span of bottom stringers, in m; supporting structures of bottom stringers are to be transverse bulkheads, truss pillars;

K — material factor.

12.4.2.4 The section modulus W of bottom webs (including bottom chords of transverse trusses) is not to be less than that obtained from the following formula:

$$W = CSDl^2K \quad \text{cm}^3$$

where: S — average width of areas supported by bottom webs, in m;

D — moulded depth, in m;

l — span of bottom web, in m; supporting structures of bottom webs are to be ship side, longitudinal bulkheads or truss pillars;

C — coefficient, taken as:

$C = 11$, for rake-ended bow of pontoon barges;

C = 9.5, for others;

K — material factor.

12.4.2.5 Primary bottom members (bottom stringers and webs) are to comply with the following requirements:

(1) The web depth h of primary members is not to be less than 2 times the depth of the slot for the passage of secondary members (bottom frames and longitudinals), and not to be less than that obtained from the following formula:

$$h = 125l \quad \text{mm}$$

where: l — span of primary member, in m.

(2) The web thickness t of primary members is not to be less than that obtained from the following formula:

$$t = h/100 + 3 \quad \text{mm, not less than 7 mm}$$

where: h — web depth of primary member, in mm.

12.4.3 Side framing of pontoons

12.4.3.1 The section modulus W of frames is not to be less than that obtained from the following formula:

$$W = 9.5shl^2K \quad \text{cm}^3$$

where: s — spacing of frames, in m;

l — span of frame, in m;

h — head taken in calculation, in m; vertical distance measured from the midpoint of span of the frame to deck at side, but not to be less than $0.01L + 0.7$ m, L being length of ship, in m;

K — material factor.

12.4.3.2 The section modulus W of side longitudinals is not to be less than that obtained from the following formula:

$$W = Cshl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinal, in m;

h — head taken in calculation, in m; vertical distance measured from the side longitudinal to deck at side, but not to be less than $0.01L + 0.7$ m, L being length of ship, in m;

C — coefficient, taken as:

C = 9.0, for rake-ended bow of pontoon barges;

C = 8.0, for others;

K — material factor.

12.4.3.3 The section modulus W of longitudinally framed web frames is not to be less than that obtained from the following formula:

$$W = CShl^2K \quad \text{cm}^3$$

where: S — spacing of web frames, in m;

l — span of web frame, in m;

h — head taken in calculation, in m; vertical distance measured from the midpoint of span of the web frame to deck at side, but not to be less than $0.01L + 0.7$ m, L being length of ship, in m;

C — coefficient, taken as:

C = 9.5, for rake-ended bow of pontoon barges;

C = 8.5, for others;

K — material factor.

12.4.3.4 Longitudinally framed web frames are to comply with the relevant requirements of 12.4.2.5 of this Section.

12.4.4 Deck framing of pontoons

12.4.4.1 The section modulus W of transversely framed deck beams is not to be less than that obtained from the following formula:

$$W = 4.5shl^2K \quad \text{cm}^3$$

where: s — spacing of deck beams, in m;

l — span of deck beam, in m;

h — head taken in calculation, in m; $h = 0.14p + 0.3$, but not to be less than $0.02L + 0.76$ m, L being length of ship, in m, p being design load, in kPa;

K — material factor.

12.4.4.2 The section modulus W of longitudinally framed deck longitudinals is not to be less than that obtained from the following formula:

$$W = 5shl^2K \quad \text{cm}^3$$

where: s — spacing of deck longitudinals, in m;

l — span of deck longitudinal, in m;
h — head taken in calculation, in m, the same as in 12.4.4.1 of this Section;
K — material factor.

12.4.4.3 The section modulus W of deck girders (including top chords of longitudinal trusses) is not to be less than that obtained from the following formula:

$$W = 5Shl^2K \quad \text{cm}^3$$

where: S — average width of areas supported by girders, in m;
l — span of girders, in m;
h — head taken in calculation, in m, the same as in 12.4.4.1 of this Section;
K — material factor.

12.4.4.4 The section modulus W of deck transverses (including top chords of transverse trusses) is not to be less than that obtained from the following formula:

$$W = 5Shl^2K \quad \text{cm}^3$$

where: S — average width of areas supported by transverses, in m;
l — span of transverses, in m;
h — head taken in calculation, in m, the same as in 12.4.4.1 of this Section;
K — material factor.

12.4.4.5 Primary structural members of deck (including deck girders and transverses) are to comply with the following requirements:

(1) The web depth h of primary members is not to be less than 2 times the depth of the slot for the passage of secondary members (deck beams and longitudinals), and not to be less than that obtained from the following formula:

$$h = 58.5l \quad \text{mm}$$

where: l — span of primary member, in m.

(2) The web thickness t of primary members is not to be less than that obtained from the following formula:

$$t = h/100 + 3 \quad \text{mm, not less than 7 mm}$$

where: h — web depth of primary members, in mm.

12.4.4.6 Where wheeled vehicles are stowed on the deck, the deck framing is also to comply with the relevant requirements in Section 21, Chapter 2 of this PART.

12.4.4.7 Where containers are carried on the deck, stacking devices are to be fitted on supporting members, and the strength of deck framing is to be checked by direct calculation. The static load of containers is to be taken as the load in calculation, and permissible stresses are as follows:

Permissible normal stress $[\sigma] = 0.5R_{eH}$
Permissible shear stress $[\tau] = 0.292\ R_{eH}$

where: R_{eH} — yield stress of material, in N/mm^2.

12.4.5 Truss structure of pontoon barges

12.4.5.1 Pontoon barges are to be fitted with trusses extending either fore and aft or athwartships for the support of hull structure.

12.4.5.2 A truss is comprised of top and bottom girders, pillars and diagonal bracings.

12.4.5.3 The top and bottom girders of longitudinal trusses are deck and bottom girders respectively.

12.4.5.4 The top and bottom girders of transverse trusses are deck transverses and bottom webs respectively.

12.4.5.5 Pillars are to comply with the relevant requirements of Section 10, Chapter 2 of this PART, and the load P acting on pillars is to be taken as the greater of the values obtained from the following formulae:

$$P_1 = pa_1b_1 \quad \text{kN}$$
$$P_2 = 10D\ a_2b_2 \quad \text{kN}$$

where: p — design cargo load, in kPa;
a_1 — average length of deck area supported by pillar, in m;
b_1 — average width of deck area supported by pillar, in m;
D — moulded depth, in m;
a_2 — average length of bottom area supported by pillar, in m;
b_2 — average width of bottom area supported by pillar, in m.

12.4.5.6 Diagonals are generally to have an angle of inclination with the horizontal of 45º, and a cross-sectional area of generally 50% of that of the adjacent pillar.

Section 5 STRENGTHENING AT ENDS OF SHIP

12.5.1 General requirements

12.5.1.1 The ends of barges with general sea-going-ship-shaped bow forms are to be strengthened in accordance with Section 15, Chapter 2 of this PART.
12.5.1.2 The ends of fore rake end pontoon barges are to be strengthened in accordance with this Section. Figure 12.5.1.2 shows the shape and structural arrangement of a typical fore rake end.

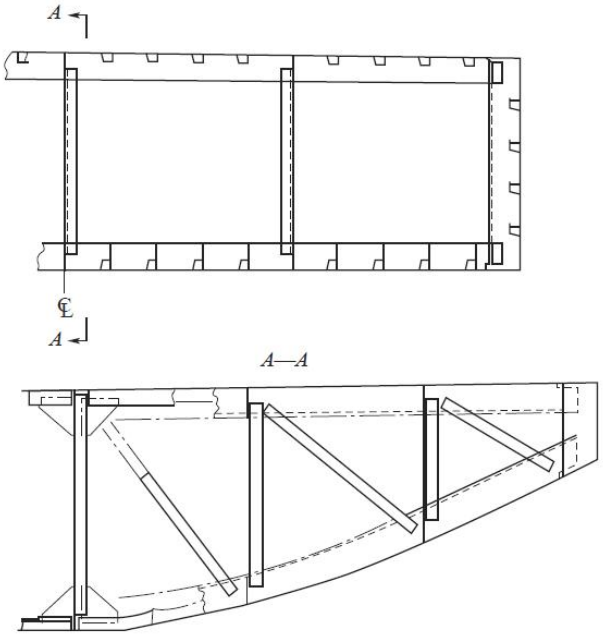


Figure 12.5.1.2

12.5.2 Structural requirements for fore rake end
12.5.2.1 The structural requirements for fore rake end apply to the bottom forward plating of the forward rake from the forward headlog to the lower turn of the rake. Where the collision bulkhead is located aft of the lower turn of the rake, these requirements apply to the bottom forward plating of the forward rake from the forward headlog to the collision bulkhead.
12.5.2.2 The span of bottom longitudinals is not to exceed 2.5 m. Bottom longitudinals may be supported by transverse bulkheads or bottom webs.
12.5.2.3 The span of bottom frames is not to exceed 2.5 m. Bottom frames may be supported by longitudinal bulkheads or bottom girders.
12.5.2.4 The scantlings of primary members are to comply with the relevant requirements for pontoons in Section 4 of this Chapter and in addition, the following requirements:
(1) In general, the web depth of primary members is not to be less than 2.5 times the depth of the slot for the passage of secondary members.
(2) The web depth h of primary members is not to be less than that obtained from the following formula:

$$h = Cl \quad \text{mm}$$

where: l — span of primary members, in m;
C — coefficient, taken as follows:
83.5 for deck transverses;
125 for side transverses;
156 for bottom webs.
12.5.2.5 The bottom shell plating thickness is to be maintained up to the summer load waterline for the rake plating. Above this point the thickness may be tapered to that of the side shell requirements from a point not less than 1 m above the load waterline.

12.5.3 Strengthening of structures of bottom forward against slamming
12.5.3.1 The structures of bottom forward are to be strengthened against slamming in accordance with 2.15.3 of Section 15, Chapter 2 of this PART.
12.5.3.2 Where pontoon barges are towed or pushed at a speed of less than 10 kn and minimum fore draught equal to or greater than $0.01L$ (L being length of ship, in m), with trim being kept at zero, the requirements for strengthening of bottom forward in Section 15, Chapter 2 of this PART may be dispensed with.

Appendix METHOD OF CHECKING TRANSVERSE STRENGTH OF PONTOON BARGES

1. General Requirements

1.1 Application

1.1.1 This method is applicable only to the check of transverse strength of pontoon barges in accordance with 12.1.4.7 of this Chapter.

1.1.2 This method is not applicable to the strength assessment of local structures subjected to a concentrated load (e.g. large foundation, heavy cargo support and struts).

2. Loads

2.1 Load types

2.1.1 Only the effects of maximum permissible deck load and external water pressure are taken into account for design conditions of transverse strength. The effects of hull girder bending moments (both vertical and horizontal ones) are not taken into account.

2.1.2 The load due to external water pressure consists of hydrostatic pressure and hydrodynamic wave pressure as follows:

at baseline: $P_B = 10d \pm 1.5C$ kN/m^2

at waterline: $P_w = \pm 3C$ kN/m^2

at side top: $P_s = 3P_0$ kN/m^2

where: C – see 2.2.3.1 of Section 2, Chapter 2;

d – draught, in m;

P_0 – to be calculated as follows:

$P_0 = C - 0.67(D - d)$ kN/m^2;

D – moulded depth, in m.

In order to take account of the effects of beam sea acting along the ship's length in local areas, such effects are simulated by applying asymmetric external water pressure on both sides for design conditions. A superimposition of hydrostatic pressure and wave pressure may be assumed on one side and the effects of hydrostatic pressure and reverse hydrodynamic wave pressure on the other side (C being taken negative in the above formula), where any value below zero is to be taken as zero.

The distribution of load effects is shown in Figure 2.1.2.

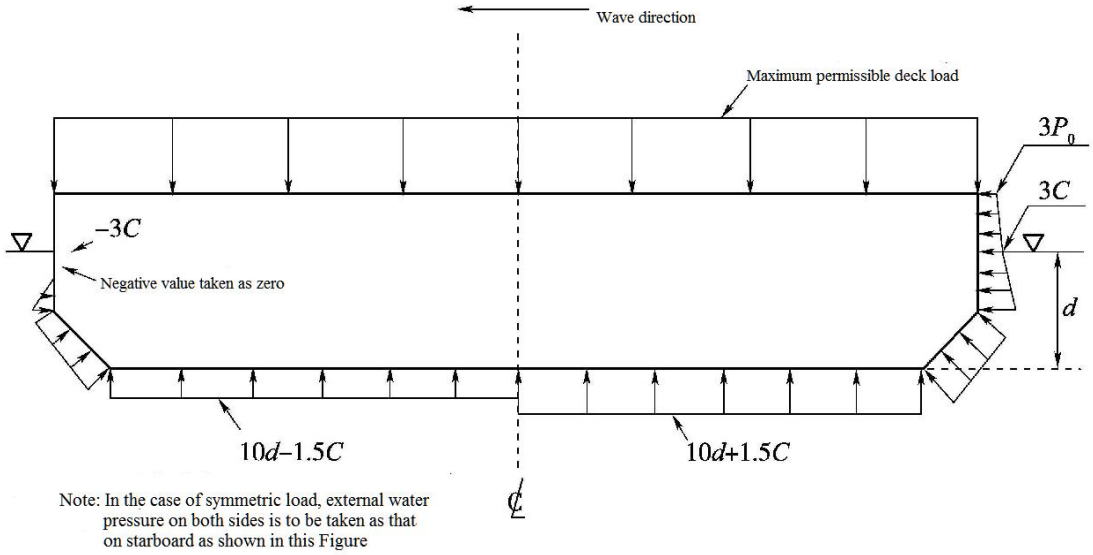


Figure 2.1.2

2.1.3 The following two conditions are taken into account for design conditions:

(1) **Symmetric condition**: Maximum permissible deck load+ external hydrostatic pressure + hydrodynamic wave pressure acting symmetrically inwards on both sides;

(2) **Asymmetric condition**: Maximum permissible deck load + external hydrostatic pressure + antisymmetric hydrodynamic wave pressure acting inwards on one side and outwards on the other side.

3. Structural Models

3.1 Structural modelling

3.1.1 Model extent

① Longitudinal direction: In general, a typical midship hold/tank is to be taken for analysis, with fore and aft end faces (A and B) being at transverse bulkheads covered by the model;

② Transverse direction: Total breadth of the ship;

③ Vertical direction: Total moulded depth.

See Figure 3.1.1.

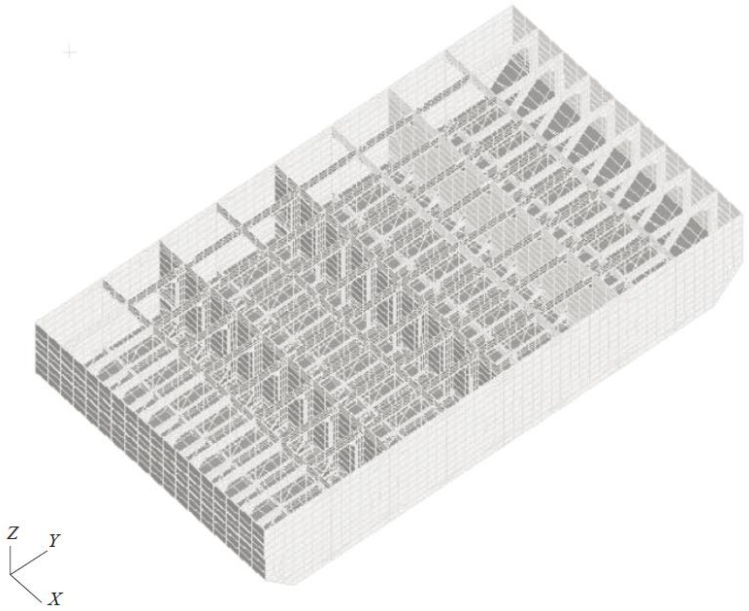


Figure 3.1.1 Model Extent (deck not shown)

3.1.2 Elements and meshing size of models

3.1.2.1 The elements and meshing size of models are to be in accordance with those specified for general finite element hold models, refer to 1.5.6, Chapter 1 of this PART.

3.1.2.2 The diagonals of transverse trusses are generally simulated by rod elements.

3.1.3 Boundary conditions

3.1.3.1 All nodes at edges of fore and aft end transverse bulkheads are to be restrained for 3 linear deflections, see Figure 3.1.3.1.

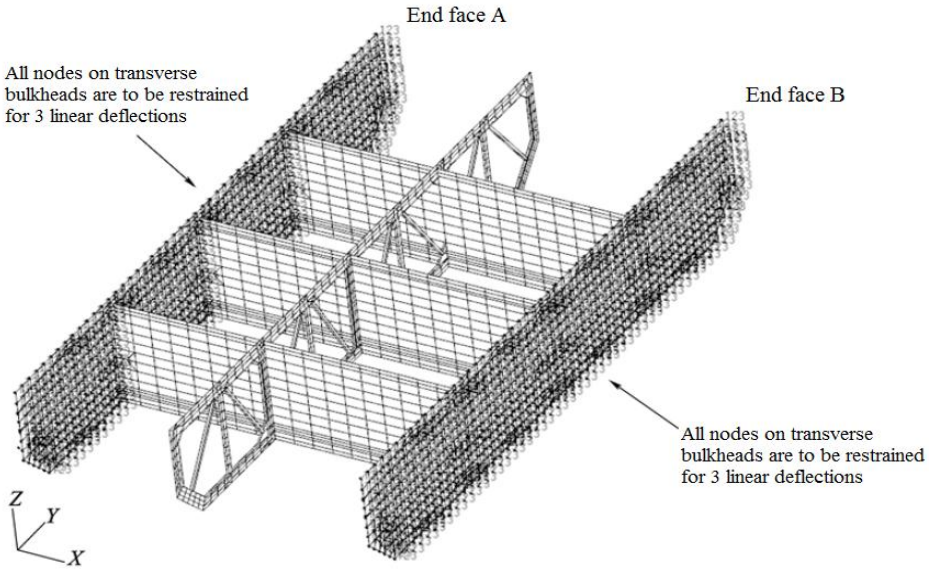


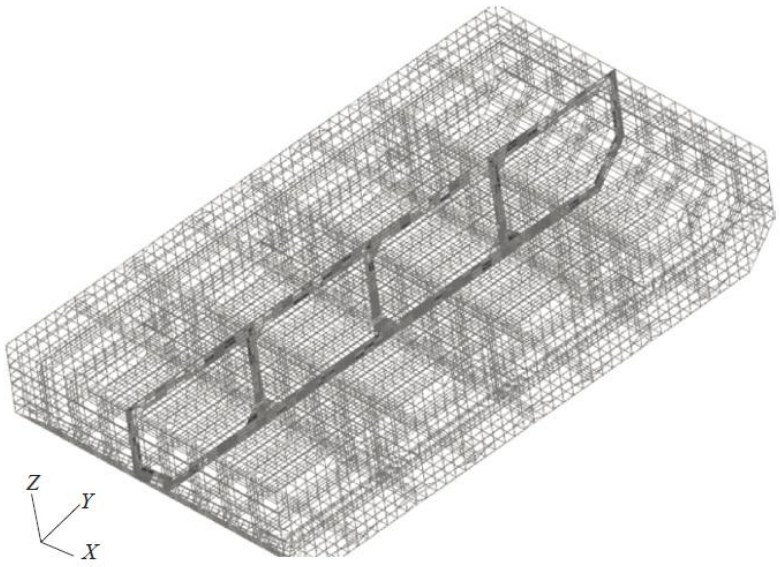
Figure 3.1.3.1 Boundaries Conditions of Model

4. Strength Assessment

4.1 General requirements

4.1.1 Assessment of results

4.1.1.1 The range of values for assessment of the results of finite element analysis is to be based on one of the web frames of the model, see Figures 4.1.1.1.



Figures 4.1.1.1

4.1.1.2 For floors and beam webs, the average shear stress based on the total height of webs may be taken as the shear stress in calculation.

4.2 Assessment of yield strength

4.2.1 Strength criteria

4.2.1.1 In all conditions, the calculated stress of individual structural members is not to be greater than the corresponding permissible values given in Tables 4.2.1.1(1) and (2).

Plate Element **Tables 4.2.1.1(1)**

Structural member	$[\sigma_e]$	$[\tau]$
Side transverse web, longitudinal bulkhead vertical girder web	170/K	–
Deck transverse web, bottom floor	170/K	90/K

Beam and Rod Elements **Tables 4.2.1.1(2)**

Structural member	$[\sigma_{rod}]$
Beam element simulating web faceplate of strength member of transverse web frame or beam fitted on transverse members	170/K
Cross tie of transverse truss	141/K

where: σ_e – equivalent stress of plate element (i.e. Von Mises stress), in N/mm^2;

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2}$$, based on membrane stress at centroid of the element

σ_x – stress of element in direction X, in N/mm^2;
σ_y – stress of element in direction Y, in N/mm^2;
τ_{xy} – shear stress of element in plane XY, in N/mm^2;
τ – average shear stress based on the total height of webs, in N/mm^2;
σ_{rod} – axial stress of rod element or normal stress of beam element (excluding bending stress component), in N/mm^2;
K – material factor.

CHAPTER 13 FLOATING CRANES

Section 1 GENERAL PROVISIONS

13.1.1 Application

13.1.1.1 This Chapter applies to single-deck crane barges with both deck and bottom being framed longitudinally.

13.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

13.1.2 Class notation

13.1.2.1 Floating cranes complying with the requirements of this Chapter will be eligible to be assigned the class notation of Floating Crane.

13.1.3 Definitions

13.1.3.1 Fore end and aft end: The fore end and aft end of non-self-propelled floating cranes are to be determined according to their operation conditions. During transit, the floating cranes are to be treated as ordinary ships with the fore end of the hull in the forward direction being called the fore end and the opposite end the after end. In conditions other than transit, the end where the crane jib is fitted is called the fore end and the opposite end the aft end.

13.1.4 Arrangement and structures

13.1.4.1 The continuous longitudinal members of the hull are to be continuous from the fore end to the aft end as far as possible.

13.1.4.2 Two or more continuous longitudinal bulkheads (or longitudinal trusses) are to be fitted from the fore end to the aft end.

13.1.4.3 One transverse watertight bulkhead is to be fitted at a suitable position at each end of the barge. Between the end bulkheads, at least one intermediate transverse watertight bulkhead is to be fitted for barges not exceeding 50 m in length, and at least two intermediate transverse watertight bulkheads are to be fitted for barges exceeding 50 m in length. Such transverse bulkheads are to be arranged reasonably uniform.

13.1.4.4 Longitudinal or transverse supporting bulkheads or other effective structures with sufficient strength and rigidity are to be fitted underneath the cranes to provide adequate support. Such strengthened structures are to be so arranged as to effectively transmit stresses. The deck plating in way is to be increased in thickness or fitted with doublers. The thickness of doublers is not to be less than that of the deck plating. In addition, local strengthening is to be provided to the hull structure in way of other deck machinery or where heavy loads are imposed.

Section 2 LONGITUDINAL STRENGTH

13.2.1 General requirements

13.2.1.1 The longitudinal strength is to comply with the relevant requirements in Section 2, Chapter 2 of this PART. Transit and lifting conditions are to be taken into account.

13.2.1.2 For fixed type floating crane, where the still water bending moment obtained from calculation is a sagging moment in lifting conditions, an additional bending moment (sagging moment) induced by the maximum horizontal component force which is imposed on the hull structure by the maximum load lifted is to be added.

13.2.1.3 For lifting conditions, the wave bending moment and wave shear force regarding the intended area of operation may be determined according to Section 2, Chapter 2 of PART TEN.

Section 3 SHELL PLATING

13.3.1 Minimum thickness

13.3.1.1 The minimum thickness t of shell plating is not to be less than that obtained from the following formula:

$$t = 0.044L + 5.6 \quad \text{mm}$$

where: L — length of ship, in m.

13.3.2 Bottom shell

13.3.2.1 The thickness t of bottom shell plating within $0.5L$ amidships is not to be less than that obtained from the following formula:

$$t = 1.32s\sqrt{LK} + 2.5 \quad \text{mm}$$

where: s — spacing of longitudinals, in m;
L — length of ship, in m;
K — material factor.

13.3.3 Side shell plating

13.3.3.1 The thickness t of side shell plating within $0.5L$ amidships is not to be less than that obtained from the following formula:

$$t = 1.27s\sqrt{LK} + 2.5 \quad \text{mm}$$

where: s — spacing of frames, in m;
L — length of ship, in m;
K — material factor.

Section 4 DECKS

13.4.1 Thickness of deck plating

13.4.1.1 The thickness t of strength deck plating within $0.5L$ amidships is not to be less than that obtained from the following formula:

$$t = 8.75s\sqrt{K}+2.5 \quad \text{mm}$$

where: s — spacing of longitudinals, in m;
K— material factor.

13.4.1.2 The thickness t of strength deck plating outside $0.5L$ amidships is not to be less than that obtained from the following formula:

$$t = 7.13s\sqrt{K}+2.5 \quad \text{mm}$$

where: s — spacing of longitudinals, in m;
K— material factor.

13.4.1.3 The thickness of deck plating in the cargo area is, in addition, not to be less than that obtained from the following formula:

$$t = 4.5s\sqrt{hK} \quad \text{mm, but not less than 6 mm}$$

where: s — spacing of beams or longitudinals, in m;
h — design head, in m, to be taken as $0.14p + 0.3$, p being the design load, in kPa;
K — material factor.

Section 5 SINGLE BOTTOMS

13.5.1 Centre keelson

13.5.1.1 Floating cranes are to be provided with a centre keelson, with side keelsons being fitted on each side of the centre keelson, spaced not more than 2.5 m apart.

13.5.1.2 The web thickness t and the sectional area A of the face plate of the centre keelson are not to be less than:

$$t = 0.065L + 5 \quad \text{mm}$$
$$A = 0.60L + 9 \quad \text{cm}^2$$

where: L — length of ship, in m.

13.5.2 Side keelsons

13.5.2.1 The web thickness t and the sectional area A of the face plate of side keelsons are not to be less than:

$$t = 0.065L + 5 \quad \text{mm}$$
$$A = 0.24L + 10 \quad \text{cm}^2$$

where: L — length of ship, in m.

13.5.3 Plate floors

13.5.3.1 The spacing of plate floors is not to exceed 2.5 m.

13.5.3.2 The section modulus W of plate floors is not to be less than that obtained from the following formula:

$$W = 4Shl^2K \quad \text{cm}^3$$

where: S — spacing of floors, in m;
K — material factor;
h — design head, in m, to be taken as d or $0.66D$, whichever is the greater (d and D being draught and moulded depth respectively, in m);
l — span of floor, in m.

13.5.3.3 The web depth h of floors is not to be less than that obtained from the following formula and in addition, this depth is to be greater than 2.5 times the depth of the slot for the passage of longitudinals:

$$h = 60l_1 \quad \text{mm}$$

where: l_1 — horizontal distance between longitudinal bulkheads or between the longitudinal bulkhead and side shell, in m.

13.5.4 Bottom longitudinals

13.5.4.1 The section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 11.90shl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
K — material factor;
h — design pressure head, in m, to be taken as d or $0.66D$, whichever is the greater (d and D being draught and moulded depth respectively, in m);
l — span of longitudinal, in m.

Section 6 DOUBLE BOTTOMS

13.6.1 General requirements

13.6.1.1 Where double bottoms are provided, the height h of the double bottom is to be determined by the following formula, but not to be less than 700 mm:

$$h = b/18 \quad \text{mm}$$

where: b — horizontal distance between longitudinal bulkheads (or longitudinal trusses), in mm.

13.6.1.2 The thickness of the centre girders, side girders, plate floors and inner bottom plating within the machinery space is to be increased by 2 mm above that obtained from the respective formulae given below in this Section.

13.6.2 Centre girders

13.6.2.1 The thickness t of centre girders is not to be less than that obtained from the following formula:

$$t = 0.05L + 4 \quad \text{mm}$$

where: L — length of ship, in m.

13.6.3 Side girders

13.6.3.1 The thickness t of side girders is not to be less than that obtained from the following formula:

$$t = 0.60\sqrt{L} + 2 \quad \text{mm}$$

where: L — length of ship, in m.

13.6.4 Plate floors

13.6.4.1 The thickness t of plate floors is not to be less than that obtained from the following formula:

$$t = 0.60\sqrt{L} + 2 \quad \text{mm}$$

where: L — length of ship, in m.

13.6.5 Inner bottom plating

13.6.5.1 The thickness t of inner bottom plating is not to be less than that obtained from the following formula:

$$t = 0.67s\sqrt{LK} + 2.5 \quad \text{mm}$$

where: s — spacing of the inner bottom longitudinals, in m;
K — material factor;
L — length of ship, in m.

13.6.6 Longitudinals

13.6.6.1 The section modulus of bottom longitudinals is to be determined in accordance with 13.5.4.1 of this Chapter.

13.6.6.2 The section modulus of inner bottom longitudinals is to be 85% of that of the bottom longitudinals.

Section 7 SIDE FRAMING

13.7.1 Side transverses

13.7.1.1 Side transverses are to be fitted in line with plate floors and their section modulus W is not to be less than that obtained from the following formula:

$$W = 9.5Shl^2K \quad \text{cm}^3$$

where: S — spacing of side transverses, in m;
K — material factor;
h — vertical distance, in m, measured from the mid-point of span of the side transverse to upper deck at side;
l — span of side transverse, in m.

13.7.1.2 The web depth h of side transverses is not to be less than that obtained from the following formula and in addition, this depth is to be greater than twice the depth of the slot for the passage of longitudinals:

$$h = 100l \quad \text{mm}$$

where: l — span of side transverse, in m.

Section 8 STRENGTH DECK FRAMING

13.8.1 Strength deck loading

13.8.1.1 The design head h of the strength deck is to be selected from Table 13.8.1.1.

Design Head *h* **Table 13.8.1.1**

Item	Deck longitudinals	Deck girders and deck transverses	Pillars
Design head h, in m	$0.02L + 0.76$	$0.085L - 1.04(D - d)$	$0.098L - 1.1(D - d)$

Note: L is length of ship, D moulded depth and d draught, in m.

13.8.1.2 Where the deck is subject to load, the design head is to be taken as $0.14p$ (p being the design load, in kPa), in m, but not to be less than the corresponding design head h given in Table 13.8.1.1.

13.8.2 Deck girders

13.8.2.1 The section modulus W of deck girders is not to be less than that obtained from the following formula:

$$W = 3.5bhl^2K \quad \text{cm}^3$$

where: b — mean width, in m, of deck area supported by the girder;
K — material factor;
l — span of deck girder, in m;
h — design head of deck, in m, see 13.8.1 of this Section.

13.8.3 Deck transverses

13.8.3.1 Deck transverses are to be fitted in line with side transverses and their section modulus W is not to be less than that obtained from the following formula:

$$W = 3.9ShlK \quad \text{cm}^3$$

where: S — spacing of deck transverses, in m;
K — material factor;
l — span of deck transverse, in m;
h — design head of deck, in m, see 13.8.1 of this Section.

13.8.3.2 The web depth of deck transverses is not to be less than twice the depth of the slot for the passage of longitudinals.

13.8.4 Deck longitudinals

13.8.4.1 The section modulus W of deck longitudinals is not to be less than that obtained from the following formula:

$$W = 8.5shlK \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
K — material factor;
h — design head of deck, in m, see 13.8.1 of this Section;
l — span of longitudinal, in m.

Section 9 PILLARS AND TRUSSES

13.9.1 Pillars

13.9.1.1 Pillars are to comply with the relevant requirements of Section 10 of Chapter 2 of this PART, but the design head h of pillars underneath the strength deck is to be determined according to 13.8.1 of this Chapter.

13.9.2 Longitudinal trusses

13.9.2.1 Longitudinal trusses are to be composed of deck girders, keelsons, pillars and diagonals.

13.9.2.2 The sectional area of pillars of the longitudinal trusses is to comply with the requirements of Section 10 of Chapter 2 of this PART.

13.9.2.3 Diagonals of trusses

(1) The angle of inclination of diagonals of trusses is to be about 45°.

(2) The sectional area of diagonals of trusses is not to be less than 0.5 times that of the pillars calculated according to Section 10 of Chapter 2 of this PART and the ratio of the length of the diagonal to its minimum sectional radius of inertia is not to exceed 120.

CHAPTER 14 DREDGERS

Section 1 GENERAL PROVISIONS

14.1.1 Application

14.1.1.1 This Chapter applies to self-propelled or non-self-propelled steel dredgers with a single deck, including:

(1) trailing suction dredger;
(2) cutter suction/cutter wheel dredger;
(3) bucket dredger;
(4) grab dredger;
(5) hopper barge;
(6) reclamation craft;
(7) split hopper dredger;
(8) split hopper barge.

Dipper dredgers may be referred to the requirements given in this Chapter and are to be adequately strengthened.

14.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

14.1.1.3 The provisions of this Chapter are applicable to the following proportions of principal dimensions of dredgers:

For hopper dredgers: $B/D \leq 3$

For other types of dredgers: $B/D \leq 5$

Where any of the above values is exceeded, the transverse strength is to be checked by direct calculation.

14.1.2 Class notations

14.1.2.1 Dredgers complying with the requirements of this Chapter will be eligible to be assigned one of the following class notations:

(1) for trailing suction dredgers: Trailing Suction Dredger;
(2) for cutter suction dredgers: Cutter Suction Dredger;
(3) for cutter wheel dredgers: Cutter Wheel Dredger;
(4) for bucket dredgers: Bucket Dredger;
(5) for grab dredgers: Grab Dredger;
(6) for reclamation craft: Reclamation Craft;
(7) for dipper dredgers: Dipper Dredger;
(8) for hopper barges: Hopper Barge;
(9) for split hopper dredgers: Split Hopper Dredger;
(10) for split hopper barges: Split Hopper Barge;
(11) for back-hoe dredgers: Back-hoe Dredger.

14.1.2.2 Dredgers whose bottom structure has been specially strengthened in accordance with the requirements of Section 7 of this Chapter regarding bottom strengthening for operating aground are to be assigned the following special feature notation:

Bottom Strengthened for Operating Aground.

14.1.3 Plans and documents

14.1.3.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, those covering the following items are to be submitted for approval:

(1) Sections through hoppers, pump rooms, dredging machinery spaces and wells;
(2) Hopper and well bulkheads (including sloping bottom structure) and associated regions;
(3) Scarfing arrangements at hopper and well bulkheads (including sloping bottom structure);
(4) Plans of any special arrangements for dismantling, storage and re-assembly (where dredging equipment is stored during voyages);
(5) Seats of dredging equipment (directly affecting the primary hull structure) together with their supporting structures;
(6) for split hopper barges and split hopper dredgers:
① Structure of junction piece of hydraulic installation;
② Deck hinges, deckhouse hinges (appropriate strength calculations are submitted for information);

③ Connection of hinges to hull structure;
④ Connection of junction piece of hydraulic installation to hull structure;
⑤ Longitudinal load-bearing plating in bottom plane and deck plane;
⑥ Longitudinal load-bearing plating of deckhouse and its connection to hull structure;
⑦ Transverse load-bearing plating.

14.1.3.2 The following plans and documents are to be submitted for information (where applicable):
(1) Arrangement of dredging equipment (including the design load of dredging equipment).

14.1.4 Definitions

14.1.4.1 **Hopper:** A hopper is a hold designed to carry dredged spoil and arranged to enable such spoil to be automatically discharged through doors in the bottom of the dredger or hopper barge.

14.1.4.2 **Box keel:** The box keel is a built-up box-shaped structure on the centreline, consisting of bottom plating, side plating in the hopper and internal framing, arranged longitudinally at the lower portion, and between the fore and aft end bulkheads, of the hopper or hoppers.

14.1.4.3 **Cross beam:** The cross beam is a built-up beam spanning transversely the longitudinal bulkheads or hatch coaming of the hopper within the lines of deck openings.

14.1.4.4 **Longitudinal cross beam:** The longitudinal cross beam is a longitudinal built-up beam spanning longitudinally the fore and aft end bulkheads of the hopper within the lines of deck openings.

14.1.4.5 **Well:** The recess or well in the hull of dredgers for arranging the dredging gear.

14.1.4.6 **Split hopper barge or split hopper dredger:** A hopper barge or hopper dredger composed of two independent half hulls separated longitudinally along the hull, with the half hulls being connected by deck hinges and hydraulic installations at the fore and aft transverse bulkheads of the hopper.

Section 2 LONGITUDINAL STRENGTH

14.2.1 General requirements

14.2.1.1 The provisions of this Section are applicable to dredgers and barges 65 m or over in length. The requirements for longitudinal strength of split hopper dredgers and barges are given in Section 9 of this Chapter.

14.2.1.2 The continuous longitudinal members such as longitudinal bulkheads of hoppers, box keels and well bulkheads are to be so arranged as to ensure smooth transition at the break, and abrupt changes of section are to be avoided.

14.2.1.3 For dredgers and barges complying with the requirements of 14.1.1.1, the strength of large openings at hoppers need not be checked.

14.2.2 Bending strength of hull girders

14.2.2.1 The midship section modulus is to comply with the following requirements:
(1) The minimum midship section modulus W_o is not to be less than that obtained from the following formula:

$$W_0 = CL^2B(C_b + 0.7)K \quad \text{cm}^3$$

where: C — coefficient, to be determined according to 2.2.3.1 of Section 2, Chapter 2 of this PART;
L — length of ship, in m;
B — breadth of ship, in m;
C_b — block coefficient at design summer load waterline, but to be taken as not less than 0.6;
K — material factor.

The value of W_o is to be generally maintained throughout 0.4L amidships. However, it may be reduced away from the midship point provided that it complies with the requirements in (2) below.
(2) The section modulus W at deck, keel and top of hopper hatch coaming (where applicable) in way of each transverse section within 0.4L amidships is not to be less than that obtained from the following formulae:

For dredging condition: $W = \dfrac{M_{sd} + M_w}{[\sigma]} \times 10^3$ cm^3

For transit condition: $W = \dfrac{M_s + M_w}{[\sigma]} \times 10^3$ cm^3

where: M_{sd} — still water bending moment in dredging, in kN·m, to be determined according to 14.2.5.1 of this Section;

M_s — still water bending moment in transit, in kN·m, to be determined according to 14.2.5.1 of this Section;

M_w — wave bending moment, in kN·m, to be determined according to 2.2.3.1 of Section 2, Chapter 2 of this PART, which is to comply with relevant requirements of 2.2.1.2 of Section 2, Chapter 2 of this PART;

$[\sigma]$ — permissible bending stress, in N/mm², to be in compliance with 2.2.5.4(2) of Section 2, Chapter 2 of this PART.

14.2.3 Midship section moment of inertia

14.2.3.1 For hopper dredgers and hopper barges, the midship section moment of inertia I about the horizontal neutral axis is not to be less than that obtained from the following formula:

$$I = 3.5W_0 L / K \quad \text{cm}^4$$

where: W_0 — midship section modulus, in cm³, as required in 14.2.2.1(1) of this Section;

L — length of ship, in m;

K — material factor.

14.2.4 Shear strength of hull girders

14.2.4.1 For hopper dredgers and hopper barges, the shear stress is to be checked.

14.2.4.2 The shear stress τ at hull sections near fore and aft hopper end bulkheads is to comply with the following requirements:

For dredging condition: $\tau = \dfrac{|F_{sd} + F_w|}{2Dt} \le [\tau]$ N/mm²

For transit condition: $\tau = \dfrac{|F_s + F_w|}{2Dt} \le [\tau]$ N/mm²

where: F_{sd} — still water shear force when dredging, in kN, to be calculated in accordance with 14.2.5.1 of this Section;

F_s — still water shear force in transit, in kN, to be calculated in accordance with 14.2.5.1 of this Section;

F_w — wave shear force, to be calculated in accordance with 2.2.3.2 of Section 2, Chapter 2 of this PART, which is to comply with relevant requirements of 2.2.1.2 of Section 2, Chapter 2 of this PART;

D — moulded depth, in m;

t — sum of mean thicknesses of side plating and longitudinal bulkhead plating respectively, or mean thickness of side plating, in mm;

$[\tau]$ — the same as that in 2.2.6.2 of Section 2, Chapter 2 of this PART, but $[\tau]$ = 110 N/mm² where higher tensile steel is adopted partially for the hull.

Where the shear stress obtained is greater than $[\tau]$, the thickness of shell plating is to be increased. The strengthening along the length of ship is to be extended beyond both hopper end bulkheads for a distance of not less than 0.04L (L being length of ship, in m).

14.2.5 Design still water bending moment and design still water shear force

14.2.5.1 The still water bending moment and still water shear force of each transverse section of hull girders are to be calculated in accordance with the following dredging condition and transit condition, taking the influence of departure and arrival into account:

(1) maximum loaded condition corresponding to maximum dredging draft;

(2) where more than one hopper are fitted, the partially loaded conditions when the hoppers are not emptied simultaneously;

(3) transit condition at summer load waterline draft;

(4) ballast transit condition with hopper spaces being empty, if applicable;

(5) loading conditions which are more severe than above ones.

14.2.6 Calculation of midship section modulus and moment of inertia

14.2.6.1 When calculating the midship section modulus and moment of inertia, the following requirements are to be complied with:

(1) The strength deck and all continuous longitudinal members below it may be considered in the calculation of the midship section modulus and moment of inertia.

(2) For continuous hatch coamings, where efficiently supported by the longitudinal bulkheads or deep webs, 100% of their sectional areas may be considered in the calculation, otherwise only 80% of their sectional areas may be considered.
(3) For longitudinal cross beams with smooth transition at their ends, 60% of their sectional areas may be considered.
(4) For box keels with smooth transition at their ends, 85% of their sectional areas may be considered.
(5) Where the openings cut in the web of longitudinal girders exceed 20% of the height of the web, the sectional areas of the openings are to be deducted.
In general, the sectional areas of the overflows at side need not be deducted, provided the overflows comply with the requirements of 14.10.3.1, Section 10 of this Chapter.

Section 3 SHELL ENVELOPE PLATING

14.3.1 Bottom shell

14.3.1.1 The thickness of bottom shell plating of hopper dredgers and barges is to be 15% greater than that required in 2.3.1.2 and 2.3.1.3 of Section 3, Chapter 2 of this PART.

14.3.2 Plate keel

14.3.2.1 Where a well or a hopper door is provided on the longitudinal centerline, a plate keel is to be fitted on each side of the well or the hopper door opening. The width of each plate keel is not to be less than half that required in 2.3.2.1 of Section 3, Chapter 2 of this PART. The position of the plate keel is to be indicated on the docking plan.
14.3.2.2 The thickness of the plate keel is to be 2 mm greater than that required for the bottom shell.

14.3.3 Openings in shell plating

14.3.3.1 The corners of hopper door openings or wells in the bottom are to be rounded, and the ratio of the radius of corners to the width of openings is not to be less than 1/10.
14.3.3.2 Openings are generally not to be cut in sheer strakes, otherwise the requirements of 14.10.3.1, Section 10 of this Chapter are to be complied with.

14.3.4 Local strengthening and special requirements

14.3.4.1 The thickness of the bottom shell connected to the hopper longitudinal bulkheads or to the well bulkheads is to be 1 mm greater than that required in this Section, and the width of which is not to be less than that of the plate keel.
14.3.4.2 Where the hopper is extended outside 0.4L amidships, the thickness of side shell amidships is to be maintained for at least two frame spaces beyond both end bulkheads of the hopper and gradually tapered to the thickness of fore and aft ends of the ship.
14.3.4.3 The thickness of the shell plating in way of the suction pipe connections of trailing suction dredgers and in way of the positioning spuds of cutter suction dredgers or bucket dredgers, as well as the thickness of well bulkheads are to be 2 mm above that required for side shell.
14.3.4.4 In areas where the drag head may run against bilge and side shell, strengthening is to be provided, e.g. plating of increased thickness, additional framing or fitting of fenders.
14.3.4.5 Where suction pipe ladder wells cut into shell plating are provided at the side of trailing suction dredgers, a sheathing long enough along the length of the ship is to be provided. The sheathing thickness is not to be less than that of shell plating, and the sheathing breadth is to cover the ladder wells. The sheathing is to be strengthened by side transverses and stringers at its inner side. The stringers are to be sufficiently sized to bear the load transferred from side longitudinals so as to keep the continuity of longitudinal structural members.
14.3.4.6 The well width of bucket dredgers is to be such that the overhanging part of the bucket chain will not chafe the lower well wall under the maximum allowable working inclination of the hull.
14.3.4.7 The thickness of the bottom shell of bucket dredgers that is connected to end well bulkheads is to be increased by 50% for a distance not less than twice the well width along the breadth of the ship, and for at least two frame spaces from both end bulkheads along the length of the ship.
14.3.4.8 Fenders are to be fitted to the longitudinal bulkheads of wells in bucket dredgers to guard against damages due to the movement of bucket ladders.

Section 4 DECKS AND DECK FRAMING

14.4.1 Strength deck

14.4.1.1 The thickness of midship strength deck plating is, in addition to complying with the requirements of Section 2 of this Chapter, is to be increased by 1 mm above that required in Section 4, Chapter 2 of this PART.

14.4.1.2 In the case of dredgers having closed hopper spaces, the thickness of deck plating in way of the hopper spaces is to be adequately increased.

14.4.2 Half sectional area of deck

14.4.2.1 For dredgers and hopper barges less than 65 m in length, the half sectional area a of midship strength deck plating is not to be less than that obtained from the following formula:

For box-shaped ship:

$$a = C_1 \frac{B}{D} - C_2 D t_1 + C_3 (B - b)\, t_2 \quad \text{cm}^2$$

For hopper barge:

$$A = C_1 \frac{B}{D} - 1.6 D t_1 - 3.05 D t_3 \quad \text{cm}^2$$

where: B — breadth of ship, in m;

D — moulded depth, in m;

b — the width of well or opening at the midship bottom, in m;

t_1 — the thickness of side shell required in 2.3.4 of Section 3, Chapter 2 of this PART, in mm, t_1 is to be included in the thickness of longitudinal bulkheads for ships having continuous longitudinal bulkheads within 0.4L amidships;

t_2 — the thickness of continuous inner bottom plating within 0.4L amidships, in mm;

t_3 — the thickness of web of continuous longitudinal hatch coamings, in mm;

C_1 = $0.065L^2 - L + 9$ (L being length of ship, in m);

C_2, C_3 — coefficient, to be taken from Table 14.4.2.1.

Values of C_2 and C_3 **Table 14.4.2.1**

Type of ship structure	C_2	C_3
Box-shaped ship without continuous longitudinal bulkhead within 0.4L amidships	2.15	0.32
Box-shaped ship with continuous longitudinal bulkheads within 0.4L amidships	3.07	0.205

The above-mentioned half sectional area of deck plating is the sum of sectional areas of continuous longitudinal members, such as deck plating, stringer strakes, deck longitudinals and deck girders, outside the lines of large openings and at one side of the longitudinal midship line of the deck. For longitudinal cross beams having smooth transition at both ends, 60% of their sectional areas may be included.

The thickness of deck plating derived from the half sectional area of decks is not subject to reduction for service categories.

14.4.3 Deck framing

14.4.3.1 Where the deck of side tanks is framed transversely, deck transverses are to be fitted in the plane of web frames in the side tanks, the web height of which is to be 2/3 of that of the web frame, and the web thickness and the face plate area of which are to be the same as those of the web frame.

14.4.3.2 For dredgers having a closed hopper space, the section modulus of deck framing within the hopper region is to be increased by 10% of that required in Section 8, Chapter 2 of this PART.

14.4.3.3 For trailing suction dredgers, the section modulus of deck longitudinals within the hopper and side tank region is to be increased by 20% of that required in Section 8, Chapter 2 of this PART.

14.4.4 Local strengthening

14.4.4.1 For bucket and cutter suction dredgers, the thickness of deck plating connected with the well bulkheads is to be increased by 1 mm, and the width of which is not to be less than that of the plate keel.

14.4.4.2 The plate thickness and framing design of decks connected with heavy dredging machinery seats are to provide sufficient strength and rigidity and where necessary, local strength is to be checked, see the requirements of 14.10.6 of Section 10.

14.4.4.3 The deck plating and deck framing in the following regions are to be sufficiently strengthened:

(1) in way of the main gantry and the bucket ladder gantry;

(2) in way of cutter ladders and of supporting of the gantry (the region in way of supporting of the hydraulically lifted cutter ladders is to have sufficient strength and rigidity and where necessary, local strength is to be checked);
(3) in way of the gantry supporting the suction pipe;
(4) in way of supporting of the spud;
(5) in way of towing bollards;
(6) in way of the winch seating;
(7) in way of the grab machinery;
(8) the thickness of stringer strakes in way of suction pipe ladder wells of trailing suction dredgers is to be increased by 60%, and the increased thickness is to be maintained for at least one frame space from the side transverse at both ends of the well;
(9) in way of other working regions of machinery.

Section 5 BOTTOM FRAMING

14.5.1 General requirements

14.5.1.1 The bottom framing in pump rooms is to be strengthened in accordance with the requirements for machinery spaces.
Where the double bottom is interrupted in the pump room due to the arrangement of dredging pumps, the bottom framing in way is to be specially strengthened.
The requirements for dredging pump seatings are not to be inferior to those for main engine seatings specified in Section 16, Chapter 2 of this PART.
Where the bottom framing is connected with the seatings of other dredging equipment or special machinery, and with the bottom table of grabs or dipper machines as well as the main gantry of bucket dredgers, such bottom framing is to be adequately strengthened.
14.5.1.2 For trailing suction dredgers of 65 m or over in length, a double bottom is, as far as possible, to be arranged from the fore peak bulkhead to the after peak bulkhead except the region of hopper spaces.
14.5.1.3 The double bottom structure is to comply with the requirements of Section 6, Chapter 2 of this PART.
For double bottoms framed longitudinally, the spacing of plate floors is, furthermore, to comply with the requirements for the spacing of web frames in 14.6.2.1, Section 6 of this Chapter.
14.5.1.4 The bottom longitudinal members in hoppers that are tapered to both ends are to be continuous. Additional side girders are to be fitted in the double bottom below the bracket of hopper longitudinal bulkheads and longitudinal well bulkheads. The additional side girders are to be extended for at least 3 frame spaces from the end of brackets.

14.5.2 Single bottom with transverse framing

14.5.2.1 Plate floors are to be fitted to each frame at both sides of side tanks and wells.
The section modulus W, web height h and web thickness t of plate floors are not to be less than those obtained from the following formulae:

$$W=(16.4sdl^2+150)K \quad \text{cm}^3$$
$$h = 110l \quad \text{mm}$$
$$t = (0.01h + 3.5)\sqrt{K} \quad \text{mm}$$

where: s — spacing of floors, in m;
K — material factor;
d — draught, in m;
l — span of floor, in m, the distance measured from the inner surface of shell plating along the face plate of floors to the inner surface of the longitudinal bulkhead or side well bulkhead of the hopper, taken as $0.3B$ for $l < 0.3B$, (B being the breadth of ship, in m).

14.5.2.2 Where the distance between the ship's side and the side bulkhead of the hopper at the bottom exceeds 3.5 m, a side keelson is to be fitted in side tanks. The thickness of the side keelson is to be equal to that of the floor in way.

14.5.3 Single bottom with longitudinal framing

14.5.3.1 The section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 11.5sdl^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
K — material factor;
d — draught, in m;
l — span of longitudinal, in m.

The connection of bottom longitudinals to transverse bulkheads or floors is to comply with the requirements of 1.2.6 of Section 2, Chapter 1 of this PART.

14.5.3.2 The section modulus W of floors in side tanks is not to be less than that obtained from the following formula:

$$W = 16.4SdlK \quad \text{cm}^3$$

where: S — spacing of floors, in m;
K — material factor;
d — draught, in m;
l — span of floor, in m, the distance measured from the inner surface of shell plating along the face plate of floors to the inner surface of the hopper longitudinal bulkhead.

The depth of the web of floors in side tanks is not to be less than 1/9 of the span of the floor, and is not to be less than 2.5 times the depth of the slot for the passage of bottom longitudinals. The thickness of the web of floors is not to be less than 0.01 times the depth of the floor plus 4.5 mm.

Where one side keelson is fitted in the side tank, the section modulus of the floors may be reduced by 5%.

14.5.3.3 For box-shaped ships fitted with two longitudinal bulkheads, the floors in side tanks are to comply with the requirements of 14.5.3.2 of this Section.

The section modulus W of floors in the center tank is not to be less than that obtained from the following formula:

$$W = 9SdlK \quad \text{cm}^3$$

where: S — spacing of floors, in m;
K — material factor;
d — draught, in m;
l — span of floor in the center tank, in m, the distance between the longitudinal bulkheads.

The section modulus of floors in the center tank is also not to be less than that of floors in the side tanks. The depth of the web of floors in the center tank is not to be less than 1/12 of the span of the floor, and is not to be less than 2.5 times the depth of the slot for the passage of bottom longitudinals. The thickness of the web of floors is not to be less than 0.01 times the depth of the floor plus 4.5 mm.

14.5.3.4 Vertical stiffeners are to be fitted to the web of floors in way of every bottom longitudinal. The thickness of stiffeners is to be equal to that of the web of floors, and the width is to be 8 times its thickness.

14.5.4 Double bottom with transverse framing

14.5.4.1 Where the distance between the ship's side and the side bulkhead of the hopper at the bottom exceeds 3.5 m, side girders are to be fitted in side tanks, and the thickness of the side girders is to be equal to that of floors in way.

14.5.5 Double bottom with longitudinal framing

14.5.5.1 The section modulus W of bottom longitudinals is not to be less than that required in 14.5.3.1 of this Section.

The section modulus of inner bottom longitudinals is not to be less than 85% of that of bottom longitudinals.

Section 6 SIDE FRAMING

14.6.1 Transverse side framing

14.6.1.1 Side stringers are, as far as practicable, to be fitted in side tanks of hopper barges.

14.6.2 Longitudinal side framing

14.6.2.1 The spacing of web frames is not to be more than $0.01L + 2.5$ m (L being the length of ship, in m). For trailing suction dredgers, the spacing of web frames is also to comply with the requirements for the spacing of hopper strength frame rings.

The section modulus of web frames is to be determined in accordance with the requirements of 2.7.6.2 of Section 7, Chapter 2 of this PART.

Where horizontal cross ties and diagonal braces complying with the requirements of 14.6.3 of this Section are fitted, the section modulus of web frames may be reduced by 50%.

14.6.2.2 Tripping brackets are to be fitted to web frames in way of the cross ties and other positions in accordance with the requirements of 1.2.5.4 of Section 2, Chapter 1 of this PART.

14.6.3 Horizontal cross ties and diagonal braces

14.6.3.1 Where horizontal cross ties or diagonal braces are fitted in the side tanks, the sectional area A and moment of inertia I of which are not to be less than those obtained from the following formulae:

$$A=(1.5abh+10)K \quad \text{cm}^2$$

$$I = 3Al^2/K \quad \text{cm}^4$$

where: a — spacing of cross ties or braces, in m;

b — width supported by the cross tie or brace, in m, i.e. half the sum of lengths of the frame above and below the intersected cross tie or brace;

K — material factor;

h — pressure head under consideration, in m, the distance measured from the supporting point to the top of air pipe;

l — length of the cross tie or brace including the bracket, in m.

Section 7 BOTTOM STRENGTHENING FOR OPERATING AGROUND

14.7.1 Application

14.7.1.1 Where the dredgers are to operate aground or are allowed to be run aground in operation, the bottom structure is to comply with the requirements this Section.

14.7.2 Bottom structure strengthening

14.7.2.1 The thickness of bottom plating is to be 20% more than that required in 2.3.1.2 and 2.3.1.3 of Section 3, Chapter 2 of this PART.

14.7.2.2 Transversely framed single bottom structures are to be strengthened as follows:

(1) Vertical stiffeners are to be fitted at bottom floor webs, spaced not greater than 1.25 m;

(2) The spacing of side keelsons is not to be greater than 2.2 m, and intermediate bulb plate longitudinals with webs of 100 mm × 10 mm or equivalent members are to be fitted.

14.7.2.3 Longitudinally framed single bottom structures are to be strengthened as follows:

(1) Bottom floors are to be spaced generally not greater than 3 frame spacings, and vertical stiffeners having the same thickness as that of bottom floors are to be fitted at bottom longitudinals;

(2) The spacing of side keelsons is not to be greater than 3 bottom longitudinal spacings;

(3) Intercostal frames are to be fitted at the midspan of bottom longitudinals.

14.7.2.4 Transversely framed double bottom structures are to be strengthened as follows:

(1) Solid bottom floors are to be fitted at each frame, with vertical stiffeners spaced generally not greater than 1.25 m;

(2) The spacing of side girders is not to be greater than 2.2 m, and bottom longitudinals are to be fitted at the mid-spacing of bottom girders. The section modulus of bottom longitudinals is to be referred to 2.6.12.2 of Section 6, Chapter 2 of this PART.

14.7.2.5 Longitudinally framed double bottom structures are to be strengthened as follows:

(1) Solid floors are to be spaced generally not greater than 3 frame spacings, and vertical stiffeners having the same thickness as that of solid floors are to be fitted at bottom longitudinals;

(2) The spacing of side girders is generally not to be greater than 4 bottom longitudinal spacings;

(3) Intercostal frames are to be fitted at the midspan of bottom longitudinals.

Section 8 HOPPERS

14.8.1 Application

14.8.1.1 The requirements of this Section for bottom framing are applicable to box-shaped single-bottom hoppers.

14.8.2 Box keels

14.8.2.1 The thickness of side plates and the section modulus of stiffeners of box keels are to comply with the relevant requirements of this Section for hopper bulkheads. Box keels are to be adequately strengthened in way of the hopper plate floors and the bottom end of pillars.
14.8.2.2 Where the box keel is interrupted at the hopper end bulkhead, transitional brackets of a length not less than two frame spaces are to be fitted or other effective means provided to ensure a smooth transition of the box keel.
14.8.2.3 A strength frame ring is to be provided to the box keel in the plane of hopper floors so as to ensure the continuity of transverse strength within the breadth of the ship.

14.8.3 Floors in hoppers (spoil spaces)

14.8.3.1 The depth of hopper floors is not to be less than $0.13B$ (B being the breadth of ship, in m). The spacing of the plate floors is not to be more than 4.5 m, and the spacing of box floors is generally not to be more than 6 m from centre to centre. Where the spacing of box floors is more than 6 m from centre to centre, the depth of the box floors is to be increased appropriately.
14.8.3.2 The web thickness of the plate floors is not to be less than that required in 14.3.1.1, Section 3 of this Chapter. The net cross-sectional area A of the web of plate floors after deducting openings, in the region for a distance equal to half depth of the floor from the ends of the calculated span, is not to be less than that obtained from the following formula:

$$A = 0.93(h_1 Sl - \alpha s_0 h_1 - \rho f S + 0.102p')K \quad \text{cm}^2$$

where: S — spacing of floors, in m;
K — material factor;
l — span of floor, in m, the mean value of the distances, measured between the hopper longitudinal bulkheads along the upper and lower edges of the floor respectively;
h_1 = $\rho(D + h_f) - d + 1.25$, in m, to be taken as d for $h_1 < d$;
ρ — density of spoil, in t/m³, see 14.8.4.2 of this Section;
D — moulded depth, in m;
h_f — vertical distance, in m, measured from the level of the overflow weir to the deck line at side; where the level of the overflow weir is below the deck line at side, the value h_f is negative;
d — draught, in m;
s_0 — area of bottom door, in m²;
f — cross sectional area of box keel, in m²;
p' — load on the pillar in one floor spacing, in kN, to be calculated according to the requirements of 14.8.8.2 of this Section;
α — coefficient:
for ram bottom door, $\alpha = 2$;
for hinged bottom door, $\alpha = 1$;
for drawer bottom door, $\alpha = 0$.

In other regions, the net cross-sectional area A may be reduced by 20%.
14.8.3.3 Vertical stiffeners are to be fitted to the web of plate floors, spaced not more than $80t$ apart (t being the thickness of web, in mm), and the section modulus W of stiffeners is not to be less than that obtained from the following formula:

$$W = 40slK \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;
K — material factor;
l — span of stiffener, in m.

The upper edge of floors is to be strengthened by means of a flat bar or rolled section.
14.8.3.4 The thickness of side plates of box floors and the section modulus of stiffeners are to comply with the relevant requirements of this Section for hopper bulkheads.

14.8.4 Hopper bulkheads

14.8.4.1 Watertight transverse bulkheads extending from starboard to port are to be provided at both ends of the hopper and the well end.
Both ends of hopper longitudinal bulkheads are to be further extended by means of upper and lower brackets. The upper brackets are to be connected to deck girders or the strength frame ring, while the lower brackets are to be connected to side keelsons or side webs. The length extended is not to be less than two frame spaces, and the height of the brackets is not to be less than 1/4 hopper depth.
14.8.4.2 The thickness t of hopper bulkhead plating is not to be less than that obtained from the following formula, and not less than 8 mm, or not less than 10 mm when a grab is used for loading and unloading:

$$t=3.95s\sqrt{\rho hK}+2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;
K — material factor;
ρ — density of spoil, in t/m³, $\rho = P/V$;
P — the maximum spoil mass, in t, in hopper at maximum dredging draft;
V — hopper volume, in m³, up to the sill of the uppermost overflow weir;
h — vertical distance, in m, measured from the lower edge of bulkhead plating to the level of the uppermost overflow weir, or to the upper edge of hopper coaming where no overflow weir is provided.

14.8.4.3 The thickness of the lowest plating of hopper bulkheads within the height of $0.1D$ from bottom is not to be less than that of the bottom plating in way, D being the moulded depth.

14.8.4.4 For those portions of hopper bulkheads that are liable to wear, a wear addition of 2 mm to the plate thickness may be considered in design.

14.8.4.5 The section modulus W and sectional moment of inertia I of hopper bulkhead stiffeners are not to be less than those obtained from the following formulae:

$$W=8s\rho hl^2K \quad \text{cm}^3$$
$$I = 2.3Wl/K \quad \text{cm}^4$$

where: s — spacing of stiffeners, in m;
K — material factor;
ρ — density of spoil, in t/m³, the same as that in 14.8.4.2;
h — vertical distance, in m, measured from the mid-span of the stiffener to the level of the uppermost overflow weir, or to the upper edge of hopper coaming where no overflow weir is provided;
l — span of stiffener, in m, or distance between the end of the stiffener and the girder or between girders where girders are fitted.

Where horizontal stiffeners are fitted, the scantlings of two top stiffeners are to be the same as those of the third one below the deck.

The ends of the stiffeners are to be bracketed. The scantlings of the brackets are to be determined according to 1.2.6 of Section 2, Chapter 1 of this PART.

14.8.4.6 The section modulus W and sectional moment of inertia I of hopper bulkhead girders are not to be less than those obtained from the following formulae:

$$W=11.7b\rho hl^2K \text{ cm}^3$$
$$I = 2.5Wl/K \quad \text{cm}^4$$

where: b — breadth of area supported by girder, in m;
K — material factor;
ρ — density of spoil, in t/m³, the same as that in 14.8.4.2;
h — vertical distance, in m, measured from the mid-span of the girder to the level of the overflow weir, or to the upper edge of hopper coaming where no overflow weir is provided;
l — span of girder, in m.

Where cross ties or braces are provided as required in 14.6.3, Section 6 of this Chapter, the section modulus of hopper bulkhead girders may be reduced by 50%.

14.8.4.7 The web depth of hopper bulkhead girders is not to be less than 2.5 times that of the cut-outs for the passage of bulkhead stiffeners. The breadth of the face plate of the girders is not to be greater than the web depth or 35 times the thickness of the face plate, whichever is the lesser.

14.8.4.8 Hopper bulkhead girders are to be fitted with tripping brackets as required in 1.2.5.4 of Section 2, Chapter 1 of this PART.

14.8.4.9 For trailing suction dredgers, the section modulus of hopper bulkhead stiffeners and girders may be reduced by 10% of that required in 14.8.4.5 and 14.8.4.6.

14.8.5 Transverse bulkheads and strength frame ring in side tanks

14.8.5.1 Transverse bulkheads or strength frame rings are to be fitted in the centre plane of hopper plate floors or box floors within side tanks.

The strength frame ring is to be composed of floors, web frames, vertical girders on the hopper longitudinal bulkhead, web beam and/or cross ties (if fitted), and the scantlings of which are to comply with the relevant requirements of this Chapter.

Where the spacing of floors in hopper spaces or of transverse bulkheads or strength frame rings in side tanks exceeds the specified limit, the transverse strength of the hopper region is to be checked.

14.8.5.2 Where the transverse bulkheads in side tanks are watertight or deep bulkheads, the bulkhead plating and stiffeners are to comply with the requirements of Section 12 or Section 13, Chapter 2 of this PART.

14.8.5.3 Where the transverse bulkheads in side tanks are non-watertight, the thickness t of bulkhead plating is not to be less than that obtained from the following formula:

$$t = 0.03L + 5.6 \quad \text{mm}$$

where: L — length of ship, in m.

The section modulus of stiffeners on the bulkhead may be deducted by 40% from that of the stiffeners on the watertight bulkhead. Stiffeners are to be fitted with brackets at both ends. However, the sectional area of the stiffeners supporting longitudinals, girders etc. is also to comply with the requirements of Section 11, Chapter 2 of this PART.

14.8.5.4 The transverse bulkheads in side tanks are to be adequately strengthened in way of the connection with the hopper floors.

14.8.6 Hopper web beams and cross beams

14.8.6.1 Web beams or cross beams are to be fitted in the plane of floors in the hoppers (spoil spaces).

14.8.6.2 The section modulus W of hopper web beams is not to be less than that obtained from the following formula:

$$W = (5.75Shl^2 + 0.102CFl)\,K \quad \text{cm}^3$$

where: S — spacing of web beams, in m;

K — material factor;

h — pressure head under consideration, in m, to be taken in accordance with 2.8.1.1 of Section 8, Chapter 2 of this PART;

l — span of web beam, in m, the distance between hopper longitudinal bulkheads where no intermediate pillar is fitted, or the distance between the hopper longitudinal bulkhead and the centreline of the intermediate pillar where an intermediate pillar is fitted;

F — maximum mechanical acting force, in kN, when the bottom door is opened or closed;

C — coefficient:

with intermediate pillar, $C = 100K(1 - K)^2$;

without intermediate pillar, $C = 100K(1 - K)$

where K is the ratio of the distance between the point of the acting force and the nearest end to l.

14.8.6.3 The section moment of inertia I of the hopper web beam is not to be less than that obtained from the following formula:

$$I = 2Wl/K \quad \text{cm}^4$$

where: W, l, K are same as defined in 14.8.6.2 of this Section.

The web depth of hopper web beams is not to be less than twice that of the slot for the passage of longitudinals, and the web thickness is not to be less than 1% of the web depth plus 4 mm.

14.8.6.4 The connection of the hopper web beam to the hopper longitudinal bulkhead is to comply with the requirements of 2.8.7.9 of Section 8, Chapter 2 of this PART.

14.8.6.5 The section modulus W of cross beams is to comply with the requirements of 14.8.6.2 of this Section, where S and l are respectively the face plate breadth and the span of cross beams, in m; where no intermediate pillar is fitted, the span l is the distance between hopper longitudinal bulkheads and where an intermediate pillar is fitted, l is the distance measured from the hopper longitudinal bulkhead to the centreline of the pillar.

Where cross beams support the crane and/or suction pipes, the section modulus is to be increased and is to be determined through calculation. Both ends of the cross beam are to be assumed as rigidly fixed in calculation, and the allowable bending stress is to be taken as $98/K$ N/mm^2.

The total net sectional area A of cross beams after deducting openings is not to be less than that obtained from the following formula:

$$A = 2S(C_1D^2 + C_2l^2) + 20)\,K \quad \text{cm}^2$$

where: S — spacing of floors, in m;

K — material factor;

D — moulded depth, in m;

l — span of floor, in m, to be measured in accordance with the requirements of 14.8.3.2 of this Section;

C_1, C_2 — coefficients, to be taken from Tables 14.8.6.5(1) and (2). Where the value of $C_1D^2 + C_2l^2$ is negative, to be taken as an absolute value.

Value of C_1 **Table 14.8.6.5(1)**

d_1/D \ $(D + h_f)/D$	1.0	1.1	1.2	1.3	1.4	1.5
0.4	-0.1849	-0.2637	-0.3616	-0.4804	-0.6222	-0.7890
0.5	-0.1808	-0.2596	-0.3575	-0.4763	-0.6181	-0.7850
0.6	-0.1727	-0.2515	-0.3494	-0.4682	-0.6100	-0.7768
0.7	-0.1593	-0.2381	-0.3360	-0.4548	-0.5966	-0.7634
0.8	-0.1394	-0.2182	-0.3161	-0.4350	-0.5767	-0.7435

Value of C_2 **Table 14.8.6.5(2)**

d_1/D \ $(D + h_f)/D$	1.0	1.1	1.2	1.3	1.4	1.5
0.4	0.1157	0.1327	0.1497	0.1667	0.1837	0.2007
0.5	0.1083	0.1253	0.1423	0.1593	0.1763	0.1933
0.6	0.1010	0.1180	0.1350	0.1520	0.1690	0.1860
0.7	0.0937	0.1107	0.1277	0.1447	0.1617	0.1787
0.8	0.0864	0.1034	0.1204	0.1374	0.1544	0.1724

Note: $d_1 = d - 1.25$, in m; h_f — see 14.8.3.2 of this Section; C_2 taken from the Table is to be increased by 15% for hinged bottom door.

For $C_1D^2 + C_2l^2 > 0$, the minimum moment of inertia I of cross beams is not to be less than that obtained from the following formula:

$$I = 3Al_1^2/K \quad \text{cm}^4$$

where: A — total sectional area of the cross beam, in cm²;
K — material factor;
l_1 — span of cross beam, in m.

Where the floors in the hopper are spaced more than 4 m apart, the scantlings of the cross beams are to be verified by direct calculation, with openings being deducted from the sectional area. The assumptions for the calculation model and the permissible stresses are the same as above.

14.8.7 Deck girders and longitudinal cross beams

14.8.7.1 The section modulus W of deck girders or longitudinal cross beams supporting the opening/closing mechanism for the bottom doors is not to be less than that obtained from the following formula:

$$W = (5.3bhl^2 + 1.94Fl)\,K \quad \text{cm}^3$$

where: b — mean width of deck area supported by the deck girder, in m, for longitudinal cross beams b being the width of the face plate, in m;
h — pressure under consideration, in m, to be determined according to 2.8.1.1 of Section 8, Chapter 2 of this PART;
K — material factor;
l — span of deck girder or longitudinal cross beam, in m;
F — maximum mechanical acting force, in kN, when the bottom door is opened or closed.

14.8.8 Pillars

14.8.8.1 Where a box keel is fitted, pillars are, in general, to be fitted for connecting the hopper floors to hopper web beams or cross beams. The scantlings of steel tubular pillars are to comply with the requirements of 2.10.2.1 and 2.10.3.1 of Section 10, Chapter 2 of this PART, except that the wall thickness of which is to be 1 mm more than that obtained from 2.10.3.1 of this PART, and not to be less than 7 mm.

14.8.8.2 The load P' supported by the pillar is not to be less than that obtained from the following formula:

$$P' = 7.06abh + \frac{2Fe}{l} + \Delta P \quad \text{kN}$$

where: a — length of deck area supported by the pillar under consideration, in m, or width of the face plate for cross beams;
b — width of deck area supported by the pillar under consideration, in m, or half the length of the face plate for cross beams;
h — considered pressure head of the deck supported by the pillar under consideration, in m, to be taken according to 2.8.1.1 of Section 8, Chapter 2 of this PART;

F — maximum mechanical acting force, in kN, when the bottom door is opened or closed;
e — distance measured from the point of the mechanical acting force to the end of web beam, in m, when the bottom door is opened or closed;
l — span of the web beam or cross beam, in m;
ΔP — the acting force on the crane and/or suction pipe supported by pillars, in kN.

14.8.9 Continuous coamings

14.8.9.1 Coamings are to have a plate thickness of not less than that obtained from 14.8.4.2 of this Section for the longitudinal bulkhead strakes in hoppers.

Horizontal stiffeners of the coaming are to be spaced apart not more than 80 times the plate thickness of the coaming for the lower panel of plating, and not more than 65 times the plate thickness of the coaming for the upper panel of plating. The moment of inertia I of the horizontal stiffener is not to be less than that obtained from the following formula:

$$I = 2Al^2 \quad \text{cm}^4$$

where: A — total sectional area of the horizontal stiffener with attached plating, in cm^2;
l — spacing of coaming brackets, in m.

14.8.9.2 The coamings are to be extended beyond both ends of the hopper for a distance of at least 1.5 times the coaming height in general.

14.8.9.3 The upper edge of the coaming is to be stiffened by a fabricated flange, or an equivalent structure capable of achieving a good rigidity of the coaming.

14.8.9.4 The coaming brackets are to be arranged in way of each deck transverse. The thickness of brackets is to be equal to that of the coaming plating. The width of the lower end of brackets is not to be less than 1/3 times the height of the coaming plating. Where the coaming and the hopper longitudinal bulkhead are not in the same plane, the breadth of the lower end of brackets is not to be less than twice the distance between the hopper longitudinal bulkhead and the coaming, and supporting brackets having a thickness equal to that of the coaming are to be fitted within the hopper in the same plane of coaming brackets. The brackets are to have a flange or face plate with a width 10 times their thickness.

Section 9 SPLIT HOPPER DREDGERS AND BARGES

14.9.1 General requirements

14.9.1.1 This Section applies to self-propelled or non-self-propelled steel split hopper barges and dredgers with a single deck. Those not covered in this Section are to comply with other applicable requirements of this Chapter.

14.9.1.2 A chain locker and a chain are usually to be provided on each half hull. For split hopper barges, only a single windlass may be provided on one of the half hulls. However, an appropriate guide gear is to be fitted so as to retract and release conveniently the chain on the other half hull.

Unmanned split hopper barges may be provided with only a single bower anchor. The length of the chain may be half the length as specified.

14.9.1.3 A rudder and a steering gear are to be provided on each half hull, and an automatic system for synchronized operation of both rudders is to be provided.

14.9.1.4 Where the hopper extends beyond 0.4L amidships, the thickness of shell plating and deck plating amidships is to be maintained for two frame spaces from hopper end bulkheads and gradually tapered in the fore and aft direction.

14.9.1.5 Shell plating and longitudinals in bilge areas are to be sufficiently strengthened.

14.9.1.6 In addition to the grades of steel required in 1.3.2 of Section 3, Chapter 1 of this PART, grade D steel is to be adopted for the plates bearing high stresses (reaction forces of hinges, hydraulic installations, load-bearing plates, etc.) and having a thickness greater than 20 mm, and grade E steel is recommended where the thickness of such plates is greater than 40 mm.

14.9.1.7 For solid floors in each half hull, B in the formula may be taken as the breadth of the half hull when it is calculated according to 2.5.4.1, Section 5, Chapter 2 of this PART.

14.9.2 Longitudinal strength

14.9.2.1 The midship section modulus of split hopper barges and dredgers of 65 m or over in length is to comply with the requirements of 14.2.2.1(1), Section 2 of this Chapter. The semi-sectional area of the midship strength deck of split hopper barges and dredgers less than 65 m in length is to comply with the requirements of 14.4.2.1, Section 4 of this Chapter.

14.9.2.2 For all split hopper barges and dredgers, the longitudinal strength of half hulls is to be checked for transit and dredging conditions, taking the influence of departure and arrival into account.

14.9.2.3 The longitudinal bending stress at any point of the cross section of half hulls within 0.4L amidships is to be obtained from the following formula, and not to be greater than 175/K, in N/mm², where K is material factor:

$$\sigma = \left(\frac{M_X}{I_X} Y - \frac{M_Y}{I_Y} X \right) \times 10^5 \quad \text{N/mm}^2$$

where: M_X, M_Y — bending moment about main axis of inertia, in kN · m, to be calculated in accordance with 14.9.2.4;

X, Y — coordinate value of the considered point in coordinate system GXY of main axis of inertia, in m, see Figure 14.9.2.3;

I_X, I_Y — moment of inertia about main axis of inertia, in cm⁴.

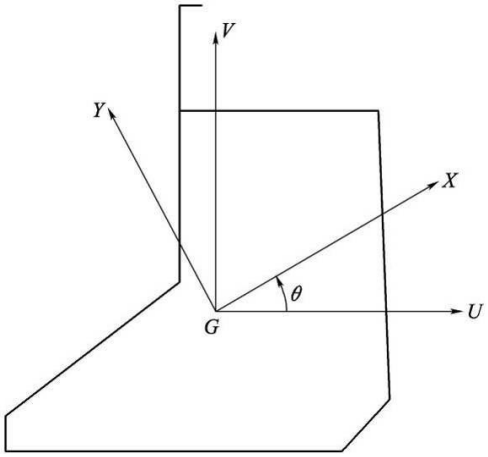


Figure 14.9.2.3

14.9.2.4 Bending moments M_X and M_Y about the main axis of inertia (GX, GY) of half hulls are to be obtained from the following formulae:

$$M_X = M_u \cos\theta + M_v \sin\theta \quad \text{kN} \cdot \text{m}$$
$$M_Y = -M_u \sin\theta + M_v \cos\theta \quad \text{kN} \cdot \text{m}$$

where: M_u, M_v — vertical bending moment and horizontal bending moment of section, in kN·m, respectively.

14.9.2.5 The vertical bending moment acting on half hulls in the midship area is to be obtained from the following formulae:

For transit condition: $M_u = 0.5(M_s + M_{wv})$ kN · m

For dredging condition: $M_u = 0.5(M_{sd} + M_{wv})$ kN · m

where:

M_s, M_{sd} — the maximum vertical still water bending moment under corresponding conditions, in kN · m, hogging moment being positive while sagging moment being negative;

M_{wv} — vertical wave bending moment, to be calculated in accordance with 2.2.3.1 of Section 2, Chapter 2 of this PART.

14.9.2.6 The horizontal bending moment acting on half hulls in the midship area is to be determined by the following formulae:

For transit condition: $M_v = M_{sH} + M_{wH}$ kN · m

For dredging condition: $M_v = M_{sHd} + M_{wH}$ kN · m

where: M_{wH} — horizontal wave bending moment, in kN · m, the positive and negative values being the same as those of M_{sH} or M_{sHd}, calculated in accordance with the following formula:

$M_{wH} = \pm 0.2\, L^{2.25}(d + 0.3B)C_b$ kN · m

where: L — length of ship, in m;

B — breadth of ship, in m;

d — draft under corresponding condition, in m;

C_b — block coefficient under corresponding condition;

M_{sH} — horizontal still water bending moment under transit condition, in kN · m, generally $M_{sH} = 0$;

M_{sHd} — horizontal still water bending moment under dredging condition, in kN · m. Where side edge is compressed, the horizontal still water bending moment is positive; where side edge is tensed, the horizontal still water bending moment is negative, calculated in accordance with the following formula:

$$M_{sHd} = \pm 0.125\, PL_p\,(2L_d - L_p) \quad \text{kN} \cdot \text{m}$$

where: L_p — length of hopper, in m, see Figure 14.9.2.6;

L_d — spacing of deck hinges, in m, see Figure 14.9.2.6;

P — horizontal load per unit length, in kN/m, calculated in accordance with the following formula:

$$P = 4.9\rho\,(h_1 - a)^2 - 5.0(d - a)^2$$

where: ρ — density of spoil, in t/m³, the same as that in 14.8.4.2;

h_1 — maximum height of spoil loaded above baseline, in m;

a — height of bottom sealing installation, in m;

d — draft under corresponding condition, in m.

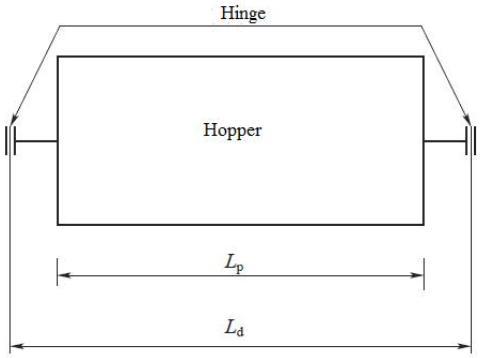


Figure 14.9.2.6

14.9.3 Deck hinges and hydraulic installations

14.9.3.1 The hydraulic installations connecting two half hulls is to have sufficient power so as to ensure that the half hulls can be opened and closed efficiently under any predicted sea conditions and that the half hulls will not be accidentally parted due to motion and vibration of the ship.

14.9.3.2 Local structures in way of connection to deck hinges and hydraulic installations are to be sufficiently strengthened, and are to efficiently transmit the load to the hull structure.

14.9.3.3 The scantlings of the members connecting deck hinges and hydraulic installations to two half hulls are to be determined by direct calculation. The load acting on such members is to be determined in accordance with the appropriate combination of predicted maximum static load and dynamic load under different design conditions.

14.9.3.4 The combined force F_h born by deck hinges under different design conditions is to be calculated in accordance with the following formula:

$$F_h = \sqrt{(F_{sh} + F_{dh})^2 + F_{dv}{}^2} \quad \text{kN}$$

where: F_{sh} — horizontal static force of deck hinges, in kN, to be calculated in accordance with 14.9.3.6(1) of this Section;

F_{dh} — horizontal dynamic force of deck hinges, in kN, to be calculated in accordance with 14.9.3.7 of this Section;

F_{dv} — vertical dynamic force of deck hinges, in kN, to be calculated in accordance with 14.9.3.7 of this Section.

14.9.3.5 The horizontal force F_r born by hydraulic installations under different design conditions is to be calculated in accordance with the following formula:

$$F_r = F_{sr} + F_{dr} \quad \text{kN}$$

where: F_{sr} — horizontal static force of hydraulic installations, in kN, to be calculated in accordance with 14.9.3.6(2) of this Section;

F_{dr} — horizontal dynamic force of hydraulic installations, in kN, to be calculated in accordance with 14.9.3.7 of this Section.

14.9.3.6 The horizontal static force of deck hinges and hydraulic installations is to be determined as follows:

(1) Horizontal static force F_{sh} of hinges:

$$F_{sh} = 0.5\left[F_w - F_s + 2(1-\frac{h_4}{h_5})F_{sr} + \frac{M}{h_5}\right] \quad \text{kN}$$

where: F_w — external still water pressure within hopper, in kN, to be calculated by the following formula:

$$F_w = 5.0(d-a)^2 L_p$$

F_s — horizontal pressure of spoil, in kN, to be calculated by the following formula:

$$F_s = 4.9\rho(h_1-a)^2 L_p$$

ρ, h_1, d, a, L_p — the same as those in 14.9.2.6;

F_{sr} — horizontal action force of hydraulic installations, in kN, to be determined according to (2) below;

M — moment, in kN · m, positive for opened half hull and negative for closed hull, determined by the following formula:

$$M = F_s h_2 - F_w h_3 + \Delta b_1 - W_l b_2 - W_s b_3$$

h_2 — vertical distance from horizontal pressure of spoil to hinge point, in m;

h_3 — vertical distance from external still water force to hinge point, in m;

h_4 — vertical distance from horizontal force of hydraulic installation to hinge point, in m;

h_5 — vertical distance from deck hinges to baseline, in m;

Δ — still water buoyancy of loaded half hull, in kN;

W_l — gravity of empty half hull, in kN;

W_s — gravity of half hull spoil, in kN;

b_1, b_2, b_3 — horizontal distance from Δ, W_l, W_s to hinge point respectively. See Figure 14.9.3.6.

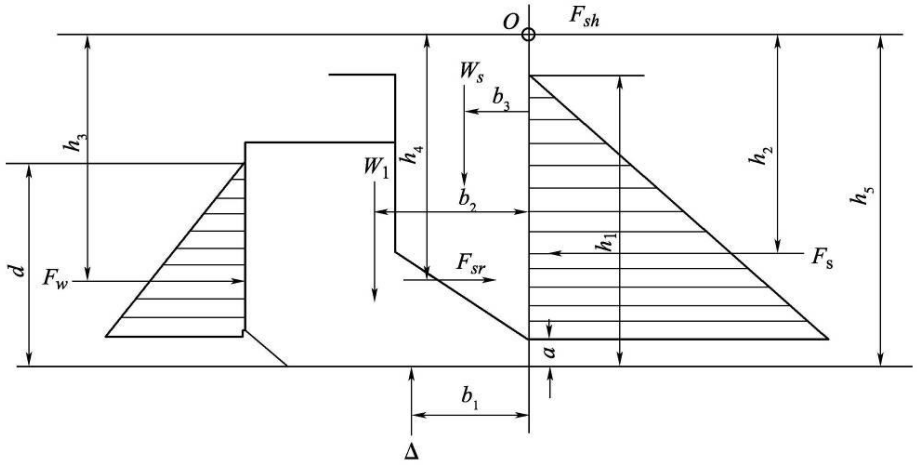


Figure 14.9.3.6

(2) The horizontal static force F_{sr} of hydraulic installations is equal to the pressure F_P acting on the end surface of the hydraulic cylinder piston, in kN, and its moment about the hinge point is to be equal to or more than the opening moment M so as to ensure the closure of two half hulls, i.e.:

$$F_{sr} = F_p \geq \frac{M}{2h_4} \quad \text{kN}$$

14.9.3.7 The dynamic load induced by the ship's motions in waves and acting on deck hinges and hydraulic installations is to be obtained from the dynamic calculation and statistic analysis in accordance with sea conditions for predicted operations. Where the significant wave height is no more than 3 m in sea conditions for predicted operations, the dynamic load may also be calculated in accordance with the following formulas:

Horizontal dynamic force of deck hinges: $F_{dh} = 0.28 f B^2 L$ kN

Vertical dynamic force of deck hinges : $F_{dv} = 0.055 f B^2 L^2 / d$ kN

where: L——ship length, in m;

B——ship width, in m;

d——distance between deck hinges, in m;

f——coefficient, taken f=1.5.

14.9.3.8 The formulae in 14.9.3.6 of this Section are only applicable to such condition where one deck hinge and one hydraulic installation are respectively fitted at both ends of the hopper. Where the number of

hinges and/or hydraulic installations are not the same, the calculation regarding systems of static and dynamic forces acting on the hull is required.

14.9.3.9 The scantlings of different parts of hinges are to be obtained as follows:

(1) The diameter d of the hinge pin is not to be less than that obtained from the following formulae:

$$d_1 = 54\sqrt{\frac{F}{R_{eH}}} \quad \text{mm}$$

$$d_2 = 13.2\sqrt[3]{\frac{F(2a - t_{2c})}{R_{eH}}} \quad \text{mm}$$

where: F — resultant force of hinges, in kN, to be calculated in accordance with 14.9.3.4 of this Section;

a — distance, in mm, between inner edges of eye plates at both sides or between inner edges of bushes of eye plates at both sides;

t_{2c} — length of contact, in mm, between centre eye plate or its bush and hinge pin;

R_{eH}— yield strength of hinge pin material, in N/mm².

(2) Eye plates are to comply with the following:

For centre eye plates: $b_{2c}t_{2c} + b_{1c}t_{1c} \geq \dfrac{2500\ F}{R_{eH}}$ mm²

For side eye plates: $b_{2s}t_{2s} + b_{1s}t_{1s} \geq \dfrac{1250\ F}{R_{eH}}$ mm²

where: F — the same as that in (1);

R_{eH}— yield strength of the material of eye plates, in N/mm²;

b_{1c}, b_{2c}, b_{1s}, b_{2s}, t_{1c}, t_{2c}, t_{1s}, t_{2s}, — see Figure 14.9.3.9.

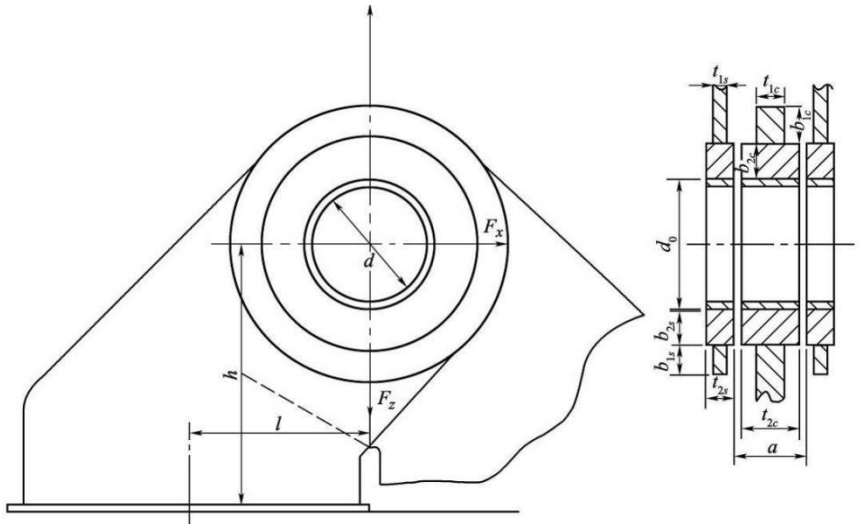


Figure 14.9.3.9

(3) The section of connection of centre eye plate and side eye plates to deck is to comply with the following formula:

$$\left(\frac{F_z}{A} + \frac{F_x h + F_z l}{W}\right) \times 10^3 \leq 0.6R_{eH} \quad \text{N/mm}^2$$

where: F_x — horizontal force of hinges, in kN, to be obtained from the following formula:

$$F_x = F_{sh} + F_{dh}$$

F_z — vertical force of hinges, in kN, to be obtained from the following formula:

$$F_z = F_{dv}$$

h — vertical distance from pintle centre to deck, in mm;

l — horizontal distance from centre of the hinge pin to sectional neutral axis, in mm;

A — sectional area, in mm²;

W — section modulus, in mm³;

R_{eH} — yield strength of the material of eye plates, in N/mm².

14.9.4 Hinges of deckhouses

14.9.4.1 The load acting on deckhouses is to be determined in accordance with the loading condition and movement of the ship.

14.9.4.2 The force born by deckhouses may be divided into three component forces of F_x, F_y and F_z, as shown in Figure 14.9.4.2, where OX is the central axis of rolling; F_x, F_y and F_z are acting at the centre of gravity of deckhouses.

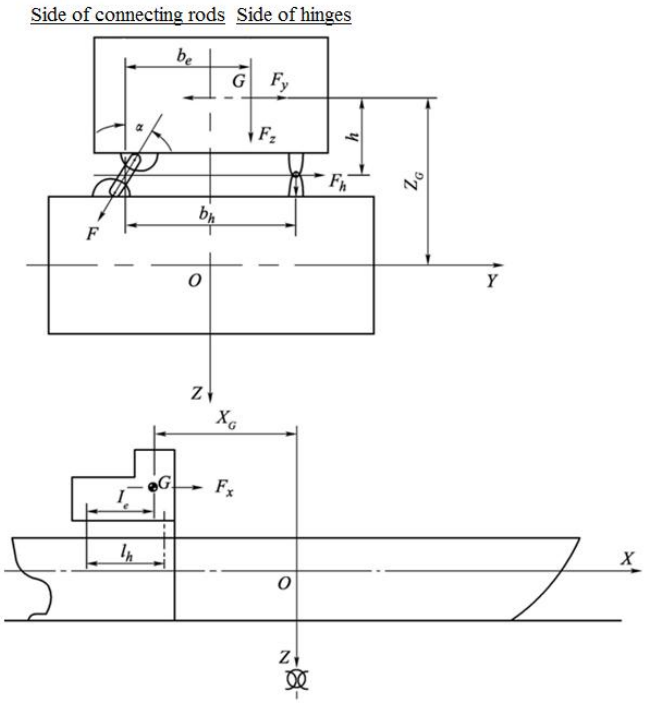


Figure 14.9.4.2

14.9.4.3 The distance from the central axis of rolling to baseline may be taken as the lesser of $\frac{D}{4}+\frac{d}{2}$ and $\frac{D}{2}$,where D and d are moulded depth and draft respectively, in m.

14.9.4.4 The longitudinal and transverse component forces F_x, F_y parallel to deck and the vertical component force F_z normal to deck are to be obtained from the following formulae:

$$F_x = Mg\,(0.19 + 0.026\,Z_G) \quad \text{kN}$$
$$F_y = Mg\,(0.5 + 0.039\,Z_G) \quad \text{kN}$$
$$F_z = Mg\,(1.17 + 0.026\,X_G) \quad \text{kN}$$

where: M — mass of deckhouses, in t;
Z_G — vertical distance from the center of gravity of deckhouses to OXY plane, in m;
X_G — horizontal distance from the center of gravity of deckhouses to OYZ plane, in m;
g — gravity acceleration, in m/s².

14.9.4.5 Where longitudinal load-bearing plates are provided to both half hulls, it may be assumed that the transverse component force F_y and the vertical component force F_z be born by hinges of deckhouses, and that the longitudinal component force F_x be born by longitudinal load-bearing plates. Otherwise, the hinges of deckhouses are also to bear the longitudinal component force F_x.

14.9.4.6 The forces born by the hinges of deckhouses are to be obtained by solving an equilibrium equation of force systems, according to the type and position of hinges and the actual position of the center of gravity of deckhouses.

14.9.4.7 Where the hinges of deckhouses are composed of two hinges and two end-hinged connecting rods, as shown in Figure 14.9.4.2, the forces born by the hinges are to be obtained by the following formulae:

For axial force F on connecting rods:

$$F = \frac{l_e}{l_h \cos\alpha}\left[F_y \frac{h}{b_h} + F_z\left(1 - \frac{b_e}{b_h}\right)\right] \quad \text{kN}$$

For transverse force F_h on hinges:

$$F_h = \frac{l_e}{l_h}\left[F_y(1 - \frac{h}{b_h}\tan\alpha) + F_z(1 - \frac{b_e}{b_h})\tan\alpha \right] \quad \text{kN}$$

For vertical force F_v on hinges:

$$F_v = \frac{l_e}{l_h}(F_y \frac{h}{b_h} + F_z \frac{b_e}{b_h}) \quad \text{kN}$$

For horizontal force F_c on each load-bearing plate:

$$F_c = \frac{1}{n_c} \quad F_x \quad \text{kN}$$

where: F_x, F_y, F_z — component forces acting on the center of gravity of deckhouses, in kN, to be determined in accordance with 14.9.4.4 of this Section;

α — the angle between the centreline of connecting rod and a vertical line, in degrees.;

l_e — longitudinal distance from the center of gravity of deckhouses to the farther hinge, in m;

b_e — transverse distance from the center of gravity of deckhouses to the vertical line at the centre of connecting rod, in m;

h — vertical distance from the center of gravity of deckhouses to the horizontal centreline of hinges;

b_h — transverse distance between hinge centre and connecting rod centre;

l_h — longitudinal distance between the centres of fore and aft hinges, in m;

n_c — number of load-bearing plates.

14.9.4.8 The scantlings of different parts of hinges of deckhouses are to be determined in accordance with 14.9.3.9 of this Section.

Section 10 MISCELLANEOUS

14.10.1 Bulwarks, guardrails and freeing ports

14.10.1.1 In open hopper dredgers and barges, bulwarks are not to be fitted in way of the hopper region, but guardrails or reliable anti-slip arrangements are to be provided. For dredgers fitted with bulwarks, freeing ports with adequate areas are to be fitted throughout the length of bulwarks.

14.10.2 Fenders

14.10.2.1 Dredgers and hopper barges are generally to be fitted with fenders along deck side throughout the ship's length, in accordance with their operation characteristics. Dredgers designed to work in conjunction with hopper barges are to be fitted also with fenders extending down to their lowest normal operating waterline. Vertical fenders, suitably spaced apart, are also to be fitted between such upper and lower fenders. The thickness of fenders may be taken as the thickness of the side shell plating at 0.4L amidships. Stiffeners are to be fitted inside the fenders.

14.10.3 Overflows

14.10.3.1 The cutting of overflow discharge trunk openings in the sheer strake is to be avoided wherever practicable. In ships over 65 m in length, hopper space overflow discharge trunk openings are not to be cut within 800 mm of the upper edge of the sheer strake. They are to have corner radii of not less than 150 mm, and suitable compensation is to be arranged. In no case is a discharge trunk to pierce the sheer strake in way of discontinuities such as breaks of superstructure.

14.10.4 Watertight trunk

14.10.4.1 Watertightness is to be kept around dredging pumps, within local range of holds in way of suction pipes and suction of trailing suction dredgers, penetrating through the hull.

14.10.5 Cofferdams

14.10.5.1 Ladder wells of bucket dredgers are to be isolated by cofferdams, the extent and widths of which are to be sufficient to contain any damage to the well side bulkheads or bottom shell plating that could result from the impact of large objects brought up in the dredge buckets. The cofferdams are to be accessible.

14.10.6 Supporting structures and seats of operating equipment

14.10.6.1 The local supporting structures connected with equipment members and foundations, as well as the seats of operating equipment are to have sufficient strength where necessary, the strength is to be checked.

14.10.6.2 Where direct calculation for check is applied, the model and strength criteria may refer to 3.7.2.5 and 3.7.2.6 of Chapter 3 of this PART. The loads are to be applied based on the working loads of equipment (e.g. working supporting loads of hydraulic winch), and the strength criteria may refer to Table 3.7.3.12 of Chapter 3 of this PART.

CHAPTER 15 SEMI-SUBMERSIBLE VESSELS

Section 1 GENERAL PROVISIONS

15.1.1 Application

15.1.1.1 This Chapter applies to the semi-submersible vessels intended for the carriage of ships, offshore installations or other massive goods.

15.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

15.1.2 Definitions

15.1.2.1 **Semi-submersible vessel** means a ship, designed to load and unload cargoes, which is capable of being in a semi-submerged condition, with large open weather cargo deck and generally fitted with a forward or aft high superstructure or deckhouse or pontoon.

15.1.2.2 **Semi-submerged condition** means any condition in which the lifting cargo deck is submerged and reserve buoyancy is provided by the superstructure or deckhouse or pontoon only.

15.1.2.3 **Lifting cargo deck** means an open weather deck which is used for the carriage of goods and is submerged during loading/unloading operation.

15.1.2.4 **Maximum submerged depth** means a maximum draft to which the vessel is allowed to be submerged in semi-submerged operation conditions.

15.1.3 Class notation

15.1.3.1 Semi-submersible vessels complying with this Chapter are eligible to be assigned the class notation: Semi-Submersible Vessel.

15.1.4 Drawings and information

15.1.4.1 In addition to those stipulated in Section 1, Chapter 2 of this PART, the following drawings and information are to be submitted for reference:

(1) Hydrostatic curves, lifting and submersing curves;

(2) Operating manual.

Section 2 STRUCTURAL STRENGTH

15.2.1 General requirements

15.2.1.1 All ballast tanks are to be provided with air pipes, the diameters of which are to be in compliance with the relevant provisions of the Rules. A certain number of manholes are to be cut in suitable positions of longitudinal and transverse strength members of all ballast tanks so that each part of the tanks can be easily reached and in addition, ventilation will be achieved when the tanks are empty.

15.2.1.2 Where a non-self-propelled semi-submersible barge is to be towed, the towing strength is to be calculated and consideration is to be given to the arrangement of towing equipment and relevant structural strengthening.

15.2.1.3 The normal tensile steel or higher tensile steel used for the hull structure of semi-submersible vessels is to be in compliance with the relevant provisions of the Rules.

15.2.1.4 Where direct calculation or other commonly used empirical formulae are applied to determine the scantlings of each member, the relevant calculations together with assumptions used and descriptions are to be submitted to CCS for examination.

15.2.2 Longitudinal strength

15.2.2.1 The longitudinal strength is to meet the following requirements:

(1) The longitudinal strength is to meet the requirements of Chapter 2 of this PART under sea-going condition;

(2) For typical operation conditions of the semi-submersible vessel, longitudinal wave load is to be taken 50% of the value required in 2.2.3 of Chapter 2 of this PART;

(3) For loading and unloading conditions in harbor under mooring condition, longitudinal wave load is to be taken 20% of the value required in 2.2.3 of Chapter 2 of this PART;

(4) Possible or assumed most critical operation condition is also to be considered.

15.2.2.2 The minimum section modulus W_0 at deck and keel within at least 0.25L amidships of semi-submersible vessel is to meet the requirements of 2.2.5.1 of Chapter 2 of this PART.

15.2.2.3 The structural members considered in the calculation of the section modulus in respect to longitudinal strength are to be longitudinally continuous within 0.4L amidships. However, the crane trail is not to be considered in section modulus calculation.

15.2.3 Transverse strength

15.2.3.1 The transverse strength is to be checked for the typical transverse structures throughout the length of the vessel.

15.2.3.2 The conditions used for the transverse strength calculation are to cover the typical operation conditions of the semi-submersible vessel, including the assumed most critical operation condition to be expected.

15.2.3.3 The following loads are to be taken into account in the check of transverse strength:

(1) Self-weight of the semi-submersible vessel including supporting blocks;

(2) Maximum weight of objects to be carried;

(3) External hydrostatic pressure at a given draught;

(4) Internal hydrostatic pressure due to the level of evenly distributed ballast water associated with the draught as in (3) when lifting at maximum capacity.

15.2.3.4 The bending stresses are not to exceed 170/K, in N/mm², the shear stresses are not to exceed 95/K, in N/mm² and the combined stress at any point is not to exceed 180/K, in N/mm² (K being the material factor).

15.2.4 Local strength

15.2.4.1 The local strength under sea-going condition is to be calculated according to the relevant requirements of Section 13, Chapter 2 of this PART, and the strength under the lifting and submersing conditions (including the process of adjusting the ballast water level) is to be calculated in accordance with the requirements of this Section.

15.2.4.2 The thickness of boundary plating of ballast water tanks, oil tanks, fresh water tanks, bilge tanks, empty tanks, etc., is not to be less than the value obtained from the following formula:

$$t = t_0 + 2.5 \quad \text{mm, and not to be less than 7.5 mm}$$

where: $t_0 = 3.95 s\sqrt{\rho h K}$, t_0 is also to be multiplied by $1.1 - \frac{s}{2.5l}$ for $l/s<4$;

K — material factor;

s — spacing of stiffeners, in m;

ρ — density of liquid, in t/m^3, taken as not less than 1.025 for calculation;

h — calculated pressure head, in m, see Table 15.2.4.2, to be measured from the lower edge of plate;

l — span of stiffener, in m.

Table 15.2.4.2

Position of members	Pressure head h (m)
1. Boundary plating subjected to external hydrostatic pressure and internal hydrostatic pressure on both sides, such as shell plating of wing tanks, etc.	h_1: The maximum differential head in the position obtained from the lifting and submersing curve
2. Boundary of ballast water tank	h_2: The maximum differential head between two sides, not less than 3.5 m
3. Watertight boundary of empty hold	The greatest of the following heads: h_1: The maximum differential head in the position obtained from the lifting and submersing curve (if applicable) h_2: The maximum differential head between two sides, not less than 3.5 m (if applicable) h_3: The vertical distance from the considered point to the deepest submersing water level, not less than 3.5 m h_4: The differential head in the deepest submerging position obtained from the lifting and submerging curve
4. Ballast tank where compressed air is used to discharge water (if applicable)	The greatest of the following heads: h_1: The maximum differential head in the position obtained from the lifting and submersing curve (if applicable) h_2: The maximum differential head between two sides, not less than 3.5 m (if applicable) h_3: The vertical distance from the considered point to the deepest

Position of members	Pressure head h (m)
	submersing water level, not less than 3.5 m h_4: The differential head in the deepest submerging position obtained from the lifting and submerging curve h_5: Water head equivalent to the compressed air, not less than 3.5 m

15.2.4.3 For structural members subjected to lateral pressure on tank boundary plating as defined in 15.2.4.2 of this Section, such as bulkhead stiffeners, longitudinals, beams and ordinary frames, etc., the minimum section modulus W is not to be less than that obtained from the following formula:

$$W = 7shl^2K \qquad \text{cm}^3$$

where:

s — spacing of stiffeners, in m;
K — material factor;
l — span of stiffener, in m;
h — calculated pressure head, in m, see Table 15.2.4.2, to be taken the middle point of span.

15.2.4.4 The section modulus W of primary members (such as transverses, web frames, girders, etc.) is not to be less than:

$$W = 7bhl^2K \qquad \text{cm}^3$$

where:

b — breadth of supporting, in m, taken as the spacing of primary structural members;
K — material factor;
l — the considered span, in m;
h — calculated pressure head, in m, see Table 15.2.4.2, to be taken the middle point of span.

15.2.4.5 The thickness of non-watertight pillar bulkhead plating and the scantlings of stiffeners may be determined in accordance with the relevant requirements of the Rules, provided that the loading P is taken as the actual load supported by the pillars.

15.2.4.6 The sectional area, plate thickness and end reinforcement of cross ties are to be in accordance with the relevant requirements of Section 10, Chapter 2 of this PART, provided that the load P is taken as follows:

$$P = 9.8shl \qquad \text{kN}$$

where:

s — spacing of cross ties, in m;
h — maximum differential head, in m, to be measured from the lower edge of cross ties to the water level at maximum differential head;
l — vertical midspan-to-midspan distance between two girders immediately over and under the cross tie, in m.

CHAPTER 16 ORE CARRIERS

Section 1 GENERAL PROVISIONS

16.1.1 Application

16.1.1.1 This Chapter applies to the determination of structural arrangements and scantlings within the cargo region of self-propelled single deck ore carriers with machinery aft, having two longitudinal bulkheads in the cargo region and a double bottom throughout the centre hold, intended for the carriage of ore cargoes in the centre hold. A typical cross section of such ore carriers is shown in Figure 16.1.1.1. Ore carriers of 250 m and over in length and engaged in unrestricted service are to satisfy the requirements of CCS Rules for Structures of Ore Carriers.

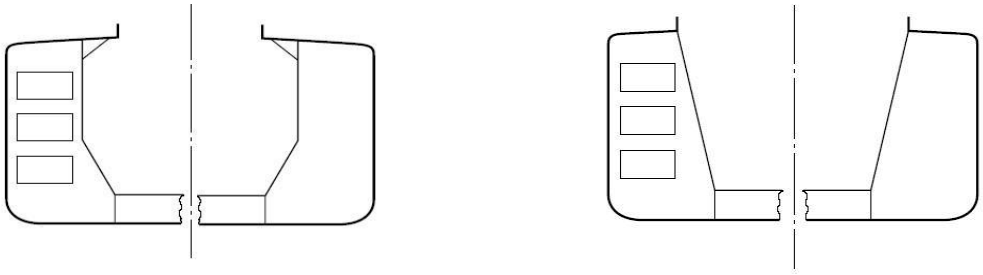


Figure 16.1.1.1

16.1.1.2 The fitting of a forecastle, the loading manual and loading instrument, cargo hold hatch covers and the flooding condition (where applicable) are to comply with the relevant requirements of Chapter 8 of this PART.

16.1.1.3 The strengthening for grabs is to comply with the relevant requirements of Section 23, Chapter 2 of this PART.

16.1.1.4 The requirements of Sections 3 and 4 of this Chapter are only applicable to the cargo hold area. Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

16.1.1.5 Ore carriers of 150 m and over in load line length and carrying solid bulk cargoes having a density of 1.0t/m^3 and above, as defined in SOLAS regulation XII/1, are to comply with the relevant requirements of Section 15, Chapter 8 of this PART.

16.1.2 Class notation

16.1.2.1 Ore carriers complying with the requirements of this Chapter are eligible to be assigned the class notation of Ore Carrier.

16.1.2.2 When requirements for loading and unloading in multiple ports have not been raised in the design of ore carriers in accordance with CCS Guidelines for Direct Strength Analysis of Hull Structure of Ore Carriers, No MP notation is to be assigned to indicate the limitation.

16.1.2.3 Ore carriers complying with the requirements of Section 5 of this Chapter are eligible to be assigned the class notation of **EL100**.

16.1.3 Arrangements and structural configuration

16.1.3.1 The bottom, and the strength deck outside the line of cargo hatchway openings, are to be framed longitudinally within the cargo region. Inside the line of openings, the strength deck is to be framed transversely.

16.1.3.2 The transverse watertight bulkheads in centre holds within the cargo region are to be located in the same plane with those in wing tanks as far as practicable, otherwise means are to be provided to ensure the continuity of transverse strength. However, the form of construction used for transverse watertight bulkheads in centre holds may be different from that used in wing tanks.

16.1.3.3 Strength frame rings, transverse watertight bulkheads and wash bulkheads, which may be fitted in wing tanks within the cargo region, are to be in the same plane with bottom floors of center holds.

16.1.3.4 Where necessary, the bottom between strength frame rings may be fitted with intermediate floors.

16.1.4 Direct strength calculation and fatigue strength assessment for hull structure

16.1.4.1 For ore carriers of 150 m and over in length, direct strength calculation in respect to primary members of the hull is to be carried out in accordance with the requirements of CCS Guidelines for Direct Strength Analysis of Hull Structure of Ore Carriers.

16.1.4.2 For ore carriers of 150 m and over in length, fatigue strength assessment in respect to the following locations within the cargo region is to be carried out in accordance with the requirements of CCS Guidelines for Fatigue Strength of Ship Structure:

(1) connections of longitudinals (bottom, side, deck and longitudinal bulkhead) to transverse web frames;

(2) connections of longitudinals (bottom, side, deck and longitudinal bulkhead) to transverse bulkheads;

(3) connections of longitudinal bulkheads to inner bottom plates;

(4) connections of inner bottom plates to lower stools;

(5) longitudinal bulkhead knuckles (if any).

16.1.4.3 For ore carriers of 250 m and over in length, special consideration is to be given to the effects of springing and whipping on hull structure fatigue strength. For detailed methods, see CCS Guidelines for Direct Calculation Assessment of Hull Structure Including Springing and Whipping.

Section 2 LONGITUDINAL STRENGTH

16.2.1 General requirements

16.2.1.1 The longitudinal strength is to comply with the requirements of Section 2, Chapter 2 of this PART.

16.2.1.2 Where the hold deck opening is large, the longitudinal strength in respect to a combination of bending moment and torque is to be checked in accordance with the requirements of Section 10, Chapter 7 of this PART, with the torque of cargo being taken as zero in general.

16.2.2 Ultimate strength of hull girder

16.2.2.1 The ultimate bending capacity of any transverse section of hull girder during navigation is to comply with the following requirements.

(1) The vertical ultimate bending capacity of hull girder is to comply with the following criteria:

$$\gamma_s \overline{M}_s + \gamma_w M_w \le \frac{M_U}{\gamma_R}$$

where: $\overline{M}_s$ — permissible still water bending moment, in kN·m;

M_w — wave bending moment, in kN·m;

M_U — vertical ultimate bending capacity of hull girder, in kN·m;

γ_s, γ_w, γ_R — partial safety factors, to be taken as:

$\gamma_s = 1.0$;

$\gamma_w = 1.2$;

$\gamma_R = \gamma_M \cdot \gamma_{DB}$;

where:

γ_M — partial safety factor, covering material, geometric and strength prediction uncertainties, to be taken as: $\gamma_M = 1.05$;

γ_{DB} — partial safety factor, covering the effect of double bottom bending, to be taken as:

$\gamma_{DB} = 1.10$ for hogging condition;

$\gamma_{DB} = 1.0$ for sagging condition.

(2) Curve M-χ

The ultimate bending capacities of a hull girder transverse section M_U, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered.

The curvature χ is positive for hogging condition and negative for sagging condition.

The curve M-χ is to be obtained by means of an incremental-iterative approach in accordance with Appendix 5, Chapter 7 of this PART.

(3) The hull girder transverse sections are constituted by the elements contributing to the hull girder longitudinal strength, and the standard diminution thickness given in Table 16.2.2.1 is to be deducted in calculation.

Standard thickness deduction **Table 16.2.2.1**

Position		Standard thickness deduction (mm)
Within 1.5 m below weather deck	One side connected to ballast water	1.0
	Two sides connected to ballast water	2.0
Elsewhere		1.0

16.2.2.2 For ore carriers of 250 m and over in length, special consideration is to be given to the effects of whipping on hull girder ultimate strength. For detailed methods, see CCS Guidelines for Direct Calculation Assessment of Hull Structure Including Springing and Whipping.

Section 3 HULL FRAMING

16.3.1 Double bottom

16.3.1.1 Unless provided otherwise in this Section, the structural arrangement and scantlings of double bottom are to comply with the relevant requirements of Section 6, Chapter 2 and Section 2, Chapter 8 of this PART. For ore carriers of 230 m and over in length, however, plate floors may be spaced not more than 2.8m apart.

16.3.1.2 The width and depth of the double bottom in way of centre holds are to comply with the strength requirements of this Chapter and in addition, the requirements for stability in loaded conditions.

16.3.1.3 Where the proposed depth of the double bottom exceeds 1.5 times the minimum depth required in Section 6 of Chapter 2 of this PART, the scantlings of the stiffeners on floors and girders are to be increased and the buckling of stiffeners, floors and girders is to be checked.

16.3.1.4 The scantlings of the stiffeners of watertight floors and girders in double bottom are to comply with the requirements for the stiffeners on bulkheads in deep tanks, and the stiffeners are to be bracketed at both ends.

16.3.1.5 Where single bottom is fitted in way of wing tanks, attention is to be given to a smooth transition of the inner bottom plating of the double bottom in way of center holds into single bottom wind tanks. The inner bottom plating is to be extended into the wing tank with a sufficient width and bracketed to the bulkhead or strength frame ring. The thickness t (mm) of bracket is not to be less than $5+0.025L$, where the L is the length of ship (to be taken not greater than 300m for calculation), and the thickness of bracket is to be given a smooth transition of inner bottom plating.

16.3.1.6 Where single bottom is fitted in way of wing tanks and if intermediate floors are fitted only in way of centre hold bottom between strength frame rings, attention is to be given to a smooth transition of the floors into wind tanks, and vertical brackets are to be fitted in corresponding positions within wing tanks. Such brackets are, in general, to extend transversely over a sufficient width and vertically to a sufficient height above the extension of inner bottom plating in wing tanks. The thickness of the brackets may be the same as that of plate floors. The thickness of brackets may be directly calculated for ore carriers with the length of 150m and above, but not less than the minimum thickness of solid floors required in 16.3.1.8.

16.3.1.7 Where the double bottom is interconnected with wing tanks or centre holds are used as storm ballast tanks, the scantlings of which are also to comply with the requirements in Section 13, Chapter 2 of this PART for deep tanks.

16.3.1.8 The minimum thickness of solid floors is not to be less than the value calculated by the following formula:

$$t_{\min} = \max\left(0.6\sqrt{L} + 2.5, 12\right) \qquad \text{mm}$$

where: L – length of ship, in m, to be taken not greater than 300 m for calculation.

16.3.2 Single bottom

16.3.2.1 The section modulus W of bottom longitudinals is not to be less than that obtained by the following formula:

$$W = 11.5sdl^2K \qquad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
d — draught, in m;
l — span of longitudinal, in m;
K — material factor.

16.3.2.2 The scantlings of bilge longitudinals are to be graduated between those required for the bottom

and lowest side longitudinals.

16.3.2.3 Floors are to be spaced not more than 3.6 m apart. The section modulus W and the net floor area A of floors at the span point are not to be less than those obtained as follows, but not greater than those of corresponding centre hold floors:

$$W = 4.59\ SDl^2K \text{ cm}^3$$
$$A = 0.56\ SDlK \quad \text{cm}^2$$

where: S — spacing of floors, in m;
D — moulded depth, in m;
l — span of floor, in m;
K — material factor.

16.3.2.4 The spacing and scantlings of bottom girders are to be determined by direct calculation.

16.3.3 Deck framing

16.3.3.1 The deck framing is to comply with the relevant requirements of Section 8, Chapter 2 of this PART.

16.3.3.2 The buckling of deck structure between hatchways is to be checked.

16.3.4 Side framing

16.3.4.1 The ship's sides are normally longitudinally framed, and the side longitudinals within $0.1D$ from bottom and deck are to continuously pass through transverse bulkheads. The section modulus W of side longitudinals is, in addition to satisfying relevant requirements of 2.7.5, Chapter 2 of this PART, not to be less than that obtained by the following formula:

$$W = 7.2s(h+1.2)l^2K \qquad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
h — vertical distance measured from the longitudinal under consideration to deck line at side amidships, in m, but not less than 2.5 m;
l — span of longitudinal, in m;
K — material factor.

16.3.4.2 Web frames are to be fitted in the plane of plate floors of longitudinally framed bottom.

16.3.4.3 The section modulus W of web frames is not to be less than that obtained by the following formula:

$$W = CS(h + 1.2)l^2K \quad \text{cm}^3$$

where: S — spacing of web frames, in m;
h — vertical distance measured from the mid-span of web frame to deck line at side, in m;
l — span of web frame, in m;
C — coefficient: $C = 11$, without horizontal strut; $C = 3.2$, with 1 horizontal strut; $C = 3$, with 2 horizontal struts;
K — material factor.

16.3.4.4 The net web area A of web frames is not to be less than that obtained by the following formula:

$$A = C_1S(h + 1.2)lK \quad \text{cm}^2$$

where: S — spacing of web frames, in m;
h — vertical distance measured from the mid-span of web frame to deck line at side, in m;
l — span of web frame, in m;
C_1 — coefficient: $C_1 = 0.5$ at section of span points and 0.25 at other sections, with 1 horizontal strut; $C_1 = 0.66$ at section of span points and 0.33 at other sections, with 2 horizontal struts;
K — material factor.

16.3.4.5 The dimensions of web frames may be directly calculated for ore carriers with the length of 150 m and above.

16.3.5 Strength frame rings in wing tanks

16.3.5.1 The strength frame ring in wing tanks is composed of web beams, web frames, plate floors, vertical girders on the longitudinal bulkhead and cross ties.

16.3.5.2 The spacing S of strength frame rings is not to be more than that obtained by the following formula:

$$S = 0.006L + 3.2 \quad \text{m, but not greater than 5.6 m}$$

where: L — length of ship, in m.

16.3.5.3 Cross ties are to comply with the relevant requirements of Section 8, Chapter 5 of this PART. The dimensions of cross ties may be directly calculated for ore carriers with the length of 150m and above.

16.3.5.4 The cross ties are to be subject to integral buckling check as beams.

16.3.5.5 The minimum thickness of webs of strength frame rings in wing tanks is not to be less than the value calculated by the following formula:

$$t_{\min} = \max\left(0.6\sqrt{L} + 2.5, 12\right) \qquad \text{mm}$$

where: L – length of ship, in m, to be taken not greater than 300m for calculation.

16.3.6 Cargo hold boundary

16.3.6.1 Cargo hold boundary means longitudinal bulkhead, corrugated transverse bulkhead as well as upper and lower stool (if any), plane transverse bulkhead, upper deck and hatch coaming in the cargo hold (except for inner bottom) which are in contact with cargo.

16.3.6.2 Thickness t of cargo hold boundary plate is not to be less than the value obtained from the following formula:

$$t = 4.65 C_1 s \sqrt{\frac{K_C H K}{\gamma}} \qquad \text{mm}$$

where: s — length of shorter side of plate panel, in m;

γ — loading rate, in m^3/t, not to be more than 0.833;

H — vertical distance measured from lower edge of panel to deck in way of midship side, in m;

$C_1 = 1.2 - \frac{s}{2l}$, where l is length of longer side of plate panel, C_1 is to be taken as 1 for $C_1 > 1$;

K_C — cargo pressure coefficient, to be taken as:

$Kc = \cos^2\alpha + (1 - \sin\psi)\sin^2\alpha$ for transverse bulkhead and longitudinal bulkhead, lower stool, vertical upper stool and hatch coaming;

$Kc = 0$ for upper deck and inclined upper stool;

where: α — included angle between considered plate and horizontal plane, in degree;

Ψ — angle of repose assumed for cargo in bulk, in degree, to be taken as 35° for carriage of ore;

K — material factor.

16.3.6.3 Section modulus W of cargo hold boundary stiffener is not to be less than the value obtained from the following formula:

$$W = \frac{8.5}{\gamma} K_C H s l^2 K \qquad \text{cm}^3$$

where: γ and K_C — the same as those in 16.3.6.2;

l — span of stiffener, in m;

s — spacing of stiffeners, in m;

H — vertical distance measured from the midpoint of span of stiffener to deck in way of midship side, in m;

K — material factor.

16.3.7 Web stiffeners of non-watertight primary members within cargo hold area

16.3.7.1 Where the dimensions of web stiffeners of non-watertight primary members within cargo hold area are calculated, the thickness deduction listed in 16.3.7.1 is to be reduced.

Thickness Deduction Table 16.3.7.1

Location	Thickness deduction (mm)
Both sides within ballast tanks	2.0
Elsewhere	1.0

16.3.7.2 Net thickness of web stiffeners is to satisfy the following criteria:

(1) Minimum net thickness of stiffener web plate

The net thickness of stiffener web plate is not to be less than 3.0+0.015L, where L is ship length (L need not be taken greater than 300 m during calculation).

(2) Stiffener web plate

$$t_w \geq \frac{h_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

(3) Flange

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where: C_w, C_f — slenderness coefficient given in Table 16.3.7.2;
$b_{f\text{-}out}$ — maximum distance, in mm, from mid thickness of the web to the flange-edge, as shown in Figure 16.3.7.2;
h_w — depth of stiffener web, in mm, as shown in Figure 16.3.7.2;
t_f — net flange thickness, in mm;
t_w — net thickness of plate, in mm;
R_{eH} — Specified minimum yield stress of the plate material, in N/mm^2.

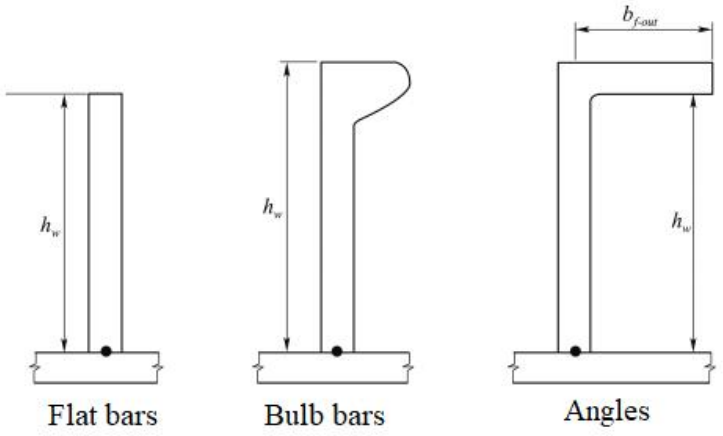


Figure 16.3.7.2 Stiffener Scantling Parameters

Slenderness Coefficients Table 16.3.7.2

Type of stiffener	C_w	C_f
Angle bars	75	12
Bulb bars	45	-
Flat bars	22	-

16.3.7.3 The total flange breadth b_f, in mm, for angle and T-bars is to satisfy the following criterion:

$$b_f \geqslant 0.25h_w$$

where: h_w — as defined in 16.3.7.2;

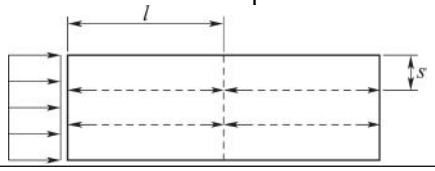
16.3.7.4 Bending stiffness of web stiffeners

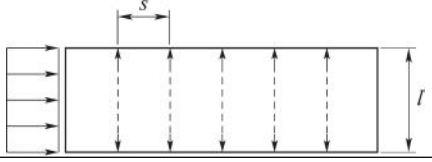
The net moment of inertia, in cm^4, of web stiffener, I_{st}, fitted on non-watertight primary members within cargo hold area onboard ore carriers, with effective attached plate, s_{eff}, is not to be less than the minimum moment of inertia defined in Table 16.3.7.4, the breadth of effective attached plate s_{eff}, is to be calculated by the following formula:

$$s_{eff} = 0.8s \quad \text{mm}$$

where: s — breadth of web plate panel, in mm, to be taken as the spacing of web stiffeners.

Stiffness Criteria for Web Stiffeners Table 16.3.7.4

Stiffener arrangement		Minimum moment of inertia of web stiffeners, in cm^4
A	Web stiffeners fitted along the primary member span 	$I_{st} \geq Cl^2 A_{eff} \frac{R_{eH}}{235}$

Stiffener arrangement		Minimum moment of inertia of web stiffeners, in cm^4
B	Web stiffeners fitted normal to the primary member span 	$I_{st} \geq 1.14 l s^2 t_w \left(2.5 \frac{1000l}{s} - 2 \frac{s}{1000l} \right) \frac{R_{eH}}{235} \cdot 10^{-5}$

where: C — slenderness coefficient to be taken as:
$C = 1.43$ for longitudinal stiffeners including sniped stiffeners;
$C = 0.72$ for other stiffeners.
l — length of web stiffener, in m.
(1) For web stiffeners welded to local supporting members, the length is to be measured between the flanges of the local supporting members.
(2) For sniped web stiffeners, the length is to be measured between the lateral supports, e.g. the total distance between the flanges of the primary member as shown for stiffener arrangement B.
A_{eff} — net section area of web stiffeners, including attached plate with effective width assumed to be 80% of stiffener spacing s, in cm^2.
t_w — net web thickness of the primary member, in mm.
R_{eH} — specified minimum yield stress of the material of the web plate of the primary member, in N/mm^2.

Section 4 BULKHEADS

16.4.1 Transverse watertight bulkheads

16.4.1.1 Transverse watertight bulkheads are to be fitted with plate floors at bottom.

16.4.1.2 The scantlings of upper and lower stools of transverse watertight bulkheads are, if fitted, to comply with the requirements of this Section and in addition, the relevant requirements of Section 12, Chapter 2 of this PART.

16.4.1.3 The transverse bulkheads forming the boundary of ballast holds are to comply with the requirements of Section 13, Chapter 2 of this PART for deep tank bulkheads.

16.4.1.4 The thickness of the lowest strake of transverse watertight bulkheads is to be not less than that of inner bottom plating defined in 2.22.3.4 and 2.23.3.1 of Chapter 2 in this PART and is to be gradually tapered upwards.

16.4.2 Longitudinal watertight bulkheads

16.4.2.1 Longitudinal watertight bulkheads are to be plane, and framed longitudinally in general.

16.4.2.2 The longitudinal bulkheads are to be fitted with continuous bottom girders.

16.4.2.3 The scantlings of the longitudinal bulkheads are to comply with the requirements of this Section and in addition, the relevant requirements of Section 12, Chapter 2 of this PART.

16.4.2.4 The thickness of the longitudinal bulkhead plating in way of the knuckle is to be appropriately increased and the knuckle may be strengthened by horizontal girders to improve resistance to transverse compressive buckling stresses. The scantlings of the horizontal girders are to be determined by direct calculation.

16.4.2.5 Primary members are to be fitted at any vertical knuckle of longitudinal bulkhead. Distance between knuckle and primary members is not to be greater than 70 mm. Where the knuckle is not vertical, it is to be strengthened appropriately with normal stiffeners in the same line with the knuckle or other equivalent measures are to be taken.

16.4.2.6 Bulkhead plating

(1) The thickness t of bulkhead plating is not to be less than that obtained by the following formula:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;
h — vertical distance, in m, measured from lower edge of strake to tank top on the centreline, but not less than $0.4D$;
K — material factor.

(2) The thickness t of bulkhead plating within $0.1D$ from deck is not to be less than that obtained by the

following formula:

$$t = 4.2s\sqrt{DK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;
D — moulded depth, in m;
K — material factor.

(3) The thickness t of bulkhead plating is to additionally comply with the following:

$$t \geq as/27D \quad \text{mm}$$

where: s — spacing of stiffeners, in m;
a — vertical distance, in m, measured from $D/2$ to the centre of panel;
D — moulded depth, in m.

(4) The thickness of the lowest strake of the longitudinal bulkheads is not to be less than that of adjacent inner bottom plating defined in 2.22.3.4 and 2.23.3.1 of Chapter 2 in this PART and is to be gradually tapered to the thickness of longitudinal bulkhead plating.

(5) The thickness of longitudinal bulkhead plating within 0.1D from deck need not exceed the sheer strake thickness with the same spacing of frames.

16.4.2.7 Vertical webs

(1) The vertical webs on longitudinal bulkheads are to be fitted within wing tanks, and the dimensions of the vertical webs are to be calculated according to 16.3.4.3 of this Chapter, and direct strength calculation may be carried out for ore carriers with the length of 150m and above.

(2) The brackets at both ends of the vertical web are to comply with the relevant requirements of 1.2.7 of Chapter 1 of this PART.

(3) Buckling-restrained stiffeners are generally to be fitted onthe vertical web plating.

16.4.2.8 Horizontal stiffeners

(1) The section modulus W of horizontal stiffeners is not to be less than that obtained by the following formula:

$$W = 7.2s(h+1.2)l^2K \quad \text{cm}^3$$

where: s — spacing of horizontal stiffeners, in m;
h — vertical distance, in m, measured from horizontal stiffener to tank top on the centreline, but not less than 2.5 m;
l — span of horizontal stiffener, in m;
K — material factor.

(2) Horizontal stiffeners are to continuously pass through transverse bulkheads within 0.1D from deck and inner bottom.

16.4.3 Wash bulkheads

16.4.3.1 Where necessary, plane perforated wash bulkheads are to be fitted in wing tanks.

16.4.3.2 Wash bulkheads are to comply with the relevant requirements of Section 11, Chapter 5 of this PART.

Section 5 EASY LOADING REQUIREMENTS

16.5.1 General requirements

16.5.1.1 This Section applies to ore carriers having a single hold being capable of loading 100% (easy loading) capacity in one step for all cargo holds.

16.5.1.2 Average loading rate during easy loading is not to be more than the provisions in Table 16.5.1.2. Higher average loading rate is to be specially considered.

Average loading rate **Table 16.5.1.2**

Deadweight tonnage (t)	Average loading rate (t/h)
220,000 ~ 250,000	14,000
> 250,000	16,000

16.5.2 Class notation

16.5.2.1 Ore carriers complying with the provisions of this Section are to be assigned class notation EL100.

16.5.3 Hull structure strength

16.5.3.1 In the whole process of easy loading, actual still water bending moment and still water shearing force of hull girder are not to exceed permissible still water bending moment and permissible still water shearing force in harbor condition.
16.5.3.2 In the whole process of easy loading, it is to be ensured that double bottom and transverse bulkhead have sufficient local strength, and direct calculation of structural strength is to be carried out in accordance with CCS Guidelines for Direct Strength Analysis of Hull Structure of Ore Carriers.

16.5.4 Equipment provision and requirements
16.5.4.1 If ballast adjustment is required to control that actual still water bending moment and still water shearing force of hull girder do not exceed permissible still water bending moment and still water shearing force in harbor condition, requirements of 16.5.4.2 and 16.5.4.3 are to be complied with.
16.5.4.2 The ballast system is to be able to match the requirements of mean loading rate in 16.5.1.2, including ballast tank arrangement, capacity of ballast pump and arrangement of ballast piping system.
16.5.4.3 The ship is to be provided with tank (e.g. ballast tank, fuel oil tank, etc.) remote control sounder and ship draught reading system, which are synchronous with loading instrument on board. It is not necessary to consider fuel oil tanks without level change during loading.

16.5.5 Requirements of easy loading manual
16.5.5.1 Easy loading manual which is approved by CCS is to be provided on board or may be included in other approved loading manual.
16.5.5.2 Easy loading sequence is to include operation sequence of each step of loading from the beginning to the end as well as synchronous ballast adjustment, so as to ensure that the requirements of 16.5.3.1 are complied with during loading (including each cargo hold from empty load to full load).
16.5.5.3 Easy loading manual is at least to include following:
(1) loading capacity in each hold for each step;
(2) ballast water adjustment in each ballast tank for each step;
(3) maximum still water bending moment and shearing force at the end of each step;
(4) ship’s draught and trim at the end of each step.

CHAPTER 17 LAUNCHING WORK BARGES

Section 1 GENERAL PROVISIONS

17.1.1 General requirements

17.1.1.1 This Chapter applies to non-self-propelled work barges dedicated to launching ships or offshore installations under construction, or moving from water to shore, within shipyard and/or port waters, and short-distance movement within the above-mentioned waters.

17.1.1.2 For those not covered in this Chapter, the relevant requirements of Chapter 2 of this PART and of CCS Rules for Classification of Floating Docks are to be complied with.

17.1.2 Plans and documents

17.1.2.1 The following plans and documents are to be submitted for information in addition to those as specified in Section 1, Chapter 2 of this PART:

(1) Hydrostatic curves, lifting and submersing curves;

(2) Operating manual.

17.1.3 Definitions

17.1.3.1 **Launching work barge** means a dedicated barge used for launching operation, having larger open pontoon deck, bow and/or stern, and higher superstructure or deck house on both sides. The superstructure on both sides may be arranged discontinuously along the longitudinal direction, and some of the superstructure or deck house may be removed where necessary. Special crane rails and trolleys are to be provided on the pontoon deck. Where the objects intended for moving is being moved from shore to water or from water to shore, the pontoon deck is to be maintained on the same level as the shore land, then the object is to be moved by the trolley. The in-water loading/unloading operation may be carried out by the ship's lifting and submerging. Cranes are not provided onboard. Figure 17.1.3.1 shows a diagram of typical launching work barge.

17.1.3.2 **Semi-submerged condition** means any condition in which the pontoon deck is submerged and reserve buoyancy is provided by the superstructure or deckhouse or pontoon only.

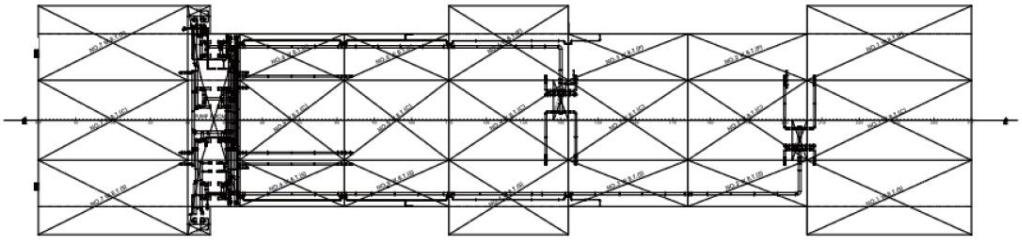
17.1.3.3 **Pontoon deck** means an open weather deck which is used for the carriage of objects intended for moving and is submerged during loading/unloading operation, also referred to as lifting cargo deck.

17.1.3.4 **Maximum submerged depth** means a maximum draft to which the vessel is allowed to be submerged in semi-submerged operating conditions.

17.1.3.5 **Length of pontoon L_D (m)** means a distance from the aft end of the aftermost pontoon to the fore end of the forward pontoon of a launching work barge, but is exclusive of non-integral end platforms or swing bridges.

17.1.3.6 **Safety deck** means a deck extending over superstructure or deck house on both sides, and located below the top deck and above the ballast tank, which is watertight at the positions of ballast deck.

Longitudinal section at port



Plane of ballast tank

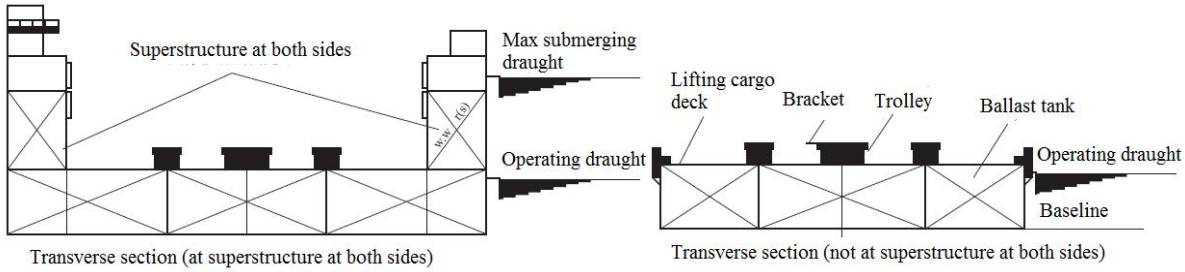


Figure 17.1.3.1 Diagram of a Certain Typical Launching Work Barge

17.1.4 Class notation

17.1.4.1 The class notation "Launching Work Barge" is to be assigned to a barge which complies with the provisions of this Chapter.

Section 2 LONGITUDINAL STRENGTH

17.2.1 General requirements

17.2.1.1 Unless otherwise specified in this Section, the longitudinal strength is to comply with the requirements of Section 2, Chapter 2 of this PART.

17.2.1.2 The longitudinal strength is to include the terminal operating conditions and harbor operating conditions, if any.

17.2.1.3 Structural members of the hull girder based on section modulus are to be maintained longitudinally continuous within $0.4L_D$ amidships, excluding the crane rails.

17.2.2 Loads

The loads of longitudinal strength are specified as follows:

(1) The buoyancy is to be assumed to distribute homogeneously along the ship's length.

(2) The weight of objects and distribution are to be assumed according to the following design conditions:

① In the case of the objects intended for moving being placed onboard: it is assumed that the total weight of objects based on designed lifting capacity is distributed to trolleys of the launching work barge according to the actual condition, then transferred to the pontoon deck below through trolleys. In calculation, the total capacity of trolleys is to be taken as the total weight of objects intended for moving, otherwise, disequilibrium of the buoyancy and weight will be caused on the general force system. In addition, the maximum load capacity of trolleys is not to be less than the distributed load on a single trolley.

② In the case of the objects being moved onboard: it is assumed that the weight distribution of object intended for moving is as the same as that in ①, and only partial length of the object is moved inboard, the bending strength and shearing strength in way of the weak section are to be checked according to the actual ballast water condition. In this case, the draught of work barge is to be based on the sea surface elevation due to tide variation, the partial weight of the object moved inboard, the weight of work barge and the hydrostatic equilibrium of buoyancy.

(3) The still water bending moment and shear force under all actual operating conditions (which are to include the typical ones of most unfavorable conditions for objects to be launched or moved to shore, and in the operation of lifting/submerging objects, etc.) are to be taken into account.

17.2.3 Longitudinal strength check

17.2.3.1 The longitudinal strength is to be checked in accordance with the requirements of Section 2, Chapter 2 of this PART, and complying with the following requirements:

(1) For terminal operating conditions, the allowable bending stress is to be taken $137/K$, in N/mm^2; the shear stress is to be taken $95/K$, in N/mm^2 (K being the material factor, but not less than 0.72).

(2) For harbor operating conditions, the allowable bending stress is to be taken $175/K$, in N/mm^2; the shear stress is to be taken $110/K$, in N/mm^2 (K being the material factor, but not less than 0.72).

(3) The minimum section modulus W_0 amidships is not required.

(4) For terminal operating conditions of launching work barges, the wave loads are not to be included.

(5) For harbor operating conditions of launched work barges, the wave loads are to be taken 50% of that as required in Section 2, Chapter 2 of this PART.

Section 3 TRANSVERSE STRENGTH

17.3.1 General requirements

17.3.1.1 The transverse strength is to be calculated for typical transverse structures throughout the length of ship in accordance with the requirements of this Section. In addition to the yield strength calculation, the plate panels and transverses subject to transverse bending moment and shear stresses are to be checked for buckling according to the requirements of 2.2.7 in Section 2, Chapter 2 of this PART.

17.3.1.2 The transverse strength of fore and aft ends of the pontoon is not to be lower than that as required for the mid-portion of the pontoon.

17.3.2 Loads

17.3.2.1 The primary transverse strength members of launching work barges, throughout its length L_D, is to be suitable for the sum of the following load components (normally, the weight of the rail, trolley and its facilities, as well as the hydrostatic pressure effect on horizontal action may be neglected):

(1) self-weight of the launching work barge (including the weight of superstructure or deck house on both sides and pontoon);

(2) weight of object intended for moving, see 17.2.2 of this Section;

(3) external hydrostatic pressure due to a given draught. The most severe condition normally occurs when the draught is equal to the depth to the top of the trolley bracket (i.e. the bottom of the object intended for moving is just lifted above the water surface);

(4) internal hydrostatic pressure due to the level of evenly distributed ballast associated with the draught as in (3) above;

(5) hydrostatic pressure of the outside of pontoon's bottom;

(6) reaction forces (if any) on superstructure or deck house longitudinal bulkheads on both sides required for achieving equilibrium of the buoyancy and weight on the section under consideration. Such reaction forces applied on internal and external longitudinal bulkheads on both sides of superstructure or deck house may be assumed as equal.

17.3.3 Calculation model

17.3.3.1 The transverse bending strength and shear strength of some typical longitudinal sections taken over the transverse length (where symmetrical, only half the breadth may be taken) of the pontoon are to be checked. The spacing of transverse bulkheads is to be taken as the longitudinal length of the section calculated, and the weak points of transverse strength are to be included in the check point of the section.

17.3.3.2 When lifting at maximum capacity with a launching work barge length less than that of the pontoon, the sections clear of the ship will experience transverse hogging due to the combination of loads in 17.3.2.1(1), (3), (4), (5) and (6). Hence, such condition is to be checked as appropriate for the sections concerned. The most severe condition will usually occur when the ballast depth is at a minimum (i.e. residual water only).

17.3.4 Transverse strength check

17.3.4.1 The permissible stress of transverse primary members are to be as follows:

permissible normal stress $[\sigma] = 170/K$ N/mm^2;

permissible shear stress $[\tau] = 95/K$ N/mm^2;

permissible equivalent stress $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 180/K$ N/mm^2.

17.3.4.2 Special care is to be taken to the maintenance of transverse strength standard (not to be lower than that of 17.3.4.1) in end sections of launching work barges with swim ends where the pontoon depth is reduced.

Section 4 LOCAL STRENGTH

17.4.1 General requirements

17.4.1.1 Scantlings of the hull structural members are not to be less than that as specified in this Section, and to be adequate to meet the requirements for longitudinal strength, transverse strength and direct calculation.

17.4.1.2 Primary structural members, such as longitudinals, beams and ordinary frames of pontoons are to be maintained continuous, and transitional brackets are to be fitted where it is interrupted.

17.4.2 Tank boundary plating

17.4.2.1 The thickness of boundary plating of ballast water tanks, oil tanks, fresh water tanks, bilge tanks, empty tanks, etc., is not to be less than that obtained from the following formula:

$$t = t_0 + 2.5 \quad \text{mm}$$

where: $t_0 = 3.95s\sqrt{\rho hK}$ mm, when l/s is less than 4, the thickness obtained from the above formula is to be multiplied by the factor: $1.1 - \frac{s}{2.5l}$;

s — spacing of stiffeners, in m;

K — material factor;

h — calculated head, in m, taken as in Table 17.4.2.1;

l — span of stiffener, in m.

Table 17.4.2.1

Location of members	Calculated head h (m)	Remarks
1. Boundary plating subjected to external hydrostatic pressure and internal hydrostatic pressure on both sides, such as longitudinal bulkhead plating of watertight ballast tank of superstructure, shell plating of pontoon, etc.	The maximum differential head in the position obtained from the lifting and submersing curve	
2. Boundary of ballast water tank	The maximum differential head between two sides, not less than 3.5 m	
3. In way of air cushion space, such as the safety deck, longitudinal bulkhead plating, inner bulkhead plating of watertight ballast tank of superstructure	Internal head on the cushion side: differential head in the position under maximum submerged depth from the lifting and submersing curve. The head is taken as the differential between internal and external pressures, not less than 3.5 m	Also in compliance with the requirements in 1 and 2 above
4. Watertight boundary of empty tank	The vertical distance from the considered point to the deepest submersing water level, not less than 3.5 m	Also in compliance with the requirements in 3 above
5. Normal oil tanks, fresh water tanks and bilge tanks other than that mentioned above	The vertical distance from the considered point to the top of tank, or half of the vertical distance from the considered point to the top of overflow pipe, whichever is the greater	

17.4.2.2 The minimum thickness of boundary plating of tanks and non-watertight bulkheads is to be 7.5 mm.

17.4.3 Stiffeners on boundary plating

17.4.3.1 For structural members subjected to lateral pressure on tank boundary plating as defined in 17.4.2.1 of this Section, such as bulkhead stiffeners, longitudinals, beams and ordinary frames, etc., the minimum section modulus W is not to be less than that obtained from the following formula:

$$W = 7shl^2K \quad \text{cm}^3$$

where: s —spacing of stiffeners, in m;

K— material factor;

l — span of stiffener, in m, between effective supporting members;

h — calculated head, in m, see 17.4.2.1, measured from the mid span.

17.4.4 Top deck plating of superstructure on both sides

17.4.4.1 The plating thickness t of top deck of superstructure on both sides within the following two areas is not to be less than the value calculated from the following formulae, and not less than 6.5 mm:

$t = 10s\sqrt{K}$ mm, within $0.4L_D$ amidships

$t = (7.8s + 2.2)\sqrt{K}$ mm, $0.1L_D$ from each end of the pontoon

where: s — spacing of longitudinals, in m;

K — material factor.

17.4.4.2 The thickness of top deck plating within 0.4 L_D amidships is to be greater than that of the end.

17.4.5 Top deck longitudinals and beams of superstructure or deck house on both sides

17.4.5.1 The section modulus W of top deck longitudinals and beams of superstructure or deck house on both sides is not to be less than the value calculated from the following formula:

$$W = Csl^2 \qquad \text{cm}^3$$

where: C —14.5 for longitudinal beam within 0.4 L_D amidships, 5.4 for transverse beam and longitudinal beam at the fore and aft ends;

s — spacing of longitudinal or transverse beams, in m;

l — span of longitudinal or transverse beams, in m.

17.4.6 Safety deck plating

17.4.6.1 The thickness t of the safety deck plating is not to be less than that obtained from the following formula:

$$t = t_0 + 2.5$$

when $l/s < 4$, t_0 is to be multiplied by the factor: $1.1 - \dfrac{s}{2.5l}$

where: $t_0 = 3.4s\sqrt{hK}$ mm;

K — material factor;

s — spacing of stiffeners, in m;

l — span of stiffener, in m;

h — height from top of safety deck beam to top of upper deck beam at side, in m.

17.4.6.2 In addition to 17.4.6.1, special consideration is to be given to the thickness of safety deck where the deck is subjected to the air cushion and goods/equipment separately.

17.4.6.3 The minimum thickness of the safety deck plating is to be 7.5 mm.

17.4.7 Longitudinals and beams of safety deck

17.4.7.1 The section modulus W of each safety deck longitudinals or beams is to be obtained from the following formula:

$$W = 4.5Kshl^2 \quad \text{cm}^3$$

where: K — material factor;

s — spacing of stiffeners, in m;

l — span of stiffener, in m;

h — height from top of safety deck beam to top of upper deck beam at side, in m.

17.4.7.2 In addition to 17.4.7.1, special consideration is to be given to the check of scantlings where the deck is subjected to the air cushion and goods/equipment separately.

17.4.8 Webs, transverses, floors and girders

17.4.8.1 For primary supporting members such as webs, transverses, floors and girders, the minimum section modulus W is not to be less than that obtained from the following formula:

$$W = 7bhl^2K \qquad \text{cm}^3$$

where: b — supporting width, in m, spacing of primary supporting members;

K— material factor;

l — calculated span, in m;

h — calculated head, in m, see 17.4.3.1, measured from the mid span.

17.4.9 Cross ties

17.4.9.1 The sectional area, web and face plate of cross ties fitted in deck house on both sides and pontoon, are to be in accordance with the requirements of 17.4.9.4 and 17.4.9.5 of this Section.

17.4.9.2 The load P supported by the horizontal cross ties is not to be less than that obtained from the following formula:

$$P = p \qquad \text{kN}$$

where: $p = 9.8shl_1$;

where: h — maximum differential head, in m;

s — spacing of cross ties, in m;

l_1 — vertical midspan-to-midspan distance between two members immediately over and under the horizontal cross ties, in m, see Figure 17.4.9.3.

17.4.9.3 The load P supported by the diagonal cross ties is not to be less than that obtained from the following formula:

(1) For diagonal cross tie 1 (see Figure 17.4.9.3):

$$P = \frac{p \sin \beta}{\sin (\alpha + \beta)} \qquad \text{kN}$$

where: p — see 17.4.9.2, and h to be measured from the lower edge of diagonal cross ties to the water level at maximum differential head;

α, β — angles between diagonally arranged cross ties and horizontal plane, (º), see Figure 17.4.9.3.

(2) For diagonal cross tie 2 (see Figure 17.4.9.3):

$$P = \frac{p \sin \alpha}{\sin (\alpha + \beta)} \qquad \text{kN}$$

where: P, α and β — same as defined in (1).

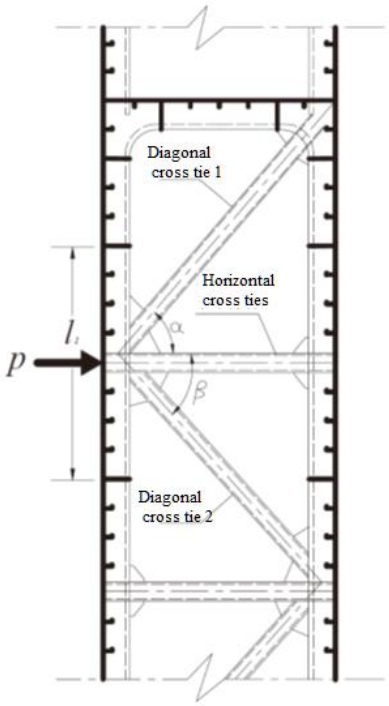


Figure 17.4.9.3 Vertical midspan-to-midspan Distance l_1 between Two Members immediately over and under the Horizontal Cross Ties

17.4.9.4 The cross-section area A of cross ties is to comply with the requirements of 2.10.2, Section 10, Chapter 2 of this PART.

17.4.9.5 The built or rolled-section cross ties are to comply with the requirements of 2.10.3.2, Section 10, Chapter 2 of this PART.

17.4.10 Local strength of pontoon supporting structure below the trolley rail

17.4.10.1 The local strength of pontoon supporting structure below the trolley rail may be calculated and analysed as specified in 17.2.2 of this Section, based on the loads subjected to the supporting structure throughout the length of pontoon. The strength criteria are given in 17.3.4.1 of this Section. Check of such local strength may be included in the direct calculation of global strength.

17.4.11 Platforms extending from ends of pontoon

17.4.11.1 The load supported by the platform structures is generally to be assumed as 5.75 kN/m^2, the permissible stress $[\sigma]$ to be $60/K$, N/mm^2 and the permissible shear stress $[\tau]$ to be $35/K$, N/mm^2. Where a large load is to be expected or required, special consideration is to be given.

17.4.12 Swing bridges at ends of pontoon

17.4.12.1 The load supported by the bridge structures of launching work barge is generally to be assumed as 3.59 kN/m^2, the permissible stress [σ] to be 60/K, N/mm^2 and the permissible shear stress [τ] to be 35/K, N/mm^2. Where a large load is to be expected or required, special consideration is to be given.

Section 5 DIRECT STRENGTH CALCULATION

17.5.1 General requirements

17.5.1.1 Direct calculation of global strength is to be carried out for launching work barges as required in Appendix 1 of this Chapter, and to be submitted to CCS.

Appendix 1 DIRECT STRENGTH CALCULATION OF LAUNCHING WORK BARGES

1 General Provisions

1.1 Application

1.1.1 This Appendix applies to the direct strength calculation of launching work barges required by this Chapter.

1.1.2 For those not covered in this Appendix, the relevant requirements of Section 9, Chapter 1 of this PART are to be complied with.

2 Design Loads

2.1 General requirements

2.1.1 The design loads are at least to include the following:

(1) self-weight of launching work barge;

(2) the weight of object intended for moving assumed in 17.2.2 of this Chapter only to be supported by pontoon;

(3) hydrostatic pressure of the outside of pontoon's bottom and external hydrostatic pressure;

(4) hydrostatic pressure on the immersed pontoon deck;

(5) hydrostatic pressure of the ballast tank.

3 Calculation Conditions

3.1 General requirements

3.1.1 The calculation conditions are at least to include the following, and to comply with the requirements of 17.2.2 of this Chapter and the characteristics of the ship:

(1) condition 1: the operating condition;

(2) condition 2: the condition that the top of the trolley bracket are just submerged by the water when the launching work barge is lifting at maximum capacity;

(3) condition 3: the severe condition likely to occur while distributing ballast water when the floating dock sinks or rises.

3.1.2 The equilibrium of total buoyancy and weight of model is to be maintained as far as possible, see 1.5.7.6 of Section 5, Chapter 1 of this PART.

3.1.3 In applying the load of the object intended for moving, the coordinate of the maximum value of the weight curve is to be assumed to be at the center of the global ship model.

4 Structural Modeling

4.1 General requirements

4.1.1 The extent of global ship model is as follows:

(1) for longitudinal extent (in x-direction): total length of the ship;

(2) for transverse extent (in y-direction): total breadth of the ship;

(3) for vertical extent (in z-direction): from baseline to the top deck.

4.1.2 The relevant requirements for model element and mesh scantling are given in Section 5, Chapter 1 of this PART.

4.1.3 The boundary conditions are to restrict the rigid displacement for the global ship model, in general, the boundary is to be placed at fore and aft ends or web frame section of amidships, see Figure 4.1.3.

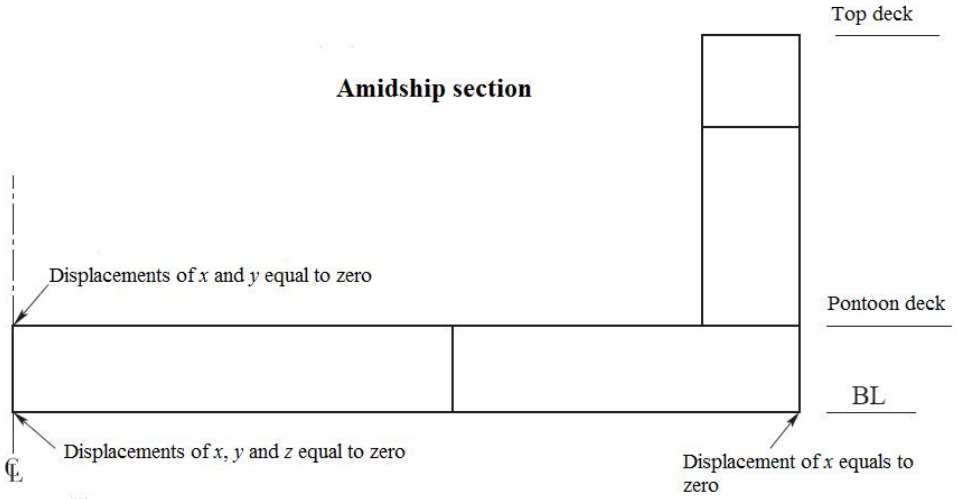


Figure 4.1.3 Boundary Conditions

5 Yielding Strength Assessment

5.1 Permissible stress

5.1.1 The permissible stress is given in Table 5.1.1.

Permissible Stress **Table 5.1.1**

Structural component	Equivalent stress or axial stress (N/mm^2)	Shear stress (N/mm^2)
Plate element	$[\sigma_e]$ =185/K	$[\tau]$ =100/ K
Trusses in transverse sections	$[\sigma]$=141/ K	–

Note: K— material factor.

6 Buckling Strength Assessment

6.1 General requirements

6.1.1 The requirements for buckling strength assessment are given in Appendix 1, Chapter 5 of this PART.

CHAPTER 18 TWIN-HULL CRAFT

Section 1 GENERAL PROVISIONS

18.1.1 General requirements

18.1.1.1 This Chapter applies to twin-hull craft of which the main body is composed of the two demi-hulls connected by cross-deck.

18.1.1.2 For those not covered in this Chapter, the relevant requirements of Chapter 2 of this PART are to be complied with.

18.1.2 Definitions

18.1.2.1 Length L (m) means the length measured along summer load line from the leading edge of the foremost vertical strut to the trailing edge of the aftermost vertical strut, plus 50% of difference between the length of lower hull from forward to end and the overall length of the underwater watertight envelope of the rigid hull (excluding appendages at or below the design waterline).

18.1.2.2 Breadth B (m) means the breadth of the broadest part of the moulded watertight envelope of the rigid hull, excluding appendages at or below the design waterline.

18.1.2.3 Moulded depth D (m) means the vertical distance measured at the middle of the length L from the top of keel to the lower surface of freeboard deck along the outside of demi-hull.

18.1.2.4 Breadth b (m) of demi-hull means the maximum horizontal distance measured at the middle of the length L between the outside surfaces of internal and external sides of demi-hull.

18.1.2.5 Breadth b_1 (m) of cross-deck structure means the horizontal distance measured at the middle of the length L between outside surfaces of internal sides of port and starboard sets of struts of wet deck.

18.1.2.6 Cross-deck structure means the deck and other accessory strength (boxlike) structure that spans the port and starboard sets of struts.

18.1.2.7 Wet deck means the lower plated surface of the cross structure.

18.1.2.8 Port and starboard sets of struts means the longitudinal mono-hull structures in way of both sides below the cross-deck structure, respectively.

18.1.3 Class notation

18.1.3.1 The class notation “Catamaran” is to be assigned to the twin-hull craft which comply with the provisions of this Chapter.

Section 2 STRUCTURAL STRENGTH

18.2.1 General requirements

18.2.1.1 For port or starboard set of strut of twin-hull craft, the applicable requirements for mono-hull craft of this PART may be complied with.

18.2.1.2 For cross-deck structure, the minimum scantling is to meet the requirements of the Rules for strength deck of mono-hull craft, and a suitable strengthening is to be provided for resistance to the slamming effect on wet deck of cross-deck structure by wave loads.

18.2.1.3 The overall strength (including longitudinal strength, transverse strength and torsional strength) of twin-hull craft with cross-deck structure is to be checked in accordance with the direct calculation of global strength of twin-hull craft as specified in Appendix 1 of this Chapter.

18.2.1.4 The shear strength of the longitudinal section of cross-deck structure is to be calculated and checked with the shear force as specified in 18.3.2.4 of this Chapter and the shear stress is to meet the requirements of the following formula (K is the material factor):

$$\tau \leqslant 90/K \quad \text{N/mm}^2$$

Section 3 TOTAL LOAD

18.3.1 General requirements

18.3.1.1 The total load of ship may be determined in accordance with 18.3.2 of this Section or direct calculation of load may be carried out in accordance with 18.3.1.2 and 18.3.1.3 of this Section (if applicable) for twin-hull passenger ship and public service ship with the following characteristics:

$$L \leqslant 60\ \text{m}$$
$$L/D \leqslant 15$$
$$B/D \leqslant 3.5$$
$$b_1/B \leqslant 0.4$$

18.3.1.2 The total load of twin-hull craft beyond the scope of 18.3.1.1 is to be determined by direct calculation. The direct calculation of wave loads is to be carried out in accordance with 2.2.9 of Section 2, Chapter 2 of this PART. If strip theory is adopted, the analysis is to consider the hydrodynamic interaction between twin hulls.

18.3.1.3 Where the wave loads are obtained directly from model testing, the related calculation principles/calculation procedure or test program (if applicable) is to be approved in advance.

18.3.2 Load under consideration

18.3.2.1 The longitudinal bending moment M_{by} of the twin-hull craft is the superposition of still water bending moment M_{bys} and wave bending moment M_{byw}. The wave bending moment M_{byw} is to be taken as twice the wave bending moment of the demi-hull which is to be determined in accordance with 2.2.3 of Section 2, Chapter 2 of this PART. The still water bending moment M_{bys} is to be determined in accordance with 2.2.2 of Section 2, Chapter 2 of this PART. The still water bending moment is to be taken as the maximum value within 0.4L midship under various loading conditions and the wave bending moment is to be taken within 0.4L midship.

18.3.2.2 The transverse bending moment M_{bx} of the cross-deck of twin-hull craft may be obtained by the following formula:

$$M_{bx} = 9.81 C_1 C_2 C_3 \Delta\ (b + b_1) \qquad \text{kN}\cdot\text{m}$$

where: $C_1 = 0.150(\frac{b}{D})^2 - 0.778\frac{b}{D} + 0.866$

$$C_2 = -2.386\frac{b_1}{B} + 1.937$$

where:

b — breadth of demi-hull, in m;

b_1 — breadth of cross-deck, in m;

D — moulded depth of craft, in m;

B — breadth of craft, in m;

C_3 — service coefficient, taken as 1.0;

Δ — displacement of twin-hull craft, in t.

18.3.2.3 The transverse torque M_{ty} of the cross-deck of twin-hull craft may be obtained by the following formula:

$$M_{ty} = 1.226 C_3 \Delta L \qquad \text{kN}\cdot\text{m}$$

where: C_3 — service coefficient, taken as 1.0;

Δ — displacement of twin-hull craft, in t;

L — length of craft, in m.

18.3.2.4 The vertical shear force Q_t of the cross-deck of twin-hull craft may be obtained by the following formula:

$$Q_t = 9.81 C_1 C_2 C_3 \Delta \qquad \text{kN}$$

where: $C_1 = 0.164(\frac{b}{D})^2 - 0.874\frac{b}{D} + 0.974$

$$C_2 = -1.958\frac{b_1}{B} + 1.783$$

where:

b — breadth of demi-hull, in m;

b_1 — breadth of cross-deck, in m;

D — moulded depth of craft, in m;

B — breadth of craft, in m;

C_3 — service coefficient, taken as 1.0;

Δ — displacement of twin-hull craft, in t.

Appendix 1 DIRECT STRENGTH CALCULATION OF TWIN-HULL CRAFT

1 General Provisions

1.1 General requirements

1.1.1 This Appendix applies to the direct strength calculation of twin-hull craft.

1.1.2 For those not covered in this Appendix, the relevant requirements of Section 5, Chapter 1 of this PART are to be complied with.

2 Loads

2.1 General requirements

2.1.1 During direct calculation, the loads may be applied in the form of equivalent loads as specified in 2.2.1 to 2.2.3 or may be carried out by the equivalent design wave method as specified in 2.2.4.

2.1.2 Where the equivalent loads are applied, the longitudinal bending moment M_{by}, transverse bending moment M_{bx}, transverse torque M_{ty} are to be calculated in accordance with Section 3 of this Chapter and the loads include still water loads and wave loads.

2.2 Application of loads

2.2.1 For longitudinal bending moment M_{by} of twin-hull craft, equivalent force $q(x)$ vertically distributed along craft length or a series of equivalent concentrated forces may be applied on calculation model. The loads are to be applied on longitudinal primary members of demi-hull, such as craft side, longitudinal bulkheads, bottom centre girders or other girders. The force acting on the same cross section of one hull may be divided into portions symmetrical to the longitudinal centerline section at port and starboard sides and the loads applied on two demi-hulls are to be symmetrical to the longitudinal centerline section of twin-hull craft. Where a series of concentrated forces are applied, each concentrated force is to be equal to the product of the distributed force multiplied by the length of areas loaded by the concentrated forces. $q(x)$ is to be obtained by the following formula:

$$q(x) = q_0\left(\sin\frac{\pi x}{L} - 0.637\right) \qquad \text{kN/m}$$

where: $q_0 = \dfrac{46}{L^2} M_{by}$ kN/m

where: M_{by} is to be calculated in accordance with 18.3.2.1 of this Chapter.

2.2.2 For transverse bending moment M_{bx} of cross-deck, its equivalency may be achieved by applying the transverse split force on the series nodes along the inside of the bilge of demi-hull, as shown in Figure 2.2.2. The transverse split force f_y is to be obtained by the following formula:

$$f_y = \frac{M_{bx}}{nz} \qquad \text{kN}$$

where: M_{bx} — transverse bending moment of cross-deck, in kN·m, to be calculated in accordance with this Chapter;

z — the vertical distance from the application point of transverse split force to neutral axis of the longitudinal centerline section of cross-deck, in m;

n — total number of nodes on which the transverse split force is applied for one demi-hull.

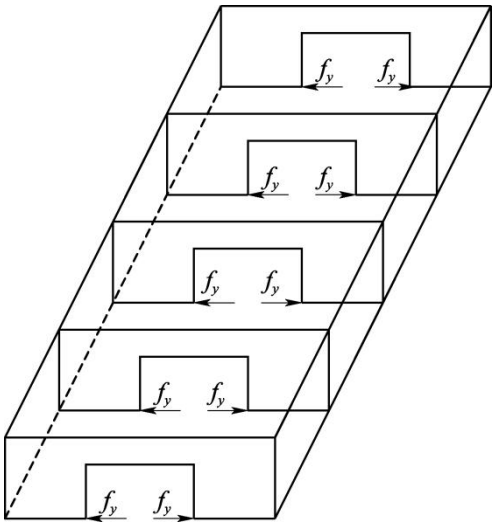


Figure 2.2.2 The application of transverse bending moment through transverse split force

2.2.3 For transverse torque M_{ty} of twin-hull craft, its equivalency may achieved by applying the uniformly distributed vertical force which is asymmetrically distributed on longitudinal centerline section of the demi-hull. "Asymmetrically distributed" means uniformly distributed equivalent vertical force, namely to be asymmetrically to the longitudinal centerline section and transverse centerline section of twin-hull craft, as shown in Figure 2.2.3. The uniformly distributed equivalent vertical load p_x is to be calculated by the following formula:

$$p_x = \frac{4M_{ty}}{L^2} \quad \text{kN/m}$$

where: L — length of twin-hull craft, in m;

M_{ty} — torque of cross-deck, in kN·m, to be calculated in accordance with this Chapter.

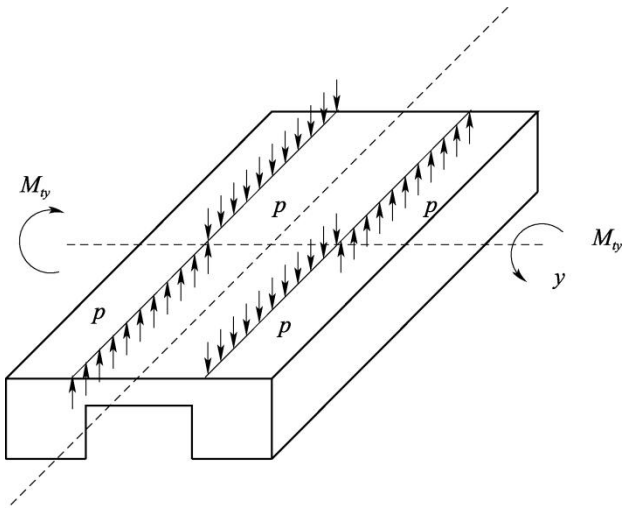


Figure 2.2.3 The application of transverse torque through asymmetrically distributed vertical force

2.2.4 The application of loads may also be carried out in accordance with 1.5.7 of Section 5, Chapter 1 of this PART. Relevant equivalent design wave is to be searched in accordance with the load combination conditions as specified in 3.1.1 of this Appendix.

3 Calculation Conditions

3.1 General requirements

3.1.1 The direct calculation of the structural strength of twin-hull craft is to be carried out in accordance with the load combination conditions (1) to (6) below and supplementary calculation is to be carried out in accordance with the load combination conditions (7) to (12) below for ships over 50 m in length:
(1) M_{bx} (inward);
(2) M_{bx} (outward);
(3) 0.8 M_{bx} (inward)＋0.6M_{ty};
(4) 0.8 M_{bx} (outward)＋0.6 M_{ty};
(5) 0.6 M_{bx} (inward)＋0.8 M_{ty};
(6) 0.6 M_{bx} (outward)＋0.8 M_{ty};
(7) M_{by} (hogging);
(8) M_{by} (sagging);
(9) 0.8 M_{by} (hogging)＋0.6 M_{ty};
(10) 0.8 M_{by} (sagging)＋0.6 M_{ty};
(11) 0.6 M_{by} (hogging)＋0.8 M_{ty};
(12) 0.6 M_{by} (sagging)＋0.8 M_{ty}.

4 Structural Modeling

4.1 General requirements

4.1.1 The global ship model is to contain all structural members of shell plating, longitudinal/transverse bulkheads, deck structure, cross-deck, struts, etc., of the hull structure.
4.1.2 The relevant requirements for model element and mesh scantling are given in Section 5, Chapter 1 of this PART.
4.1.3 In general, the following areas are to be subject to fine mesh analysis:
(1) interior angle in connection of the front end bulkhead of cross deck of twin-hull craft (or web beams) to twin hulls;
(2) interior angle in connection of the after end bulkhead of cross deck of twin-hull craft (or web beams) to twin hulls;
(3) positions in the actual structural shape that can not be expressed truly in any coarse mesh model;
(4) other areas where the stress considered for the global coarse mesh model exceeds 95% of the allowable stress.
4.1.4 During the fine mesh analysis, the mesh size of elements in refined area is not to be greater than 50 mm × 50 mm. The meshing is to be such that the transition from refined to coarse meshes is smooth.

4.2 Boundary conditions

4.2.1 For global FE model under an equilibrium condition, the boundary supports and constraint conditions given in Table 4.2.1 and Figure 4.2.1 may be used.

Boundary Conditions of Global FE Model **Table 4.2.1**

Position	Displacement constraint			Rotation constraint		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Supporting point *A*	Cons.	Cons.	Cons.	–	–	–
Supporting point *B*	–	Cons.	Cons.	–	–	–
Supporting point *C* (*C'*)	–	– (Cons.)	Cons. (–)	–	–	–

Notes:
① The combination of *A*, *B*, *C'* is used for torsion condition, of which the point *C'* position in *z* direction is at wet deck of the cross-deck longitudinal centerline.
② In the case of longitudinal bending condition, the disequilibrium (if any) of force system in *z* direction may cause reaction of the additional supports in way of point *A* and point *B*. In this case, the results in way of point *A* and point *B* are to be neglected (such condition is for midship region only).

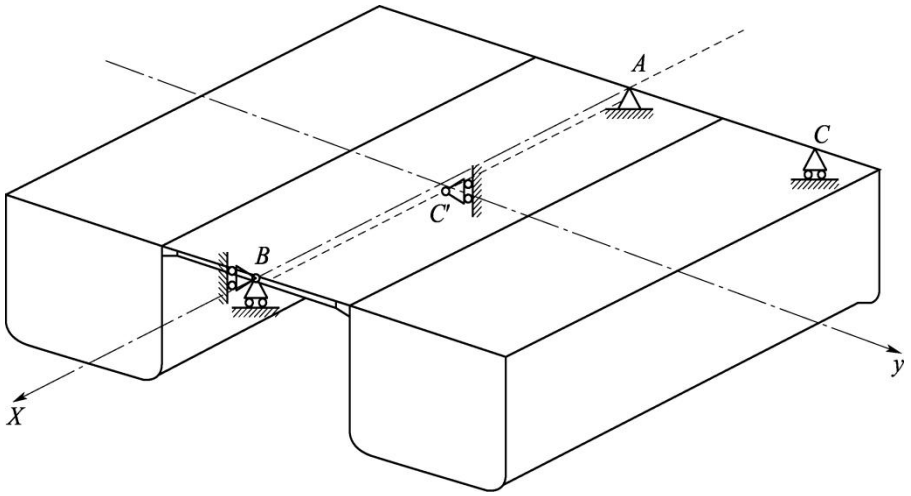


Figure 4.2.1

5 Yielding Strength Assessment

5.1 Permissible stress

5.1.1 The permissible stress is given in Table 5.1.1.

Permissible Stress **Table 5.1.1**

Structural component	Equivalent stress $[\sigma_e]$ (N/mm^2)	Shear stress $[\tau]$ (N/mm^2)
Plate element	200/K	90/K

Note: K— material factor.

5.1.2 Where the loads are applied in accordance with 2.2.1 to 2.2.3 of this Appendix, the equivalent stress of plate element within fine mesh area is not to be greater than $1.2\times235/K$ (K is material factor). Where the loads are applied through equivalent design wave in 2.2.4 of this Appendix, the equivalent stress of plate element within fine mesh area is not to be greater than $1.5\times235/K$ (K is material factor).

6 Buckling Strength Assessment

6.1 General requirements

6.1.1 The requirements for buckling strength assessment are given in Appendix 1, Chapter 5 of this PART.

CHAPTER 19 SAND CARRIERS

Section 1 GENERAL PROVISIONS

19.1.1 Application

19.1.1.1 This Chapter applies to self-discharging sand carriers (hereinafter referred to as sand carriers), with the transverse section of typical sand carriers given in Figures 19.1.1.1(1) and 19.1.1.1(2).

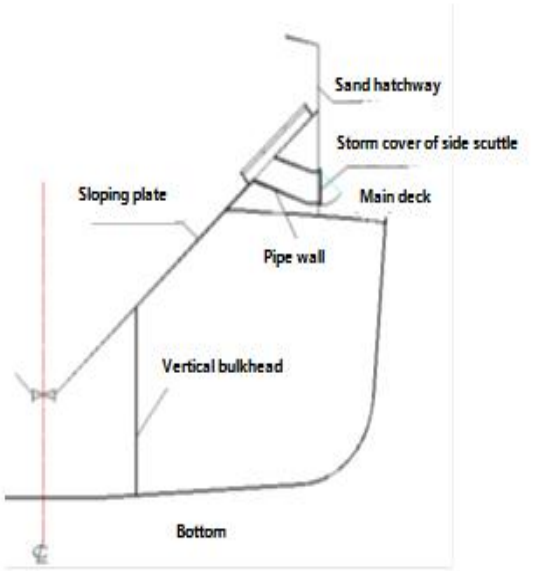


Figure 19.1.1.1(1)

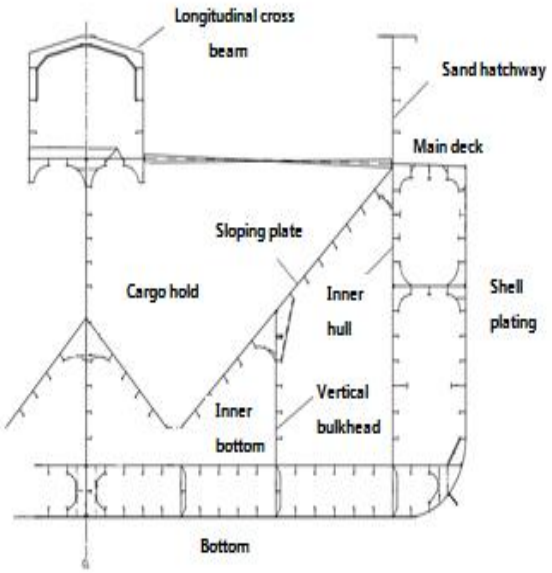


Figure 1 9.1.1.1(2)

19.1.1.2 This Chapter applies to the sand carriers with the main dimensions of $B/D \leq 3.5$.

19.1.1.3 For those not covered in this Chapter, the relevant requirements of Chapter 14 and Chapter 2 of this PART, as applicable, are also to be complied with.

19.1.2 Class notation

19.1.2.1 Ships complying with the requirements of this Chapter may be assigned with the class notation "Sand Carrier".

Section 2 SPECIAL REQUIREMENTS FOR STRUCTURES WITHIN SAND CARGO HOLD REGION

19.2.1 Sloping plate and its supporting structure

19.2.1.1 One bulkhead is to be provided under each sloping plate (at port and starboard), respectively for cargo hold fitted with sloping plates complying with the requirements of watertight bulkhead. The sloping structure of cargo hold is to meet the applicable requirements for hopper bulkheads in Chapter 14 of this PART and be in compliance with the requirements for hopper tanks in Chapter 8 of this PART.

19.2.1.2 The sectional area of bulkhead stiffeners or vertical webs with attached plating (bulkhead plating) is to comply with the requirements for pillars in Section 10, Chapter 2 of this PART. In calculation of the load P supported by pillars, P_0 is to be taken as the mud volumetric weight acting on sloping plate above within the loaded area $a \times b$.

19.2.1.3 For strength check of pillar under sloping plate, the mud volumetric weight acting on its above or the mud volumetric weight on hatch coamings and sloping plate supported by stiffeners is to be considered.

19.2.2 Bottom floors

19.2.2.1 For cargo hold structures in 19.2.1.1 above, the strength of bottom floors may be checked in accordance with the requirements of 14.5.2.1 of Section 5, Chapter 14 of this PART.

19.2.2.2 Vertical stiffeners are to be provided on web of solid floors for supporting pillars under sand hold

sloping plate between side longitudinal bulkheads and centerline, with the same thickness as that of the floor and 100 mm in width, both ends are to be snipped, see Figure 19.2.2.2.

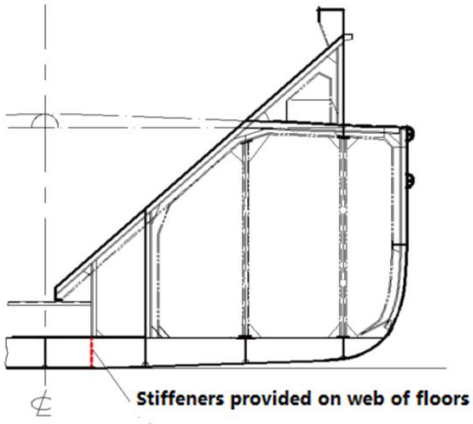


Figure 19.2.2.2 Stiffeners provided on web of floors

CHAPTER 20 MEMBRANE TANK LIQUEFIED GAS CARRIERS

Section 1 GENERAL PROVISIONS

20.1.1 Application

20.1.1.1 This Chapter applies to ships constructed with double hull side, double bottom, double deck and cofferdam transverse bulkheads, with engine room at stern and maximum vapor pressure less than 0.07 MPa, for the carriage of bulk liquefied natural gases in integral membrane type tanks.

20.1.1.2 For those not covered in this Chapter, the relevant applicable requirements of Chapters 1, 2 and 5 of this PART, and CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk are to be complied with.

20.1.2 Class notations

20.1.2.1 Membrane tank liquefied gas carriers complying with the requirements of this Chapter will be eligible to be assigned the class notations as follows:

Liquefied Gas Carrier, Type XG, Membrane Tanks; Max. Vapour Pressure ××× MPa; Min. Cargo Temperature ×××℃; Max. Cargo Density ××× t/m^3; FL(××).

20.1.2.2 Ship mainly used for carrying one or some of the products listed in Chapter 19 of PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and complying with the requirements of this Chapter, "for + name of product" may be added after "Carrier" and the name of product is in accordance with column a of the List of Minimum Requirements in Chapter 19, PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, for example:

Liquefied Gas Carrier for Ethane, Ethylene

Membrane tank liquefied gas carriers specially used for carrying liquefied natural gas and complying with the requirements of this Chapter will be eligible to be assigned the class notations as follows:

LNG Carrier，Type 2G, Membrane Tanks; Max. Vapour Pressure ×××MPa; Min. Cargo Temperature ×××℃; Max. Cargo Density ××× t/m^3； FL(××)

20.1.2.3 A minimum design fatigue life of at least 20 years is specified in this Chapter. Where a membrane tank liquefied gas carrier is designed for a minimum design fatigue life of 25 years or more, the class notation FL (minimum design fatigue life) may be assigned at 5-year intervals starting from the 25th year, e.g. FL(25), FL(30), etc. For fatigue assessment based on spectrum analysis in accordance with the requirements of CCS Guidelines for Fatigue Strength Assessment of Ship Structure based on Spectrum Analysis, the service/route for which the ship is intended may be added in the class notation, e.g. SFA (NA, 25).

20.1.3 Plans and documents

20.1.3.1 Relevant applicable requirements of Chapter A3, PART TWO in CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk are to be complied with in addition to the plans and documents specified in Section 1, Chapter 2 of this PART.

20.1.3.2 The following plans and documents related to the structural strength assessment of pump tower are also to be submitted for approval:

(1) pump tower arrangement;

(2) main structures of pump tower (including base foundations and liquid dome structures).

20.1.3.3 For the calculation of temperature field, the following plans and documents are also to be submitted for information:

(1) structure of insulation boxes;

(2) arrangement of insulations and details of their connections;

(3) temperature field calculation report.

20.1.4 Arrangement and structural configuration

20.1.4.1 The cargo tanks of membrane tank liquefied gas carriers are of complete double hull structure, having double side, double bottom, double deck and cofferdam transverse bulkheads. The dihedral between inner hull and inner deck/inner bottom is rendered 135° to reduce sloshing effects of cargo.

20.1.4.2 Cofferdams are to be provided forward of the foremost cargo tank and aft of the aftmost cargo tank as well as between cargo tanks. Integral double hull segregation is to be provided by cofferdams

between cargo tanks. For each cargo tank, the integral double hull is to be divided by void spaces including double bottom, double side, double deck and cofferdam transverse bulkheads.

20.1.4.3 Subdivision, width of double side and height of double bottom are to comply with the relevant requirements in Chapter 2, PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gas in Bulk.

20.1.4.4 Structural configuration of cargo tanks

(1) Typical sketch of midship section and structural members of membrane tank liquefied gas carriers are shown in Figure 20.1.4.5.

Trunk deck is the continuous weather deck within cargo area and is higher than the upper deck.

Inner deck is the deck within cargo area and above the upper deck, forming a part of the inner hull in the ship.

(2) In general, the deck, bottom and inner bottom within cargo tank region of membrane tank liquefied gas carriers are to be longitudinally framed. The side shell and inner hull are also to be longitudinally framed. The hull structures beyond the cargo tank region may be framed either transversely or longitudinally. Constructional arrangements are to be made to ensure a gradual transition from the longitudinal framing to the transverse framing.

(3) The box framing of double deck of membrane tank liquefied gas carriers is formed by inner deck, upper deck and trunk deck as well as interconnected longitudinal girders and transverse floors.

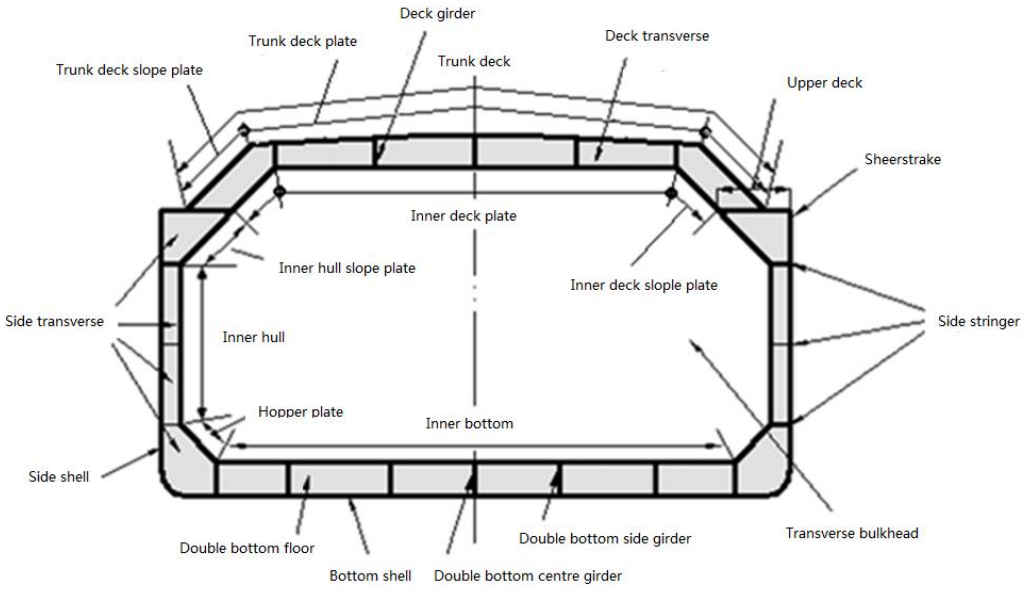


Figure 20.1.4.4 Typical sketch of midship section and structural members

(4) Cargo tanks are enclosed by double bottom, double side, cofferdams and double box trunk deck. Loading of fuel oil in double bottom, double hull, cofferdams and double box trunk deck directly adjacent to the insulation box of cargo tanks is not permitted.

20.1.4.5 Relevant requirements for cargo containment systems with regard to hull structural size and arrangement are to be approved by cargo containment system equipment manufacturer.

20.1.5 Minimum thickness

20.1.5.1 The minimum plate thickness for cargo tanks as well as other areas is to comply with the requirements of 5.1.6, Chapter 5 of this PART.

20.1.6 Direct calculation of hull structural strength

20.1.6.1 Direct calculation of structural strength related to membrane tank liquefied gas carriers is to be carried out according to the following requirements:

(1) for membrane tank liquefied gas carriers of 150 m in length and upward, hull structural strength assessment of direct calculations within the cargo tank region is to be carried out according to Appendix 1 of this Chapter;

(2) for membrane tank liquefied gas carriers with 4 and more cargo tanks or ship length of more than 250 m, direct calculation of global strength of ships is to be carried out according to Appendix 4 of this Chapter.

20.1.7 Structural strength under sloshing loads

20.1.7.1 The strength of the hull structure and pump tower structure of cargo tank region under sloshing loads, as well as of the liquid dome and base foundation structures of the pump tower, is to be checked and vibration evaluation of the pump tower structure is to be carried out according to the requirements of Appendix 2 of this Chapter.

20.1.8 Temperature field and thermal stress analysis

20.1.8.1 Appendix 3 of this Chapter applies to the temperature field prediction analysis of the hull structure and pump tower structure as well as thermal stress calculation of the pump tower structure of cargo tank region of membrane tank liquefied gas carriers under the low-temperature effect of the cargo, and the calculation report is to be submitted for information.

20.1.9 Fatigue assessment of hull structure

20.1.9.1 For membrane tank liquefied gas carriers of 150 m in length and upward, fatigue strength check is to be carried out for the following positions according to CCS Guidelines for Fatigue Strength of Ship Structure.:

(1) connection of longitudinals (bottom, side and deck) to transverse web frames;

(2) connections of longitudinals (bottom, side and deck) to transverse bulkheads;

(3) pump tower structures

For ships intended to apply for SFA notation, the fatigue strength check is to be carried out according to CCS Guidelines for Spectrum-based Fatigue Assessment of Hull Structure.

20.1.9.2 When implementing the requirements of 20.1.9.1 above, fatigue strength check is to be carried out by fine mesh finite element method to at least the following hull structures.

(1) the connection of lower and upper knuckle joints of hopper slope plating to inner bottom plating and inner hull longitudinal bulkhead in way of transverse web frames, as shown in Figure 20.1.9.2(1);

(2) the connection of inner bottom plating to transverse bulkhead in way of double bottom girder, as shown in Figure 20.1.9.2(2);

(3) the connection of inner hull plating to transverse bulkhead in way of double side stringer, as shown in Figure 20.1.9.2(3);

(4) the connection of liquid/gas dome opening and coaming to trunk deck, as shown in Figure 20.1.9.2(4).

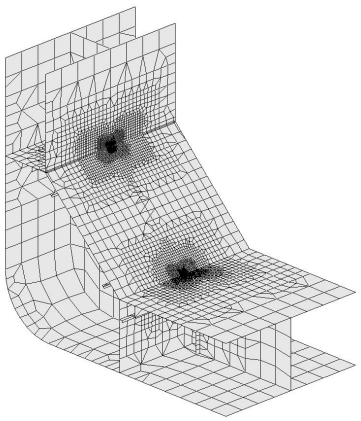


Figure 20.1.9.2(1) Connection of lower and upper knuckle joints of hopper slope plating to inner bottom plating and inner hull longitudinal bulkhead

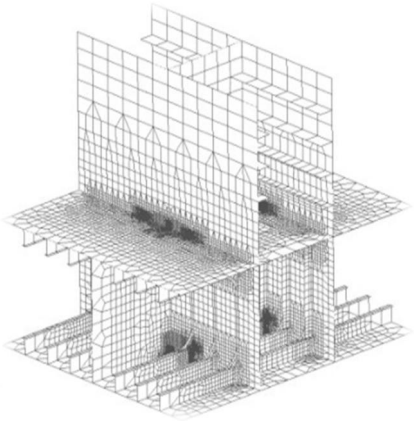


Figure 20.1.9.2(2) Connection of inner bottom plating to transverse bulkhead

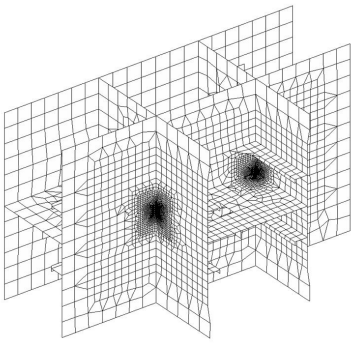


Figure 20.1.9.2(3) Connection of inner hull plating to transverse bulkhead

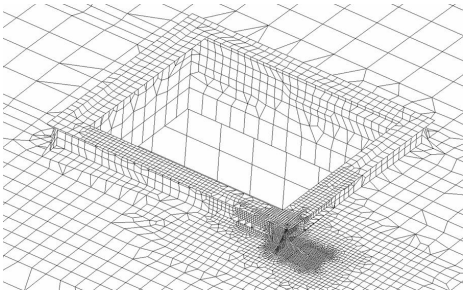


Figure 20.1.9.2(4) Connection of liquid/gas dome opening and coaming to trunk deck

Section 2 HULL GIRDER LONGITUDINAL STRENGTH AND ULTIMATE STRENGTH

20.2.1 Hull girder longitudinal strength

20.2.1.1 Membrane tank liquefied gas carriers are to comply with the longitudinal strength requirements specified in Section 2, Chapter 2 of this PART.

20.2.2 Hull girder ultimate strength

20.2.2.1 Evaluation of hull girder ultimate bending capacity within 0.4*L* amidships for intact hull structures in sea-going conditions is to be carried out to membrane tank liquefied gas carriers of 150 m in length and upward. Evaluation of hull girder ultimate bending capacity of membrane tank liquefied gas carriers of less than 150 m in length may also refer to the requirements of this Section.

20.2.2.2 Vertical hull girder ultimate bending capacity is to satisfy the following criterion:

$$\gamma_s \overline{M}_s + \gamma_w M_w \le \frac{M_U}{\gamma_R}$$

where:

$\overline{M}_s$ — permissible still water bending moment, in kN·m;

M_W — wave bending moment, in kN·m;

M_U — vertical hull girder ultimate bending moment, in kN·m;

$\gamma_s, \gamma_w, \gamma_R$ — partial safety factors, for membrane tank liquefied gas carriers,

γ_s=1.0,

γ_w=1.3,

$\gamma_R = \gamma_M \cdot \gamma_{DB}$

γ_M — partial safety factor, for membrane tank liquefied gas carriers, γ_M = 1.1;

γ_{DB} — to be taken as:

- γ_{DB} = 1.25 in hogging condition;
- γ_{DB} = 1.00 in sagging condition.

20.2.2.3 Curve *M*-χ

The ultimate bending moment of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment *M* versus the curvature χ of the transverse section considered (see Figure 20.2.2.3).

The curvature χ is positive for hogging condition and negative for sagging condition.

The curve *M*-$\chi$is to be obtained by means of an incremental-iterative approach in accordance with Appendix 2, Chapter 5, Part 9-1 of the Rules.

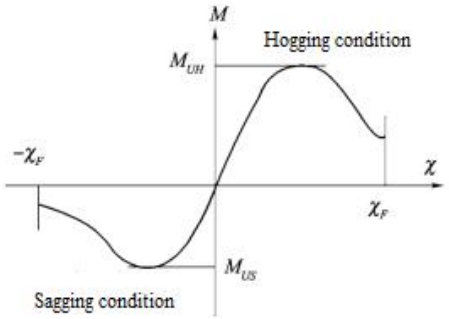


Figure 20.2.2.3 Curve Bending Moment *M* Versus Curvature χ

20.2.2.4 The hull girder transverse sections are constituted by the elements contributing to the hull girder longitudinal strength, and the standard thickness deduction given in Table 20.2.2.4 is to be deducted in calculation.

Standard Thickness Deduction **Table 20.2.2.4**

Structures	Standard thickness deduction, in mm
Trunk deck, trunk deck sloping plate	1
Side shell plating, sheer strake	1.5
Bilge strake, bottom plating and keel plate	1.25
Upper deck	1.25
Inner hull longitudinal bulkhead plating	1
Inner bottom plating	1
Horizontal girders in ballast tanks of double side	1.5
Girder in ballast tanks of double bottom	1.5
Side wall of pipe duct of double bottom	1.25
Structural members in ballast tanks	1.5
Structural members in dry spaces	0.5
Others	0.5

Section 3 SHELL PLATING

20.3.1 General requirements

20.3.1.1 Bottom shell, plate keel, side shell and sheer strake of membrane tank liquefied gas carriers are normally to be longitudinally framed.

20.3.1.2 The formulae in this Section apply to the determination of the thickness of longitudinally framed bottom shell, plate keel, bilge strakes, side shell and sheer strake within 0.4L amidships.

20.3.2 Bottom shell

20.3.2.1 The thickness t of bottom shell plating within 0.4L amidships is not to be less than the values obtained from the following formulae:

$$t_1 = 0.052 s_1 (L + 170)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 3.95 s \sqrt{K \rho_w h_1} + 2.5 \quad \text{mm}$$

where: s_1 — spacing of longitudinals, in m, not to be less than standard spacing of longitudinals;

s — spacing of longitudinals, in m;

L — length of ship, in m, need not be greater than 190 m;

K — material factor;

ρ_w — density of sea water, to be taken as 1.025 t/m^3;

F_b — reduction factor, see Section 2, Chapter 2 of this PART;

h_1 — to be taken according to following formula, in m;

$h_1 = h_0 - 0.35d$ if $Z = 0$;

$h_1 = h_0$ if $Z \geq d$;

Values in-between are obtained from linear interpolation.

h_0 — vertical distance, in m, measured from the lower edge of plate to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

Z — vertical distance from base line to the point under consideration, in m;

Z_n — height of neutral axis, from base line, of hull cross section, in m;

d — draught, in m.

20.3.2.2 The breadth b of the plate keel within the cargo tank region is not to be less than that obtained from the following formula:

$$b = 900 + 3.5L \quad \text{mm}$$

The thickness of plate keel is not to be less than that of the adjacent bottom shell plating, and the thickness t is not to be less than the following value, if docking brackets are fitted in way of plate keel:

$$t = t_0 + 2.0 \quad \text{mm}$$

where: L — length of ship, in m;

t_0 — thickness of bottom shell plating defined by 20.3.2.1 of this Section, in mm.

20.3.3 Bilge strake

20.3.3.1 The thickness of bilge stakes within 0.4*L* amidships is not to be less than those of the adjacent bottom shell plating and side shell plating. See 5.2.4.2, Chapter 5 of this PART for the requirements of bilge strakes. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check in direct calculation, the value of *K* for a lower strength level may be taken.

20.3.4 Side shell plating

20.3.4.1 The thickness t of the side shell plating within 0.4L amidships is to comply with the following requirements:

(1) The thickness *t* of the side shell plating above $\frac{3}{4}D$ from base is not to be less than the values obtained from the following formulae:

$$t_1 = 0.058 s_1 (L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 3.95 s\sqrt{\rho_w K h_1} + 2.5 \quad \text{mm}$$

(2) The thickness *t* of side shell plating below $\frac{1}{4}D$ from base is not to be less than the values obtained from the following formulae:

$$t_1 = 0.06 s_1 (L_1 + 110)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 3.95 s\sqrt{\rho_w K h_1} + 2.5 \quad \text{mm}$$

where: s — spacing of longitudinals, in m;

s_1 — spacing of longitudinals, in m, not to be less than standard spacing of longitudinals;

L — length of ship, in m, need not be greater than 190 m;

K — material factor;

ρ_w — density of sea water, to be taken as 1.025 t/m^3;

F_b, F_d — reduction factor, see Section 2, Chapter 2 of this PART;

h_1 — see 20.3.2.1 of this Section.

(3) For the formulae for the thickness *t* of side shell plating between $\frac{1}{4}D$ and $\frac{3}{4}D$ from base, see 5.2.5.1(3) of Chapter 5, where the plating thickness used for calculation is based on the results of 20.3.4.1(1) and (2) of this Section.

20.3.5 Sheer strake

20.3.5.1 The width of the sheer strake is to comply with the requirements of 5.2.6.1 of Chapter 5 of this PART.

20.3.5.2 Thickness *t* of sheer strake within 0.4*L* amidships is not to be less than the values obtained from the following formulae, nor less than that of the adjacent side shell plating or of the stringer plate of the upper deck:

$$t_1 = 0.06 s_1 (L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9 s_1 F_{c_deck}\sqrt{(L+80)K} + t_c \quad \text{mm}$$

where: s_1 — spacing of longitudinals, in m; not to be less than standard spacing of longitudinals;

L — length of ship, in m;

$L_1 = L$, where L is length of ship, in m, but need not be greater than 190 m;

$F_{c_deck} = 0.922\left[L/(L+80)\right]^{1/2}$;

F_d — reduction factor, see Section 2, Chapter 2 of this PART;

K — material factor;

t_c — corrosion allowance, for ballast tanks, to be taken as 2.5 mm; for cofferdams, to be taken as 1.0 mm.

Section 4 DECKS

20.4.1 General requirements

20.4.1.1 The formulae in this Section apply to the determination for thickness of trunk deck plating and upper deck plating within cargo tank region.

20.4.2 Trunk deck plating

20.4.2.1 Thickness of trunk deck plating

(1) Thickness t of trunk deck plating within 0.4L amidships is not to be less than the values obtained from the following formulae:

$$t_1 = 0.06 s_1 (L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9 s_1 F_{c_deck}\sqrt{(L+80)K} + t_c \quad \text{mm}$$

(2) Thickness t of trunk deck plating beyond 0.4L amidships within cargo tank region is not to be less than the values obtained from the following formulae, and is to be gradually tapered to end thickness of the cargo tank region:

$$t_1 = 0.06 s_1 (L_1 + 105)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9 s_1 F_{c_deck}\sqrt{(L+80)K} + t_c \quad \text{mm}$$

where: s_1 — spacing of longitudinals, in m, which is not to be less than the standard spacing of longitudinals;

L— length of ship, in m;

$L_1 = L$, where L is length of ship, in m, need not be greater than 190 m;

K— material factor;

F_d — reduction factor, see Section 2, Chapter 2 of this PART;

$F_{c_deck} = 0.922\left[L/(L+80)\right]^{1/2}$;

t_c — corrosion allowance, for ballast tanks, to be taken as 2.5 mm; for cofferdams, to be taken as 1.0 mm.

20.4.2.2 Thickness of trunk deck slope plating

(1) Thickness t of trunk deck slope plating within 0.4L amidships is not to be less than the values obtained from the following formulae:

$$t_1 = 0.051 s_1 (L_1 + 115)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9 s_1 F_{c_deck}\sqrt{(L+80)K} + t_c \quad \text{mm}$$

(2) Thickness t of trunk deck slope plating beyond 0.4L amidships within cargo tank region is not to be less than the values obtained from the following formulae, and is to be gradually tapered to end thickness of the cargo tank region:

$$t_1 = 0.051 s_1 (L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9 s_1 F_{c_deck}\sqrt{(L+80)K} + t_c \quad \text{mm}$$

For symbols in the formulae, see 20.4.2.1 of this Section.

20.4.3 Upper deck plating

20.4.3.1 Thickness t of upper deck plating within 0.4L amidships is not to be less than the values obtained from the following formulae:

$$t_1 = 0.06 s_1 (L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9 s_1 F_{c_deck}\sqrt{(L+80)K} + t_c \quad \text{mm}$$

$$t_3 = 3.95s\sqrt{K\rho_w h_0} + 2.5 \quad \text{mm, and not less than 7.5 mm}$$

where: s — spacing of longitudinals, in m;

s_1 — spacing of longitudinals, in m; not to be less than standard spacing of longitudinals;

L — length of ship, in m;

$L_1 = L$, where L is length of ship, in m, but need not be greater than 190 m;

K — material factor;

ρ_w — density of sea water, to be taken as 1.025 t/m^3;

F_d — reduction factor, see Section 2, Chapter 2 of this PART;

$$F_{c_deck} = 0.922\left[L/(L+80)\right]^{1/2};$$

h_0 — vertical distance, in m, measured from the lower edge of plate to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

t_c — corrosion allowance, for ballast tanks, to be taken as 2.5 mm; for cofferdams, to be taken as 1.0 mm.

20.4.3.2 Thickness t of upper deck plating beyond 0.4L amidships within cargo tank region is not to be less than the values obtained from the following formulae, and is to be gradually tapered to end thickness of the cargo tank region:

$$t_1 = 0.06s_1(L_1 + 105)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s_1F_{c_deck}\sqrt{(L+80)K} + t_c \quad \text{mm}$$

$$t_3 = 3.95s\sqrt{K\rho_w h_0} + 2.5 \quad \text{mm , and not less than 7.5 mm}$$

For symbols in the formulae, see 20.4.3.1 of this Section.

Section 5 DECKS STRUCTURES

20.5.1 General requirements

20.5.1.1 Formulae in this Section apply to the determination of arrangement and scantlings of double box type trunk deck structures within cargo tank region.

20.5.2 Structural arrangement

20.5.2.1 Double box type trunk deck structures of membrane tank liquefied gas carriers are longitudinally framed by trunk deck, inner deck, deck transverses, deck girders and deck longitudinals.

20.5.2.2 Deck transverses are to be fitted in double box trunk deck in line with double bottom floors, and transverse framing or vertical webs in double side form transverse ring frames.

20.5.2.3 Deck girders are to be fitted in line with double bottom girders as far as possible, and deck girders are to be fitted in way of inner deck knuckle.

20.5.3 Deck girders

20.5.3.1 Side girders are to be fitted at the knuckle line of inner deck in double box trunk deck. The deck girders are to be equally spaced so far as practicable.

20.5.3.2 The web depth h of centre and side girders is not to be less than that obtained from the following formula:

$$h = 35B_e + 100 \quad \text{mm, and not less than 1,000 mm}$$

where: B_e —maximum breadth of trunk deck, in m, see Figure 20.5.3.2.

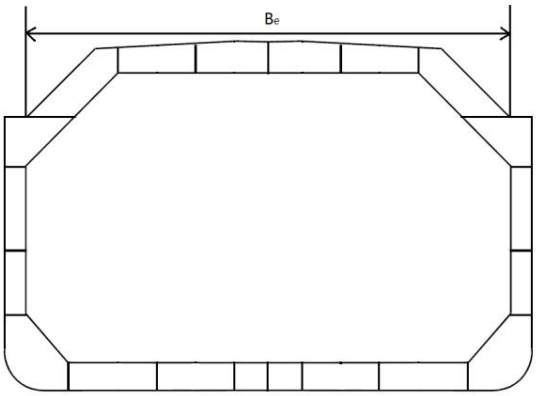


Figure 20.5.3.2 Maximum Breadth of Trunk Deck

20.5.3.3 The minimum web thickness t of centre girders is not to be less than that obtained from the following formula:

$t = (0.006h + 1.0)\sqrt{K}$ mm, but need not be greater than 16 mm

where: h — same as that specified in 20.5.3.2 of this Section;

K — material factor.

20.5.3.4 The minimum web thickness t of side girders is not to be less than that obtained from the following formula:

$t = (0.006h + 0.5)\sqrt{K}$ mm, but need not be greater than 16 mm

where: h — same as that specified in 20.5.3.2 of this Section;

K — material factor.

20.5.4 Deck transverses

20.5.4.1 Web thickness t of deck transverses is not to be less than that obtained from the following formula:

$$t = (0.006h + 0.5)\sqrt{K}$$, but need not be greater than 16 mm

where: h — same as that specified in 20.5.3.2 of this Section;

K — material factor.

20.5.4.2 Attention is to be paid to alignment where deck transverse webs are cut apart in way of deck girders so as to ensure the transverse continuity.

20.5.4.3 Vertical stiffeners are to be fitted between trunk deck longitudinals and inner deck longitudinals on deck transverse webs.

20.5.5 Trunk deck longitudinals

20.5.5.1 Section modulus W of trunk deck longitudinals is not to be less than that obtained from the following formula:

$$W = C_1 K s h l^2 \xi \qquad \text{cm}^3$$

where: l — span of longitudinals, in m, but not to be taken less than 2.5 m;

s — spacing of longitudinals, in m;

h — see 2.8.5.1, Chapter 2 of this PART;

K— material factor;

C_1 — coefficient, to be taken as 45;

ξ — coefficient, to be calculated according to following formula:

$$\xi = 0.47 - 1.065F_d + 0.839F_d^2$$

F_d — reduction factor, see Section 2, Chapter 2 of this PART.

20.5.5.2 Trunk deck longitudinals, in association with the trunk deck plating, may be gradually tapered outside 0.4L amidships towards the fore and aft ends of cargo tank region. At these ends, the section modulus of trunk deck longitudinals is not to be less than 90% of the value obtained from 20.5.5.1 of this Section.

20.5.5.3 Trunk deck longitudinals are to be continuous through the web of deck beams and welded to the web of deck transverses. These trunk deck longitudinals are to be welded to the stiffeners of deck transverses when intersecting such stiffeners.

20.5.6 Upper deck longitudinals

20.5.6.1 Section modulus W of upper deck longitudinals is not to be less than that obtained from the following formula:

$$W_1 = 8\rho_w Ksh_0 l^2 \quad \text{cm}^3$$

$$W_2 = C_1 Kshl^2 \xi \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinals, in m, but not to be taken less than 2.5 m;

ρ_w — density of sea water, to be taken as 1.025 t/m^3;

h — see 2.8.5.1, Chapter 2 of this PART;

h_0 — vertical distance, in m, measured from center of the stiffener span to the top of the tank in way of the ship's longitudinal centerline section, or half the distance to the top of overflow, whichever is the greater;

K— material factor;

C_1 — coefficient, to be taken as 45;

ξ— coefficient, to be calculated according to following formula:

$$\xi = 0.47 - 1.065F_d + 0.839F_d^2$$

F_d — reduction factor, see Section 2, Chapter 2 of this PART.

20.5.6.2 Upper deck longitudinals, in association with the deck plating, may be gradually tapered outside 0.4L amidships towards the fore and aft ends. At 0.075L from the ends, the section modulus of deck longitudinals is not to be less than 80% of the value obtained from 20.5.6.1 of this Section, nor less than that required for deck longitudinals at the ends of the ship in 2.8.5.1, Chapter 2 of this PART.

20.5.6.3 Connections of upper deck longitudinals to watertight transverse bulkheads are to provide adequate fixity and upper deck longitudinals are to be continuous through the transverse bulkheads.

20.5.7 Inner deck plating

20.5.7.1 Thickness of inner deck plating

(1) Thickness t of inner deck plating within 0.4L amidships is not to be less than the values obtained from the following formulae:

$$t_1 = 0.06s_1(L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s_1 F_{c_deck}\sqrt{(L+80)K} + t_c \quad \text{mm}$$

$$t_3 = 40s\sqrt{KP_{eq}} + 1.0 \quad \text{mm}$$

(2) Thickness t of inner deck plating beyond 0.4L amidships within cargo tank region is not to be less than the values obtained from the following formulae, and is to be gradually tapered to end thickness of the cargo tank region:

$$t_1 = 0.06s_1(L_1 + 105)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s_1 F_{c_deck}\sqrt{(L+80)K} + t_c \quad \text{mm}$$

$$t_3 = 40s\sqrt{KP_{eq}} + 1.0 \quad \text{mm}$$

where: s — spacing of longitudinals, in m;

s_1 — spacing of longitudinals, in m, which is not to be less than the standard spacing of longitudinals;

L— length of ship, in m;

$L_1 = L$, where L is length of ship, in m, need not be greater than 190 m;

K— material factor;

F_d— reduction factor, see Section 2, Chapter 2 of this PART;

$F_{c_deck} = 0.922\left[L/(L+80)\right]^{1/2}$;

P_{eq} — internal pressure of tank, in MPa, as defined in 4.13.2.4, Chapter 4, PART THREE of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk;

t_c — corrosion allowance, for ballast tanks, to be taken as 2.5 mm; for cofferdams, to be taken as 1.0 mm.

20.5.7.2 Thickness of inner deck slope plating

(1) Thickness t of inner deck slope plating within 0.4L amidships is not to be less than the values obtained from the following formulae:

$$t_1 = 0.06 s_1 (L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9 s_1 F_{c_deck}\sqrt{(L+80)K} + t_c \quad \text{mm}$$

$$t_3 = 40 s\sqrt{KP_{eq}} + 1.0 \quad \text{mm}$$

(2) Thickness t of inner deck slope plating beyond 0.4L amidships within cargo tank region is not to be less than the values obtained from the following formulae, and is to be gradually tapered to end thickness of the cargo tank region:

$$t_1 = 0.05 s_1 (L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9 s_1 F_{c_deck}\sqrt{(L+80)K} + t_c \quad \text{mm}$$

$$t_3 = 40 s\sqrt{KP_{eq}} + 1.0 \quad \text{mm}$$

For symbols in the formulae, see 20.5.7.1 of this Section.

20.5.8 Inner deck longitudinals

20.5.8.1 Section modulus W of inner deck top plating longitudinals is not to be less than the value obtained from the following formula:

$$W = 644 KsP_{eq} l^2 \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinals, in m, but not to be taken less than 2.5 m;

K — material factor;

P_{eq} — internal pressure of tank, in MPa, as defined in 4.13.2.4, Chapter 4, PART THREE of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

20.5.8.2 Section modulus W of inner deck slope plating longitudinals is not to be less than the value obtained from the following formula:

$$W = 560 KsP_{eq} l^2 \quad \text{cm}^3$$

where: symbols — see 20.5.8.1 in this Section.

20.5.8.3 Inner deck longitudinals, in association with the inner deck plating, may be gradually tapered outside 0.4L amidships towards the fore and aft ends of cargo tank region. At these ends, the section modulus of inner deck longitudinals is not to be less than 90% of the value obtained from (1) above.

20.5.8.4 Connections of inner deck longitudinals to transverse bulkheads are to provide adequate fixity and the inner deck longitudinals are to be continuous through the webs of deck transverses. Inner deck longitudinals are to be welded to the web of deck transverses, and to be welded to the stiffeners of deck transverses when intersecting such stiffeners.

Section 6 DOUBLE SKIN CONSTRUCTION

20.6.1 General requirements

20.6.1.1 This Section is applicable to the determination of arrangement and scantlings of frames in double side within the cargo tank region.

20.6.1.2 Those uncovered in this Section are to comply with the provisions in Section 5, Chapter 5 of this PART.

20.6.2 Side longitudinals

20.6.2.1 Section modulus W of side longitudinals is not to be less than that obtained from the following formula:

$$W_1 = \frac{8.5}{f} Kshl^2 \quad \text{cm}^3$$

$$W_2 = 8K\rho_w s h_1 l^2 \quad \text{cm}^3$$

where: s— spacing of longitudinals, in m;

l — span of longitudinals, in m;

K— material factor;

f — factor, to be taken according to following formula and not to be greater than 1.077:

$$f=\begin{cases}1.73-F_d\dfrac{Z-Z_n}{D-Z_n} & \text{if } Z\geq Z_n;\\ 1.73-F_d\dfrac{Z_n-Z}{Z_n} & \text{if } Z<Z_n\end{cases}$$

h — design pressure head, in m, to be taken from the following formula:

$$h=0.26C+d-\frac{Z}{D}\left(0.06C+d\right)$$

C — see Section 2, Chapter 2 of this PART;

D — moulded depth, in m;

h_1— to be taken according to following formula, in m:

$h_1=h_0-0.35d$, if $Z=0$;

$h_1=h_0$, if $Z\geq d$

Values in-between are obtained from linear interpolation.

h_0 — vertical distance, in m, measured from the center of stiffener span to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

Z — vertical distance from base line to the calculation point, in m;

Z_n — height of neutral axis, from base line, of the hull cross section calculated, in m;

d — draught, in m;

ρ_w — density of sea water, to be taken as 1.025 t/m^3.

20.6.3 Inner hull slope plating and its longitudinals

20.6.3.1 The thickness of inner hull slope plating is not to be less than the values obtained from the following formulae nor less than that of the adjacent inner deck sloping plate:

$$t_1=40s\sqrt{KP_{eq}}+1.0 \quad \text{mm}$$

$$t_2=3.95s\sqrt{K\rho_w h_0}+2.5 \quad \text{mm}$$

where: s — spacing of longitudinals, in m;

K — material factor;

ρ_w — density of sea water, to be taken as 1.025 t/m^3;

h_0 — vertical distance, in m, measured from the lower edge of the plate to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

P_{eq} — internal pressure of tank, in MPa, as defined in 4.13.2.4, Chapter 4, PART THREE of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

20.6.3.2 The section modulus W of longitudinals of inner hull slope plating is not to be less than the values obtained from the following formulae nor less than that of the adjacent inner hull plating longitudinals:

$$W_1=560KsP_{eq}l^2 \quad \text{cm}^3$$

$$W_2=8K\rho_w s h_0 l^2 \quad \text{cm}^3$$

where: l — span of longitudinals, in m;

h_0 — vertical distance, in m, measured from the center of stiffener span to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

For other symbols, see 20.6.3.1 of this Section.

20.6.4 Inner hull plating and its longitudinals

20.6.4.1 The thickness of inner hull plating is not to be less than the values obtained from the following formulae:

$$t_1=40s\sqrt{KP_{eq}}+1.0 \quad \text{mm}$$

$$t_2=3.95s\sqrt{K\rho_w h_0}+2.5 \quad \text{mm}$$

where: s — spacing of longitudinals, in m;

K — material factor;

ρ_w — density of sea water, to be taken as 1.025 t/m^3;

h_0 — vertical distance, in m, measured from the lower edge of the plate to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

P_{eq} — internal pressure of tank, in MPa, as defined in 4.13.2.4, Chapter 4, PART THREE of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

20.6.4.2 The spacing of longitudinals of inner hull plating is the same as that of side shell longitudinals, and the section modulus W is not to be less than the values obtained from the following formulae:

$$W_1 = 560KsP_{eq}l^2 \quad \text{cm}^3$$

$$W_2 = 8K\rho_w s h_0 l^2 \quad \text{cm}^3$$

where: l — span of longitudinals, in m;

h_0 — vertical distance, in m, measured from the center of stiffener span to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

For other symbols, see 20.6.4.1 of this Section.

20.6.5 Hopper slope plating and its longitudinals

20.6.5.1 The thickness of hopper slope plating is not to be less than the values obtained from the following formulae nor less than that of the adjacent inner hull plating:

$$t_1 = 40s\sqrt{KP_{eq}} + 1.0 \quad \text{mm}$$

$$t_2 = 3.95s\sqrt{K\rho_w h_0} + 2.5 \quad \text{mm}$$

where: s — spacing of longitudinals, in m;

K — material factor;

ρ_w — density of sea water, to be taken as 1.025 t/m^3;

h_0 — vertical distance, in m, measured from the lower edge of the plate to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

P_{eq} — internal pressure of tank, in MPa, as defined in 4.13.2.4, Chapter 4, PART THREE of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

20.6.5.2 The section modulus of hopper slope plating longitudinals is not to be less than the values obtained from the following formulae nor less than that of the adjacent inner hull plating longitudinals:

$$W_1 = 560KsP_{eq}l^2 \quad \text{cm}^3$$

$$W_2 = 8K\rho_w s h_0 l^2 \quad \text{cm}^3$$

where: l — span of longitudinals, in m;

h_0 — vertical distance, in m, measured from the center of stiffener span to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

For other symbols, see 20.6.5.1 of this Section.

20.6.6 Stringers in double side

20.6.6.1 Structural requirements related to stringers in double side are to comply with the provisions in 5.5.6, Chapter 5 of this PART.

20.6.7 Transverse bulkheads in double side

20.6.7.1 Structural requirements related to transverse bulkheads in double side are to comply with the provisions in 5.5.7, Chapter 5 of this PART.

Section 7 DOUBLE BOTTOM STRUCTURE

20.7.1 General requirements

20.7.1.1 Unless specified otherwise in this Section, the scantlings and arrangement of the double bottoms in cargo tank region are to be as required in Section 4, Chapter 5 of this PART.

20.7.2 Bottom girders

20.7.2.1 The centre girders are to be arranged at the longitudinal centerline of double bottoms. Side girders are also to be provided at sides. At least two side girders spaced apart generally not more than 4 m are to be fitted on each side of the centerline. Side girders are to be equally spaced as far as applicable.

20.7.2.2 Side girders are to be provided in way of hopper slope plating. Additional local girders are to be arranged within double bottom in way of vertical diaphragm of transverse bulkheads. The spacing of longitudinal girders (including local girders) is generally not to exceed four longitudinal spacings, and the

thickness is in general not to be less than that of the lowest strake of the vertical diaphragm, and is to comply with the requirements of 5.4.2, Chapter 5 of this PART.

20.7.3 Bottom floors

20.7.3.1 Spacing of bottom floors is, in general, not to be greater than (0.006L + 3.2) m nor 4.2 m (whichever is lesser), L being length of ship.

20.7.3.2 Thickness of bottom floors t is not to be less than the value obtained by the following formula:

$$t = (0.006h + 1.0)\sqrt{K} \text{ mm, but it need not be greater than 12 mm}$$

where: h — considered height of centre girders, in mm, see 2.6.2.1 of Section 6 of Chapter 2 of this PART;

K — material factor.

20.7.4 Bilge brackets

20.7.4.1 Structural requirements related to bilge brackets are to comply with the provisions in 5.4.4, Chapter 5 of this PART.

20.7.5 Bottom longitudinals

20.7.5.1 Section modulus W of bottom longitudinals is not to be less than that obtained from the following formulae:

$$W_1 = \frac{8.5}{1.73 - F_b}(d + h)sl^2K \quad \text{cm}^3$$

$$W = 8K\rho_w s h_1 l^2 \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinals, in m;

K — material factor;

ρ_w — density of sea water, to be taken as 1.025 t/m^3;

h_1 — see 20.6.2.1 of this Section;

$h = 0.26C$, not to be greater than $0.2d$ for calculation;

d — draught, in m;

C — coefficient, see 2.2.3.1, Section 2, Chapter TWO of this PART;

F_b — deduction factor, see Section 2, Chapter TWO of this PART.

The bottom longitudinals in way of pipe tunnels are only to satisfy the above-mentioned requirements of section modulus W_1.

20.7.6 Inner bottom plating and inner bottom longitudinals

20.7.6.1 The thickness t of inner bottom plating is not to be less than the values obtained from the following formulae:

$$t_1 = 40s\sqrt{KP_{eq}} + 1.0 \quad \text{mm}$$

$$t_2 = 3.95s\sqrt{K\rho_w h_0} + 2.5 \quad \text{mm}$$

where: s — spacing of longitudinals, in m;

K — material factor;

ρ_w — density of sea water, to be taken as 1.025 t/m^3;

h_0 — vertical distance, in m, measured from the lower edge of the plate to the top of the tank, or half the distance to the top of overflow, whichever is the greater. Where the inner bottom plating is located in dry space or void space, h_0 is to be measured from the lower edge of plating to be calculated to the deepest equilibrium waterline obtained from damage stability calculation, and not to be less than the vertical distance measured from lower edge of plating to freeboard deck;

P_{eq} — internal pressure of tank, in MPa, as defined in 4.13.2.4, Chapter 4, PART THREE of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

20.7.6.2 Section modulus W of inner bottom longitudinals is not to be less than the values obtained from the following formulae:

$$W_1 = 560KsP_{eq}l^2 \quad \text{cm}^3$$

$$W_2 = 8K\rho_w s h_0 l^2 \quad \text{cm}^3$$

where: l — span of longitudinals, in m;

h_0 — vertical distance, in m, measured from the center of stiffener span to the top of the tank, or half the distance to the top of overflow, whichever is the greater. Where the inner bottom plating is located in dry space or void space, h_0 is to be measured from the lower edge of mid-point of span for member to be calculated to the deepest equilibrium waterline obtained from damage stability calculation, and not to be less than the vertical distance measured from lower edge of plating to freeboard deck;

For other symbols, see 20.7.6.1 of this Section.

Section 8 PLANE TRANSVERSE BULKHEAD STRUCTURES

20.8.1 General requirements

20.8.1.1 Cofferdam transverse bulkhead structures, consisting of horizontal stringers and vertical diaphragm between transverse bulkheads and horizontal or vertical stiffeners of transverse bulkhead, are to be provided between cargo tanks of membrane tank liquefied gas carriers. Manholes are to be cut in the vertical diaphragm and horizontal stringers in accordance with the requirements in Section 9 of this Chapter. Cofferdams are to be provided between cofferdam transverse bulkheads.

20.8.1.2 Solid floors are to be provided within the double bottom in way of cofferdam transverse bulkheads. Vertical diaphragm of cofferdam transverse bulkheads is to be in alignment with girders or local girders in the double bottom and in double box trunk deck.

20.8.1.3 The horizontal stringers of cofferdam transverse bulkheads are to be in line with those of the inner side. Vertical stiffeners of the cofferdam transverse bulkheads are to be in line with longitudinals of inner deck and inner bottom. Horizontal stiffeners of cofferdam transverse bulkheads are to be in line with longitudinals of inner hull, inner deck slope plating, inner hull slope plating and hopper slope plating.

20.8.2 Thickness of bulkhead plating

20.8.2.1 Thickness t of bulkhead plating is not to be less than the values obtained from the following formulae:

$$t_1 = 40s\sqrt{KP_{eq}} + 1.0 \quad \text{mm}$$

$$t_2 = 3.95s\sqrt{K\rho_c h_0} + 2.5 \quad \text{mm}$$

$$t_3 = 4.0s\sqrt{K\rho_w h_2} \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

K — material factor;

ρ_w — density of sea water, to be taken as 1.025 t/m^3;

ρ_c — density of liquid cargo, to be taken as 0.50 t/m^3 for LNG;

h_0 — vertical distance, in m, measured from the lower edge of bulkhead plate to the top of the tank in way of the ship's longitudinal centerline section, or half the distance to the top of overflow, whichever is the greater;

h_2 — vertical distance, in m, measured from the lower edge of bulkhead plate to the bulkhead deck;

P_{eq} — internal pressure of tank, in MPa, as defined in 4.13.2.4, Chapter 4, PART THREE of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

20.8.2.2 Thickness of bulkhead plating is also to comply with the requirements of 5.7.2.2, Chapter 5 of this PART, if applicable.

20.8.3 Horizontal stringers and vertical diaphragm

20.8.3.1 Thickness of horizontal stringers and vertical diaphragm is to comply with the requirements of 20.1.5 of this Chapter.

20.8.3.2 Scantlings of stiffeners of horizontal stringers and vertical diaphragm are to comply with Section 9 of this Chapter.

20.8.4 Vertical stiffeners

20.8.4.1 Section modulus W of vertical stiffeners is not to be less than the values obtained from the following formulae:

$$W_1 = 560KsP_{eq}l^2 \quad cm^3$$

$$W_2 = 8K\rho_c sh_0 l^2 \quad cm^3$$

$$W_3 = CKsh_2l^2 \qquad cm^3$$

where: s — spacing of stiffeners, in m;
l — span of stiffeners, in m;
K — material factor;
P_c — density of liquid cargo, to be taken as 0.50 t/m^3 for LNG;
P_{eq} — internal pressure of tank, in MPa, as defined in 4.13.2.4, Chapter 4, PART THREE of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk;
h_0 — vertical distance, in m, measured from the center of stiffener span to the top of the tank in way of the ship's longitudinal centerline section, or half the distance to the top of overflow, whichever is the greater;
h_2 — vertical distance, in m, measured from the center of stiffener span to the bulkhead deck, and not to be less than $0.25D$, where: D is the moulded depth, in m;
C — coefficient, to be taken as follows:
C = 6, for stiffeners unattached at both ends, or directly attached to unstiffened plating;
C = 3, for stiffeners bracketed at ends, or directly lapped to longitudinal members at ends.

20.8.5 Horizontal stiffeners

20.8.5.1 Section modulus W of horizontal stiffeners is not to be less than the values obtained from the following formulae:

$$W_1 = 560KsP_{eq}l^2 \qquad \text{cm}^3$$

$$W_2 = 8K\rho_c sh_0l^2 \qquad \text{cm}^3$$

$$W_3 = CKsh_2l^2 \qquad \text{cm}^3$$

where: h_2 — vertical distance, in m, from the stiffeners considered to the moulded depth, but not to be less than $0.25D$; D is the moulded depth, in m;
l — span of longitudinals, in m;
Other symbols — see 20.8.4.1 of this Section.

20.8.5.2 The horizontal stiffeners are to be in line with the longitudinals of inner hull, inner deck slope plating, inner hull slope plating and hopper slope plating with end brackets having the scantlings as required by Chapter 1 of this PART. Horizontal stiffeners are to be welded to the vertical diaphragm and their stiffeners when penetrating vertical diaphragm.

Section 9 STRUCTURAL DETAILS

20.9.1 General requirements

20.9.1.1 Those uncovered in this Section (excluding sloshing assessment) are to comply with the provisions of Section 12, Chapter 5 of this PART, if applicable.

20.9.1.2 When a knuckle is arranged in a primary member (shell plate, longitudinal bulkhead etc.), stiffening in the form of deep web is to be provided at the knuckle to transmit the transverse load and is to be connected to the transverse members to which they are to transfer the load (in shear). For longitudinal shallow knuckles, closely spaced carlings may be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other reinforcements need not be fitted in way of shallow knuckles that are not subject to high lateral loads or high in-plane loads across the knuckle, such as deck camber knuckles.

20.9.2 Openings

20.9.2.1 Structural details of openings are to comply with the requirements of 1.2.5.5, Chapter 1 of this PART. Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear, such as: floors or double bottom girders close to their span ends.

Where openings are unavoidable, the strength at the openings is to comply with the relevant requirements for yield and buckling assessment of panels.

Where openings larger than those given by 20.9.2.2 or 20.9.2.3 of this Section are proposed, the arrangements and compensation required will be specially considered.

20.9.2.2 For manholes and lightening holes in single skin sections not requiring reinforcement, openings cut in the web with the depth of opening not exceeding 25% of the web depth and so located that the edges are not less than 40% of the web depth from the faceplate do not require reinforcement generally. The

length of opening is not to be greater than the web depth or 60% of the local supporting member spacing, whichever is the greater. The ends of the openings are to be equidistant from the corners of cutouts for local supporting members.

20.9.2.3 For manholes and lightening holes in double skin sections not requiring reinforcement, where openings are cut in the web and are clear of high stress areas, reinforcement of these openings is not required provided that the depth of the opening does not exceed 50% of the web depth and is so located that the edges are well clear of cutouts for the passage of local supporting members.

20.9.2.4 Manholes and lightening holes requiring reinforcement may be stiffened as required by Figure 20.9.2.4, i.e. stiffeners on members contributing to longitudinal strength are to be fitted along the free edges of the openings, parallel to the vertical and horizontal axes of the opening. Stiffeners may be omitted in one direction if the shortest axis is less than 400 mm, and in both directions if the length of both axes is less than 300 mm. Edge reinforcement may be used as an alternative to stiffeners.

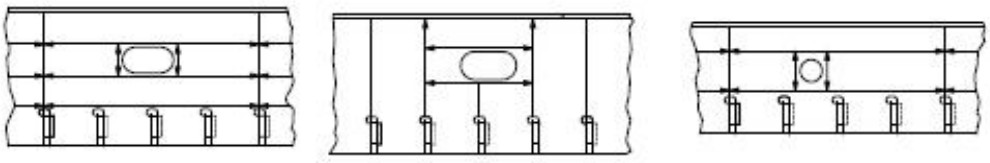


Figure 20.9.2.4 Reinforcement of manholes and lightening holes

20.9.3 Stiffeners or brackets

20.9.3.1 Requirements for stiffeners or brackets are to comply with the provisions of Section 12, Chapter 5 of this PART.

Appendix 1 DIRECT CALCULATION OF HULL STRUCTURES WITHIN THE CARGO TANK REGION

1 GENERAL REQUIREMENTS

1.1 Application

1.1.1 This Appendix applies to direct calculation and assessment of hull structures within the cargo tank region of membrane tank liquefied gas carriers required by this Chapter.

1.2 Definitions

1.2.1 Symbols

Unless otherwise specified, the following symbols in this Chapter are defined as follows:

ρ_w — density of seawater, to be taken as 1.025 t/m^3;

ρ_c —density of liquid cargo, to be taken as 0.50 t/m^3 for LNG;

ρ —density of liquid, taken as ρ_w or ρ_{LNG} as applicable;

σ_e — equivalent stress of plate element (i.e. von Mises stress), in N/mm^2, based on membrane stresses at element centroid;

R_{eH} — yield stress of material, in N/mm^2;

K — material factor, as defined in Section 3, Chapter 1 of this PART;

E — elastic modulus of material, $E = 2.06 \times 10^5$ N/mm^2 or $E = 2.06 \times 10^{11}$ N/m^2 for steel;

ν — Poisson's ratio of material, $\nu = 0.3$ for steel.

2 LOADS

2.1 General requirements

2.1.1 In the assessment of the structural strength, all load components with respect to the hull girder bending moment, internal liquid pressure and external hydrodynamic pressure and other local pressures, inertia forces due to ship's motions, structural weight as well as the weight of the insulation of cargo containment systems are to be taken into account.

2.1.2 When longitudinal bending moment, hydrodynamic pressure (external) and inertia force and added pressure heads (internal) are to be obtained by direct calculation, recognized theories and application programs are to be used for the calculation.

2.2 Static loads

2.2.1 Hull girder still water bending moment M_{sw} is covered in 2.2.2, Chapter 2 of this PART. Unless otherwise specified, loading patterns are to be considered according to Table 2.4.1 of this Appendix.

2.3 Wave loads

2.3.1 Longitudinal vertical wave bending moment

Vertical wave bending moment: $M_{w_sagging}$ (sagging) and $M_{w_hogging}$ (hogging)

$$M_{w_sagging} = k_w M_w\,(-) \qquad \text{kN·m}$$

$$M_{w_hogging} = k_w M_w\,(+) \qquad \text{kN·m}$$

where: k_w — factor, normally to be taken as 1.0;

$M_w(+)$, $M_w(-)$ – as given in 2.2.3, Chapter 2 of this PART.

2.3.2 Horizontal wave bending moment

Horizontal wave bending moment: M_H

$$M_H = \pm 84 k_w C L^2 D (C_b + 0.7) \times 10^{-3} \quad \text{kN·m} \quad \text{(positive tension port)}$$

where: k_w — as given in 2.3.1;

C — as given in 2.2.3, Chapter 2 of this PART.

2.3.3 External pressure

(1) External pressure p_{sea_side}, is the superimposition of still water pressure and hydrodynamic pressure, which can be expressed by the following equation:

$$p_{sea_side} = p_{sea_static} + p_{sea_dynamic} \quad \text{N/mm}^2 \text{ (positive inboard)}$$

p_{sea_side} will be taken as 0 if the calculated value is less than 0.

where: p_{sea_static} — still water pressure, $p_{sea_static} = 0.001\rho_w g h_s$ kN/mm²;

h_s — pressure head in still water, in m, taken as draught d in design condition;

$p_{sea_dynamic}$ — hydrodynamic pressure, $p_{sea_dynamic} = 0.001\rho_w g k_c h_{di}$ kN/mm²;

k_c— correlation factor for a specific combined load case, as given in Table 2.4.1 of this Appendix;

h_{di}— hydrodynamic pressure head at location i, in m, $h_{di}=1.36\lambda_i C_f C_w$, distributed as in Figure 2.3.3(1),

where:

λ_i — distribution factor of hydrodyn3

amic pressure head around the girth of ship at location *i,* as given in Table 2.3.3(1) or as obtained by the linear interpolation at other locations;

C_f — distribution factor of hydrodynamic pressure head along the length of the ship, to be taken as $C_f = k_{f0}$:

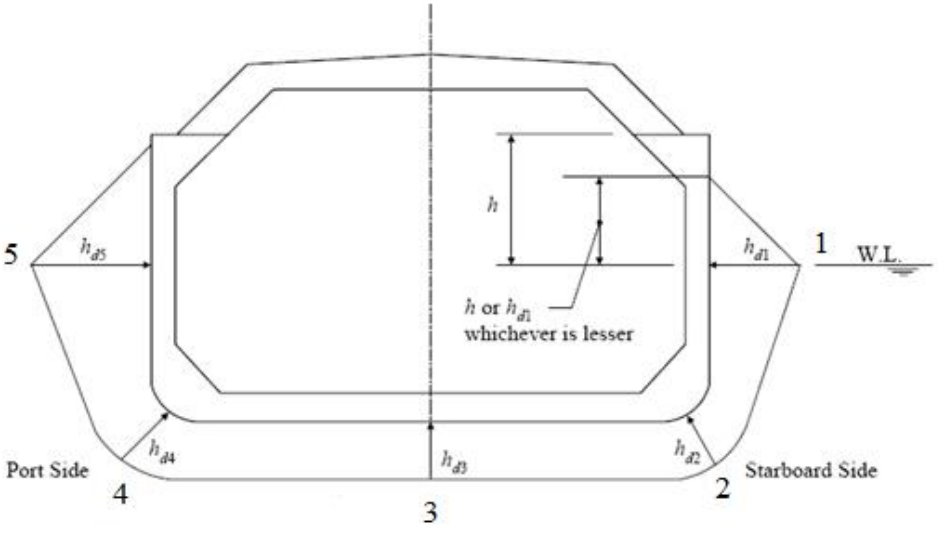
k_{f0}— factor, as given in Table 2.4.1;

θ — wave heading angle, $\theta = 0$℃ for head sea; $\theta = 90$℃ for beam sea from starboard;

C_w — wave coefficient, see coefficient C in 2.2.3.1, Chapter 2 of this PART.

Distribution factor of hydrodynamic pressure head λ_i Table 2.3.3(1)

Wave heading angle θ°	i = 1, at waterline, starboard	i = 2, at bilge, starboard	i = 3, at bottom longitudinal centerline	i = 4, at bilge, port	i = 5, at waterline, port
0° for head sea	0.750	0.300	0.300	0.300	0.750
60° for oblique sea	0.875	0.350	0.127	-0.096	-0.333
90° for beam sea	1.000	0.400	0.100	-0.200	-0.500
At any angle	$1.00 - \frac{\cos\theta}{4}$	$\frac{2}{5} - \frac{\cos\theta}{10}$	$\frac{3}{10} - \frac{\sin\theta}{5}$	$\frac{2 - 4\sin\theta + \cos\theta}{10}$	$\frac{3}{4} - \frac{5}{4}\sin\theta$

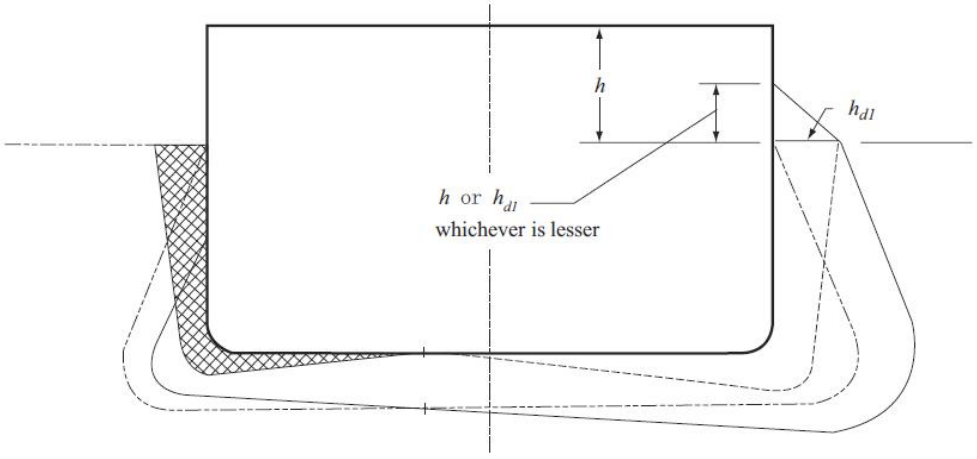


h – distance from the waterline to the highest deck of side ballast tank (lower end of trunk deck), in m.

Note: Pressure head h_{di} at waterline, starboard, is to be taken as h or $h_{di}|_{i=1}$, whichever is lesser.

Figure 2.3.3(1) Distribution of external hydrodynamic pressure

(2) Distribution of p_{sea_side}, as given in Figure 2.3.3(2).



– – – – – – – – h_d: hydrodynamic pressure head (being negative)
— - - — - - — h_s: hydrostatic pressure head in still water
———————— : total external sea pressure head
h – as given in Figure 2.3.3 (1).

Figure 2.3.3(2) Distribution of external sea combined pressure

2.3.4 Internal pressures of tanks (excluding sloshing and impact loads)

(1) Parameters of ship motions

Where data related to seakeeping analysis or model tests are not available, the equations given below may be used in calculating the parameters of ship motions:

① The pitch amplitude (positive bow up):

$$\psi = \frac{1030}{L}\left(\frac{V}{C_b}\right)^{0.25} \quad (°), \text{ but need not to be taken greater than } 10°$$

② The pitch natural period:

$$T_p = 3.5\sqrt{C_b d_i} \quad \text{s}$$

where: d_i — draught for the relevant loading conditions, in m, as given in Table 2.4.1

③ The roll amplitude (positive starboard down):

$$\phi = \phi_0 \lambda_T \quad (°), \text{ but need not to be taken greater than } 30°$$

where: ϕ_0 — basic roll amplitude,

$$\phi_0 = (1.3 - 0.025V)\{35 - 5\times10^{-6}\times10.05\times[1.06(\frac{d_i}{d}) - 0.06]LBdC_b\}$$

$$\lambda_T = \begin{cases} 0.8625+0.027T_{roll} & \text{for } T_{roll} \le 12.5 \quad \text{s} \\ 1.5375-0.027T_{roll} & \text{for } 12.5 \le T_{roll} \le 20 \quad \text{s} \\ 1 & \text{for } T_{roll} > 20 \quad \text{s} \end{cases}$$

④ The roll natural motion period:

$$T_r = \frac{2.0 r_{roll_gyr}}{\sqrt{GM}} \quad \text{s}$$

where: r_{roll_gyr} — roll radius of gyration, in m, as given in Table 2.3.4(1);
GM — metacentric height, in m, as given in Table 2.3.4(1);
d_i — same as ②.

Values of metacentric height *GM* and roll radius of gyration r_{roll_gyr}

Table 2.3.4(1)

Loading and draught	*GM*	r_{roll_gyr}
Full load	0.12B	0.35B
0.75*d*	0.18B	0.38B

⑤ Accelerations of the ship motion

Vertical acceleration: $a_v = f_v k_v a_0 g$ m/s^2, positive downward;

Longitudinal acceleration: $a_{longi} = f_l k_l a_0 g$ m/s^2, positive forward;

Transverse acceleration: $a_t = f_t k_t a_0 g$ m/s^2, positive starboard;

where: a_0 — common acceleration parameter,

$$a_0 = (1.09 + 0.029V - 0.47C_b)(\frac{2.4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2});$$

f_v — factor, $f_v = cos\,\theta + \frac{(1+2.4\frac{y}{B})sin\,\theta}{k_v}$;

k_v — factor, $k_v = \sqrt{1 + 0.65(5.3 - \frac{45}{L})^2(\frac{x}{L} - 0.45)^2}$;

f_l — factor, $f_l = 0.35 - 5.0(L - 200) \times 10^{-4}$;

k_l — factor, $k_l = 0.5 + \frac{8z}{L}$;

f_t — factor, $f_t = 1.27\sqrt{1 + 1.52(\frac{x}{L} - 0.45)^2}$;

k_t — factor, $k_t = 0.35 + \frac{z}{B}$;

x — longitudinal distance from the A.P. to the station considered, in m;

y — transverse distance from the centerline to the point considered, in m, positive starboard;

z — vertical distance from the waterline to the point considered, in m, positive upward.

The point considered above is taken as the centroid position of tanks.

(2) Internal pressures of tanks

Distribution p_i of internal pressures is determined by superimposing vapor pressure of liquefied gas, liquid pressure, wave-induced hydrodynamic inertia force and added pressure. For a completely filled tank, the distribution of internal pressures may be obtained from the following formula:

$$p_i = 0.001\rho_{LNG} g(z_{local_tank} + \Delta z_{local_tank} + h_{wave_induced}) + p_0 \quad \text{N/mm}^2$$

(Positive from geometric centroid of the tank toward tank boundaries)

where: p_0 — vapor pressure, determined according to the following formula:

$$p_0 = \begin{cases} p_{vp} - p_n & \text{in cargo tank, taken as 0 when the calculated value is less than 0} \\ 0 & \text{in ballast tank} \end{cases}$$

p_{vp} — maximum pressure setting on vacuum relief valve, in MPa; to be taken as not greater than 0.07 MPa;

p_n — standard design vapor pressure, taken as 0.025 MPa;

z_{local_tank} — local coordinate in vertical direction for tank boundaries measuring from the top of the tanks, as shown in Figure 2.3.4(2), in m;

Δz_{local_tank} — to be taken as follows:

a) 0 for the cargo tank and the ballast tank whose tank top extends to the upper deck or the trunk deck;

b) a distance equivalent to 2/3 of the distance from tank top to the top of the overflow (the exposed height is minimum 760 mm above freeboard deck or 450 mm above superstructure deck) for the lower tank whose tank top does not extend to the upper deck;

$h_{wave_induced}$ — wave-induced internal pressure head, including inertial force and added pressure head, determined as follows:

$$h_{wave_induced} = k_c(z_{tank_local}\frac{a_i}{g} + \Delta h_i)$$

where:

k_c —internal pressures, see Table 2.4.1;

a_i — effective resultant acceleration at the point considered, and may be approximated by:

$$a_i = 0.71C_{dp}[w_v a_v + w_{longi}(\frac{l}{h})a_{longi} + w_t(\frac{b}{h})a_t] \quad \text{m/s}^2$$

where:

C_{dp} — as given in Table 2.3.4(2);

a_v, a_{longi}, a_t — as given in 2.3.4(1)⑤;

w_v, w_{longi}, w_t — weighted coefficients, as specified in Table 2.4.1;

l — length of the tank, in m;

b — width of the tank, in m;

h — height of the tank, in m;

Δh_i — added pressure head due to pitch and roll motions, in m, may be calculated as follows:

a) for bow down and starboard down ($\psi_e < 0, \phi_e > 0$):

$$\Delta h_i = x_{\tan k_local} \sin(-\psi_e) + C_{ru}(y_{\tan k_local_e} \sin\phi_e \cos\psi_e + z_{\tan k_local_e} \cos\psi_e \cos\phi_e - z_{\tan k_local})$$

where:

$x_{\tan k_local}$ — local coordinate for the point considered with respect to length as in Figure 2.3.4(2), in m;

$y_{\tan k_local}$ — local coordinate for the point considered with respect to width, as in Figure 2.3.4(2), in m;

$z_{\tan k_local}$ — local coordinate for the point considered with respect to height, as in Figure 2.3.4(2), in m;

$y_{\tan k_local_e}$ — taken as $b - y_{\tan k_local}$;

$z_{\tan k_local_e}$ — taken as $z_{\tan k_local}$;

b) for bow up and starboard up ($\psi_e > 0, \phi_e < 0$):

$$\Delta h_i = (l - x_{\tan k_local}) \sin\psi_e + C_{ru}[y_{\tan k_local_e} \sin(-\phi_e) \cos\psi_e + z_{\tan k_local_e} \cos\psi_e \cos\phi_e - z_{\tan k_local}]$$

where:

$y_{\tan k_local_e}$ — taken as $y_{\tan k_local} - \delta_b$

$z_{\tan k_local_e}$ — taken as $z_{\tan k_local} - \delta_h$

δ_b , δ_h — the local coordinates for the point considered with respect to adjusted values, in m, as shown in Figure 2.3.4(2);

C_{ru} — as in Figure 2.3.4(2);

C_ψ , C_ϕ — weighted coefficients, as in Table 2.4.1;

ψ_e — taken as $0.71_C_\psi\psi$;

ϕ_e — taken as $0.71C_\phi\phi$;

ψ and ϕ — pitch and roll amplitudes, as given in 2.3.4(1).

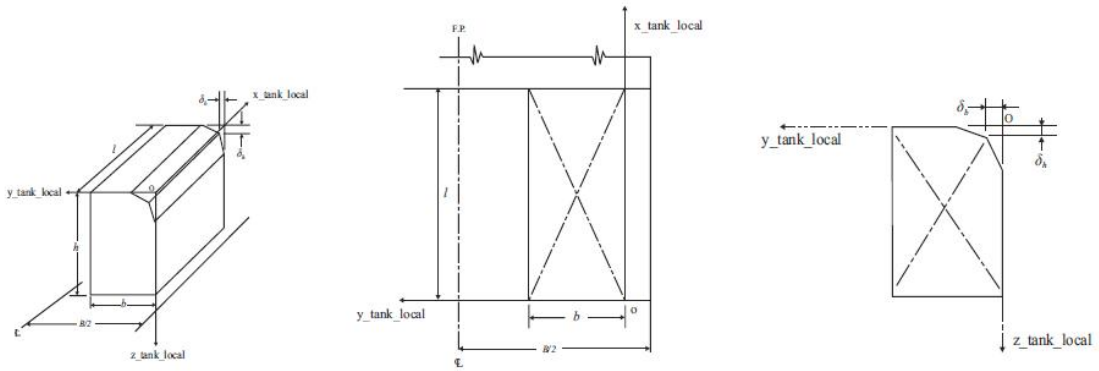


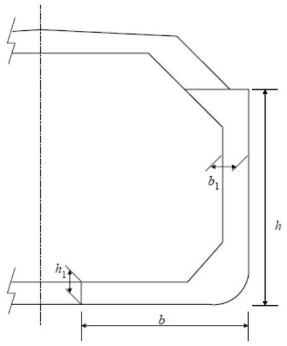
Figure 2.3.4(2) Local coordinates and geometry of tank

Definition of tank shape and associated coefficients – as given in Table 2.3.4(2).

Tank shape and associated coefficients **Table 2.3.4(2)**

Applicable conditions	Tank shape	C_{dp}	C_{ru}
$\frac{b}{b_1} \le 3.0$ or $\frac{h}{h_1} \le 3.0$	Rectangular tank	1.0	1.0
$\frac{b}{b_1} \ge 5.0$ or $\frac{h}{h_1} \ge 5.0$	J-shaped tank	0.7	1.0
$3.0 < \min\left\{\frac{b}{b_1}, \frac{h}{h_1}\right\} < 5.0$	Other tank	$1.0 - 0.15\left\{\min\left\{\frac{b_1}{b}, \frac{h}{h_1}\right\} - 3.0\right\}$	1.0

where: b – extreme breadth of the tank considered, in m;
b_1 – least breadth of wing tank part of the tank considered, in m;
h – extreme height of the tank considered, in m;
h_1 – least height of double bottom part of the tank considered, in m;
the above symbols are as shown in the figure on the right.



2.4 Combined load cases

2.4.1 The design load cases, to which the strength assessment by direct calculation as given in this Appendix applies, consist of conventional cases, accidental cases (see Table 2.4.1). Where more critical cases likely to be encountered are not covered in the above cases, if any, they are to be additionally analyzed.

2.4.2 In accordance with the principle requirements of loading and strength criteria, hull responses under static loads (S) and dynamic + static loads (S+D) are to be considered in a comprehensive manner. The weight of the insulation of cargo containment system is also to be considered. In addition, "a collision force acting on the tank corresponding to one half the weight of the tank and cargo in the forward direction" the ship is to withstand, as required in CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk is to be considered as an accidental case and listed in Table 2.4.1.

2.4.3 For the longitudinal vertical bending moment of hull girders, the resultant bending moment may be considered as follows:

$$M_V(+) = M_{sw}(+) + k_{cV} M_{w_hogging} \qquad \text{in hogging condition}$$

$$M_V(-) = M_{sw}(-) + k_{cV} M_{w_sagging} \qquad \text{in sagging condition}$$

where: M_{sw} — as given in 2.2;

$M_{w_sagging}$ and $M_{w_hogging}$ — as given in 2.3;

k_{cV} — coefficient of hull girder vertical wave bending moment applied on both ends of the model, as in Table 2.4.1.

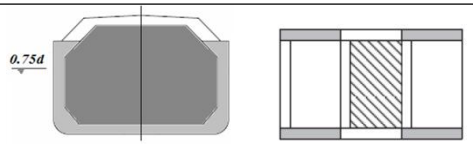
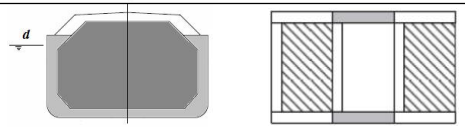
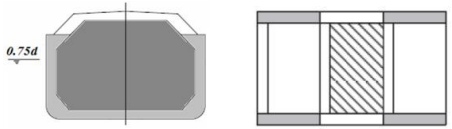
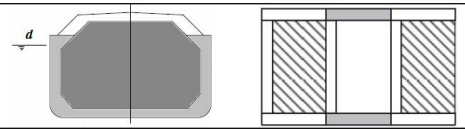
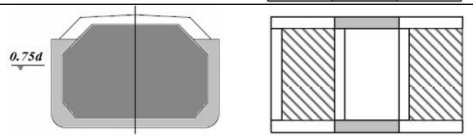
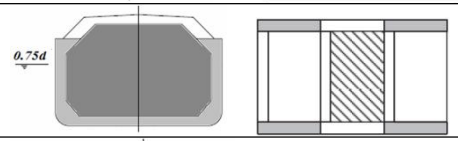
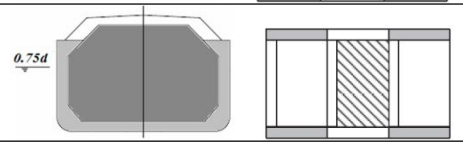
2.4.4 Other loads as given in Table 2.4.1 are to be multiplied by relevant load factors for combined load cases.

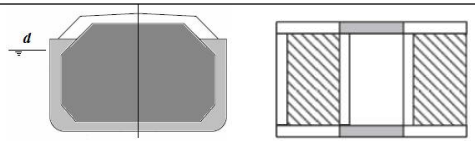
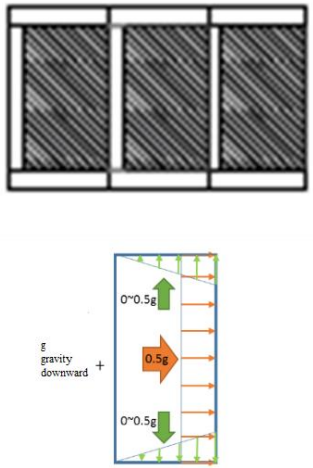
2.4.5 The length of the model considered for load patterns as shown in Table 2.4.1 is equal to three complete cargo tanks.

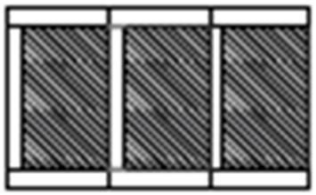
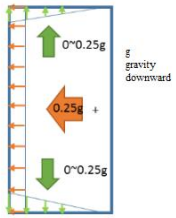
2.4.6 The distribution of resultant external pressure heads at different locations of one hull girder section is shown in Figure 2.3.3(2).

2.4.7 The bending moment of end planes of the FE model may be corrected in accordance with the simple beam theory. The bending moment applied on end planes of the model is so adjusted that the resultant vertical and horizontal bending moment applied on the mid-point of the middle tank of the 3-tank model is equal to the target value.

Load cases for cargo tank FEM analysis of membrane tank liquefied gas carriers **Table 2.4.1**

No.	Load pattern	Vertical B.M. k_{cV}	Horizontal B.M. k_{cH}	External pressures		Internal pressures								Wave heading angles and ship motions			
				k_c	k_{f0}	k_c	w_v	w_l		w_t		C_ψ, pitch	C_ϕ, roll	Wave angle	Heave	Pitch	Roll
Conventional cases - combined loads (Static loads + Dynamic loads) (S+D)																	
LC1		Sag 1.0	N/A	0.5	-1.0	0.4	0.75	Fwd Bhd 0.25	Aft Bhd -0.25	N/A	N/A	-1.0	N/A	0	Down	Bow down	N/A
LC2		Hog 1.0	N/A	0.5	1.0	0.4	-0.75	Fwd Bhd -0.25	Aft Bhd 0.25	N/A	N/A	1.0	N/A	0	Up	Bow up	N/A
LC3		Sag 0.7	N/A	0.5	-1.0	1.0	0.75	Fwd Bhd 0.25	Aft Bhd -0.25	N/A	N/A	-1.0	N/A	0	Down	Bow down	N/A
LC4		Hog 0.7	N/A	1.0	1.0	0.5	-0.75	Fwd Bhd -0.25	Aft Bhd 0.25	N/A	N/A	1.0	N/A	0	Up	Bow up	N/A
LC5		Sag 0.3	Tension Stbd. 0.3	0.5	-1.0	1.0	0.25	N/A	N/A	Port Bhd -0.75	Stbd Bhd 0.75	N/A	1.0	90	Down	N/A	Stbd down
LC6		Hog 0.3	Tension port 0.3	1.0	1.0	0.5	-0.25	N/A	N/A	Port Bhd 0.75	Stbd Bhd -0.75	N/A	-1.0	90	Up	N/A	Stbd up
LC7		Sag 0.4	Tension Stbd. 1.0	0.5	-1.0	1.0	0.4	Fwd Bhd 0.20	Aft Bhd -0.20	Port Bhd -0.4	Stbd Bhd 0.4	-0.7	0.7	60	Down	Bow down	Stbd down

No.	Load pattern	Vertical B.M. k_{cV}	Horizontal B.M. k_{cH}	External pressures		Internal pressures								Wave heading angles and ship motions			
				k_c	k_{f0}	k_c	w_v	w_l		w_t		C_ψ, pitch	C_ϕ, roll	Wave angle	Heave	Pitch	Roll
LC8		Hog 0.4	Tension port 1.0	1.0	1.0	0.5	-0.4	Fwd Bhd -0.20	Aft Bhd 0.20	Port Bhd 0.4	Stbd Bhd -0.4	0.7	-0.7	60	Up	Bow up	Stbd up
Accidental cases																	
LC9		Collision load is determined based on cargo containment system under fully loaded condition, and forward inertia force is 0.5g, where g is acceleration of gravity. In addition, vertical gravity effects are to be considered. Hull girder bending moment and shear force are not required to be applied.															

No.	Load pattern	Vertical B.M. k_{cV}	Horizontal B.M. k_{cH}	External pressures		Internal pressures						Wave heading angles and ship motions			
				k_c	k_{f0}	k_c	w_v	w_l	w_t	C_ψ, pitch	C_ϕ, roll	Wave angle	Heave	Pitch	Roll
LC10	 	Collision load is determined based on cargo containment system under fully loaded condition, and backward inertia force is 0.25g, where g is acceleration of gravity. In addition, vertical gravity effects are to be considered. Hull girder bending moment and shear force are not required to be applied.													

Note: – loaded with liquid cargoes; – loaded with ballast water; N/A- not applicable.

3 STRUCTURAL MODEL

3.1 General requirements

3.1.1 Except for buckling assessment, the dimension of finite element models covered in this Appendix are taken as the scantlings (e.g. thickness, length) specified in the drawings, namely the as-built scantlings. Where net scantlings are used, permissible stresses are to be considered otherwise.

3.2 Structural modeling

3.2.1 The length of the model is to cover the three cargo tank lengths (No.2, No.3 and No.4 tanks and/or No.3, No.4 and No.5 tanks) in the midship cargo tank region, and the length of the middle tank is to be the greatest among the three tanks, as shown in Figure 3.2.1. The transverse extent is to be the entire breadth of the ship. The vertical extent is to be the entire moulded depth. The change of moulded line of ship side in longitudinal direction is not to be taken into account.

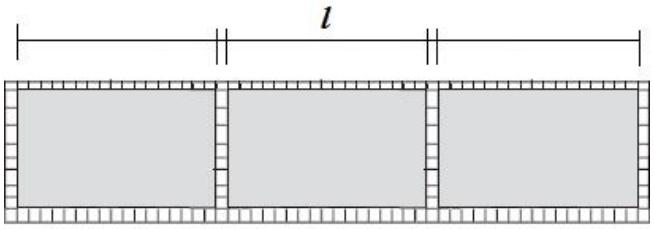


Figure 3.2.1 Extent of finite element modeling of cargo tanks

3.2.2 All primary longitudinal and transverse structural members of the hull are to be represented in the model, including bottom shell, side shell, deck plating (including trunk deck), inner deck, inner bottom, inner hull, hopper and inner hull slope plating, double bottom girders, deck girders, stringers (continuously or partially arranged) in double side tanks and longitudinals continuously arranged on such plating as well as primary transverse supporting members such as transverse web frames, deck transverses, double bottom floors, and cofferdam transverse bulkheads. In addition, all plating and stiffeners, including web stiffeners, on these structural members are to be modeled.

3.2.3 All main plating is to be simulated by plate elements. Stiffeners on the plating are to be simulated by beam elements and the attached plates are to be considered for the properties of bending (eccentricity is required in the program.).

3.2.4 The plate element mesh is to follow the stiffening system of the structure as far as practical, properly representing the geometrical characteristics of actual plate panels between stiffeners. The plate element mesh is to satisfy the following requirements:

(1) transversely and vertically, one element between every longitudinal stiffener;

(2) longitudinally, one element between every frame space, and the element length is not to be greater than two longitudinal spaces;

(3) for webs of primary supporting members (including transverse web frames, double bottom girders and floors, and vertical diaphragm and horizontal stringers on bulkheads), one element between every web stiffener, and at least three elements over the depth of these members.

3.2.5 In general, web frames in double side tanks, deck transverses and small openings in double bottom floors may be represented by deleting corresponding elements. For large (web) openings of web frames in side tanks and deck transverses, the meshing of edges and boundaries is to be fine enough to represent the curvature of the edges of the openings.

3.2.6 Normally quad plate elements are to be used and the use of triangular plate elements is to be kept to a minimum. The aspect ratio of the quad plate elements is in general not to exceed three. Where possible, the aspect ratio of plate elements in areas, where high stress or a high stress gradient is likely to occur, is to be kept close to one and the use of triangular elements is to be avoided.

3.3 Boundary conditions

3.3.1 The boundary conditions to be applied at the ends of the cargo tank FE model are as follows and also given in Table 3.3.1:

(1) the aft end of the model is assumed to be kept plane, an independent point is set in way of the neutral axis of the section, other nodal points of the end plane are linked to the independent point, and the bending moment is applied on the independent point;

(2) the fore end of the model is assumed to be kept plane, an independent point is set in way of the neutral axis of the section, other nodal points of the end plane are linked to the independent point, and the bending moment is applied on the independent point.

Boundary constraints at model ends **Table 3.3.1**

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Aft end						
Aft end (all longitudinal elements)	RL	–	–	–	RL	RL
Independent point at aft end, see Figure 3.3.2	FIX	–	–	–	$M_{v\text{-}end}$	$M_{h\text{-}end}$
Deck, inner bottom and outer shell	–	Springs	–	–	–	–
Side shell, and inner hull	–	–	Springs	–	–	–
Fore end						
Fore end (all longitudinal elements)	RL	–	–	–	RL	RL
Independent point at fore end, see Figure 3.3.2	–	–	–	–	$M_{v\text{-}end}$	$M_{h\text{-}end}$
Deck, inner bottom and outer shell	–	Springs	–	–	–	–
Side shell, and inner hull	–	–	Springs	–	–	–

where:

— – no constraint applied (free);

M_{h-end} – total vertical bending moment applied on model ends;

M_{v-end} – total horizontal bending moment applied on model ends;

δ_x – constraint of displacement along longitudinal axis;

δ_y – constraint of displacement along transverse axis;

δ_z – constraint of displacement along vertical axis;

θ_x – constraint of rotation about longitudinal axis;

θ_y – constraint of rotation about transverse axis;

θ_z – constraint of rotation about vertical axis.

3.3.2 The fore and aft end planes of the model are to be subject to end bending moment and constrained in degree of freedom. In addition, spring elements are to be arranged vertically and horizontally to precisely represent the stiffening provided to both ends of the cargo tank model by the fore and aft hull structures adjacent to the model. Ground spring elements, i.e. spring elements with one end constrained in all 6 degrees of freedom, with stiffness in global *y* degree of freedom are to be applied to the grid points along inner deck and trunk deck, inner bottom and bottom shell. Ground spring elements with stiffness in global *z* degree of freedom are to be applied to the grid points along the vertical part of the side shells and inner hulls as shown in Figure 3.3.2.

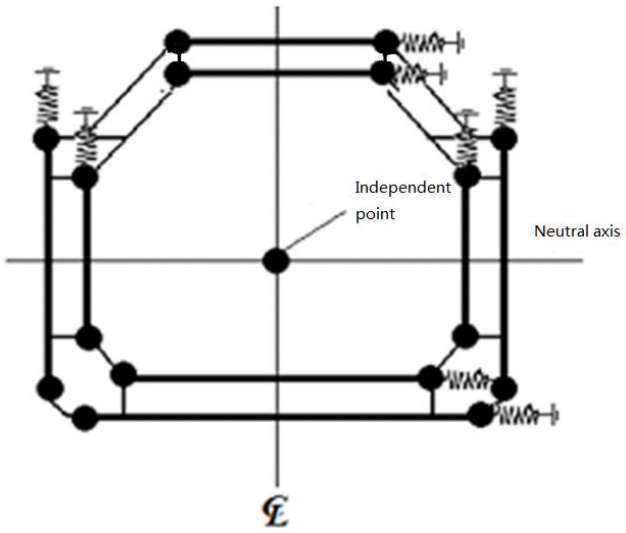


Figure 3.3.2 Boundary condition of finite element modeling

3.3.3 The stiffness, c, of individual spring elements for each structural member, to be applied at each end of the cargo tank model, is given by:

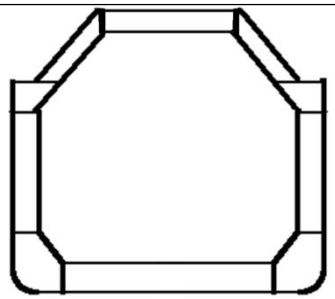
$$c = \left(\frac{E}{1+\nu}\right)\frac{A_s}{l_{tk}n} = 0.77\frac{AE}{l_{tk}n} \quad \text{N/mm}$$

where: A_s — shearing area of the individual structural member under consideration, in mm^2, i.e. plating of deck, trunk deck, inner bottom, bottom shell, side shell, or inner hull longitudinal bulkheads, see Figures 3.3.3(1) and (2) for details;

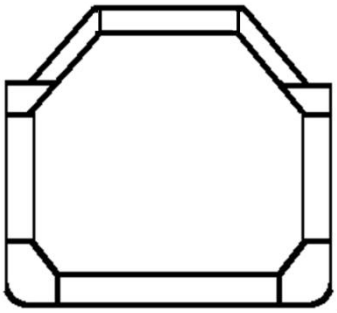
l_{tk} — length of cargo tank, between bulkheads of the middle tank of the FE model, in mm;

n — number of nodal points to which the spring elements are applied to the structural member under consideration.

Shear areas to be considered in the calculation of spring stiffness **Table 3.3.3(1)**

Vertical springs		
	Side:	Area of side shell plating, including bilge strake
	Inner hull longitudinal bulkheads:	Area of inner hull plating, including hopper sloped plate and double bottom side girder in way
	Trunk deck:	Area of sloped parts of trunk deck and inner deck plating
	Note: Where part of the structural member is not vertical, the area is to be calculated using the projected area in the vertical direction	

Shear areas to be considered in the calculation of spring stiffness **Table 3.3.3(2)**

Horizontal springs		
	Trunk deck:	Area of sloped parts of trunk deck and inner deck plating, including horizontal stringer and upper deck in way
	Inner bottom:	Area of inner bottom plating, including hopper sloped plate and horizontal stringer in way
	Bottom shell:	Area of bottom shell, plating, including bilge strake
	Note: Where part of the structural member is not horizontal, the area is to be calculated using the projected area in the horizontal direction	

4 RESULT EVALUATION

4.1 General requirements

4.1.1 The evaluation is to cover the middle tank of the three cargo tanks FE model, including the regions forward of the fore end of its forward bulkhead and aft of the aft end of its aft bulkhead up to the extent of one or two frames into the adjacent tanks, as shown in Figure 4.1.1.

4.1.2 Stress level and panel buckling capability of longitudinal structural members, primary supporting members and transverse bulkheads within the regions considered are to be verified. Particular attention is to be given to the scantlings and the assessment of required strengthening in way of transverse bulkheads against hull girder shear load, the intersection of hopper and inner hull, double side stringers, and double bottom girders and floors.

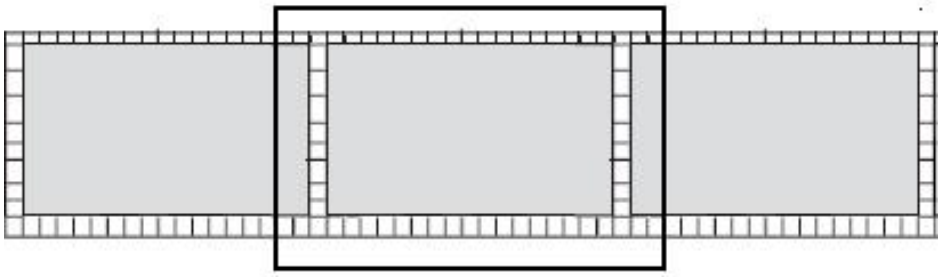


Figure 4.1.1 Strength evaluation region

4.1.3 In general, the strength criteria for the same structural member are different in static load cases and in static + dynamic load cases. In addition, special restrictions are imposed on permissible stresses for some members to avoid excessive stress strain of the insulation of cargo containment system. Strength check in respect to "the forward collision force equal to a half of the weight of cargo tank and cargo" is differently specified in this Section. For strength assessment, attention is to be drawn to the above-mentioned point.

4.2 Yield assessment

4.2.1 Yield assessment criteria for structural members in any condition to be checked are shown in Table 4.2.1.

Yield strength assessment criteria **Table 4.2.1**

Structural member	Yield utilisation factor and permissible stress restriction
Hull girder longitudinal member plating and bulkhead plating	
Bottom shell, bilge plate, side shell, upper deck, trunk deck slope plating, trunk deck plating, double bottom girders, side stringers, transverse bulkhead plating etc.	1) Conventional condition: $\lambda_y \leq 1.0$, for bottom shell and double bottom girders $\lambda_y \leq 0.9$, for other structural members. 2) Accidental ~~design~~ condition: $\lambda_y \leq 1.00$
Structures in direct contact with secondary barriers, e.g. inner bottom plating, hopper slope plating, inner hull plating, inner hull slope plating, inner deck slope plating, inner deck plating etc.	The following criteria are to be satisfied for any loading condition: $\lambda_y \leq 0.90$
Primary supporting member plating	
Primary transverse supporting structures, e.g. double bottom floors, side transverse diaphragms, deck transverses, bulkhead platform of double plane transverse bulkheads and vertical longitudinal diaphragms etc.	$\lambda_y \leq 0.75$
Notes: (1) Yield utilisation factor $\lambda_y = \frac{\sigma_e}{R_{eH}}$ for plate element; $\lambda_y = \frac{\sigma_{rod}}{R_{eH}}$, for face plate of primary supporting members modelled by rod element or beam element.	

4.2.2 Yield deformation is to be so controlled that maximum relative deformation of the plating between stiffeners of all hull panels (including inner bottom plating, hopper slope plating, inner hull plating, inner hull slope plating, inner deck plating and inner deck top plating as well as transverse bulkhead plating)/plating of unstiffened panels regarding periphery of insulations is generally not to be greater than 4.0 mm.

4.3 Buckling assessment

4.3.1 The buckling assessment criteria for structural plate and girder web plate panels in any check condition are shown in Table 4.3.1. And for panels of plates in direct contact with the insulation (secondary barrier system) of cargo containment system, e.g. inner bottom, inner hull, wing tank slope plating, inner deck and transverse bulkhead plates, deformation is to be controlled within the range of elastic buckling so that the function of insulation of cargo containment system will not be damaged.

4.3.2 Bucking assessment is to be based on elementary plate panels (EPP). An EPP is the unstiffened and unstrengthened part of the plating in the area except for the boundary ($a \times b$). Only rectangular panels are considered in the buckling calculation of panels, as shown in Figure 4.3.2.

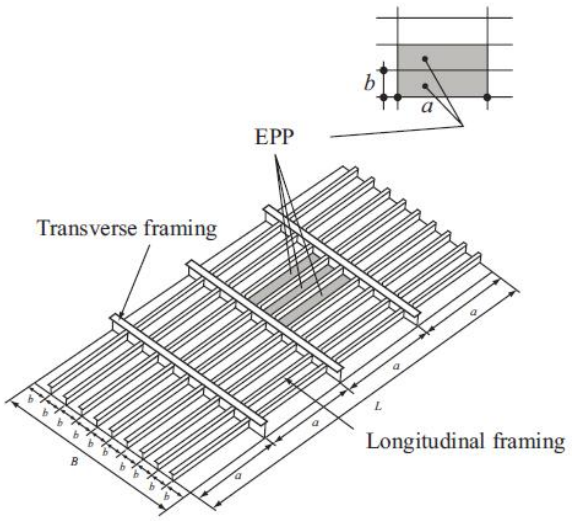


Figure 4.3.2 Elementary plate panels in buckling assessment

4.3.3 Panel bucking calculation approaches and criteria specified in this Appendix are based on elastic buckling. Other theories, calculation programs and assessment criteria are to be agreed by CCS.

Buckling assessment criteria **Table 4.3.1**

Structural member	Buckling safety factor
Double hull plating and bulkhead plating	
Stiffening plate panels under lateral loads, e.g. bilge plating, side shell plating, upper deck, trunk deck slope plating, trunk deck plating, inner bottom plating, inner hull plating, inner hull slope plating, inner deck slope plating, inner deck plating, transverse bulkhead plating etc.	$\lambda \geq 1.0$
Bottom plate, hopper slope plating, the outermost double bottom side girders	$\lambda \geq 0.8$
Primary member plating	
Primary supporting members, e.g. double bottom girders (except for the outermost side girders), double bottom floors, side stringers, side transverse diaphragms, deck girders, deck transverses, bulkhead platform of double plane transverse bulkheads and vertical longitudinal diaphragms etc.	$\lambda \geq 1.1$

4.3.4 Panel buckling is to be based on the "net thickness method". In calculation of critical buckling stress, plating thickness is to be taken as the calculated net thickness obtained from deducting the Standard Thickness Deduction, as given in Table 4.3.4, from the as-built thickness.

Standard thickness deduction **Table 4.3.4**

Location	Standard thickness deduction t_c (mm)
Structural members forming ballast tank boundary and located in ballast tanks, e.g. bottom plating, side shell plating, upper deck, inner bottom plating, hopper slope plating, inner hull plating, inner hull slope plating, transverse bulkheads (except for double plane transverse bulkhead), double bottom floors, double bottom girders and side stringers, side transverse diaphragms etc.	1.5

Location	Standard thickness deduction t_c (mm)
Other structural members	1.0

4.3.5 The combined interaction of uni-axial and bi-axial compressive stresses and shear stresses are to be considered in the buckling calculation.

4.3.6 Panel buckling calculation approaches may be referred to Section 5, Chapter 1 of this PART.

4.4 Fine mesh model and strength assessment

4.4.1 For an accurate and clear observation of stress level and distribution at local areas of stress concentration, fine mesh analysis and strength assessment are to be further carried out for the following critical locations:

(1) the connection of lower knuckle joints of hopper slope plating to inner bottom plating, upper knuckle joints to inner hull longitudinal bulkhead in way of transverse web frames, as shown in Figure 4.4.1(1);

(2) the connection of lower knuckle joints of inner hull slope plating to side stringers in way of transverse web frames, as shown in Figure 4.4.1(2);

(3) the connection of double side stringers to transverse bulkheads, as shown in Figure 4.4.1(3);

(4) the connection of double bottom girders to transverse bulkheads, as shown in Figure 4.4.1(4);

(5) double deck girders in way of the connection of transverse bulkheads to inner decks, as shown in Figure 4.4.1(5);

(6) large openings in transverse web frames, double bottom girders, double deck girders, double transverse bulkhead stringers and vertical diaphragms, in case higher stress is identified in the yield assessment of coarse mesh model.

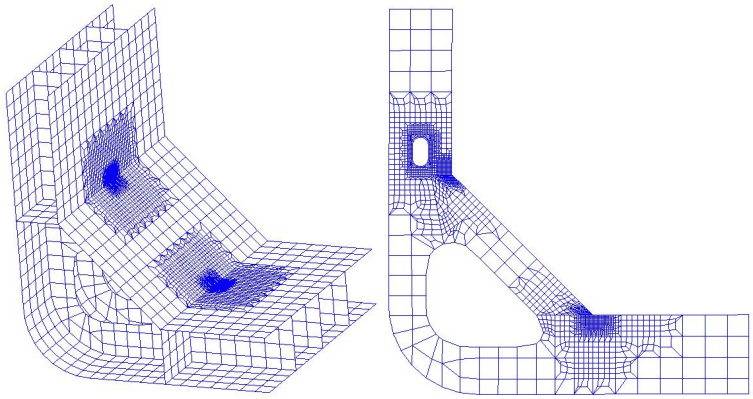


Figure 4.4.1(1) Lower and upper knuckle joints of hopper slope plating

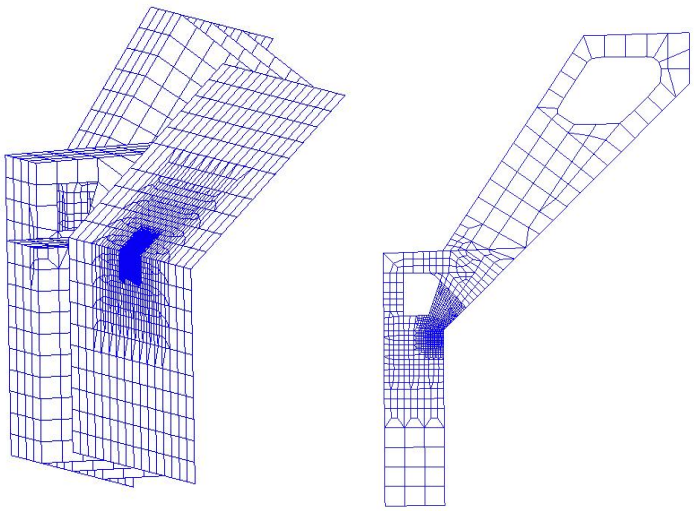


Figure 4.4.1(2) Connection of lower knuckle joints of inner hull slope plating to side stringers

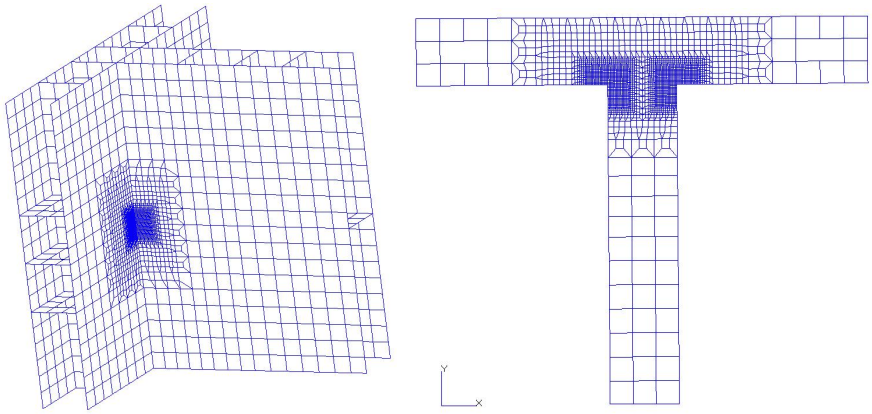


Figure 4.4.1(3) Connection of double side stringers to transverse bulkheads

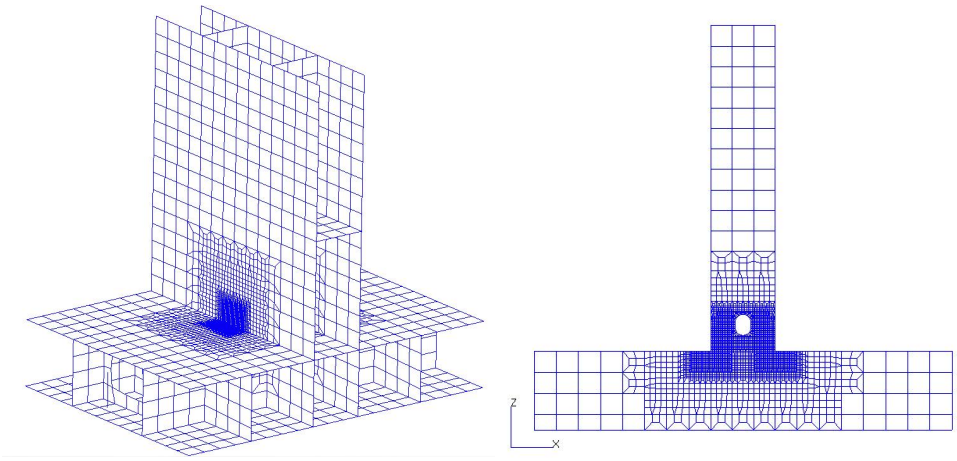


Figure 4.4.1(4) Connection of double bottom girders to transverse bulkheads

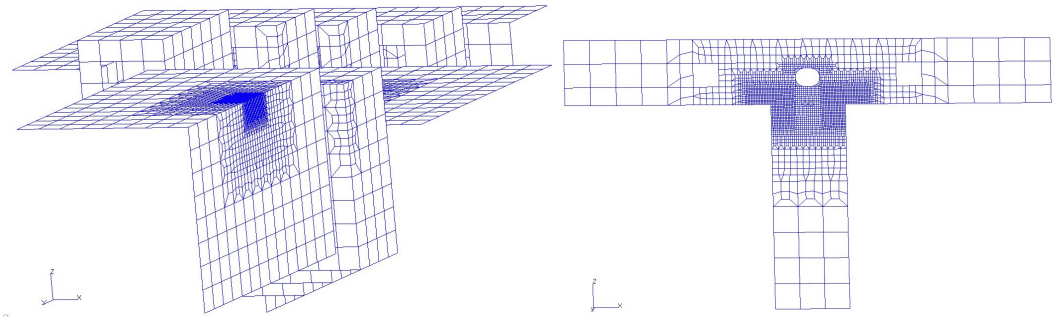


Figure 4.4.1(5) Double deck girders in way of the connection of transverse bulkheads to inner decks

4.4.2 The fine mesh analysis may be carried out by means of a separate local finite element model with fine mesh zones, in conjunction with the boundary conditions obtained from the cargo tank model, or by incorporating fine mesh zones into the cargo tank model.

4.4.3 The extent of the local finite element models is to be such that the calculated stresses at the areas of interest (i.e. areas of stress concentration under investigation) are not significantly affected by the imposed boundary conditions and application of loads. The boundary of the fine mesh model is to coincide with primary members, such as girders, stringers and floors, in the cargo tank model.

4.4.4 The mesh size in the fine mesh zones is not to be greater than 50 mm × 50 mm. In general, the extent of the fine mesh zone is not to be less than 10 elements in all directions from the area under investigation.

4.4.5 All plating within the fine mesh zone is to be represented by shell elements. A smooth transition of mesh density is to be maintained. The aspect ratio of elements within the fine mesh zone is to be kept as

close to 1 as possible. Variation of mesh density within the fine mesh zone and the use of triangular elements are to be avoided. In all cases, the elements are to have an aspect ratio not exceeding 3. Distorted elements, with element corner angle less than 60° or greater than 120°, are to be avoided. Stiffeners inside the fine mesh zone are to be modeled using shell elements. Stiffeners outside the fine mesh zone may be modeled using beam elements.

4.4.6 Where a FE sub-model is used for transverse web frames, the model is to have an extent of at least 1 + 1 web frame spaces, i.e. one web frame space extending either side of the transverse web frame under investigation. The transverse web frames forward and aft of the web frame under investigation need not be included in the sub model. In addition, the full depth and full breadth of the ship are to be modeled.

4.4.7 For transverse bulkhead stringers, due to the structural interaction between the transverse bulkhead, horizontal stringers, web frames, deck and bottom, it is recommended that the FE sub-model represents a full section of the hull. Longitudinally, the ends of the model are at least to be extended one web frame space beyond the areas that require investigation. The full breadth and depth of the ship should be modeled.

4.4.8 The fine mesh detailed stress analysis is to be carried out for the design load cases specified in this Section.

4.4.9 Where a separate local finite element model is used for the fine mesh detailed stress analysis, the nodal displacements from the cargo tank model are to be applied to the corresponding boundary nodes on the local model as prescribed displacements. Alternatively, equivalent nodal forces from the cargo tank model may be applied to the boundary nodes.

4.4.10 Where there are nodes on the local model boundaries which are not coincident with the nodal points on the cargo tank model, it is acceptable to impose prescribed displacements on these nodes using multi-point constraints. The use of linear multi-point constraint equations connecting two neighboring coincident nodes is considered sufficient.

4.4.11 All local loads in way of the structure represented by the separate local finite element model are to be applied to the model.

4.4.12 Stress check criteria and approaches for fine mesh analysis are given in Table 4.4.12 and the description thereto.

Maximum permissible membrane stresses for fine mesh analysis **Table 4.4.12**

Element stress	Yield utilisation factor
Element not adjacent to weld	$\lambda_y \leq 1.7$
Element adjacent to weld	$\lambda_y \leq 1.5$

where: (1) λ_y — yield utilisation factor

$= \frac{K\sigma_e}{235}$, for plate element

(2) Where the von Mises stress of the elements in the cargo tank FE model in way of the area under investigation by fine mesh exceeds its permissible value specified in Table 4.2.1, average von Mises stress, obtained from the fine mesh analysis, calculated over an area equivalent to the mesh size of the cargo tank finite element model is to be less than the permissible value specified in Table 4.4.12.

(3) The maximum permissible stresses are based on the mesh size of 50 mm × 50 mm as specified in 4.4.4. Where a smaller mesh size is used, assessment may be carried out by using stress averaging method, see relevant requirements of 2.7.9, Appendix 2, Chapter 7 of this PART.

(4) The yield utilisation factor may be increased by 1.3 times for accidental conditions.

APPENDIX 2 STRUCTURAL STRENGTH ASSESSMENT OF HULL AND PUMP TOWER UNDER SLOSHING LOADS

1 GENERAL PROVISIONS

1.1 Application

1.1.1 This Appendix specifies the calculation of sloshing loads of membrane tank liquefied gas carriers, the assessment requirements in respect of the hull and pump tower structure of cargo tank region under sloshing loads and the requirements for vibration evaluation of pump tower structure.

1.1.2 Unless otherwise specified in this Appendix, the calculation methods of sloshing loads are to comply with relevant requirements of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

1.1.3 Cargo tanks without partially filled conditions, i.e. filling height less than 5%h or greater than 95%h (where h is defined in Table 1.2.3 of this Appendix) may be exempted from the requirements of Sections 3 and 4 of this Appendix.

1.2 Target tank and its structural configuration

1.2.1 For the sloshing load calculation and the strength assessment of pump tower structure, the No.2 cargo tank close to the bow is to be taken as the target tank. Where it is proposed by the owner to carry out assessment of other cargo tanks, they are to be taken as additional target tanks for assessment after approval by CCS.

1.2.2 The terms of main structural configurations of cargo tanks are as shown in Figure 1.2.2.

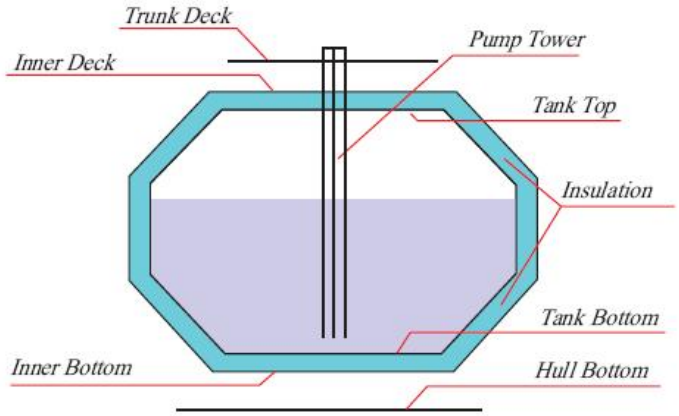


Figure 1.2.2 Terms of structural configurations of cargo tanks

1.2.3 The geometry of cargo tanks is as shown in Figure 1.2.3 and the basic parameters are defined in Table 1.2.3.

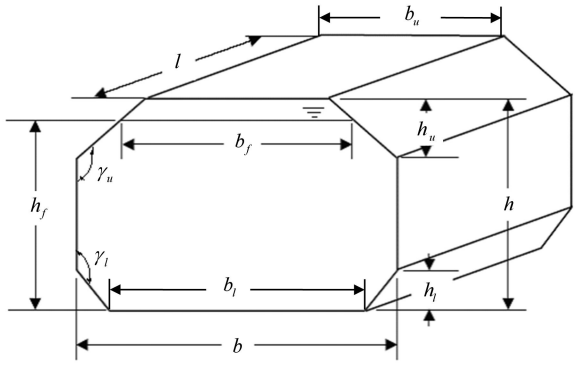


Figure 1.2.3 Main geometric parameters of cargo tanks

Definitions of geometric parameters of cargo tanks **Table 1.2.3**

No.	Variable	Definition	Unit
1	l	Length	m
2	b	Breadth	m
3	b_u	Breadth of tank top	m
4	b_l	Breadth of tank bottom	m
5	h	Depth	m
6	h_f	Filling height	m
7	b_f	Surface breadth at corresponding filling height	m
8	h_u	Upper chamfer height	m
9	γ_u	Upper chamfer angle	deg
10	h_l	Lower chamfer height	m
11	γ_l	Lower chamfer angle	deg

1.3 Definitions of parameters

1.3.1 In addition to the provisions of this Appendix, other parameters and symbols of this Appendix are defined in Section 1 and Appendix 1 of this Chapter.

1.3.2 The directions and terms of ship motions in six degrees of freedom are defined in Table 1.3.2.

Directions and definitions of ship motion in six degrees of freedom **Table 1.3.2**

Direction	Symbol	Ship motion	Displacement		Velocity		Acceleration	
			Symbol	Unit	Symbol	Unit	Symbol	Unit
X axis	ξ_1	Surge	ξ_1	m	ξ'_1	m/s	ξ''_1	m/s^2
	θ_1	Roll	θ_1	rad	θ'_1	rad/s	θ''_1	rad/s^2
Y axis	ξ_2	Sway	ξ_2	m	ξ'_2	m/s	ξ''_2	m/s^2
	θ_2	Pitch	θ_2	rad	θ'_2	rad/s	θ''_2	rad/s^2
Z axis	ξ_3	Heave	ξ_3	m	ξ'_3	m/s	ξ''_3	m/s^2
	θ_3	Yaw	θ_3	rad	θ'_3	rad/s	θ''_3	rad/s^2

2 CALCULATION OF SLOSHING LOADS

2.1 General requirements

2.1.1 This Section specifies the calculation methods of loads (including quasi-static loads, dynamic loads and impact loads) induced by free movement of the tank liquids as a result of ship motion.

2.1.2 The result of sloshing model test may be treated as sloshing design load subject to approval of CCS.

2.2 Sloshing motion levels

2.2.1 Sloshing motion levels are defined as follows:

(1) Level 1 is a static or quasi-static process. The loads due to sloshing motion at this level are mainly static loads and the dynamic motion loads may be neglected.

(2) Level 2 is a dynamic and non-magnification process of sloshing motion. The loads due to sloshing motion at this level include static and dynamic loads, but the latter have not involved the impact loads.

(3) Level 3 is a dynamic and magnification process of sloshing motion. The loads due to sloshing motion at this level include static and dynamic loads where the latter are the main loads involving impact loads.

2.2.2 Criteria for judging sloshing motion levels are as follows:

(1) Where the tank size is within the range of l <0.13L and b_f<0.56B, and the difference between natural period of tank motion and natural period of hull motion is beyond ±20%, level 1 sloshing motion is considered.

(2) Where the tank size is within the range of l <0.13L and b_f<0.56B, and the difference between natural period of tank motion and natural period of hull motion is within ±20%, or where the tank size is within the range of l ≥0.13L and b_f ≥0.56B, and the difference between natural period of tank motion and natural period of hull motion is beyond ±20%, level 2 sloshing motion is considered.

(3) Where the tank size is within the range of l ≥0.13L and b_f ≥0.56B, and the difference between tank frequency and hull natural frequency is within ±20%, level 1, level 3 sloshing motion is considered.

2.3 Loading conditions

2.3.1 The loading conditions related to the scantling assessment of hull structural members of cargo tank region, the direct calculations of cargo tanks and the assessment of structural strength of pump tower are given in Table 2.3.1.

2.3.2 For calculation required for scantling of hull structural members of cargo tank region under sloshing loads and the structural strength assessment of pump tower, the full load condition and ballast condition given in Table 2.3.1 are to be taken.

2.3.3 For FE analysis of hull structural members of cargo tank region under sloshing loads, the sloshing condition in Table 2.3.1 is to be taken.

Loading conditions **Table 2.3.1**

No.	Conditions	Draught	k	GM
1	Full load condition	d	k=0.35B	GM=0.12B
2	Ballast condition	Ballast draught at arrival	k=0.45B	GM=0.33B
3	Sloshing condition	2/3d	k=0.39B	GM=0.24B

where: k — roll radius, in m;

GM — metacentric height, in m, considering free surface correction.

2.4 Natural period of hull and tank motion

2.4.1 Based on Table 2.3.1, the hull pitch period T_p and hull roll period T_r are calculated respectively in accordance with 2.3.4, Appendix 1 of this Chapter.

2.4.2 The period of longitudinal motion T_x is calculated in accordance with the following formula:

$$T_x = \sqrt{\frac{4\pi l}{g\tanh\left(\frac{\pi h_f}{l}\right)}} \quad \text{s}$$

2.4.3 The period of transverse motion T_y is calculated in accordance with the following formula:

$$T_y = \sqrt{\frac{4\pi b_f}{g\tanh\left(\frac{\pi h_f}{b_f}\right)}} \quad \text{s}$$

2.5 Filling heights under consideration

2.5.1 All the filling heights in the loading manual are to be used as the filling heights under consideration for analysis of sloshing loads.

2.5.2 Where additional loading is required by the owner, detailed data is to be provided as the additional filling height under consideration for analysis of sloshing loads.

2.5.3 In addition to the above requirements for filling heights under consideration, four standard heights under consideration of 5%h, 10%h, 70%h and 95%h are also to be taken into account for the calculation of structural strength of pump tower.

2.6 Level 1 sloshing loads

2.6.1 Level 1 sloshing pressure acting on the tank boundary due to the still water pressure of cargo and linear variation of surface is to be calculated according to relevant provisions of Section 2 of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

2.7 Level 2 sloshing loads

2.7.1 Level 2 sloshing pressure P_2 acting on the tank boundary due to the still water pressure of cargo and sloshing motion is to be calculated according to relevant provisions of Section 2 of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

2.8 Level 3 sloshing impact loads

2.8.1 This paragraph gives rule calculation method for level 3 sloshing impact loads.

2.8.2 The impact pressure in way of inner hull slope plating:

$$\text{Transverse motion:} \quad P_3 = \frac{168\rho g}{B}\left(\frac{b_f}{B} - 0.3\right)GM^{1.5}\sin^2\gamma_u C_{t_imp1} \quad \text{kN/m}^2$$

where: γ_u — angle between the plating considered and the vertical plane;

$C_{t_imp1} = C_t$, h_f is to be taken as $0.7(h - h_u)$ in calculation of C_t;

$C_t = 0.9y_{01} / [1 + 9(1 - y_0)^2]$, to be taken not less than 0.25;

$y_0 = T_y / T_r$;

$$y_{01} = \begin{cases} y_0 & y_0 \le 1 \\ 1 / y_0 & y_0 > 1 \end{cases}$$

2.8.3 The impact pressure in way of tank top:

Longitudinal motion: $P_3 = 1.24\rho g(\frac{220l}{L} - 7.5)C_{l_imp2}$ kN/m^2

Transverse motion: $P_3 = \frac{164\rho g}{B}(\frac{b_f}{B} - 0.3)GM^{1.5}\sin^2\gamma_u C_{t_imp1}$ kN/m^2

where: $C_{l_imp2} = C_l$, h_f is to be taken as $0.7h$ in calculation of C_t;

$C_l = 0.9x_{01} / [1 + 9(1 - x_0)^2]$, to be taken not less than 0.25;

$x_0 = T_x / T_p$;

$$x_{01} = \begin{cases} x_0 & x_0 \le 1 \\ 1 / x_0 & x_0 > 1 \end{cases};$$

γ_u — angle between the plating considered and the vertical plane.

2.8.4 The area of tank top under the impact pressure is as shown in Figure 2.8.4.

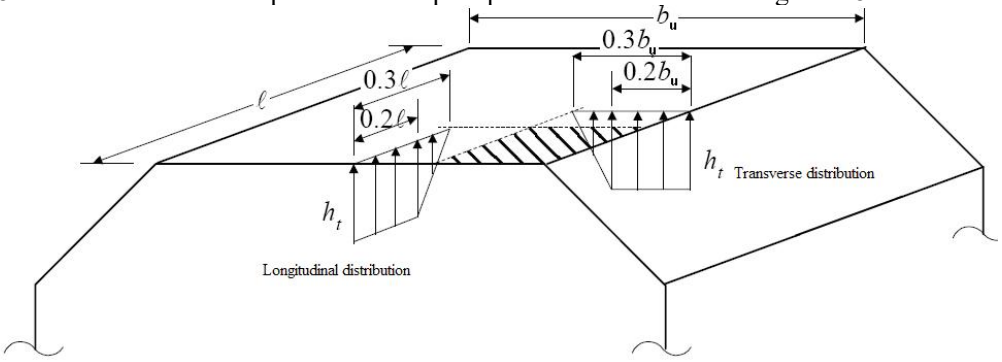


Figure 2.8.4 Area of tank top under the impact pressure

2.8.5 The impact pressure in way of the lower part of tank

(1) Within an area of $0.2b_f$ or $0.2l$ in height from the inner bottom plating, the impact loads applied to the tank bottom are as follows:

Longitudinal motion: $P_3 = 1.42\rho gkl\sin^2\delta$ kN/m^2

Transverse motion: $P_3 = 1.5\rho gb_f\sin^2\delta$ kN/m^2

where:

$$k = \begin{cases} 1 & L < 200 \\ 1.4 - 0.002L & L \ge 200 \end{cases};$$

δ — angle between the panel considered and the horizontal direction, in °.

(2) The impact loads in way of the lower part are evenly distributed within an area of $0.2b_f$ or $0.2l$ in height from the inner bottom plating and linearly reduced to 0 within the range extending 1 m upwards from such height.

2.8.6 For corners of longitudinal and transverse structures of tanks within the range of $0.15b_f$ or $0.15l$, the impact loads are determined by the following formula:

$$P_3 = \max\begin{cases} P_3(\text{longitudinal}) + 0.4P_3(\text{transverse}) \\ P_3(\text{transverse}) \end{cases}$$

2.9 Direct calculation of sloshing loads

2.9.1 This paragraph provides direct calculation method and program for sloshing loads, and with approval by CCS, other programs may be used to calculate sloshing loads.

2.9.2 Basic assumptions

The volume of fluid method is used for direct calculation of sloshing loads of cargo tanks, in association with the following assumptions:
(1) the fluid is non-compressible and viscous;
(2) free surface exists in fluid motion and no loss of fluid in tanks occurs during the motion;
(3) temperature change is not taken into consideration.

2.9.3 Basic principles

Coordinate systems are established for a two-dimensional space (x, y), as shown in Figure 2.9.3, where $O_oY_oZ_o$ is a permanent coordinate system fixed on earth, oyz is a coordinate system of motions fixed on cargo tank boundary; $(y_o(t), z_o(t))$, $\theta(t)$, $\dot{\theta}(t)$ and $(\ddot{y}_o(t), \ddot{z}_o(t))$ are respectively the position, angle, angular velocity and linear acceleration of the coordinate system of motions relative to the permanent coordinate system. Equations are developed based on basic principles of non-compressible fluid dynamics. The finite difference method is employed to discretize the equations.

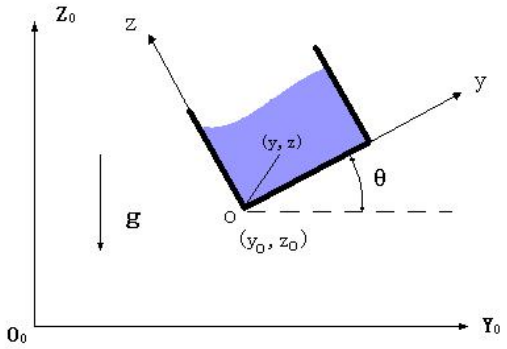


Figure 2.9.3 Two-dimensional coordinate system

2.9.4 Sloshing calculation program

CCS software for direct calculation of sloshing is employed for the calculation of sloshing loads and motion. The calculation model and distribution of grid cells are shown in Figure 2.9.4.

The size of grid cell is recommended to be 0.5 to 1 time the longitudinal spacing, and the ratio of side is to be approximate to 1 as far as possible for meshing. The hybrid factor is in general taken as 0.8.

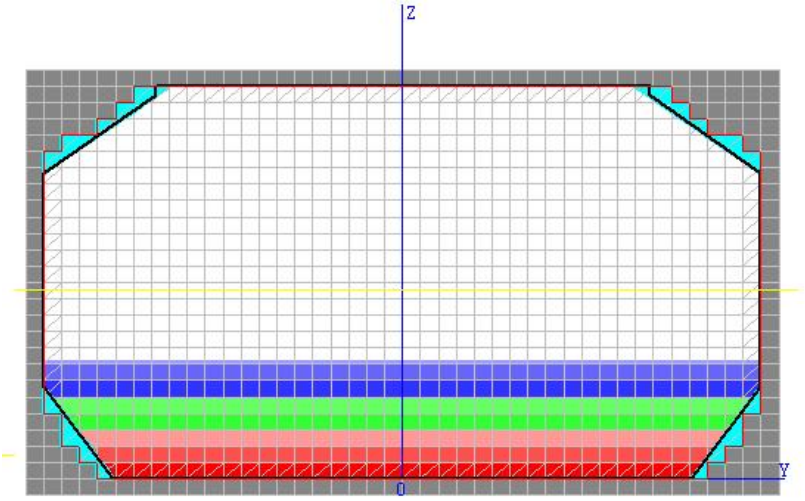


Figure 2.9.4 Grid cells in sloshing calculation

3 ASSESSMENT OF SCANTLING REQUIREMENTS FOR TANK STRUCTURE UNDER SLOSHING LOADS

3.1 General requirements

3.1.1 This Section specifies the scope of application and scantling requirements for sloshing loads applied to the hull structural members in cargo tank region.

3.1.2 The sloshing pressure used in this Section is the maximum value of sloshing loads calculated by the filling heights under consideration selected in accordance with 2.5 of this Appendix, where the level 3 sloshing load is to be based on the direct calculation of sloshing loads.

3.1.3 Assessment is to be carried out for the following structural members subjected to sloshing pressure due to longitudinal liquid motion:
(1) transverse tight bulkheads;
(2) inner deck;
(3) primary members;
(4) stiffeners on the transverse bulkheads and inner deck.
3.1.4 Assessment is to be carried out for the following structural members subjected to sloshing pressure due to transverse liquid motion:
(1) longitudinal tight bulkheads;
(2) hopper slope plating;
(3) inner hull slope plating;
(4) inner deck;
(5) primary members;
(6) stiffeners on the above structural members.

3.2 Assessment of tank structure under level 1 and level 2 sloshing loads

3.2.1 Plating forming tank boundaries

The thickness of plating forming tank boundaries, t, subjected to sloshing pressures is not to be less than that obtained from the following formula:

$$t = 0.0174\alpha_p s\sqrt{\frac{P}{C_a R_{eH}}} \quad \text{mm}$$

where: $\alpha_p = 1.2 - \frac{s}{2100 l_p}$, but to be taken not greater than 1.0;

s — stiffener spacing, in mm;

l_p — length of plate panel, to be taken as the spacing of primary members, unless carlings are fitted, in m;

P — sloshing load, to be taken as the greater of P_1 and P_2, in kN/m^2;

C_a — permissible plate bending stress coefficient, see Table 3.2.1;

R_{eH} — yield stress of the material, in N/mm^2.

Permissible bending stress coefficient, C_a, for assessment of sloshing on plates

Table 3.2.1

The permissible bending stress coefficient is to be taken as:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}} \text{ but not to be taken greater than } C_{a-\max}$$

where: β_a, α_a, $C_{a-\max}$ – permissible bending stress factors and are to be taken as follows:

Structural Member		β_a	α_a	$C_{a-\max}$
Longitudinal strength members in the cargo tank region including but not limited to: – inner deck; – inner hull plating; – longitudinal girders and stringers	Longitudinally stiffened plating	0.9	0.5	0.8
	Transversely or vertically stiffened plating	0.9	1.0	0.8
Other strength members including: – transverse bulkheads; – transverse stringers and web frames		0.8	0	0.8

σ_{hg} — hull girder bending stress calculated at the load calculation point and to be taken as:

$$\sigma_{hg} = \left(\frac{(z - z_{NA}) M_{sw}}{I_v}\right) \times 10^{-3} \quad \text{N/mm}^2$$

z — vertical coordinate of the load calculation point under consideration, in m;

z_{NA} — distance from the baseline to the horizontal neutral axis, in m;

M_{sw} — permissible hull girder hogging and sagging still water bending moment for seagoing operation, in kN.m, to be taken as the greatest absolute value;

I_v — vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4;

R_{eH} — yield stress of the material, in N/mm^2.

3.2.2 Stiffeners on tank boundaries

The section modulus, W, of stiffeners on tank boundaries subjected to sloshing pressures is not to be less than that obtained from the following formula:

$$W = \frac{1.1 P s l_{bdg}^2}{f_{bdg} C_s R_{eH}} \qquad \text{cm}^3$$

where: l_{bdg} — effective bending span of stiffeners, in m;

C_s — permissible bending stress coefficient, see Table 3.2.2;

P — sloshing load, to be taken as the greater of P_1 and P_2, in kN/m^2;

s — stiffener spacing, in mm;

R_{eH} — minimum yield stress of the material, in N/mm^2;

f_{bdg} — bending moment factor to be taken as:

$f_{bdg} = 12$ for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners;

$f_{bdg} = 8$ for stiffeners with one or both ends not fixed against rotation. This is generally to be applied to discontinuous stiffeners.

Permissible bending stress coefficient, C_s, for assessment of sloshing on stiffeners

Table 3.2.2

The permissible bending stress coefficient is to be taken as:

$C_s = \beta_s - \alpha_s \frac{|\sigma_{hg}|}{R_{eH}}$ but not to be taken greater than $C_{s-\max}$

where: β_s, α_s, $C_{s-\max}$ — permissible bending stress factors and are to be taken as follows:

Structural Member		β_s	α_s	$C_{s\text{-}max}$
Longitudinal strength members in the cargo tank region including but not limited to: – inner deck longitudinals; – stiffeners on inner hull plating	Longitudinal stiffeners	0.85	1.0	0.75
	Transverse or vertical stiffeners	0.7	0	0.7
Other strength members including: – stiffeners on transverse bulkheads		0.75	0	0.75

σ_{hg} — hull girder bending stress calculated at the load calculation point and to be taken as:

$$\sigma_{hg} = \left(\frac{(z - z_{NA}) M_{sw}}{I_v} \right) \times 10^{-3} \qquad \text{N/mm}^2$$

z — vertical coordinate of the load calculation point under consideration, in m;

z_{NA} — distance from the baseline to the horizontal neutral axis, in m;

M_{sw} — permissible hull girder hogging and sagging still water bending moment for seagoing operation, in kN.m, to be taken as the greatest absolute value;

I_v — vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4;

R_{eH} — yield stress of the material, in N/mm^2.

3.3 Assessment of tank structural members under level 3 sloshing load

3.3.1 Plating forming tank boundaries

The thickness of plating forming tank boundaries, t, subjected to level 3 sloshing pressures is not to be less than that obtained from the following formula:

$$t = \frac{0.0174 \alpha_p s}{C_d} \sqrt{\frac{P}{C_a R_{eH}}} \quad \text{mm}$$

where: P — sloshing impact load P_3, in kN/m^2, to be calculated in accordance with 2.9;

C_d = 1.3, plate capacity correction coefficient;

other parameters are the same as those in 3.2.1.

3.3.2 Stiffeners on tank boundaries

The plastic section modulus, W_{pl}, of stiffeners on tank boundaries subjected to sloshing impact pressures is not to be less than that obtained from the following formula:

$$W_{pl} = \frac{1.1Psl_{bdg}^2}{f_{bdg}C_sR_{eH}} \qquad \text{cm}^3$$

where: P — sloshing impact load P_3, in kN/m^2, to be calculated in accordance with 2.9;

$C_s = 0.9$;

f_{bdg} — bending moment factor, to be taken as:

$$f_{bdg} = 8\left(1 + n_s / 2\right)$$

where: $n_s = 2.0$ for continuous stiffeners or where stiffeners are bracketed at both ends;

other parameters — the same as those in 3.2.2.

3.3.3 Where the ends of stiffeners are not arranged to be continuous through and alternative arrangements are used, the plastic section modulus, $W_{pl\text{-}alt}$, of stiffeners is not to be less than that obtained from the following formula:

$$W_{pl-alt} = \frac{16W_{pl}}{f_{bdg}} \qquad \text{cm}^3$$

where: f_{bdg} — bending moment factor, to be taken as:

$$f_{bdg} = 8\left(1 + n_s / 2\right)$$

where: $n_s = 0$ for both ends with low end fixity (simply supported);

$n_s = 1$ for one end equivalent to built-in and the other end simply supported.

3.3.4 The shear area, A_{shr}, of primary member web at any position along its span is not to be less than that obtained from the following formula:

$$A_{shr} = 10\frac{Q_{imp}}{C_t\tau_{yd}} \qquad \text{cm}^2$$

where: Q_{imp} — the greatest shear force due to impact for the position being considered, in kN, as determined in accordance with 3.3.5;

$C_t = 0.9$, permissible shear stress coefficient;

$\tau_{yd} = \frac{R_{eH}}{\sqrt{3}}$ N/mm^2;

R_{eH} — yield stress of the material, in N/mm^2.

3.3.5 For primary members, the shear force, Q_{imp}, is calculated by the following formula:

$$Q_{imp} = f_{pt}f_{dist}F_{imp}$$

where: f_{pt} — correction factor for the proportion of patch load acting on a single primary member, to be taken as:

$$f_{pt} = 0.5(f_{imp}^3 - 2f_{imp}^2 + 2)$$

f_{imp} — patch load modification factor, to be taken as:

$$f_{imp} = 0.5\frac{b_{imp}}{S}\text{, but not to be greater than 1.0}$$

f_{dist} — factor for the greatest shear force distribution along the span, see Figure 3.3.5;

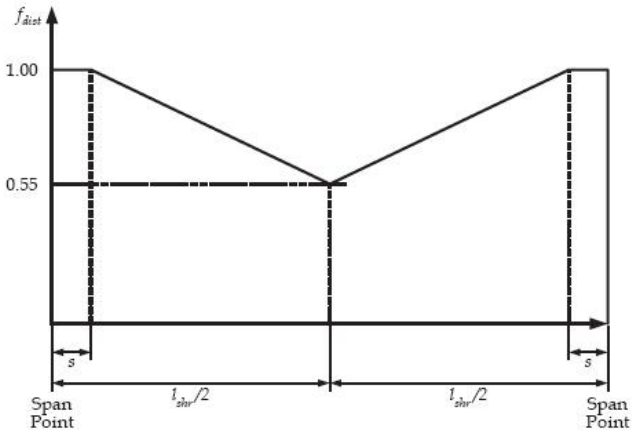


Figure 3.3.5 Distribution of f_{dist} along the Span

s — stiffener spacing, in m;

l_{shr} — effective shear span, in m;

$F_{imp} = P_3 l_{imp} b_{imp}$

where: P_3 — sloshing impact pressure, in kN/mm^2, as determined in accordance with 2.9;

l_{imp} — extent of impact load area along the span, in m, not to be greater than l_{shr} ;

b_{imp} — breadth of impact area supported by primary member, in m, not to be greater than S;

S — primary member spacing, in m.

4 DIRECT CALCULATION OF HULL STRUCTURAL STRENGTH UNDER SLOSHING LOADS

4.1 General requirements

4.1.1 This Section applies to the cargo tank FE analysis related to the hull structure of cargo tank under sloshing loads.

4.1.2 The assessment is to be carried out to primary members and transverse bulkheads in cargo tank region as well as support members of cargo containment system.

4.2 Structural FE model

4.2.1 The FE model of cargo tank used for the direct calculation and analysis of strength of cargo tank region is to comply with the requirements of Appendix 1 of this Chapter.

4.3 Loads

4.3.1 All load components with respect to the hull girder bending moment, liquid pressure inside and outside of tanks and other local pressures, inertia forces due to ship's motions are to be taken into account.

4.3.2 All load components with respect to the hull girder bending moment, liquid pressure inside and outside of tanks and other local pressures, inertia forces due to ship's motions are to be in accordance with the requirements of Section 2, Appendix 1 of this Chapter. The hull girder still water bending moment in sloshing condition is to be taken as 70% of maximum design still water bending moment value.

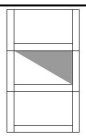
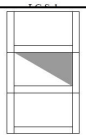
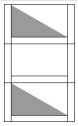
4.3.3 The sloshing pressure of liquid inside cargo tanks is to be in accordance with the requirements of 2.6~2.8, Section 2 of this Appendix.

4.4 Calculation conditions

4.4.1 The cargo tank FE analysis conditions under sloshing loads are given in Table 4.4.1.

4.4.2 The filling height under consideration in cargo tanks is to be determined in accordance with 2.5, Section 2 of this Appendix.

Sloshing load cases **Table 4.4.1**

Case	Load pattern	Draught	Coefficient of hull girder vertical wave bending moment k_{cV}	Coefficient of hull girder horizontal wave bending moment k_{cH}	External pressure		Wave heading angles and ship motions			
					k_c	k_{f0}	Wave angle	Heave	Pitch	Roll
LCA_L		2/3*d*	Sag 1.0	–	0.5	-1.0	0	Down	Bow down	–
LCA_T		2/3*d*	Sag 0.3	Tension port 0.3	0.5	-1.0	90	Down	–	Stbd up
LCB_L		2/3*d*	Hog 1.0	–	0.5	1.0	0	Up	Bow up	–
LCB_T		2/3*d*	Hog 0.3	Tension port 0.3	0.5	1.0	90	Up	–	Stbd up

4.5 Result evaluation

4.5.1 The assessment areas of FE analysis of cargo tank under sloshing loads are given in 4.1.1 and 4.1.2, Section 4, Appendix 1 of this Chapter.

4.5.2 The yield assessment criteria of structural members in sloshing condition are given in Table 4.5.2.

Yield strength assessment criteria **Table 4.5.2**

Structural member	Yield utilisation factor and permissible stress restriction
Hull girder longitudinal member plating and bulkhead plating	
Side shell, bilge plate, bottom shell, trunk deck slope plating and trunk deck plating, upper deck, cofferdam bulkheads, side watertight bulkheads, deck girders, double bottom girders, double side stringers, etc.	$\lambda_y \leq 1.0$, for bottom shell and double bottom girders $\lambda_y \leq 0.9$, for other structural members.
Inner deck plating and inner deck slope plating in direct contact with secondary barriers, side inner hull plating, inner bottom, inner hull slope plating, hopper slope plating	$\lambda_y \leq 0.90$
Primary supporting member plating	
Primary transverse supporting structures, e.g. side transverse web frames, trunk deck transverses, vertical diaphragms and horizontal stringers between cofferdam bulkheads, double bottom floors, and stiffening diaphragm plates and brackets between inner and outer hulls	$\lambda_y \leq 0.75$
Notes: (1) Yield utilisation factor $\lambda_y = \frac{\sigma_e}{R_{eH}}$ for plate element; $\lambda_y = \frac{\sigma_{rod}}{R_{eH}}$, for face plate of primary supporting members modelled by rod element or beam element. (2) For structural members subject to level 3 sloshing impact loads, the permissible stress may be taken as the yield strength R_{eH} of the material.	

4.5.3 Yield deformation is to be so controlled that maximum relative deformation of the plating between stiffeners of all hull panels (including inner bottom plating, hopper slope plating, inner hull plating, inner hull slope plating, inner deck plating and inner deck top plating as well as transverse bulkhead plating)/plating of unstiffened panels regarding periphery of insulations is generally not to be greater than 4.0 mm.

4.5.4 Refined model and assessment are to satisfy relevant requirements of 4.4, Section 4, Appendix 1 of this Chapter.

5 DIRECT CALCULATION OF STRUCTURAL STRENGTH OF PUMP TOWER UNDER SLOSHING LOADS

5.1 General requirements

5.1.1 This Section applies to the assessment of structural strength of pump tower under sloshing loads, taking into account the impact of temperature effect and inertial motion of hull.

5.1.2 The following primary structural members are to be included in the calculation model of pump tower structure:

(1) port/starboard discharge pipes;
(2) emergency pipe;
(3) filling pipe;
(4) brace;
(5) filling pipe and emergency pipe connecting bar;
(6) pump tower base;
(7) pumps.

The arrangement of primary structural members is as shown in Figure 5.1.2.

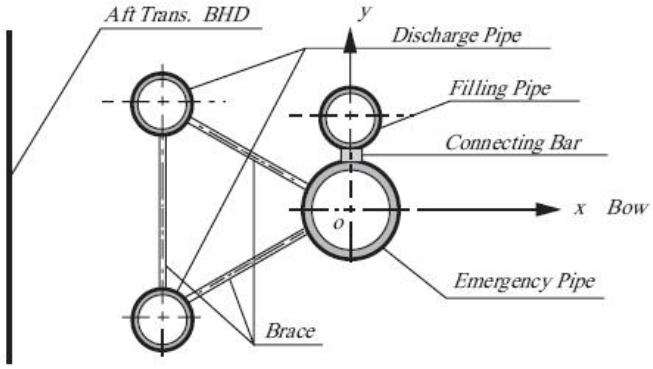


Figure 5.1.2 Arrangement of primary structural members of pump tower

5.1.3 Material properties

The pump tower is generally made of 300 series stainless steel. The physical properties of the common stainless steel 304L are given in Table 5.1.3 or reference is made to relevant provisions of Section 8, Chapter 3, PART ONE of Rules for Materials and Welding.

Properties of stainless steel 304L **Table 5.1.3**

No.	Item	Property
1	Yield strength	170 N/mm^2 at room temperature 200 N/mm^2 at -30℃ 277 N/mm^2 at -160℃
2	Tensile strength	485 N/mm^2 at room temperature
3	Elastic modulus	1.93×10^5 N/mm^2
4	Poisson ratio	0.3
5	Thermal expansion coefficient	16.8×10^{-6} /℃
6	Reference temperature	20℃

5.2 Selection of conditions and dominant load parameters

5.2.1 Calculation conditions

(1) Standard rule input conditions may be used directly as tank sloshing calculation conditions, including natural period of tank motion as well as maximum roll angle and pitch angle of hull motion, in which natural period of tank motion is calculated according to 2.4 of this Appendix, and maximum roll angle and

pitch angle are calculated according to 2.3.4(1), Appendix 1 of this Chapter.
(2) The second method is to calculate response amplitude operators (RAO) of dominant load parameters by means of seakeeping analysis based on equivalent design wave method and screen critical sloshing calculation condition. At the same time, wave encounter period and long-term extreme value of dominant load parameters are calculated for sloshing loads and structural analysis.
For method 2, according to relevant provisions of 2.3 of this Appendix, full load and ballast conditions are set as calculation condition for seakeeping analysis, and sloshing loads are calculated by the filling heights under consideration selected in accordance with 2.5 of this Appendix and applied to the FE model of pump tower. For full load conditions, filling levels of 50%*h* or more are to be selected. For ballast conditions, filling levels of less than 50%*h* are to be selected.

5.2.2 Dominant load parameters for sloshing motion

Seakeeping analysis is carried out in this Section, and dominant load parameters are determined as follows:
(1) Transverse motion

- roll motion, θ_1;
- transverse acceleration,

$$\xi''_2 + g\theta_1 - (Z_{CT} - Z_G)\theta''_1$$

(2) Longitudinal motion

- pitch motion, θ_2;
- longitudinal acceleration,

$$\xi''_1 - g\theta_2 + (Z_{CT} - Z_G)\theta''_2$$

where: Z_{CT}, in m, is the distance between the center of tank considered and the baseline; Z_G, in m, is the distance between the ship's center of gravity and the baseline.

5.3 Environmental conditions

5.3.1 Unless specially considered, the environmental condition of North Atlantic wave condition is generally required, and the North Atlantic wave data used are taken from the Wave Scatter Diagram of North Atlantic in IACS Rec. No34.

5.3.2 The two-parameter Bretschneider spectrum $S(\omega)$ is used and the wave spectrum function is given by:

$$S(\omega) = \frac{1.25\omega_p^4 H_s^2 e^{-1.25\left(\frac{\omega_p}{\omega}\right)^4}}{4\omega^5}$$

where: $S(\omega)$ — wave energy density, in m^2/s;
Ω — angular frequency, in rad/s;
ω_p — peak frequency, in rad/s, $\omega_p = 2\pi/T_p$, where T_p is defined in 2.4.1.

5.3.3 Specific sea condition

For LNG carriers intended to be partially loaded, sea conditions for the specific service area are generally to be analyzed by means of a wave scatter diagram for this area. A JONSWAP function $S(\omega)$ is used for the wave spectrum:

$$S(\omega) = \frac{\alpha g^2}{\omega^5}\exp\left[-\frac{5}{4}\left(\frac{\omega_p}{\omega}\right)^4\right] r^{\exp\left[-\frac{1}{\sigma^2}\left(\frac{\omega-\omega_p}{\omega_p}\right)^2\right]}$$

where: r — peak rise factor;
σ — peak shape factor;
α — dimensionless constant;
other parameters — as defined in 5.3.2.

5.4 Equivalent wave approach for sloshing motion

5.4.1 Analysis method

(1) The long-term extreme value prediction method is used to determine the maximum value of wave loads applied to the ship during its operation, generally corresponding to the maximum wave load encountered once in every 25 years. The long-term distribution of wave loads is calculated by combining the short-term predictions into the long term predictions based on the existing information on wave statistics, in which the extreme value of 10^{-8} probability level of exceedance is taken.

(2) A method of short-term extreme value prediction is used for the specific sea condition. At a given probability level, the sea condition corresponding to this level and having the highest wave height is to be obtained. The short-term extreme values are calculated based on this sea condition.

5.4.2 Determination of critical sloshing condition

With response amplitude operators (RAO) of dominant load parameters that are calculated from the sea-keeping analysis, the critical sloshing condition is defined on the frequency (ω) – heading (β) plane.

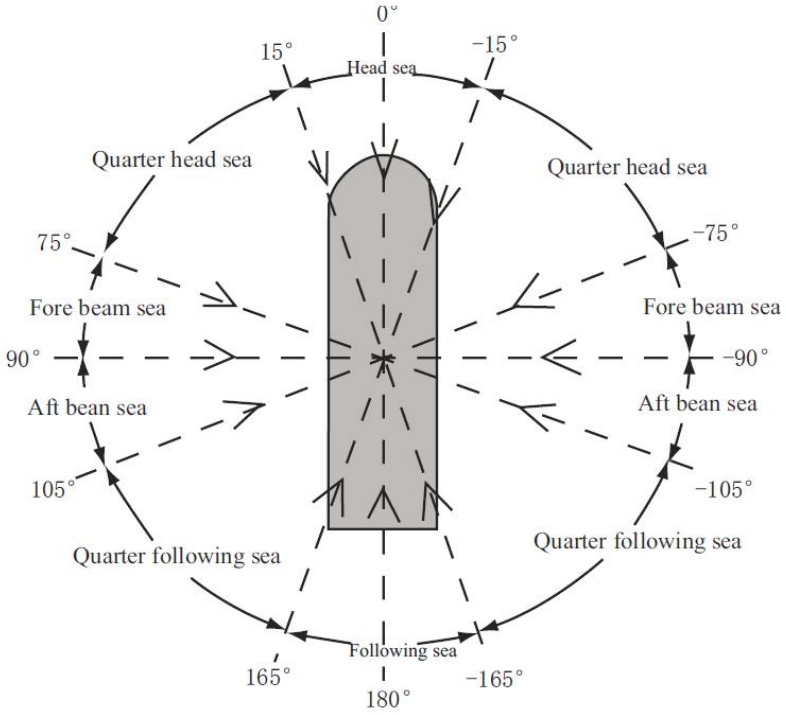


Figure 5.4.2 Distribution of wave heading angles around the girth of the ship

Figure 5.4.2 shows the distribution of wave heading angles around the girth of the ship. The following three principles are to be complied with in determining the critical sloshing condition:

- the response amplitude operator has the maximum value;
- the encounter period is in proximity to the sloshing motion period;
- the wave heading angle is within the range of maximum effects.

Based on the above principles, conditions for determining a critical sloshing condition are indicated in Table 5.4.2 below.

Conditions for determining a critical sloshing condition **Table 5.4.2**

No.	Motion	Formula for the conditions	Remarks
1	Transverse motion	$\lvert T_y - T_e \rvert < 0.3T_y$	where T_y and T_e are transverse sloshing motion period and wave encounter period respectively
		$RAO(\beta,\omega) > 0.7Max[RAO(\beta,\omega)]$	where the response amplitude operator is corresponding to the dominant load parameter
		$60^o \le \beta \le 90^o$	taking into account beam sea
2	Longitudinal motion	$\lvert T_x - T_e \rvert < 0.3T_x$	where T_x and T_e are longitudinal sloshing motion period and wave encounter period respectively
		$RAO(\beta,\omega) > 0.7Max[RAO(\beta,\omega)]$	where the response amplitude operator is corresponding to the dominant load parameter
		$0^o \le \beta \le 30^o$	taking into account head sea

5.5 Structural analysis of pump tower

5.5.1 Basic model

Global model or simplified model method can be used for pump tower structure analysis. Global model method is to have unified modeling by taking pump tower structure, pump tower liquid dome and base foundation as a global model, and simplified model method is to conduct simplified treatment to pump tower liquid dome and base foundation, or set the intersection of liquid dome and base foundations and pump tower structure as boundary condition. Models relating to pump tower liquid dome and base

foundation structure are to meet the requirements of Section 6 of this Appendix.

(1) Coordinate system

The coordinate system for pump tower finite element models is as shown in Figure 5.5.1（1）. It is a right-handed Cartesian coordinate system whose origin is located at the emergency pipe centerline. The *x*-axis is positive toward the bow, the *y*-axis is positive to port, and the *z*-axis is positive upward. A right-handed local Cartesian coordinate system is used for element whose origin is located at a node. The *x*-axis is along the element axis toward another node and the *y*-axis is normal to the element plane toward the outside.

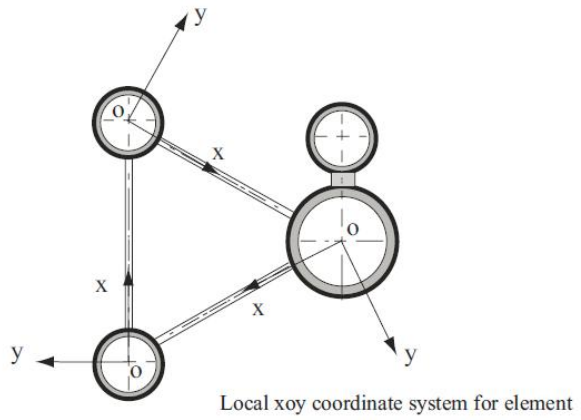


Figure 5.5.1(1) Local coordinate system for element

(2) Finite elements

The element types of pump tower components are to be in accordance with Table 5.5.1.

Finite element types **Table 5.5.1**

No	Structural component	Feature	Element type
1	Port/starboard discharge pipe, emergency pipe, filling pipe and brace	Circular piping structure	Beam element
2	Filling pipe and emergency pipe connecting bar	Rigid connection	Rigid rod element
3	Base foundation	Pump tower base foundation plate and connecting bracket	Plate element, beam element
4	Pumps	Cylindrical structure	Beam element

(3) Modeling principles

The following principles are applicable to the finite element modeling of the pump tower structure:

(a) for circular piping structures including port/starboard discharge pipes, emergency pipe, filling pipe and brace members, the FE nodes are the joint nodes;

(b) when simplified model method is used to evaluate the pump tower structure, the pump tower base structure is simulated by an “I” shape beam element. Face and web plates of the “I” shape beam are determined by the scantlings of pump tower base plates and connecting brackets. Plate or beam elements can also be used to simulate base plate and connecting bracket, and MPC (multi-point constraints) is used to connect circular pipe structure. MPC connecting method is the same as constraint condition of node 12 in Table 5.5.2.

(c) normally the pump tower is provided with two pumps. A cylindrical shell element having the same diameter, height and weight as those of the pump is employed as the equivalent, as shown in Figure 5.5.1(2).

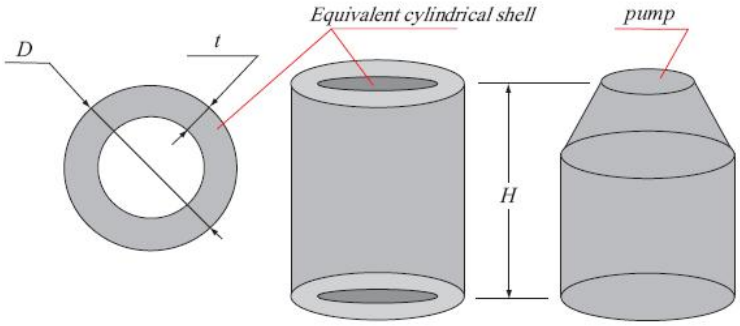


Figure 5.5.1(2) Pump and equivalent cylindrical shell

The thickness of the equivalent cylindrical shell may be calculated by the following formula:

$$t = \frac{D}{2} - \sqrt{\frac{\pi\rho HD^2 - 4W}{4\pi\rho H}}$$

where: t — thickness of the equivalent cylindrical shell, in mm;

D — pump diameter, in mm;

H— pump height, in mm;

W— pump weight, in kg;

ρ — pump material density, in kg/mm^3.

(d) When only the pump tower structure is evaluated, only boundary conditions in 5.5.2 of this Appendix may be considered for pump tower liquid dome structure. When pump tower liquid dome structure is evaluated, plate elements or beam elements are to be used to simulate inner hull deck and trunk deck. MPC (multi-point constraints) is to be used to connect main circular pipe structure of pump tower. MPC connecting method is the same as constraint condition of corresponding node in Table 5.5.2.

5.5.2 Boundary conditions

(1) Top

The boundary conditions of the nodes (i.e. 1, 2, 3, 4, 5, 6, 7 and 8) (as shown in Figure 5.5.2(1)) on the trunk deck and inner hull deck at top is given in Table 5.5.2.

(2) Bottom

The boundary conditions for displacement of node 12 at the base foundation of the pump tower FE model (as shown in Figure 5.5.2(1)) is given in Table 5.5.2.

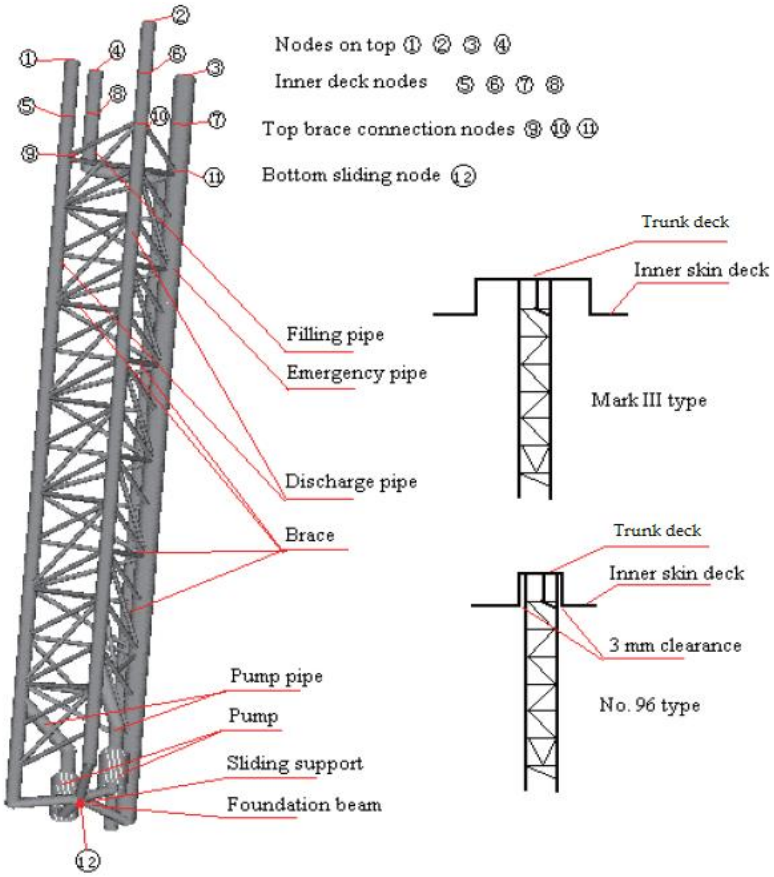


Figure 5.5.2(1) Pump tower structural model and nodes

Boundary conditions of pump tower displacement **Table 5.5.2**

No.	Displacement		Nodes for Mark III type			Nodes for No.96 type		
			1、2、3、4	5、6、7、8	12	1、2、3、4	5、6、7、8	12
1	X axis	Translation	Fixed	–	Fixed	Fixed	Fixed	Fixed
2		Rotation	–	–	Fixed	–	–	Fixed
3	Y axis	Translation	Fixed	–	Fixed	Fixed	Fixed	Fixed
4		Rotation	–	–	Fixed	–	–	Fixed
5	Z axis	Translation	Fixed	–	—	Fixed	–	–

6		Rotation	Fixed	–	Fixed	Fixed	–	Fixed

Note: "–" indicates the free motion of the nodes.

(3) Node constraint between elements

The normal connection between the FE model elements of pump tower may be simulated by the normal joint type of beam element nodes (i.e. constraint connection of six degrees of freedom). For the transverse connecting bar in way of the pump tower liquid dome structure as shown in Figure 5.5.2(2), the axial motion is free while radial motion is constrained. This end joint type may be specially dealt with by means of MPC (multi-point constraints) adopted at the ends of sliding joints as shown in Figure 5.5.2(3).

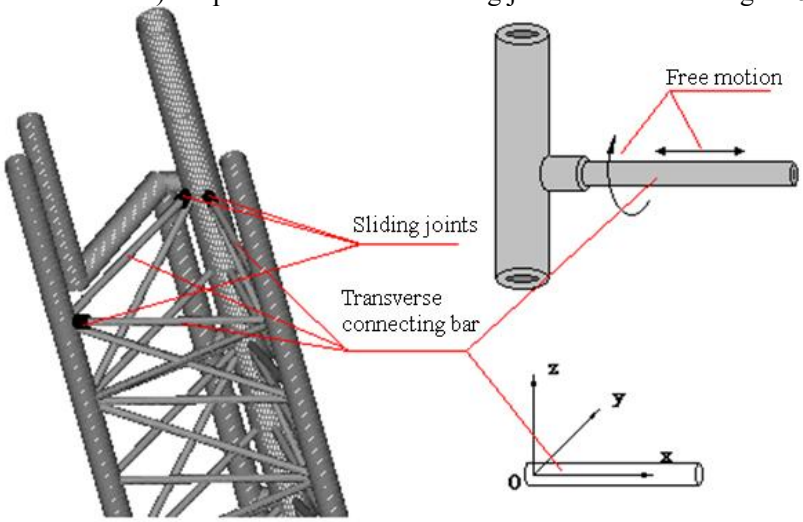


Figure 5.5.2(2) Transverse joints of pump tower liquid dome structure

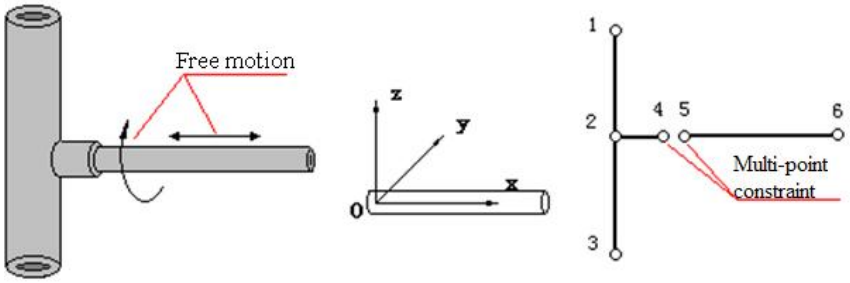


Figure 5.5.2(3) MPC adopted at the ends of sliding joints

5.5.3 Loads

(1) Sloshing loads

The liquid velocity and acceleration along the centerline of the pump tower can be obtained by means of the direct calculation of sloshing motion. The sloshing-induced load on the pump tower, i.e. Morison force $\vec{F}_M$, is calculated by the following formula:

$$\vec{F}_M = \frac{1}{2}\rho C_d \vec{U}(z)\left|\vec{U}(z)\right| D + \frac{\pi}{4}\rho C_m \vec{a}(z) D^2 \quad \text{N/m}$$

where: ρ — fluid density, in kg/m^3;

$U(z)$ — liquid velocity in the pump tower pipe centerline normal to the member, in m/s;

$a(z)$ — liquid acceleration in the pump tower pipe centerline normal to the member, in m/s^2;

D — diameter of transverse section of pump tower, in m;

C_m — inertia coefficient of Morison, normally taken as 2.0;

C_d — drag coefficient of Morison, taken as 1.2.

Morison force is exerted per unit length along the length of the structural member, and is also related with the liquid velocity and acceleration in the vertical direction. Hence the change of Morison force along the length and vertical direction of the member is to be taken into account in loading the FE model. The combined Morison force F_l acting on a structural member of the length of l is:

$$\vec{F}_l = \int_0^l \left[\frac{1}{2}\rho C_d \vec{U}(z)\left|\vec{U}(z)\right| D + \frac{\pi}{4}\rho C_m \vec{a}(z) D^2\right] dl \quad \text{N}$$

(2) Thermal loads

Thermal stresses induced by temperature changes are to be considered in the FE model. The calculation and

loading of the temperature field of pump tower are to be in accordance with the provisions of Appendix 3 of this Chapter.

(3) Inertial forces

Inertia accelerations due to ship motion and gravity are to be considered in the FE model. Inertia accelerations of pump tower in three directions can be obtained by calculation based on seakeeping analysis in this Section, or calculated according to 2.3.4(1), Appendix 1 of this Chapter.

5.6 Strength criteria

5.6.1 General requirements

(1) Stresses

In the Guidelines, the yield strength and buckling strength of the tubular elements and the punching shear strength in way of the joints are checked for various tubular structures. Primarily, the following four stresses on the tubular elements are considered:

(a) axial compressive stress σ_a;

(b) axial tensile stress σ_T;

(c) in-plane bending stress σ_I;

(d) out-of-plane bending stress σ_O.

(2) Basic parameters

Figure 5.6.1 shows the geometry of a typical tubular joint. The thick pipe is the chord while the thin one is the brace (including horizontal brace and sloping brace). Relevant parameters are given in Table 5.6.1.

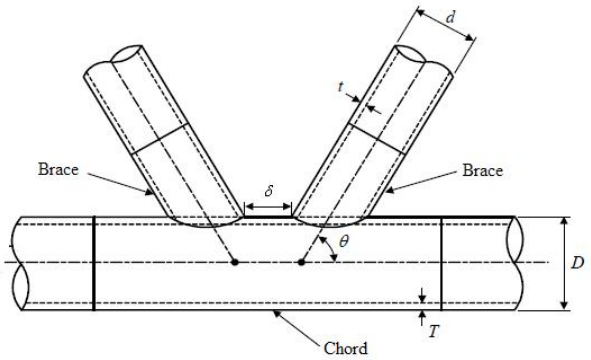


Figure 5.6.1 Typical tubular joint

Parameters **Table 5.6.1**

No.	Geometric parameter	Definition	Unit	Remark
1	l	Length without support	mm	
2	r	Radius of gyration	mm	
3	θ	Brace angle measured from chord	(°)	
4	t	Brace wall thickness	mm	
5	T	Chord wall thickness	mm	
6	δ	Clearance	mm	$\delta = 0$ for 1 brace; δ is taken as the clearance between the 2 braces furthest apart from each other for 3 or more braces when checking 2 braces furthest apart from each other
7	d	Brace diameter	mm	
8	D	Chord diameter	mm	
9	τ_a	Normal shear stress considered	N/mm^2	
10	τ_I	In-plane shear stress considered	N/mm^2	
11	τ_O	Out-of-plane shear stress considered	N/mm^2	
12	$[\sigma]_a$	Permissible axial compressive stress	N/mm^2	
13	$[\sigma]_T$	Permissible axial tensile stress	N/mm^2	
14	$[\sigma]_b$	Permissible bending stress	N/mm^2	
15	$[\tau]_a$	Permissible axial punching shear stress	N/mm^2	
16	$[\tau]_I$	Permissible in-plane punching shear stress	N/mm^2	
17	$[\tau]_o$	Permissible out-of-plane punching shear stress	N/mm^2	

No.	Geometric parameter	Definition	Unit	Remark
18	$[\sigma]_e$	Permissible Euler stress	N/mm^2	$[\sigma]_e = \dfrac{\pi^2 E}{\lambda_2^2}$
19	f_{ca}	Chord axial nominal stress	N/mm^2	σ_a or σ_T
20	f_{cI}	Chord in-plane bending stress	N/mm^2	σ_I
21	f_{cO}	Chord out-of-plane bending stress	N/mm^2	σ_O
22	f_{ba}	Brace axial nominal stress	N/mm^2	σ_a or σ_T
23	f_{bI}	Brace in-plane bending stress	N/mm^2	σ_I
24	f_{bO}	Brace out-of-plane bending stress	N/mm^2	σ_O
25	λ_1	Ratio of outer diameter to thickness of tubular elements		d/t or D/T
26	K	Effective length factor		1.0 for chord and 0.8 for brace
27	k_s	$k_s = R_{eH}/235$		
28	η	$\eta = t/T$		
29	μ	$\mu = d/D$		
30	γ	$\gamma = D/(2T)$		
31	λ_2	$\lambda_2 = Kl/r$		

Note: R_{eH} is the yield strength of the material, in N/mm^2.

5.6.2 Yield strength and buckling strength

(1) Permissible stress of tubular element

① The permissible axial compressive stress $[\sigma]_a$ is to be determined in accordance with the following formulae:

(a) For $\lambda_1 \le 60$:

$$[\sigma]_a = \begin{cases} \dfrac{k_s\left[1-0.5\left(\dfrac{\lambda_2}{C}\right)^2\right]\times 10^4}{70.922+15.957\dfrac{\lambda_2}{C}-5.319\left(\dfrac{\lambda_2}{C}\right)^3}, & \lambda_2 < C \\ \dfrac{5.147E}{\lambda_2^2}, & \lambda_2 \ge C \end{cases} \quad \text{N/mm}^2$$

where: $C = 0.29\sqrt{\dfrac{E}{k_s}}$

(b) For $\lambda_1 > 60$ and $\dfrac{k_s\lambda_1}{E}\left(642.34-90.08\lambda_1^{1/4}\right) \le 1$:

$$[\sigma]_a = \begin{cases} \dfrac{k_s\left(1-0.14024\lambda_1^{1/4}\right)\left[1-0.5\left(\dfrac{\lambda_2}{C}\right)^2\right]\times 10^4}{43.245+9.73\dfrac{\lambda_2}{C}-3.243\left(\dfrac{\lambda_2}{C}\right)^3}, & \lambda_2 < C \\ \dfrac{5.147E}{\lambda_2^2}, & \lambda_2 \ge C \end{cases}$$

where: $C = \sqrt{\dfrac{E}{k_s\left(19.53-2.739\lambda_1^{1/4}\right)}}$

(c) For $\lambda_1 > 60$ and $\dfrac{k_s\lambda_1}{E}\left(642.34-90.08\lambda_1^{1/4}\right) > 1$:

$$[\sigma]_a = \begin{cases} \dfrac{\dfrac{E}{\lambda_1}\left[1-0.5\left(\dfrac{\lambda_2}{C}\right)^2\right]\times 10}{27.78+6.25\dfrac{\lambda_2}{C}-2.083\left(\dfrac{\lambda_2}{C}\right)^3}, & \lambda_2 < C \\ \dfrac{5.147E}{\lambda_2^2}, & \lambda_2 \geq C \end{cases} \quad \text{N/mm}^2$$

where: $C = 3.236\sqrt{\lambda_1}$

② The permissible axial tensile stress is to be determined in accordance with the following formula:

$$[\sigma]_T = 141k_s \quad \text{N/mm}^2$$

③ The permissible axial bending stress is to be determined in accordance with the following formula:

$$[\sigma]_b = \begin{cases} 176.25k_s, & \lambda_1 \leq \dfrac{44}{k_s} \\ \left(197.4-\dfrac{408.9k_s\lambda_1}{E}\right)k_s, & \dfrac{44}{k_s} \leq \lambda_1 \leq \dfrac{88}{k_s} \\ \left(169.2-\dfrac{136.3k_s\lambda_1}{E}\right)k_s, & \dfrac{88}{k_s} \leq \lambda_1 \leq 300 \end{cases} \quad \text{N/mm}^2$$

(2) Strength criteria for tubular elements

① The strength criteria for axial compressive and bending is to comply with the following formulae:

(a) For $\dfrac{\sigma_a}{[\sigma]_a} > 0.15$:

$$\frac{\sigma_a}{[\sigma]_a} + \frac{([\sigma]_e - 0.4\sigma_a)}{([\sigma]_e - \sigma_a)} \cdot \frac{\sqrt{\sigma_I^2+\sigma_O^2}}{[\sigma]_b} \leq 1.0$$

$$\frac{\sigma_a}{0.6[\sigma]_a} + \frac{\sqrt{\sigma_I^2+\sigma_O^2}}{[\sigma]_b} \leq 1.0$$

(b) For $\dfrac{\sigma_a}{[\sigma]_a} \leq 0.15$:

$$\frac{\sigma_a}{[\sigma]_a} + \frac{\sqrt{\sigma_I^2+\sigma_O^2}}{[\sigma]_b} \leq 1.0$$

② The strength criteria for axial tensile and bending is to comply with the following formulae:

$$\frac{\sigma_T}{0.6[\sigma]_T} + \frac{\sqrt{\sigma_I^2+\sigma_O^2}}{[\sigma]_b} \leq 1.0$$

5.6.3 Punching shear strength

(1) Permissible punching shear stress of tubular joint

① Permissible axial punching shear stress:

$$[\tau]_a = 522C_Q \cdot \left(1.0 - \frac{\gamma\left(f_{ca}^2+f_{cI}^2+f_{cO}^2\right)}{1178133k_s^2}\right) \cdot \frac{k_s}{\gamma} \quad \text{N/mm}^2$$

② Permissible in-plane punching shear stress:

$$[\tau]_I = 522C_Q \cdot \left(1.0 - \frac{\gamma\left(f_{ca}^2+f_{cI}^2+f_{cO}^2\right)}{785422k_s^2}\right) \cdot \frac{k_s}{\gamma} \quad \text{N/mm}^2$$

③ Permissible out-of-plane punching shear stress:

$$[\tau]_O = 522C_Q \cdot \left(1.0 - \frac{\gamma\left(f_{ca}^2+f_{cI}^2+f_{cO}^2\right)}{1683047k_s^2}\right) \cdot \frac{k_s}{\gamma} \quad \text{N/mm}^2$$

The value of C_Q in the above formulae is taken in accordance with Table 5.6.3; however for the calculation of permissible axial punching shear stress, C_Q is to be taken not less than $(1.1+0.2/\mu)$. See Appendix 2A

of this Chapter for tubular joint types and categorization for pump tower.

Coefficient C_Q **Table 5.6.3**

<table>
<tr><td colspan="3">Tubular joint type</td><td colspan="2">K</td><td>T&Y</td></tr>
<tr><td colspan="3" rowspan="2">Axial tension/compression</td><td>$\gamma \le 20$</td><td>$\gamma > 20$</td><td rowspan="2">$(1.1+0.2/\mu)$</td></tr>
<tr><td>$(1.1+0.2/\mu)\cdot(1.8-0.1\delta/T)$</td><td>$(1.1+0.2/\mu)\cdot(1.8-4\delta/D)$</td></tr>
<tr><td rowspan="3">Bending</td><td colspan="2">In-plane</td><td colspan="3">$(3.72+0.67/\mu)$</td></tr>
<tr><td rowspan="2">Out-of-plane</td><td>$\mu > 0.6$</td><td colspan="3">$\frac{0.3}{\mu(1-0.833\mu)}\cdot\left(1.37+\frac{0.67}{\mu}\right)$</td></tr>
<tr><td>$\mu \le 0.6$</td><td colspan="3">$\left(1.37+\frac{0.67}{\mu}\right)$</td></tr>
</table>

(2) Punching stress considered of tubular joint

① Axial punching shear stress considered:

$$\tau_a = \eta f_{ba} \sin\theta \text{ , N/mm}^2$$

② In-plane punching shear stress considered:

$$\tau_I = \eta f_{bI} \sin\theta \text{ , N/mm}^2$$

③ Out-of-plane punching shear stress considered:

$$\tau_O = \eta f_{bO} \sin\theta \text{ , N/mm}^2$$

(3) Punching shear strength criteria

The punching shear strength of tubular joint is to comply with the following formulae:

$$\left(\frac{\tau_I}{[\tau]_I}\right)^2 + \left(\frac{\tau_O}{[\tau]_O}\right)^2 \le 1.0$$

$$\left|\frac{\tau_a}{[\tau]_a}\right| + \frac{2}{\pi}\arcsin\left(\sqrt{\left(\frac{\tau_I}{[\tau]_I}\right)^2 + \left(\frac{\tau_O}{[\tau]_O}\right)^2}\right) \le 1.0$$

6 DIRECT CALCULATION OF STRUCTURAL STRENGTH OF PUMP TOWER LIQUID DOME AND BASE FOUNDATION

6.1 General requirements

6.1.1 This Section applies to the assessment of direct calculation of structural strength of pump tower liquid dome and base foundation.

6.1.2 Structural analysis of pump tower liquid dome mainly aims at pump tower piping structure stretching into inner deck, including discharge pipe, filling pipe and emergency pipe. Pump tower base foundation analysis mainly aims at pump tower base foundation plate and supporting structure.

6.1.3 Global model method can be used to conduct modeling and analysis by taking the pump tower structure as well as pump tower liquid dome and base foundation as a global model, and independent modeling analysis can also be carried out to pump tower liquid dome and base foundation.

6.2 Structure modeling

6.2.1 For the coordinate system, element type and modeling principles of global model, see relevant requirements of Section 5 of this Appendix.

6.2.2 Pump tower base foundation model is at least to include structure model of pump tower base plate and pump tower supporting structures, as shown in Figure 6.2.2(1). Pump tower liquid dome structure model is to take pump tower center as origin, extending to girders or longitudinal bulkheads along ship breadth direction and extending to transverses or transverse bulkheads along ship length direction, as shown in Figure 6.2.2(2).

6.2.3 The mesh size of plate elements in the model is to be of reasonable distribution. For positions with complicated structure, the mesh size is not to be greater than 50 mm × 50 mm, and good transition is to be kept as a whole.

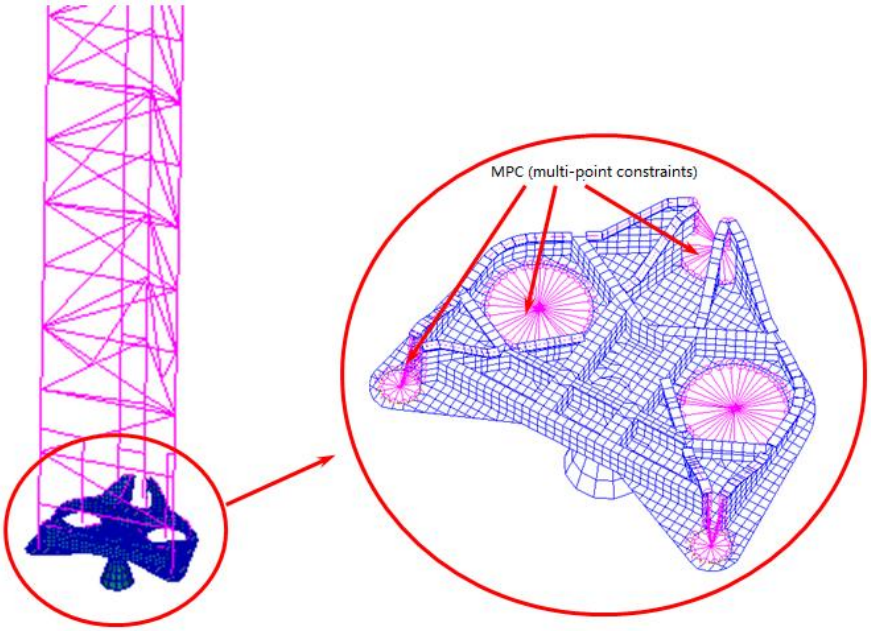


Figure 6.2.2(1) Pump tower base structure FE model

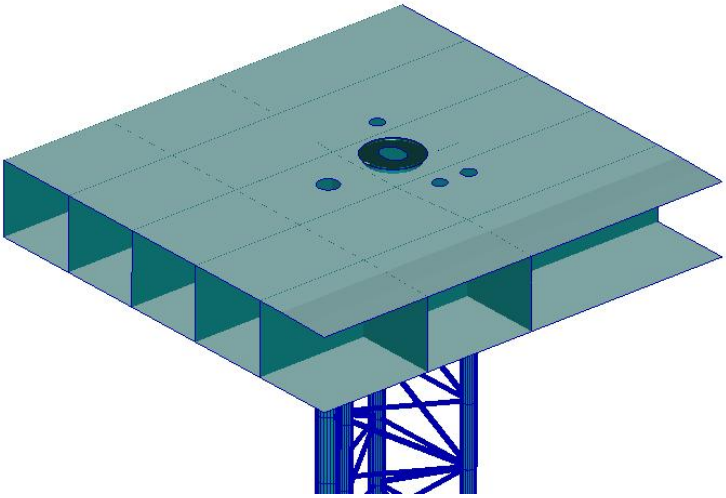


Figure 6.2.2(2) Pump tower liquid dome structure FE model

6.3 Boundary conditions

6.3.1 When the global model method is used, the connecting points of pump tower liquid dome model extending to corresponding web frame position are set as free support or fixed support. For the boundary conditions of connecting points of pump tower base and supporting structure as well as connecting points of base plate and circular pipe structure, see 5.5.2 of this Appendix.

6.3.2 When independent modeling analysis is carried out to pump tower liquid dome and base foundation, boundary conditions are to be set according to direct calculation result of the pump tower structure carried out according to Section 5 of this Appendix.

6.4 Loads

6.4.1 For loads applied to pump tower, see 5.5.3, Section 5 of this Appendix.

6.4.2 When the global model method is used, sloshing loads are to be applied to pump tower piping system, and temperature load and inertia acceleration are to be applied uniformly to the global model.

6.4.3 When independent modeling analysis is carried out to pump tower liquid dome, direct calculation of structural strength of pump tower is to be carried out according to the requirements of Section 5 of this Appendix, and node displacement, force and bending moment at the connection of top are to be extracted from calculation result as input data to be applied to corresponding nodes of liquid dome structure model.

6.4.4 When independent modeling analysis is carried out to base foundation, direct calculation of structural strength of pump tower is to be carried out according to the requirements of Section 5 of this

Appendix, and reaction force at bottom is to be extracted from calculation result as input data to be applied to corresponding position of model by converting area of contact plate at base foundation to equivalent and evenly distributed pressure.

6.5 Stress criteria

6.5.1 When yield strength of plate element and beam element of pump tower liquid dome and base foundation structure is evaluated, permissible stress is shown in Table 6.5.1.

Permissible stress **Table 6.5.1**

Structure	Element type	Equivalent stress (Von Mises stress)
Pump tower liquid dome and base foundation structure	Plate element and beam element	$0.85R_{eH}$

Note: 1 R_{eH} — yield stress of the material, in N/mm^2, and for stainless steel, 0.2% test stress is adopted. When applicable, effect of temperature on yield stress of the material is to be considered.

2 Plate element stress is to use membrane stress, i.e. mid-surface stress of plate element.

6.5.2 When the equivalent stress of elements within refined area exceeds permissible value, mean stress with area equivalent to standard mesh size and obtained from fine mesh analysis is not to exceed permissible value provided in Table 6.5.1.

7 STRUCTURAL VIBRATION EVALUATION OF PUMP TOWER

7.1 General requirements

7.1.1 This Section provides the methods and requirements for structural vibration evaluation of pump tower.

7.1.2 The type of pump tower structure is to comply with the requirements of 5.1.2, Section 5 of this Appendix.

7.2 Structure modeling

7.2.1 Pump tower structure model used for analyzing vibration characteristics is to comply with the requirements of 5.5.1, Section 5 of this Appendix.

7.2.2 Unit mass of liquid in piping system of pump tower is to be considered according to the following formula:

$m = \rho\pi\dfrac{D^2}{4}$ for the mass of liquid inside piping system:

$m = \rho C_m\pi\dfrac{D^2}{4}$ for the mass of attached liquid outside piping system:

where: ρ — fluid density, in kg/m^3;

D — diameter of piping system, in m;

C_m — coefficient, to be taken as 1.

7.3 Loading height

7.3.1 Both light ship condition and loading condition are to be considered in the pump tower structural vibration analysis.

7.3.2 For light ship condition, the loading height is equal to 0, and the inherent frequency is the upper limit value of pump tower structure.

7.3.3 The loading height under loading condition is to be in accordance with the requirements of 2.5, Section 2 of this Appendix, in which inherent frequency at 95% loading height is treated as the lower limit value of pump tower structure, and the inherent frequency at other loading heights is not to be lower than the above-mentioned limit value.

7.4 Excitation frequency

7.4.1 In addition to steam turbine propulsion type, vibration excitation frequency of main engine is to be considered.

7.4.2 Excitation frequency of propeller is to be based on revolution speed of propeller. The upper limit value is to be taken as the revolution speed of main engine at the maximum output power and the lower limit value is to be taken as 75% of revolution speed of main engine at the maximum output power.

7.5 Restrictions for avoiding resonance

7.5.1 There is to be ±20% of difference between inherent frequency of pump tower at each loading height and excitation frequency.

7.5.2 Where sufficient frequency reserve cannot be guaranteed, vibration response analysis is to be carried out to the pump tower structure in the cargo tank adjacent to the engine room of whole ship FE model. The peak value of pump tower vibration response is not to be greater than 15 mm/s.

Appendix 2A TUBULAR JOINT TYPES AND CATEGORIZATION

1 GENERAL PROVISIONS

1.1 This Appendix applies to the tubular joint types and categorization for pump tower.

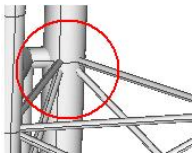
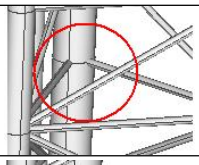
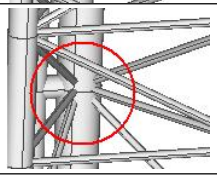
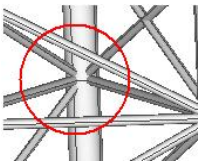
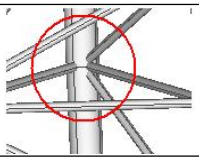
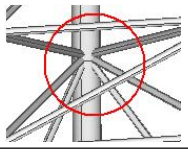
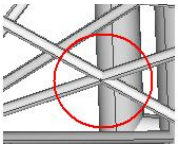
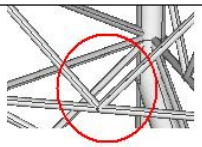
1.2 For those tubular joint types for pump tower not covered in this Appendix, the categorization and strength check are to be approved by CCS.

2 TUBULAR JOINT TYPES

2.1 Typical tubular joint types

The typical tubular joint types for pump tower are as shown in Table 2.1.

Typical tubular joint types for pump tower Table 2.1

No.	Typical joint	Description
1		(1) Emergency pipe and brace intersections; (2) Tubular joints classified as K, T & Y types; (3) Check of compressive bending strength, tensile bending strength and punching shear strength
2		
3		
4		(1) Discharge pipe and brace intersections; (2) Tubular joints classified as K, T & Y types; (3) Check of compressive bending strength, tensile bending strength and punching shear strength
5		
6		
7		(1) Brace intersections; (2) Check of compressive bending strength and tensile bending strength
8		

2.2 In calculation, the relationship between the chord and braces (e.g. the geometries and relative locations) is to be determined according to the joint structure at first. The joint is then to be classified in accordance with the magnitude and direction of loads applied on the joint ends.

3 TUBULAR JOINT CATEGORIZATION

3.1 Tubular joint categorization

A tubular joint is formed by each chord/brace intersection, classified as K, T and Y types. In a plane considered, one or more tubular joints are formed by the chord connected to one or more braces. The tubular joint needs to be classified according to the magnitude and type of axial loads applied to the braces, where K type represents the equilibrium of the axial loads of each brace and T or Y type represents the equilibrium the axial loads of brace and the shear on chord.

3.2 The specific standards for categorization are as follows:

(1) For tubular joint with only one brace on one side, it is treated as T or Y type as the axial load of brace is only balanced by the shear on chord.

(2) For tubular joint with only two braces on one side, it is treated as T or Y type where the axial load of either brace is zero (as shown in Figure 3.2(1)).

(3) For braces carrying axial loads in direct equilibrium, all tubular joints are treated as K type (as shown in Figures 3.2(2),(3),(4)).

(4) For braces carrying part of their loads in equilibrium, the proportion of each joint needs to be obtained by interpolation according to the magnitude of loads and the permissible stress is calculated by means of weighted average (as shown in Figures 3.2(5),(6)).

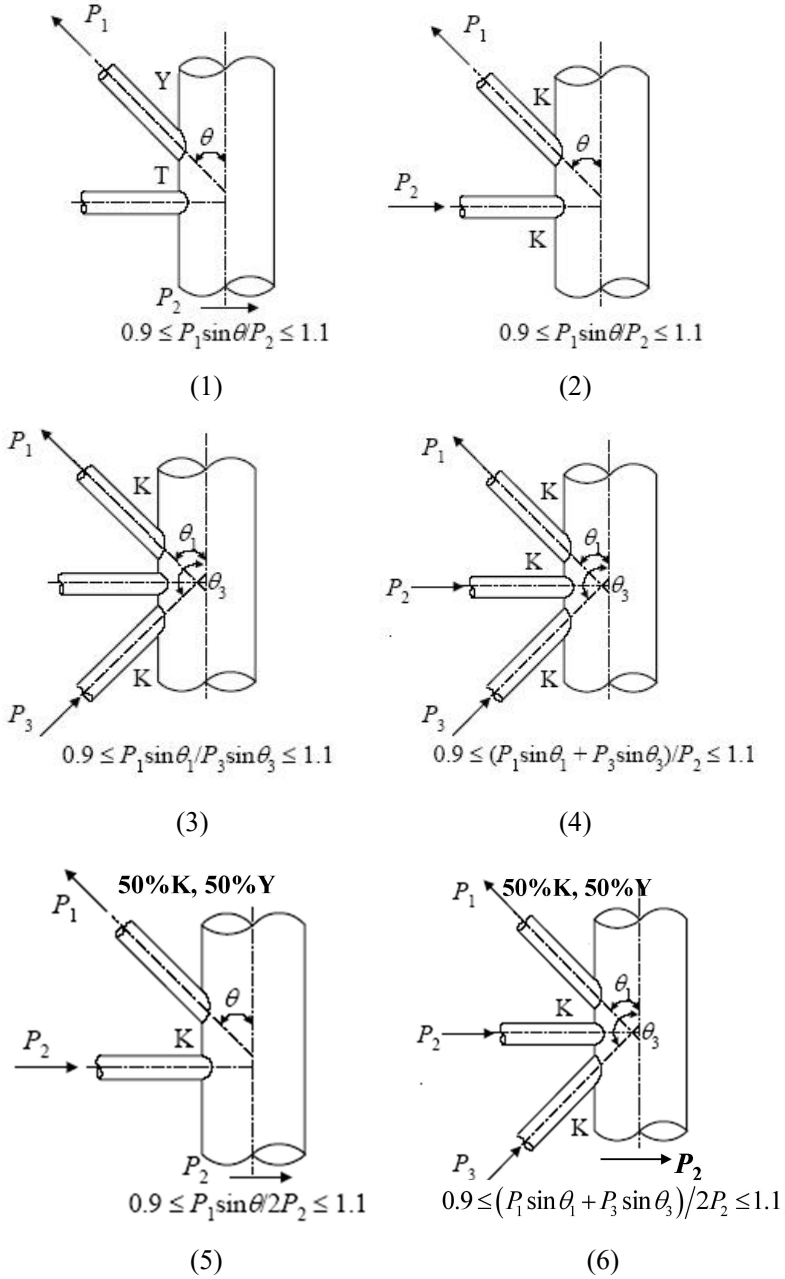


Figure 3.2 Definitions of typical tubular joint types in pump tower

APPENDIX 3 CALCULATION OF TEMPERATURE FIELD AND THERMAL STRESS

1 GENERAL PROVISIONS

1.1 General requirements

1.1.1 This Section specifies the provisions for the analysis of temperature field of three dimensional space and analysis method of thermal stress related to the cargo tank region and pump tower of membrane tank liquefied gas carriers. Where other calculation methods are used, they are to be agreed by CCS.

1.1.2 In the calculation of temperature field and thermal stress, recognized finite element thermal and structural analysis programs are to be used.

1.2 Definitions

1.2.1 The symbols of this Appendix are defined as follows (unless otherwise specified):

k_e — equivalent heat conduction coefficient, in W/(mK);

h — convective heat exchange coefficient, in W/(m^{2}K);

T — temperature, in ℃;

T_c — design temperature of liquid cargo, in ℃, to be taken as -163℃ for LNG;

α — linear expansion coefficient, in 1/K;

σ_e — equivalent calculation stress of structural element, in N/mm^2, as defined in Appendix 1 of this Chapter;

R_{eH} — yield strength of material in different temperature conditions, in N/mm^2, see Table 5.1.3, Appendix 2 of this Chapter. The intermediate value is to be obtained from linear interpolation.

2 STRUCTURAL MODEL

2.1 Model for temperature field analysis

2.1.1 The FE model for temperature field calculation is to cover the hull structure, primary and secondary insulations within the scope of the object to be analyzed (e.g. every cargo tank in the bow, amidships and stern area).

2.1.2 The analysis model is to cover the forward, aft cofferdams and cargo tanks. Where the structure and boundary condition are symmetrical from port to starboard, the 1/2 calculation model may be taken. Where the structure and boundary condition are symmetrical from port to starboard and from fore to aft, the 1/4 calculation model may be taken. A typical 1/4 FE analysis model for temperature field analysis is as shown in Figure 2.1.2.

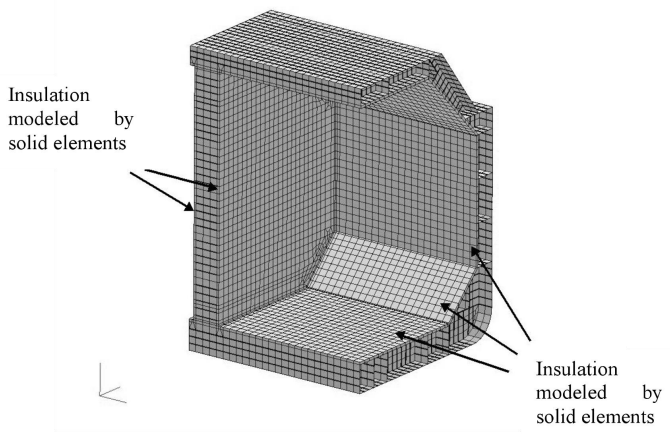


Figure 2.1.2 FE Model for temperature field calculation

2.1.3 The element types and meshing size of the FE model of hull structure are to comply with the requirements of 3.2, Appendix 1 of this Chapter.

2.1.4 The primary and secondary insulations of cargo tanks are to be modeled by solid elements, generally hexahedral elements.
2.1.5 Where the solid elements are used to model multiple layers of insulation formed by different materials, the equivalent heat conduction coefficient is to be used as the heat conduction coefficient of elements. For insulation formed by N layers of materials, its equivalent heat conduction coefficient is to be calculated in accordance with the following formula:

$$k_e = \frac{\sum_{i=1}^{N} \delta_i}{\sum_{i=1}^{N} \frac{\delta_i}{k_i}}$$

where: δ_i — thickness of the i^{th} layer of material, in m;

k_i — heat conduction coefficient of the i^{th} layer of material, in W/(mK).

2.2 Model for pump tower
2.2.1 Refer to 5.5.1, Appendix 2 of this Chapter for the requirements for the model of thermal stress calculation of pump tower and the value of material factor is taken according to 5.1.3, Appendix 2 of this Chapter.

3 CALCULATION OF TEMPERATURE FIELD OF HULL

3.1 General requirements
3.1.1 The calculation results of temperature field of this Section may be used as reference for determination of hull steel grades, analysis of structural thermal stress and calculation of daily boil off rate of cargo containment systems.
3.1.2 In this Section, the distribution of temperature field of structures is to be obtained through thermal analysis with the given ambient temperature and cargo temperature.
3.1.3 The calculation of this Appendix is based on:
(1) a steady state heat transferring in three-dimensional space, no change of material parameters and boundary conditions is made in conjunction with any temperature change in the analysis of linear heat conduction;
(2) only the effects of changes in the temperature field on the machinery field are considered without taking account of the effects of the latter on the former.
(3) the heat is transferred within the hull structure and between hull structural members by conduction, and that heat exchange between air, sea water and hull structural members is convection only.

3.2 Mode of heat transfer
3.2.1 For the calculation of hull temperature field, the following modes of heat transfer are assumed:
(1) convective heat transfer between plates of hull structure and air within tanks;
(2) convective heat transfer between plates of hull structure and external air, taking into account forced convective heat exchange for any wind speed;
(3) convective heat transfer between plates of hull structure and sea water;
(4) radiation heat transfer between plates of hull structure and external environment;
(5) radiation heat transfer between shell plating and inner hull plating (when the temperature field is used for calculation of nominal daily Boil Off Rate).

3.3 Calculation conditions
3.3.1 For different calculation purposes, the external conditions for calculation of hull temperature field are as follows:
(1) for the calculation of temperature distribution of hull structure and determination of steel grades where the primary insulation completely fails and the low-temperature cargo directly acts on the inner surface of secondary insulation;
(2) for the assessment of the efficiency of cargo containment systems of membrane tank liquefied gas carriers and calculation of nominal daily Boil Off Rate (detailed calculation methods are given in Appendix 3B of this Chapter) where equator condition is considered (see Table 3.3.2), primary and secondary insulations are complete and low-temperature cargo directly acts on the inner surface of primary insulation;
(3) other calculation purposes deemed necessary by CCS or the owner.

3.3.2 The external ambient temperature conditions are at least to include IGC condition, USCG condition and equator ambient condition, see Table 3.3.2.

External ambient conditions **Table 3.3.2**

	IGC	USCG	USCG (sea areas in Alaska)	Equator
Air temperature (℃)	5	-18	-29	45
Sea water temperature (℃)	0	0	-2	32
Wind speed (kn)	0	5	5	0
Liquid cargo (℃)	T_C			

3.4 Boundary conditions

3.4.1 The boundary condition of convective heat exchange is used between plates of hull structure and air, and between plates of hull structure and sea water. The convective heat exchange coefficient is to be selected as appropriate. Where specific values are unavailable, it may be determined by using recognized empirical formulae of thermodynamics.

3.4.2 In calculation of convective heat exchange coefficient between plates of hull structure and air, the effect of hull framing on the attached shell plating needs to be considered. In general the hull framing is considered as cooling rib.

3.4.3 For the inner surface of insulation in direct contact with cargo, the boundary condition of temperature or convective heat exchange may be defined.

3.4.4 The air temperature of enclosed tanks is to be taken as appropriate, or obtained by iterative direct calculations by referring to the recommended method in Appendix 3A of this Chapter.

3.4.5 For any heat source within the hull (e.g. the heating system provided in cofferdams), the heat source is to be applied to the hull as an appropriate boundary condition.

3.5 Selection of steel grades

3.5.1 The hull temperature field with the minimum draught in loaded condition is to be used as the loading condition for determination of steel grades of structures.

3.5.2 The scope of application of steel grades in different environmental conditions is given in Table 3.5.2.

Scope of application of steel grades **Table 3.5.2**

	IGC	USCG	USCG (Alaskan waters)	Equator
Scope of application of steel grades	Whole cargo tank area	Inner hull and connected members of cargo tank area	Inner hull and connected members of cargo tank area	Not applicable

3.5.3 The steel grades of hull materials are to be selected in accordance with Table 6.5 of Chapter 6 of PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gas in Bulk.

3.5.4 For environmental conditions of USCG and USCG (Alaskan waters), the steel grade of deck stringer plate and sheer strake is not to be lower than grade E, and the bilge strake is to be grade D or E.

4 CALCULATION OF TEMPERATURE FIELD AND THERMAL STRESS OF PUMP TOWER STRUCTURE

4.1 Calculation conditions

4.1.1 See relevant provisions of 2.5, Appendix 2 of this Chapter for determination of cargo filling height within tanks.

4.1.2 The calculation of thermal stress of pump tower may include thermal load case and load combination.

4.1.3 In thermal load case, only the effect of steady state thermal load on the pump tower structure in different loading conditions is considered.

4.1.4 The strength calculation of pump tower in load combination is to include the following loads for calculation:

(1) steady state thermal load in different loading conditions;

(2) sloshing load in corresponding loading condition, see provisions of 5.5.3(1), Appendix 2 of this Chapter;

(3) inertial force, see provisions of 5.5.3(3), Appendix 2 of this Chapter;
(4) weight of structural members.

4.2 Boundary conditions

4.2.1 See relevant provisions of 5.5.2, Appendix 2 of this Chapter for the constraint types of pump tower nodes.

4.2.2 During the analysis of temperature field of pump tower, the temperature difference between the tank top and bottom is to be considered, and as a result, the temperature distribution within the tank is generally assumed as follows: T_c is defined as below the free surface of cargo and T_{top} is the temperature of tank top. Where no specific value is available, it may be assumed that T_{top}= -30℃, and the temperature is linearly distributed from -163℃ at the free surface to -30℃ at the tank top. The distribution of temperature along the centerline of pump tower is as shown in Figure 4.2.2.

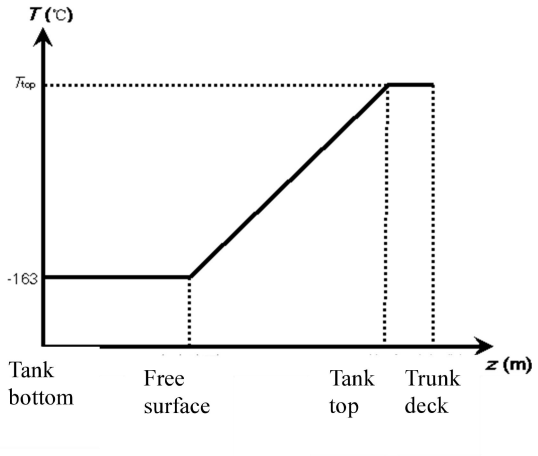


Figure 4.2.2 Assumed distribution of temperature along the centerline of pump tower

4.3 Criteria for thermal stress calculation

4.3.1 Where only the thermal load case is considered, the criteria for checking the thermal stress of pump tower structure is as follows:

$\eta \leq 0.1$

where: η — utilization factor, $\eta = \sigma_e / R_{eH}$.

4.3.2 For local area of thermal stress concentration, e.g. the connection of braces to piping and the top of pump tower, special consideration may be given to its strength criteria.

4.3.3 The criteria for the calculation of strength of pump tower in load combination is to be in accordance with 5.6, Appendix 2 of this Chapter.

Appendix 3A ITERATIVE CALCULATION METHOD IN RELATION TO THE TEMPERATURE OF AIR WITHIN TANKS OF HULL

1 General provisions

1.1.1 This Appendix provides an efficient calculation method recommended for the temperature of air within tanks of hull, which is based on the analysis of FE value.

2 Iterative calculation process

1.2.1 The air temperature within a tank is calculated in accordance with the following formula:

$$T_c = \frac{\sum h_i A_i T_{si}}{\sum h_i A_i}$$

where: T_c — air temperature of tank, in℃;

h_i — convection coefficient, in W/(m^{2}K);

A_i — area of the i^{th} plate in contact with air within the tank (during the calculation, the added surface area due to hull framing need not be considered);

T_{si} — temperature of the i^{th} plate in contact with air within the tank, in ℃, which can be taken as mean temperature of some nodes in the middle of plate.

1.2.2 The iterative calculation process of air temperature within tanks of hull is as shown in Figure 1.2.2.

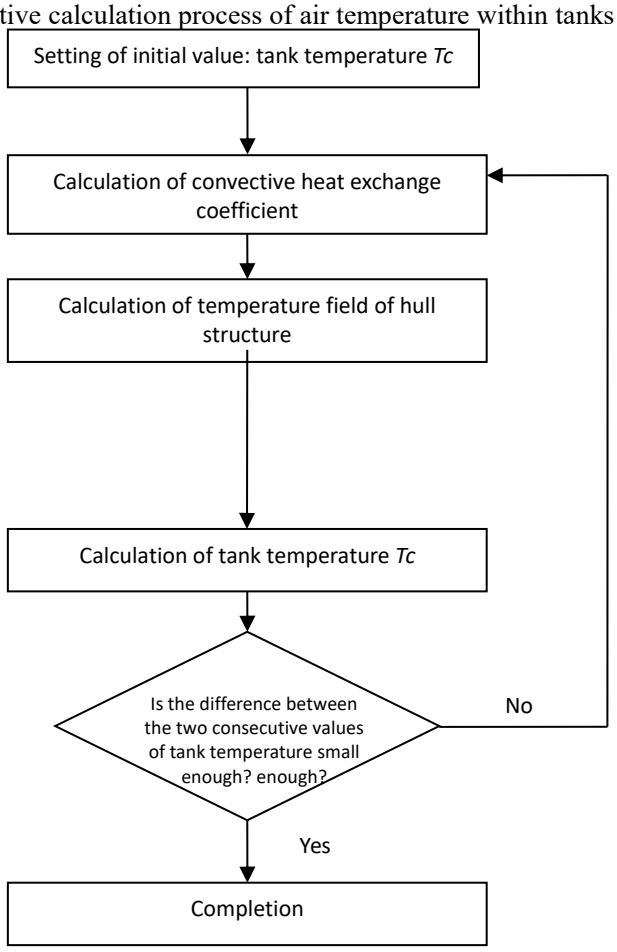


Figure 1.2.2 Calculation process of air temperature within tanks

Appendix 3B CALCULATION OF NOMINAL DAILY BOIL OFF RATE

1 General provisions

1.1.1 The nominal daily boil off rate (BOR) of LNG within cargo tanks is to be calculated and checked based on the calculation results of temperature field of hull.

2 Calculation conditions

2.1.1 During the calculation of nominal daily boil off rate, refer to the requirements of 3.2.1 of Appendix 3 for the mode of heat transfer for the calculation of hull temperature field, taking due consideration of various modes of heat transfer, e.g. those requirements in 3.2.1(4) and (5) of Appendix 3.

2.1.2 Refer to the requirements of 3.3.1(2) of Appendix 3 for calculation conditions.

3 Calculation methods

3.1.1 The nominal daily BOR is calculated in accordance with the following formula:

$$BOR = \frac{86400Q}{\gamma \rho V} \times 100\%$$

where: Q — total heat flow of heat exchange between LNG within the cargo tank of LNG carrier in steady state and the external environment, in W;

γ — boil off potential of LNG, in J/Kg; where specific value is not available, it may be taken as 5.1×10^5 J/Kg;

ρ — density of LNG, in Kg/m^3;

V— actual maximum loading capacity of cargo tank, in m^3.

3.1.2 The heat flow Q may be obtained by the following calculation method:

(1) For a surface of solid element in contact with LNG, read the heat flow density of its associated nodes to calculate the average value q_i, which is multiplied by the area A_i of the solid element, i.e. $Q_i = q_i A_i$, where Q_i is the heat flow on the element, as shown in Figure 3.1.2.

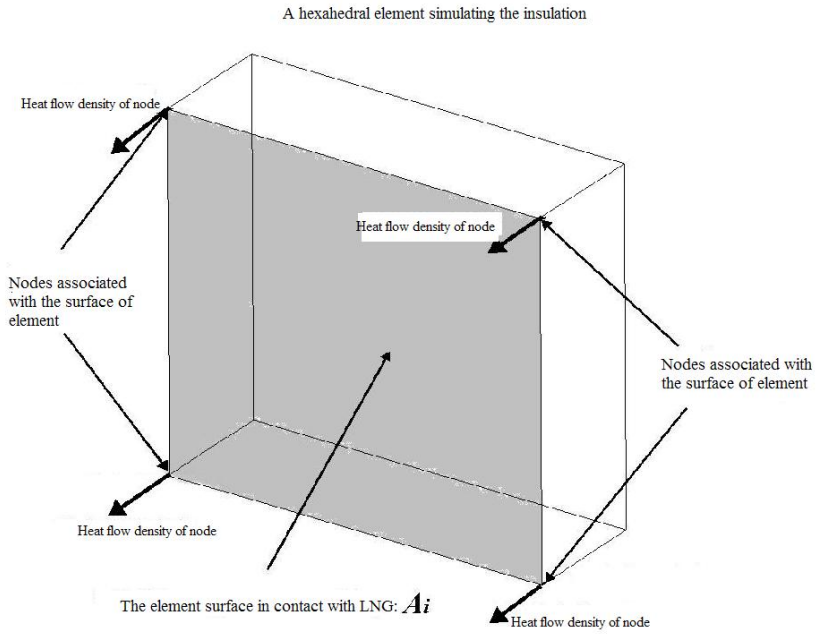


Figure 3.1.2 Calculation of heat flow

(2) Q_i of all the surfaces of solid element in contact with LNG are summed up so that $Q = \sum_i Q_i$.

4 Criteria for calculation results

4.1.1 In general, the reasonable range of nominal daily BOR in various thermal load cases is between 0.10% and 0.15%. For large membrane tank liquefied gas carrier, its BOR value is close to the lower limit

and for small membrane tank liquefied gas carrier, the value is close to the upper limit.

4.1.2 The limit value of maximum daily BOR is to be provided and guaranteed by the designer of cargo containment systems.

APPENDIX 4 DIRECT CALCULATION OF GLOBAL STRENGTH OF SHIPS

1 GENERAL PROVISIONS

1.1 General requirements

1.1.1 The global ship analysis in this Appendix is based on dynamic loading approach, wave load for global ship analysis is obtained by hydrodynamic direct calculation under design loading condition so as to truly reflect various extreme conditions that the ship encountered during navigation at sea. Structural analysis is based on whole ship FE model.

1.2 Flow chart of direct calculation of global strength of ships

1.2.1 The flow chart of direct calculation of global strength of ships is shown in Figure 1.2.1, mainly including the following process:

(1) actual loading condition is selected from the loading manual and static load is determined by the selected loading conditions;

(2) for each selected loading condition, relevant hydrodynamic analysis is carried out to obtain transfer function of each dominant load parameter (see 3.3.2);

(3) long-term prediction is carried out according to sea condition information to obtain ultimate value of dominant load parameter;

(4) equivalent design wave is determined according to the ultimate value of dominant load parameter;

(5) hydrodynamic analysis is carried out according to design wave to obtain wave load;

(6) static load is combined with dynamic load to obtain load value used for FE analysis;

(7) whole ship FE modelling is carried out and model mass property is adjusted so as to reflect full-scale ship mass distribution;

(8) modelling of refined model is carried out by means of insertion or sub-model;

(9) structural analysis and result examination are carried out, including global and local deformation, reaction force, etc.;

(10) yield strength evaluation is carried out;

(11) buckling strength evaluation is carried out;

(12) re-analysis is carried out according to design modification (if necessary).

Of the above, items (1) to (6) are for load calculation, see for details 3 and 4 of this Appendix; items (7) to (12) are for structural analysis, see for details 2 and 5 of this Appendix.

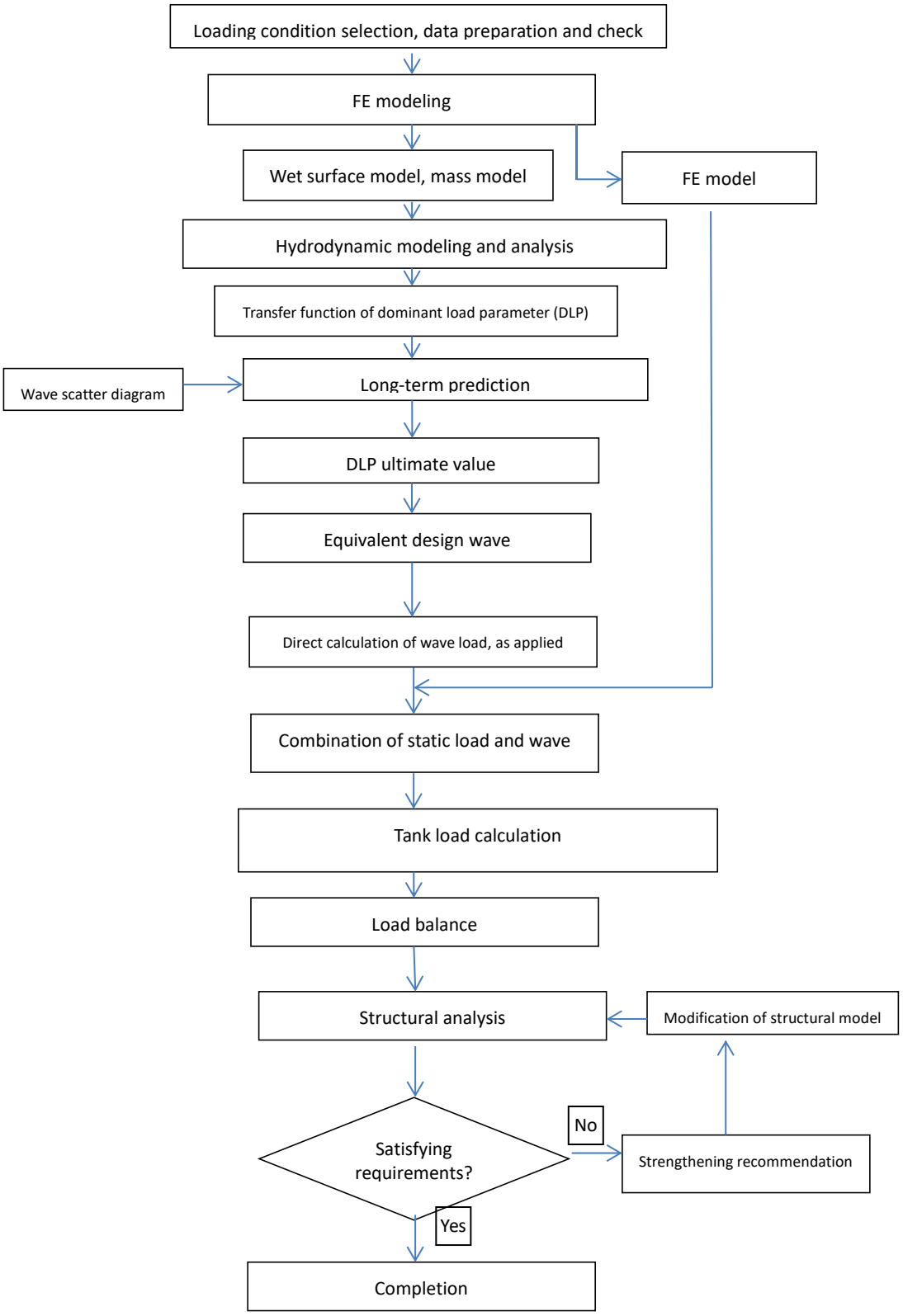


Figure 1.2.1 Flow chart of global ship analysis

2 FINITE ELEMENT MODEL

2.1 Whole ship model

2.1.1 Whole ship model is to include all main hull structure, trunk deck and deckhouse structure.

2.1.2 Inner side and outer shell plating, cofferdam transverse bulkheads, deck transverses and girders, side transverses and stringers, bottom floors and girders are to be simulated by plate elements, FE mesh is to be divided according to the spacing of longitudinals/stiffeners. Longitudinals, stiffeners and face plates of primary supporting members are to be simulated by beam elements, taking eccentric effect into consideration. Webs of primary members are to be divided into at least three elements in vertical direction.

2.1.3 The size of FE model is to be based on as-built scantlings of hull structures.

2.1.4 In order to apply inertial force accurately, FE model is to be able to reflect actual mass features of hull structures and equipment, including amount of mass, mass centroid and mass distribution. Equipment or liquids in small tanks may be simulated by mass concentration elements, but these mass elements are to be effectively connected with hull structures and the rigidity of hull structures is not to be changed.

2.2 Local fine mesh model

2.2.1 For critical areas of high stress, local fine mesh analysis is to be carried out. Sub-model or insertion method may be applied for local structural analysis.

2.2.2 Critical areas are to be selected according to the global strength analysis results so as to carry out local fine mesh analysis. Critical areas are to include the following locations (see Figures 2.2.2(1) and 2.2.2(2)):

(1) in way of upper and lower knuckle joints of hopper slope plating in way of transverse web frame, and in way of the connection of lower knuckle joints of inner hull slope plating to side stringers;

(2) at the intersection of double bottom girder and deck girder and transverse bulkhead;

(3) at the intersection of side stringer and transverse bulkhead;

(4) transitional bracket toes at fore and aft ends of trunk deck;

(5) openings on longitudinal bulkhead around the connection of deckhouse and trunk deck;

(6) transitional area at the end of inner hull longitudinal bulkhead in No.1 tank;

(7) trunk deck gas dome openings and longitudinal coaming toes (if any).

For the above-mentioned areas, if stress of coarse mesh exceeds 85% allowable stress, refining analysis is to be carried out. For other areas, if stress of coarse mesh exceeds 95% allowable stress, refining analysis is to be carried out.

2.2.3 The size of fine mesh is not to be more than 50 mm × 50 mm, and for detailed requirements of refined mesh, see 4.4, Appendix 1 of this Chapter.

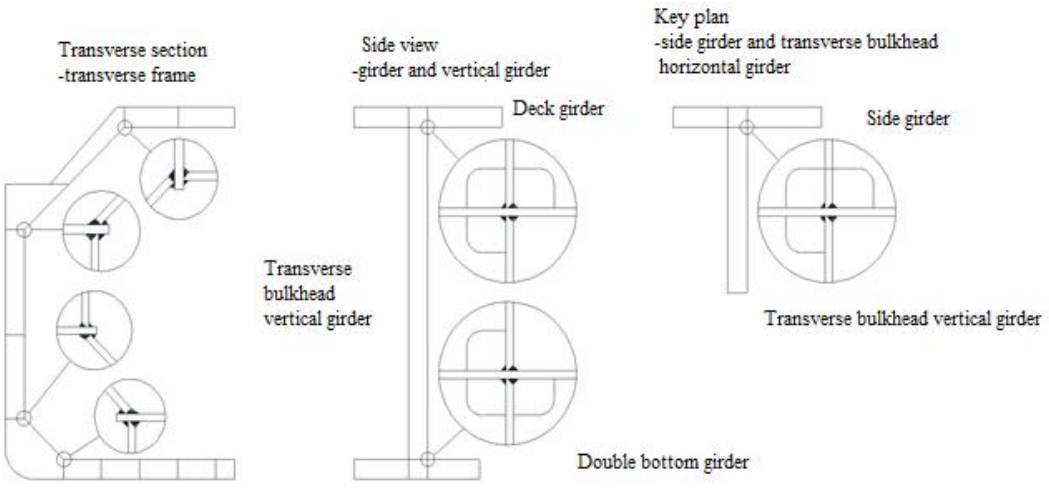


Figure 2.2.2(1) Refined area of cargo tank structure

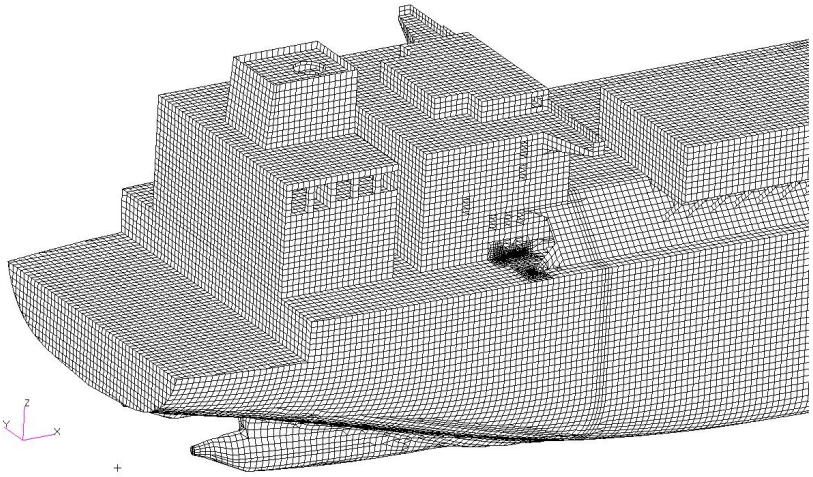


Figure 2.2.2(2) Aft end of trunk deck and deckhouse opening

3 CALCULATION CONDITION

3.1 Calculation conditions

3.1.1 Calculation conditions are composed of loading condition and wave condition.

3.2 Loading condition

3.2.1 Loading condition is to be selected from the loading manual, which is generally to include:
(1) full load (maximum design liquid cargo density); (F)
(2) normal ballast; (B)
(3) one tank void (if any); (V1,V2…)
(4) two adjacent tanks void (if any). (V12,V23…)
(5) sing tank load (if any) (V234, V124…)
At the same time, other worse loading conditions in the loading manual are also to be taken into account.
where: V1 means that the first tank is void and so on for other symbols.

3.3 Wave condition

3.3.1 Ships will be affected by various wave loads (sea water dynamic pressure, inertia force, tank pressure, etc.) during navigation at sea, such loads constitute a dynamic spatial force system. Load parameters are used to describe certain characteristics of these loads as an integrity, e.g. bending moment at amidship, shearing force in way of 1/4*L*, acceleration at bow, heeling angle, etc.
3.3.2 When a certain load parameter reaches the ultimate value, the ship will be affected by ultimate wave load, and this may be the dangerous condition. Specific load parameter is to be selected according to various ship types to determine wave condition considered. The load parameter reaching ultimate value is to be treated as dominant load parameter.
3.3.3 Wave load is induced by equivalent design wave which is determined according to dominant load parameter. Therefore, dominant load parameter reaches ultimate value due to equivalent design wave, and meanwhile, all other wave loads acting on hull may also be determined.
3.3.4 In global ship analysis for membrane tank liquefied gas carrier, the following wave dominant load parameters are to be taken into account respectively for wave conditions:
(1) vertical wave bending moment (hogging and sagging); (BM)
(2) vertical wave shearing force (+/-), considering two positions in way of 0.25*L* and 0.75*L* along the ship's length; (SFA, SFF)
(3) vertical acceleration at bow (upward/downward), the considered point is taken as the top of intersection between forward bulkhead of No.1 cargo tank and the longitudinal central line; (VA)
(4) transverse acceleration at bow (port/starboard), and the point considered is taken as the same

as (3). (TA)

3.4 Condition combination

3.4.1 Calculation conditions are composed of loading condition and wave condition, which are determined according to 3.2 and 3.3 of this Appendix respectively, and the calculation condition combination is shown in Table 3.4.1.

Calculation condition **Table 3.4.1**

Dominant load parameter / Loading condition	Bending moment at amidship	Shearing force in way of 1/4*L*	Shearing force in way of 3/4*L*	Vertical acceleration at bow	Transverse acceleration at bow
Full load	F_BM	F_SFA	F_SFF	F_VA	F_TA
Ballast	B_BM	B_SFA	B_SFF	B_VA	B_TA
One tank void	V1_BM V2_BM …	V1_SFA V2_SFA …	V1_SFF V2_SFF …	V1_VA V2_VA …	V1_TA V2_TA …
Two adjacent tanks void	V12_BM V23_BM …	V12_SFA V23_SFA …	V12_SFF V23_SFF …	V12_VA V23_VA …	V12_TA V23_TA …
Single tank load	V234_BM V134_BM …	V234_SFA V134_SFA …	V234_SFF V134_SFF …	V234_VA V134_VA …	V234_TA V134_TA …

Note: Definitions of symbols in various conditions are shown in 3.2.1 and 3.3.4.

4 CALCULATION LOAD AND BOUNDARY CONDITIONS

4.1 Load component

4.1.1 Load is to be divided into static load and dynamic load.

4.1.2 Static load is determined by the selected loading conditions, including gravity of hull and stores, external hydrostatic pressure and tank static pressure.

4.1.3 Dynamic load is obtained by direct calculation according to equivalent design wave, including inertia force of hull and stores, sea water dynamic pressure and tank dynamic pressure.

4.2 Hydrodynamic analysis and transfer function

4.2.1 Three-dimensional potential flow procedure is to be used for hydrodynamic analysis so as to calculate hull response on wave. In calculation, the viscous damping of rolling motion is to be taken into account, of which the value may be obtained by test or semi-empirical formula. In the case of absence of relevant information, 5%~10% critical damping may be taken.

4.2.2 Each mass model for hydrodynamic analysis is to reflect full-scale mass characteristics under the corresponding loading conditions, and hydrodynamic mesh is to reflect actual hull configuration and floating condition (draught, trim and heel).

4.2.3 In order to apply gravity and inertia force on the FE model accurately, mass property of FE model is to be adjusted so as to reflect mass distribution of full-scale ship. The full-scale FE model as adjusted is to be used as mass model in hydrodynamic analysis. At the initial stage of design, a simplified model which can simulate mass property of full-scale ship accurately may also be used.

4.2.4 In hydrodynamic analysis, transfer function of dominant load parameter mentioned in 3.3.4 is to be calculated so as to carry out long-term prediction analysis to determine the ultimate value of dominant load parameter. Where hydrodynamic analysis is carried out, transfer function at wave heading angle and frequency which the hull may be affected is to be calculated. The input wave parameters are:

(1) wave frequency: 0.2~1.5 rad/s for extent, 0.05 rad/s for step length;

(2) wave heading angle: 0º ~180º for extent, 15º for step length.

4.2.5 If hydrodynamic analysis is carried out by time domain method, time history is to be converted to transfer function by proper means, i.e. time history after reaching stable condition is to be selected for conversion.

4.2.6 The maximum value of frequency-wave heading angle combination is to be selected from transfer function of each dominant load parameter to determine the design wave. In general, the

maximum transfer function of vertical bending moment and vertical shearing force occurs under the heading wave condition, and the maximum heeling angle, maximum vertical acceleration and maximum transverse acceleration will occur under beam sea or oblique sea condition.

4.3 Sea condition information and load prediction

4.3.1 In the unrestricted service, scatter diagram and wave spectrum given by IACS REC.34 are to be used for sea condition information.

4.3.2 The ultimate value of dominant load parameter is to be obtained by long-term prediction according to transfer function. When a long-term prediction of dominant load parameter is carried out, exceedance probability of 10^{-8} is generally to be taken.

4.3.3 When a long-term prediction is carried out, short-crested wave is to be used, and square of cosine is to be taken for energy spreading function.

4.3.4 Considering operational experience at ultimate sea conditions, when the prediction of horizontal and vertical accelerations and heeling angle is carried out, exceedance probability of $10^{-6.5}$ may be taken.

4.4 Equivalent design wave

4.4.1 Each wave condition has its corresponding equivalent design wave. The equivalent design wave determined in 4.2.6 makes dominant load parameter reach its ultimate value and meanwhile determines other wave loads under such condition. Equivalent design wave may be defined by wave heading angle, wave length, phase and wave amplitude.

4.4.2 The combination which makes transfer function of dominant load parameter reach the maximum value is to be taken for wave heading angle and wave length of equivalent design wave, and the phase which makes transfer function reach the ultimate value is to be taken for the phase of equivalent design wave.

4.4.3 Under full load condition, the design wave amplitude of vertical wave hogging bending moment determined by direct calculation may be adjusted based on the wave hogging bending moment in 2.2.3.1, Chapter 2 of this PART so as to make its bending moment value equivalent. The design wave amplitude obtained by this method may be treated as the hogging design wave amplitude under other loading conditions and the sagging design wave amplitude under various loading conditions.

4.4.4 Except for those mentioned in 4.4.3, the design wave amplitude is to be obtained by dividing ultimate value of dominant load parameter by maximum value of transfer function.

4.4.5 Each wave load (sea water dynamic pressure, inertia force, etc.) used for structural analysis is to be determined according to design wave. Either non-linear method or combination of linear hydrodynamic procedure and wave surface correction may be used for direct calculation of wave load.

4.4.6 For wave dynamic load and inertia force, the corresponding load value obtained by above-mentioned methods are to be directly applied on FE model. Wave dynamic pressure is to be applied on shell in the form of positive normal pressure, and inertial force is to be applied on FE model by means of acceleration field and mass distribution.

4.5 Internal pressure of tank

4.5.1 In calculation of internal pressure of tank, the effects of steam pressure, gravity, motion and acceleration are to be taken into account. Where linear hydrodynamic analysis is used, the horizontal component of gravity due to ship's attitude (roll angle, pitch angle) is not taken into account for acceleration. Therefore the effects of acceleration component are to be included in the tank pressure calculation.

4.5.2 In calculation of tank pressure, an acceleration vector is first to be calculated according to acceleration and ship's attitude (roll angle, pitch angle), to obtain positions of reference points for tank pressure calculation. Then, the pressure on any point may be obtained according to the vector and reference point. Schematic plan is shown in Figure 4.5.2. In actual calculation, the combination of vectors in three directions is to be considered.

4.5.3 Acceleration is to be obtained in way of the center of tank considered according to the result of hydrodynamic calculation. For the bulkhead with tanks at both sides, loading is carried out according to the tank conditions respectively.

4.5.4 Considering static load and wave load, the combined tank pressure is to be calculated by

the following formula:

$$p = p_0 + \rho h\left[\left(g + a_v\right)^2 + \left(g_T + a_T\right)^2 + \left(g_L + a_L\right)^2\right]^{1/2} \times 10^{-3} \quad \text{MPa}$$

where: p_0 —steam pressure, in MPa;

ρ —liquid density, in t/m^3;

h —distance from pressure calculation point to reference point for tank pressure calculation, in m;

a_v — vertical acceleration at the center of tank considered, in m/s^2;

a_T — transverse acceleration at the center of tank considered, in m/s^2;

a_L — longitudinal acceleration at the center of tank considered, in m/s^2;

g_T — transverse component of gravity acceleration due to ship roll in ship coordinate system, in m/s^2;

g_L — longitudinal component of acceleration of gravity due to ship pitch in ship coordinate system, in m/s^2.

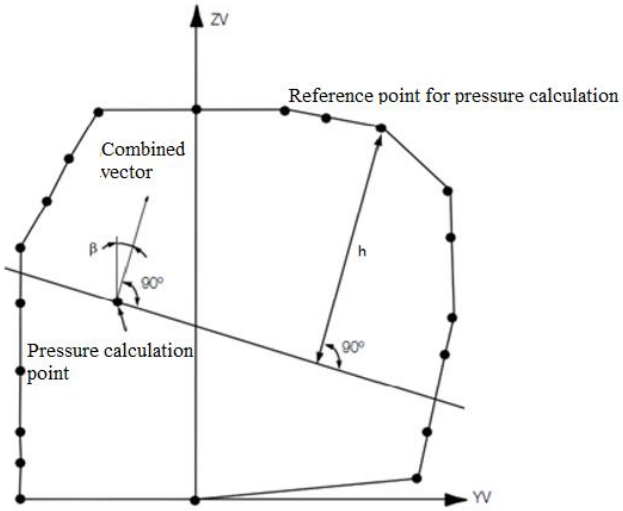


Figure 4.5.2 Tank pressure calculation method

4.6 Load equilibrium adjustment

4.6.1 By the action of above-mentioned loads, the whole ship FE model is to be in a dynamic balance state of total force system.

4.6.2 Prior to structural calculation, unbalanced force and moment on each direction of model are to be calculated, and equilibrium adjustment is to be carried out by proper means, e.g. the above-mentioned unbalanced force and moment may be removed by means of adjustment of floating condition.

4.7 Boundary conditions

4.7.1 As the model is in an equilibrium state, only the boundary conditions restraining rigid body motion of six degrees of freedom need to be set for structural analysis, as shown in Figure 4.7.1:

(1) Node 1 at the aft end: restraining the displacement in transverse direction;

(2) Node 2 at the fore end: restraining the displacement in three directions;

(3) Nodes 3 and 4 at port and starboard sides of stern transom plate: restraining the displacement in vertical direction.

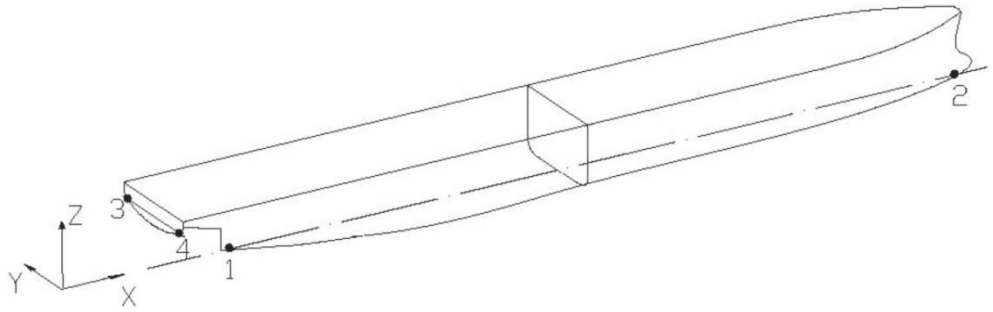


Figure 4.7.1 Diagram of boundary conditions

5 STRENGTH EVALUATION

5.1 Evaluation areas

5.1.1 Evaluation areas are to cover the whole cargo tank area and the transition structures of main longitudinal members in the engine room area and bow area. The following structural members in the evaluation areas are to be verified in accordance with the criteria in 5.2 and 5.3:
(1) main structural members (longitudinal, transverse) in the cargo tank area;
(2) forward transverse bulkheads of the engine room area and main supporting members, as well as the transition structures of trunk deck and inner deck in the engine room area;
(3) collision bulkheads and main supporting members, as well as the transition structures of trunk deck and inner deck in the bow area.

5.2 Yield strength

5.2.1 Yield strength criteria are as follows:

$$\sigma \le [\sigma]$$

where: σ —work stress, i.e. Von Mises equivalent stress of plate element center corresponding to longitudinal spacing mesh area, or axial stress of beam element, in N/mm^2;
$[\sigma]$—allowable stress, in N/mm^2, to be calculated by the following formula:

$$[\sigma] = \lambda_y \times \frac{223}{K} \quad \text{for coarse mesh;} \quad [\sigma] = \lambda_y \times \frac{357}{K} \quad \text{for refined area}$$

where: K—material factor;
λ_y —see Table 5.1.1.

Table 5.1.1

Structural members	λ_y
Bottom plating, inner bottom plating, transverse bulkhead plating	0.8
Deck plating, side shell and inner hull plating, hopper slope plating, bilge plating, watertight bracket and girder	0.9
Plating of all non-watertight members, face plate of primary members	1
Other structural members except for those mentioned above	1

5.3 Buckling strength

5.3.1 The buckling strength is to be checked with reference to the provisions for buckling strength check of hull structure in Appendix 1 of this Chapter.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2025

PART THREE MACHINERY INSTALLATIONS

CONTENTS

CHAPTER 1 GENERAL 3-1
Section 1 REQUIREMENTS FOR CLASSIFICATION 3-1
Section 2 GENERAL PROVISIONS 3-1
Section 3 ARRANGEMENT 3-5
CHAPTER 2 PUMPING AND PIPING SYSTEMS 3-7
Section 1 GENERAL PROVISIONS 3-7
Section 2 CARBON, LOW ALLOY STEELS AND stainless steelS 3-9
Section 3 COPPER AND COPPER ALLOYS 3-12
Section 4 OTHER MATERIALS 3-14
Section 5 CONNECTION OF PIPE LENGTHS, HEAT TREATMENT AND NON-DESTRUCTIVE TESTING 3-15
Section 6 PUMPS, VALVES AND FITTINGS 3-21
Section 7 TESTS 3-22
Section 8 ARRANGEMENT 3-23
Appendix 1 PRODUCTION AND APPLICATION OF PLASTIC PIPING SYSTEMS ON SHIPS 27
Appendix 2 FLEXIBLE HOSES 3-35
Appendix 3 TYPE APPROVAL OF MECHANICAL JOINTS 3-37
Appendix 4 AIR PIPE CLOSING DEVICES 3-43
CHAPTER 3 SHIP'S PIPING AND VENTILATING SYSTEMS 3-47
Section 1 GENERAL PROVISIONS 3-47
Section 2 DRAINAGE OF COMPARTMENTS, OTHER THAN MACHINERY SPACES 3-47
Section 3 BILGE DRAINAGE OF MACHINERY SPACES 3-49
Section 4 BILGE PUMPS AND BILGE PIPING 3-50
Section 5 ADDITIONAL REQUIREMENTS FOR BILGE DRAINAGE FOR PASSENGER SHIPS 3-53
Section 6 ADDITIONAL REQUIREMENTS FOR BILGE DRAINAGE 3-53
Section 7 DRAINAGE ARRANGEMENTS AND BALLAST PIPING FOR NON-SELF-PROPELLED SHIPS 3-54
Section 8 BALLAST AND SCUPPER SYSTEMS 3-55
Section 9 REMOTELY CONTROLLED BILGE AND BALLAST SYSTEMS 3-56
Section 10 AIR, OVERFLOW AND SOUNDING PIPES 3-56
Section 11 VENTILATION 3-59
Section 12 ADDITIONAL REQUIREMENTS TO WATER LEVEL DETECTION AND DEWATERING OF FORWARD SPACES OF BULK CARRIERS 3-60
CHAPTER 4 MACHINERY PIPING SYSTEMS 3-62
Section 1 GENERAL PROVISIONS 3-62
Section 2 OIL FUEL SYSTEMS 3-62
Section 3 STEAM PIPING SYSTEMS 3-67
Section 4 FEED, BLOW-OFF AND CONDENSATE SYSTEMS 3-68
Section 5 COOLING WATER SYSTEMS 3-69
Section 6 LUBRICATING OIL SYSTEMS 3-69
Section 7 HYDRAULIC TRANSMISSION PIPING SYSTEMS 3-71
Section 8 THERMAL OIL SYSTEM 3-71
Section 9 REQUIREMENTS CONCERNING USE OF CRUDE OIL OR SLOPS AS FUEL FOR TANKER BOILERS 3-73
Section 10 EXHAUST PIPELINES 3-75
CHAPTER 5 PIPING SYSTEM FOR OIL TANKERS 3-76
Section 1 GENERAL PROVISIONS 3-76
Section 2 CARGO HANDLING SYSTEM 3-77
Section 3 BILGE, BALLAST AND OTHER PIPING SYSTEMS 3-79
Section 4 CARGO OIL HEATING 3-80
Section 5 CARGO TANK LEVEL SOUNDING 3-81
Section 6 CARGO TANK VENTING ARRANGEMENTS 3-81
Section 7 REQUIREMENTS FOR DOUBLE HULL SPACES OF OIL TANKERS 3-83
Section 8 REQUIREMENTS FOR OIL TANKERS INTENDED FOR CARRIAGE OF CARGO OIL HAVING A FLASH POINT EXCEEDING 60℃ 3-83

CHAPTER 6 BOILERS AND PRESSURE VESSELS 3-84
Section 1 GENERAL PROVISIONS 3-84
Section 2 DESIGN AND MANUFACTURE 3-85
Section 3 BOILER MOUNTINGS AND FITTINGS 3-89
Section 4 FITTINGS OF PRESSURE VESSELS 3-93
Section 5 THERMAL OIL HEATERS 3-94
Section 6 INSTALLATION AND TEST 3-95
Appendix 1 STRENGTH CALCULATION OF WATER TUBE BOILERS 3-97
Appendix 2 STRENGTH CALCULATION OF HORIZONTAL SMOKE TUBE BOILERS 3-107
Appendix 3 STRENGTH CALCULATION OF VERTICAL AUXILIARY BOILERS 3-115
Appendix 4 STRENGTH CALCULATION OF PRESSURE VESSELS 3-119
Appendix 5 OPENINGS AND COMPENSATION 3-120
Appendix 6 STRENGTH CALCULATION OF STANDPIPES, DOORS FOR MANHOLES AND SIGHT HOLES 3-124
CHAPTER 7 STEAM TURBINES 3-125
Section 1 GENERAL PROVISIONS 3-125
Section 2 MATERIALS 3-125
Section 3 DESIGN 3-126
Section 4 FITTINGS 3-126
Section 5 TESTS AND TRIALS 3-128
CHAPTER 8 GAS TURBINES 3-130
Section 1 GENERAL PROVISIONS 3-130
Section 2 MATERIALS 3-131
Section 3 DESIGN AND CONSTRUCTION 3-131
Section 4 FITTINGS 3-133
Section 5 TESTS AND TRIALS 3-134
CHAPTER 9 DIESEL ENGINES 3-136
Section 1 GENERAL PROVISIONS 3-136
Section 2 INSPECTION, TEST AND CERTIFICATION OF DIESEL ENGINE PARTS 3-140
Section 3 DESIGN AND CONSTRUCTION 3-143
Section 4 PIPING SYSTEMS 3-143
Section 5 STARTING ARRANGEMENTS 3-144
Section 6 SCAVENGING AND SUPERCHARGING ARRANGEMENTS 3-146
Section 7 FITTINGS 3-149
Section 8 INSTALLATION 3-153
Section 9 ALARMS AND SAFEGUARDS FOR EMERGENCY DIESEL ENGINES 3-153
Section 10 SURVEY AND CERTIFICATION 3-154
Appendix 1 SAFETY OF NATURAL GAS FUEL ENGINES 3-156
Appendix 2 GUIDELINES FOR ELECTRONICALLY CONTROLLED DIESEL ENGINES 3-166
Appendix 3 APPRAISAL OF CRANKSHAFT STRENGTH OF DIESEL ENGINES 3-170
Appendix 4 TYPE TEST OF DIESEL ENGINES 3-226
Appendix 5 APPROVAL AND CERTIFICATION OF DIESEL ENGINES 3-230
Appendix 6 WORKS ACCEPTANCE TEST AND SHIPBOARD TRIALS OF DIESEL ENGINES 3-246
Appendix 7 TYPE TESTING PROCEDURE FOR CRANKCASE EXPLOSION RELIEF VALVES 3-250
Appendix 8 TYPE TESTING PROCEDURE FOR CRANKCASE OIL MIST DETECTION AND ALARM EQUIPMENT 3-254
Appendix 9 TYPE TESTING PROCEDURE OF EXPLOSION RELIEF DEVICES FOR COMBUSTION AIR INLET AND EXHAUST GAS MANIFOLDS OF I.C. ENGINES USING GAS AS FUEL 3-258
Appendix 10 SAFETY OF METHANOL/ETHANOL FUEL ENGINES 3-262
Appendix 11 SAFETY OF AMMONIA FUEL ENGINES 3-269
CHAPTER 10 TRANSMISSION GEARING 3-277
Section 1 GENERAL PROVISIONS 3-277
Section 2 MATERIALS 3-277
Section 3 DESIGN AND CONSTRUCTION 3-278
Section 4 TESTS 3-280
Appendix 1 APPRAISAL OF GEAR STRENGTH 3-281

CHAPTER 11 SHAFTING AND PROPELLERS 3-311
Section 1 GENERAL PROVISIONS 3-311
Section 2 SHAFTING 3-312
Section 3 SHAFT TRANSMISSION UNITS 3-315
Section 4 PROPELLERS 3-320
CHAPTER 12 SHAFT VIBRATION AND ALIGNMENT 3-326
Section 1 GENERAL PROVISIONS 3-326
Section 2 TORSIONAL VIBRATION 3-327
Section 3 AXIAL VIBRATION 3-330
Section 4 WHIRLING VIBRATION 3-331
Section 5 SHAFTING ALIGNMENT 3-331
Appendix 1 ENHANCED SHAFT ALIGNMENT 3-335
CHAPTER 13 STEERING GEAR AND WINDLASSES 3-337
Section 1 STEERING GEAR 3-337
Section 2 WINDLASSES 3-344
Appendix 1 GUIDELINES FOR THE ACCEPTANCE OF NON-DUPLICATED RUDDER ACTUATORS FOR TANKERS, CHEMICAL TANKERS AND GAS CARRIERS OF 10,000 GROSS TONNAGE AND UPWARDS BUT OF LESS THAN 100,000 TONS DEADWEIGHT 3-349
CHAPTER 14 STRENGTHENING FOR NAVIGATION IN ICE 3-351
Section 1 GENERAL PROVISIONS 3-351
Section 2 PROPULSION MACHINERY 3-353
Section 3 STARTING ARRANGEMENTS AND COOLING WATER SYSTEM 3-373
CHAPTER 15 VAPOUR CONTROL SYSTEM 3-375
Section 1 GENERAL PROVISIONS 3-375
Section 2 VAPOUR PIPING SYSTEMS 3-376
Section 3 INSTRUMENTATION 3-377
Section 4 ADDITIONAL REQUIREMENTS FOR VCS-T 3-378
Section 5 INSTRUCTION MANUAL 3-378
CHAPTER 16 ADDITIONAL REQUIREMENTS FOR MACHINERY INSTALLATIONS OF SMALL SHIPS 3-380
Section 1 GENERAL PROVISIONS 3-380
Section 2 ADDITIONAL REQUIREMENTS FOR MACHINERY INSTALLATIONS 3-380

CHAPTER 1 GENERAL

Section 1 REQUIREMENTS FOR CLASSIFICATION

1.1.1 Conditions of classification for machinery installations

1.1.1.1 Main propulsion and auxiliary machinery installations together with their associated equipment, boilers, pressure vessels, pumping and piping systems, and gearing fitted in ships are to comply with the relevant requirements prescribed in this PART.

1.1.1.2 For the requirements for machinery installations of small ships and ships in restricted service, reference is made to the provisions in Chapter 16 of this PART and Chapter 3 of PART TEN.

1.1.1.3 In addition, the machinery installations are to comply with the applicable requirements of PART ONE of the Rules.

1.1.2 Class notations

1.1.2.1 For the specific class notations of ships, reference is made to the relevant provisions in Chapter 2, PART ONE of the Rules.

1.1.3 Plans and documents

1.1.3.1 Prior to the commencement of ship construction, plans and documents as listed in the respective Chapters of this PART are to be submitted for approval. Other plans and documents may be required to be submitted as deemed necessary for individual cases.

1.1.3.2 Any major alterations to basic design, materials or other aspects of the approved plans are to be re-submitted to CCS for approval.

1.1.3.3 For products approved by CCS, the submission of such plans and detailed information are not necessary.

1.1.4 Product survey

1.1.4.1 For the certification requirements and product survey of machinery installations, reference is made to the relevant provisions in Chapter 3, PART ONE of the Rules.

Section 2 GENERAL PROVISIONS

1.2.1 Ambient conditions

1.2.1.1 The main and auxiliary engines, shafting and machinery equipment essential to classification are to be so designed, type-selected and arranged as to ensure compliance with the provisions of 1.2.1.2 and 1.2.1.3.

1.2.1.2 Considering the type, size and service conditions of the ship, smaller angles of inclination may be permitted. See Table 1.2.1.2 for specific requirements.

Angle of inclination of ships **Table 1.2.1.2**

Installations and equipment	Angle of inclination① (°)			
	Athwartships		Fore-and-aft	
	static	dynamic	static	dynamic
Main and auxiliary machinery	15	22.5	5②	7.5
Safety equipment: e.g. emergency power installations, emergency fire pumps and their device	22.5③	22.5③	10	10

Notes: ① Athwartships and fore-and-aft inclinations may occur simultaneously.

② Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as $500/L$ degrees, where L = length of the ship, in m.

③ For ships carrying liquefied gases and chemicals, the emergency source of electrical power is also to remain operable with the ship being flooded to a final athwartship inclination up to a maximum of 30°.

1.2.1.3 Main propulsion and steering machinery and auxiliary machinery that is essential to the propulsion and steering, and the safety of the ship are to be capable of operation under the effects of acceleration and motions.

Documented evidence of equipment suitability is to be submitted to CCS according to the following requirements.

(1) Documentation

For ships subject to the SOLAS Convention, ship builders are to identify and document the ship accelerations and motions periods to which machinery and equipment might be subjected to. The expected accelerations and ship motions periods are to be within machinery and equipment manufacturers requirements. The estimations are to consider vessel type, machinery or equipment location and expected service conditions.

(2) Evaluation of equipment suitability

Machinery and equipment manufacturers are to submit the following evidence to the Classification Society to demonstrate that their machinery or equipment can operate under the required conditions stated in 1.2.1.2 and at least at the levels of shipboard accelerations as stated in this paragraph:

① Report of testing under representative conditions; or

② Report of theoretical verification using recognised computational techniques accompanied by detailed and relevant validation data: or

③ Historical data which provides relevant demonstration of satisfactory experience in service.

(3) Installation and operation

Machinery and equipment manufacturers are to submit details of the requirements /recommendations for installation of the machinery and equipment onboard to ensure satisfactory operation in service under the required conditions as described in 1.2.1.2 and at least at the levels of shipboard accelerations as stated in 1.2.1.4 .

Note: Consideration is to be given for positioning machinery in order to minimize the dynamic load on bearings due to ship motion.

Shipbuilders are to submit details demonstrating that the installation of the machinery and equipment onboard is in accordance with manufacturer's requirements /recommendations.

1.2.1.4 The machinery installations relevant to classification of ships are to be so designed and arranged as to ensure normal operation under the ambient temperature conditions as shown in Table 1.2.1.4.

For ships in restricted service, ambient temperature may be taken according to the actual condition of navigation area.

Ambient temperature **Table 1.2.1.4**

Environment	Location	Temperature range (℃)
Air	In enclosed spaces	0 to 45
	Within specific space or on machinery installations	According to actual temperature of specific space or equipment
	On the open deck	-25 to 45
Seawater	All positions	32

1.2.1.5 For the purpose of determining the rating of main and auxiliary reciprocating internal combustion engines, the following ambient reference conditions apply to ships for unrestricted service:

Total barometric pressure	0.1 MPa
Air temperature	45℃
Relative humidity	60%
Sea water temperature (charge air coolant-inlet)	32℃

The engine manufacturers are not expected to provide simulated ambient reference conditions at a test bed.

1.2.1.6 In the case of ships for restricted service, the rating is to be suitable for the temperature conditions associated with the geographical limits of the restricted service.

1.2.2 Vibration

1.2.2.1 The propulsion installations are to be so designed, constructed and installed that any mode of their vibrations is not to cause undue stresses in them in the normal operating ranges.

1.2.3 Strengthening for navigation in ice

1.2.3.1 For ships navigating in ice and granted relevant additional notations, their main propulsion machinery and auxiliary equipment are to comply with the provisions of Chapter 14 of this PART.

1.2.4 Astern power

1.2.4.1 In order to maintain sufficient manoeuvrability and secure control of the ship in all normal

circumstances, the main propulsion machinery is to be capable of reversing the direction of thrust so as to bring the ship to rest from the maximum service speed. The main propulsion machinery is to be capable of maintaining in free route astern at least 70% of the ahead revolution.

1.2.4.2 Where steam turbines are used for main propulsion, they are to be capable of maintaining in free route astern at least 70% of the ahead revolution for a period of at least 15 min. The astern trial is to be limited to 30 min or in accordance with manufacturer's recommendation to avoid overheating of the turbine due to the effects of "windage" and friction.

1.2.4.3 For the main propulsion systems with reversing gears, controllable pitch propellers or electric propeller drive, running astern is not to lead to the overload of propulsion machinery.

1.2.4.4 Main propulsion systems are to undergo tests to demonstrate the astern response characteristics. The tests are to be carried out at least over the manoeuvring range of the propulsion system and from all control positions. A test plan is to be provided by the yard and accepted by the surveyor. If specific operational characteristics have been defined by the manufacturer these are to be included in the test plan①.

1.2.4.5 The reversing characteristics of the propulsion plant, including the blade pitch control system of controllable pitch propellers, are to be demonstrated and recorded during trials②.

1.2.5 Overload power

1.2.5.1 Prime movers of main engines and electric generators are to be capable of running at an overload power corresponding to 110% of its rated power.

1.2.6 Dead ship starting

1.2.6.1 Ship's machinery is to be so arranged that it can be brought into operation from the dead ship condition using only the facilities available on board without external aid.

Dead ship condition is to be understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting and operating the propulsion plant, the main source of electrical power and other essential auxiliaries is assumed to be available.

Where the emergency source of power is an emergency generator which complies with 9.5.3 of this PART and 2.2.1.6 of PART FOUR of the Rules, this generator may be used for restoring operation of the main propulsion plant, boilers and auxiliaries where any power supplies necessary for engine operation are also protected to a similar level as the starting arrangements.

Where there is no emergency generator installed or an emergency generator does not comply with the above-mentioned requirements, the arrangements for bringing main and auxiliary machinery into operation are to be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board ship without external aid. If for this purpose an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor.

The arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 min of a dead ship condition. For steam main propulsion unit, 30 min means time from dead ship condition to successful ignition of first main boiler.

1.2.7 Automation of machinery installations

1.2.7.1 Automatioin for machinery installations is to comply with the relevant requirements of PART SEVEN of the Rules.

1.2.8 Materials

1.2.8.1 The materials used in the construction of main components for main propulsion and auxiliary machinery installations and propulsion shafting systems, boilers and pressure vessels are to be in compliance with the relevant requirements of CCS Rules for Materials and Welding.

1.2.8.2 For all ships, new installation of materials which contain asbestos are prohibited.

1.2.9 Fuel

---

① This paragraph applies to:
(1) ships contracted for construction on or after 1 July 2018.
(2) ships other than those specified in the preceding (1) on which astern testing is carried out in accordance with 5.9.4.10, Chapter 5, PART ONE of the Rules on or after 1 July 2018.

② Same as ① above.

1.2.9.1 The flash point (closed cup test) of oil fuel for the main propulsion machinery and prime movers to drive generators or boilers are, in general, not to be less than 60℃ For the prime movers of emergency generators, oil fuel having a flash point of not less than 43℃ is permissible.
1.2.9.2 The use of oil fuel having a flashpoint of less than 60℃ but not less than 43℃ may be permitted (e.g. for feeding the emergency fire pump's engines and the auxiliary machines which are not located in the machinery spaces of category A) subject to the following:
(1) fuel oil tanks except those arranged in double bottom compartments are to be located outside of machinery spaces of category A;
(2) provision for the measurement of oil temperature are to be provided on the suction pipe of the oil fuel pump;
(3) stop valves and/or cocks are provided on the inlet side and outlet side of the oil fuel strainers;
(4) pipe joints of welded construction or of circular cone type or spherical type union joint are to be applied as much as possible;
(5) the whole fuel system is to be located outside the machinery spaces of category A;
(6) the arrangement of fuel oil tank is to comply with the requirements of 3.2.1.5(1)-(5) of Chapter 3 of PART SIX of the Rules.
1.2.9.3 In cargo ships the use of fuel having a lower flashpoint than 43℃ may be permitted provided that such fuel is not stored in any machinery space and the arrangement for the complete installation has been submitted for approval.
1.2.9.4 Ships using distillates with a sulphur content not more than 0.10% m/m are to comply with the relevant requirements of this PART and in addition, the requirements of CCS Guidelines for Use of Low Sulphur Distillate Fuels in Ships.

1.2.10 Emission treatment
1.2.10.1 Ships installed with exhaust gas cleaning systems (hereinafter referred to as the EGC systems) for reduction of SO_x emission from fuel oil combustion units are, in addition to the relevant provisions of this PART, to comply with the requirements of CCS Guidelines for Testing and Survey of Exhaust Gas Cleaning Systems and Guidelines for Design and Installation of Exhaust Gas Cleaning Systems.
1.2.10.2 Ships installed with selective catalytic reduction systems (hereinafter referred to as the SCR systems) for reduction of NO_x emission from diesel engines are, in addition to the relevant provisions of this PART, to comply with the requirements of CCS Guidelines for Approval and Survey of Selective Catalytic Reduction (SCR) systems and Guidelines for Application of Selective Catalytic Reduction (SCR) Systems Onboard Ships.
1.2.10.3 Ships installed with exhaust gas recirculation systems (hereinafter referred to as the EGR systems) and related auxiliary systems for reduction of NOx emission from diesel engines are, in addition to the relevant provisions of this Part, to comply with the requirements of CCS Guidelines for Application of Exhaust Gas Recirculation Systems onboard Ships.

1.2.11 Clean energy and power
1.2.11.1 Ships other than liquefied gas carriers using natural gas as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of the Rules for Natural Gas Fuelled Ships.
1.2.11.2 Liquefied gas carriers using natural gas as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of the Guidelines for Design and Installation of Gas Fuel Engine Systems of Liquefied Gas Carriers.
1.2.11.3 Liquefied gas carriers using liquefied gas other than natural gas as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of 16.9, Chapter 16, PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.
1.2.11.4 Ships using methyl/ethyl as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of CCS Guidelines for Ships Using Methanol/Ethanol Fuel.
1.2.11.5 Ships using biodiesel fuel or the mixture of biodiesel and regular fuel as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of CCS Guidelines for Ships Using Biofuel.
1.2.11.6 Ships provided with the fuel cell power system are, in addition to the relevant provisions of this PART, to comply with relevant requirements of CCS Guidelines for Ships Using Fuel Cell Power Installations.
1.2.11.7 Ships using liquefied petroleum gas as fuel are, in addition to the relevant provisions of this PART, to comply with relevant requirements of CCS Guidelines for Ships Using Liquefied Petroleum Gas Fuel.
1.2.11.8 Ships using ammonia as fuel are, in addition to the relevant provisions of this PART, to comply

with relevant requirements of CCS Guidelines for Ships Using Ammonia Fuel.

1.2.12 Trials

1.2.12.1 The mooring and sea trials for machinery installations are to be carried out in accordance with the relevant provisions of the Rules and the approved test programs.

On completion of the trials, corresponding technical documents and trial reports are to be furnished by the shipyard.

Section 3 ARRANGEMENT

1.3.1 Means of escape

1.3.1.1 Means of escape in machinery spaces are to comply with the requirements specified in PART SIX of the Rules.

1.3.2 Boiler arrangement

1.3.2.1 Where boilers are located in machinery spaces on tween-decks and the boiler rooms are not separated from the machinery spaces by watertight bulkheads, the tween-decks are to be provided with coamings at least 200 mm in height to prevent the oily water that might leak from spreading and dropping to the lower level. This area may be drained to the bilges. The drain tank is not to form part of an overflow system.

1.3.2.2 The clearance between boilers and fuel oil tank boundaries is not to be less than that specified in Table 1.3.2.2.

The clearance between boilers and fuel oil tank boundaries (mm) Table 1.3.2.2

		Top plate of double-bottom fuel oil tank	Fuel oil bulkhead
Water-tube boiler	Outer wall	—	450
	Bottom	600	—
Fire-tube boiler	End plate	—	600
	Bottom	450	—

1.3.3 Skylights of machinery casings

1.3.3.1 Skylights located in machinery spaces of category A are to be of steel and are not to contain glass panels. Suitable arrangements are to be made to permit the release of smoke in the event of fire, from the space to be protected.

1.3.4 Ventilation

1.3.4.1 Machinery spaces are to be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions including heavy weather, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery.

1.3.4.2 All spaces, where flammable or toxic gases or vapors may accumulate, are to be provided with adequate ventilation.

1.3.5 Position of emergency equipment on passenger ships

1.3.5.1 Emergency sources of electrical power, fire pumps, bilge pumps except those specifically serving the spaces forward of the collision bulkhead, any fixed fire-extinguishing system required in PART SIX of the Rules and other emergency installations which are essential for the safety of the ship, except anchor windlasses, are not to be installed forward of the collision bulkhead.

1.3.6 Protection

1.3.6.1 In places where the working of machinery and equipment may cause injuries to the operating personnel, handrails, protecting casings or screens are to be provided.

1.3.6.2 Placards or labels are to be provided for illustrating the correct procedures of operation, so as to avoid any mistakes in the operation or change-over of the machinery or systems.

1.3.6.3 All surfaces of machinery and pipes where the hot surfaces may injure personnel are to be protected by handrails or shields. Where the surface temperature may exceed 220℃, they are to be effectively shielded to prevent ignition caused by flammable liquids. Where the insulation covering these surfaces is oil-absorbing or previous to oil, such insulation is to be encased in steel or equivalent.

1.3.7 Communication

1.3.7.1 At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the engines are normally controlled: one of these is to be an engine-room telegraph which provides visual indication of the orders and responses both in the machinery space and in the navigation bridge. Appropriate means of communication is to be provided from the navigation bridge and the engine-room to any other positions from which the speed of direction of thrust of the propellers may be controlled.

1.3.8 Accessibility

1.3.8.1 Accessibility, for the purposes of control, maintenance, inspection and repair of various machinery and equipment, is to be provided in machinery and boiler spaces.

1.3.9 Stuffing boxes for shaftings

1.3.9.1 Stuffing boxes are to be fitted on the watertight bulkhead of the engine room where the shafts pass through. They are to be so arranged as to be convenient for tightening and renewing the packings from the engine room side. The fore sealing ends of the stern tubes as well as the plummer blocks are to be easily accessible for maintenance.

1.3.10 Earthing

1.3.10.1 Suitable earthing arrangements are to be provided to prevent excessive electrical potential difference between the crankshaft/shafting of main propulsion diesel engines and hull.

CHAPTER 2 PUMPING AND PIPING SYSTEMS

Section 1 GENERAL PROVISIONS

2.1.1 General requirements

2.1.1.1 Unless otherwise stated, this Chapter applies to piping systems of all ships. Chemical cargo piping, chemical process piping, liquefied gases cargo piping, liquefied gases process piping and fuel piping such as liquefied natural gas, liquefied petroleum gas, ammonia, methanol/ethanol, etc. are to satisfy relevant requirements of applicable CCS rules and guidelines such as Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, Rules for Ships Using Natural Gas Fuels, Guidelines for Ships Using Liquefied Petroleum Gas as Fuel, Guidelines for Ships Using Ammonia as Fuel, and Guidelines for Ships Using Methanol/Ethanol as Fuel, respectively.

2.1.1.2 The certification requirements and product survey of pumps, pipes, valves and fittings in piping systems are to comply with the relevant requirements specified in Chapter 3 of PART ONE of the Rules.

2.1.2 Plans and documents

2.1.2.1 For all ships, the following plans and documents are to be submitted for approval:

(1) arrangement of machinery and boiler spaces;
(2) bilge piping and ballast piping;
(3) arrangement of air pipes, sounding pipes and overflow pipes;
(4) fuel oil feeding system for main and auxiliary engines and boilers;
(5) fuel oil transfer system;
(6) lubricating oil piping for main and auxiliary engines;
(7) cooling water piping system for main and auxiliary engines;
(8) compressed air piping system;
(9) steam piping;
(10) condensate and exhaust steam piping;
(11) boiler feed and blow-off piping;
(12) oil fuel heating piping;
(13) purgative system for fuel oil and lubricating oil;
(14) exhaust gas piping for main and auxiliary engines;
(15) arrangement of ventilation pipes for engine room;
(16) hydraulic systems;
(17) arrangement of drain pipes;
(18) additional plans and documents as may be deemed necessary by CCS.

2.1.2.2 For oil tankers, the following plans and documents are to additionally be submitted for approval:

(1) cargo oil piping system;
(2) bilge piping system of cargo pump rooms and cofferdams;
(3) cargo oil heating piping;
(4) arrangement of venting systems (including purge, gas-free systems);
(5) closed ullage system (where applied);
(6) arrangement of cargo pump tank.

2.1.2.3 For all ships, the following plans and documents are to be submitted for information (if relevant information is reflected in the submitted plans, submission of following plans and documents is not necessary):

(1) specifications of machinery installations;
(2) particulars of machinery equipment;
(3) calculations of machinery equipment.

2.1.2.4 The materials, sizes, types, design pressures and design temperatures of pipes, valves and fittings, and the set pressure of safety valves are to be clearly marked on plans. Where separate calculations are not submitted, necessary rule calculations are to be affixed to the plans.

2.1.3 Design pressure

2.1.3.1 The design pressure for piping is the maximum permissible working pressure and it is not to be less than the highest set pressure of any safety valve or relief valve.

2.1.3.2 For pipes containing fuel oil, the design pressure is to be taken as given in Table 2.1.3.2.

Design pressure for pipes containing fuel oil **Table 2.1.3.2**

Working temperature / Working pressure	T ≤ 60℃	T > 60℃
P ≤ 0.7 MPa	0.3 MPa or highest working pressure, whichever is greater	0.3 MPa or highest working pressure, whichever is greater
P > 0.7 MPa	Highest working pressure	1.4 MPa or highest working pressure, whichever is greater

2.1.3.3 For special cases, the design pressure is to be specially considered.

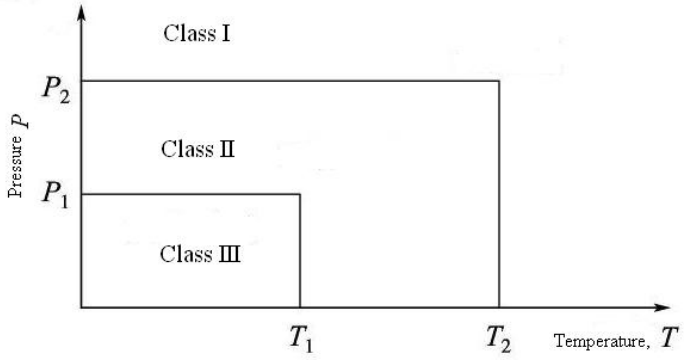
2.1.4 Design temperature

2.1.4.1 The design temperature is to be taken as the maximum temperature of the internal fluid.
In the case of pipes for superheated steam, the temperature is to be taken as the designed operating steam temperature for the pipeline, provided that the temperature at the superheater outlet is closely controlled. Where temperature fluctuations exceeding 15℃ above the designed temperature are expected in normal service, the steam temperature to be used for determining the allowable stress is to be increased by the amount of this excess. For special cases, the design temperature is to be specially considered.

2.1.5 Classes of pipes

2.1.5.1 For the purpose of assigning appropriate testing requirements, types of joints to be adopted, heat treatment and weld procedure, pressure piping systems are divided into three classes in accordance with their design pressure and design temperature, as indicated in Table 2.1.5.1.

Piping system class **Table 2.1.5.1**



Piping system	Class I		Class II		Class III	
	Design pressure > P_2 (MPa)	Design temperature > T_2 (℃)	Design pressure ≤ P_2 (MPa)	Design temperature ≤ T_2 (℃)	Design pressure ≤ P_1 (MPa)	Design temperature ≤ T_1 (℃)
Steam	> 1.6	or > 300	≤ 1.6	and ≤ 300	≤ 0.7	and ≤ 170
Thermal oil	> 1.6	or > 300	≤ 1.6	and ≤ 300	≤ 0.7	and ≤ 150
Fuel oil, lub-oil, flammable hydraulic oil	> 1.6	or > 150	≤ 1.6	and ≤ 150	≤ 0.7	and ≤ 60
Other media	> 4.0	or > 300	≤ 4.0	and ≤ 300	≤ 1.6	and ≤ 200

Notes:

① For Class I piping, one parameter for design pressure and design temperature of Class I specified in the Table is to be met; For Class II or Class III piping, both the parameters for design pressure and design temperature specified in the Table are to be met.

② Toxic or corrosive media, flammable media heated above flash point or with flash point below 60℃ media and liquefied gas belong to class I. If means of special safeguards for preventing leakage and its consequences are provided (e.g. pipes led in positions where leakage of internal fluids will not cause a potential hazard or damage to surrounding areas which may include the use of pipe ducts, shielding, screening etc.), they may also belong to class II, but except toxic media.

③ Cargo pipes belong to class III.

④ Class III pipes may be used for open ended piping, e.g. drains, overflows, vents boiler waste steam pipes, etc.
⑤ Other media mean air, gases, water, and non-flammable hydraulic oil and urea for the selective catalytic reduction (SCR) system (when the piping material is selected according to ISO 18611-3:2014), etc.
⑥ Thermal oil means the circulating oil used in the thermal oil system as specified in Section 8, Chapter 4 of this PART; in addition, the oxygen and acetylene piping is to be Class I piping (except for discharge pipes with openings).

2.1.6 Materials

2.1.6.1 Materials to be used for pipes, valves and fittings are to be suitable for the medium and service for which the piping is intended. In the case of especially corrosive media, the material for the piping system is to be taken into consideration in each particular case.
2.1.6.2 Material for pipes, valves and relative fittings belonging to Classes I and II and for valves and pipes fitted on the ship's side and for valves fitted on the collision bulkhead are to be tested in accordance with the relevant requirements of CCS Rules for Materials and Welding.
2.1.6.3 Materials for pipes, valves and fittings of Class III are to be tested in accordance with applicable standards.

Section 2 CARBON, LOW ALLOY STEELS AND stainless steelS

2.2.1 Carbon and low alloy steel pipes, valves and fittings

2.2.1.1 Classes I and II pipes are to be seamless steel pipes or welded pipes fabricated with a welding procedure approved by CCS.
2.2.1.2 In general, carbon and carbon-manganese steel pipes, valves and fittings are not to be used for medium temperatures above 400℃. Nevertheless, they may be used for higher temperatures if their metallurgical behavior and time dependent strength (UTS after 100,000 h) are in compliance with national or international codes or standards and if such values are guaranteed by the steel manufacturer.
Special alloy steel pipes, valve and fittings are to be employed according to the relevant requirements of CCS Rules for Materials and Welding.

2.2.2 Calculation of wall thickness

2.2.2.1 The minimum wall thickness δ of steel pipes subject to internal pressure is not to be less than that determined by the following formula[①]:

$$\delta = \delta_0 + b + c \quad \text{mm}$$

where: δ_0 — the basic wall thickness, in mm, see 2.2.2.2 of this Section;
b — allowance for bending, in mm. The value for this allowance is to be chosen in such a way that the calculated stress in the bend, due to the internal pressure only, does not exceed the permissible stress. When this allowance is not determined by a more accurate procedure, it is to be taken according to 2.2.2.3 of this Section;
c — corrosion allowance, in mm, to be obtained from Table 2.2.2.1.

Corrosion allowance *C* for steel pipes **Table 2.2.2.1**

Usage of piping	*C*	Usage of piping	*C*
Overheat steam piping	0.3	Lubricating oil piping	0.3
Saturated steam piping	0.8	Fuel oil piping	1.0
Steam heating piping in cargo tank	2.0	Cargo oil piping	2.0
Boiler open-type feed piping	1.5	Refrigerant piping of refrigerating installation	0.3
Boiler close-type feed piping	0.5	Fresh water piping	0.8
Boiler blow-off piping	1.5	Sea water piping	3.0
Compressed air piping	1.0	Salt water piping in refrigerated hold	2.0
Hydraulic oil piping	0.3		

For pipes passing through tanks, an additional corrosion allowance is to be taken, depending on the external medium, in order to account for the external corrosion. Where pipes and any integral pipe joints are efficiently protected against corrosion by means of coating, lining, etc., the corrosion allowance may be reduced by not more than 50%. In the case of use of special alloy steel with sufficient corrosion resistance, the corrosion allowance may be reduced, even to zero.
2.2.2.2 The basic wall thickness δ_0 for steel pipes is to be determined by the following formula:

① The formula applies to pipes where the ratio outside-diameter to inside-diameter does not exceed the value 1.7.

$$\delta_0 = \frac{pD}{2[\sigma]e + p} \quad \text{mm}$$

where: p — design pressure, in MPa, see 2.1.3 of this Chapter;
D — outside diameter of steel pipes, in mm;
$[\sigma]$ — permissible stress of steel pipes, in N/mm^2, see 2.2.2.4 of this Section;
e — welding efficiency factor. For seamless steel pipes and electric resistance or induction welded steel pipes, e is to be taken as 1; for pipes made by other methods, e will be specially considered.

2.2.2.3 Bending allowance b is not to be less than that determined by the following formula:

$$b = 0.4\ \frac{D}{R}\delta_0 \quad \text{mm}$$

where: R — radius of curvature of a pipe bend at the centre line of the pipe, in mm, in general, R is not to be less than $3D$;
D — outside diameter of steel pipes, in mm;
δ_0 — basic wall thickness, in mm, see 2.2.2.2 of this Section.

2.2.2.4 Permissible stress $[\sigma]$ of steel pipes is to be taken as the lowest of the following values:

$$[\sigma] = \frac{R_m}{2.7} \quad \text{N/mm}^2$$

$$[\sigma] = \frac{R_{eH}^T}{1.6} \quad \text{N/mm}^2$$

$$[\sigma] = \frac{\sigma_D^T}{1.6} \quad \text{N/mm}^2$$

$$[\sigma] = \sigma_c^T \quad \text{N/mm}^2$$

where: R_m — tensile strength of material at room temperature, in N/mm^2;
R_{eH}^T — yield stress or 0.2% proof stress ($R_{p0.2}$) of material at design temperature, in N/mm^2;
σ_D^T — average stress of material to produce rupture in 100,000 h at design temperature, in N/mm^2;
σ_c^T — average stress to produce 1% creep in 100,000 h at the design temperature, in N/mm^2;
$R_m, R_{eH}^T, \sigma_D^T$ are to comply with the relevant requirements of CCS Rules for Materials and Welding. National or international standards may be accepted for R_{eH}^T. σ_c^T may be used as appropriate based on reliable conditions if it is deemed necessary.

2.2.2.5 The minimum wall thickness δ mentioned in 2.2.2.1 above has not taken into account the negative manufacturing tolerance, where there is any negative tolerance allowable in manufacture, the nominal thickness δ_m of pipes is not to be less than that determined by the following formula:

$$\delta_m = \frac{\delta}{1 - \frac{a}{100}} \quad \text{mm}$$

where: a — percentage of negative manufacturing tolerance on thickness.

2.2.2.6 Where the minimum thickness calculated by the formula specified in 2.2.2.5 is less than that shown in Table 2.2.2.6(1), Table 2.2.2.6(2) or Table 2.2.2.6(3), the minimum nominal thickness for the appropriate standard pipe size shown in the Tables is to be used.
For threaded pipes, the thickness is to be measured at the bottom of the thread.

External diameter and minimum nominal thickness for steel pipes, in mm Table 2.2.2.6(1)

External diameter, *D*	Minimum nominal thickness (δ)			
	General pipe③④⑥⑧⑨⑩	Air pipe, overflow pipe and sounding pipe of tank related to hull structure①②③④⑥⑦⑧	Bilge and ballast pipe, general sea water pipe and steam heating coil in liquid tank①③④⑤⑥⑦⑧	Bilge pipe, air pipe, overflow pipe and sounding pipe through ballast tank and fuel oil tank. Ballast pipe through fuel oil tank and fuel oil pipe through ballast tank①②③④⑤⑥⑦⑧
10.2~12	1.6			
13.5~19.3	1.8			
20	2.0			
21.3~25	2.0		3.2	
26.9~33.7	2.0		3.2	
38~44.5	2.0	4.5	3.6	6.3
48.3	2.3	4.5	3.6	6.3
51~63.5	2.3	4.5	4.0	6.3
70	2.6	4.5	4.0	6.3
76.1~82.5	2.6	4.5	4.5	6.3
88.9~108	2.9	4.5	4.5	7.1
114.3~127	3.2	4.5	4.5	8.0
133~139.7	3.6	4.5	4.5	8.0
152.4~168.3	4.0	4.5	4.5	8.8
177.8	4.5	5.0	5.0	8.8
193.7	4.5	5.4	5.4	8.8
219.1	4.5	5.9	5.9	8.8
244.5~273	5.0	6.3	6.3	8.8
298.5~368	5.6	6.3	6.3	8.8
406.4~457	6.3	6.3	6.3	8.8

Notes:

① Where pipes and any integral pipe joints are efficiently protected against corrosion by means of coating, lining, etc., the minimum wall thickness may be reduced by an amount up to 1 mm.

② For sounding pipes, except those for cargo tanks with cargo having a flash point less than 60℃, the minimum wall thickness is intended to apply to the part outside the tank.

③ For threaded pipes, where allowed, the minimum wall thickness is to be measured at the bottom of the thread.

④ The external diameters and thicknesses have been selected from ISO Recommendations R336 for welded and seamless steel pipes. For pipes covered by other Standards, slightly reduced thicknesses may be accepted.

⑤ The minimum wall thickness for bilge lines and ballast lines through deep tanks will be subject to special consideration. The minimum wall thickness for ballast lines through cargo tanks is not to be less than that specified in Table 5.3.4.2 of Section 3, Chapter 5 of this PART.

⑥ The minimum wall thickness for pipes larger than 457 mm nominal size is to be in accordance with a national or international standard and in any case not less than the minimum wall thickness of the appropriate column indicated for 406.4 to 457 mm pipe size in Table 2.2.2.6(1).

⑦ The minimum internal diameters of bilge, sounding, air and overflow pipes are to be:

Bilge 50 mm
Sounding 32 mm
Air and overflow 50 mm

⑧ In general, the minimum thickness listed in this Table is the nominal wall thickness and no allowance need be made for negative tolerance and reduction in thickness due to bending.

⑨ The minimum wall thickness of exhaust gas pipe will be subject to special consideration.

⑩ The minimum wall thickness for cargo oil lines will be subject to special consideration.

External diameter and minimum nominal thickness δ for stainless steel pipes, in mm **Table2.2.2.6(2)**

External diameter (D)	Minimum nominal thickness (δ)
≤10	1.0
11~18	1.5
19~83	2.0
84~169	2.5
170~246	3.0
247~340	3.5
341~426	4.0
427~511	4.5
512~597	5.0

External Diameter and Minimum Nominal Wall Thickness for Austenitic Stainless Steel Pipes, in mm **Table 2.2.2.6(3)**

External diameter (D)	Minimum nominal wall thickness (δ)
10.2 ~ 17.2	1.0
21.3 ~ 48.3	1.6
60.3 ~ 88.9	2.0
114.3 ~ 168.3	2.3
219.1	2.6
273.0	2.9
323.9 ~ 406.4	3.6
> 406.4	4.0

Note: Diameters and thicknesses according to national or international standards may be accepted.

2.2.2.7 The minimum wall thickness of the scuppers and discharge pipes is to comply with the relevant requirements of regulation 22, Annex I to Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

2.2.2.8 The minimum wall thickness of air pipes above the weather deck is to comply with the relevant requirements of 1.12.7.5 of PART TWO of the Rules.

Section 3 COPPER AND COPPER ALLOYS

2.3.1 Copper and copper alloy pipes, valves and fittings

2.3.1.1 Copper and copper alloy pipes used in Classes I and II piping systems are to be seamless.

2.3.1.2 Materials of copper and copper alloys for Class III piping systems are to be manufactured and tested in accordance with the approved standards.

2.3.1.3 In general, copper and copper alloy pipes, valves and fittings are not be used for media having a temperature above the following limits:

copper and aluminum brass: 200℃;

copper nickel: 300℃;

special bronze suitable for high temperature services: 260℃.

2.3.2 Calculation of wall thickness

2.3.2.1 The minimum wall thickness δ of copper and copper alloy pipes subject to internal pressure is not to be less than that determined by the following formula①:

$$\delta = \delta_0 + b + c \quad \text{mm}$$

where: δ_0 — the basic wall thickness, in mm, see 2.3.2.2 of this Section;

b — allowance for bending, in mm. The value for this allowance is to be chosen in such a way that the calculated stress in the bend, due to the internal pressure only, does not exceed the permissible stress. When this allowance is not determined by a more accurate procedure, it is to be taken according to 2.3.2.3 of this Section;

c — corrosion allowance, in mm; for copper, brass and similar alloys, copper-tin alloys except those with lead contents, and copper-nickel alloys where the nickel content is less than 10%, c = 0.8 mm; copper-nickel alloys where the nickel content is 10% or greater, c = 0.5

① The formula applies to pipes where the ratio outside-diameter to inside-diameter does not exceed the value 1.7.

mm; where the media are non-corrosive relative to the pipe material, $c = 0$.

2.3.2.2 The basic wall thickness of copper and copper alloy pipes is to be determined by the following formula:

$$\delta_0 = \frac{pD}{2[\sigma]e + p} \quad \text{mm}$$

where: p — design pressure, in MPa, see 2.1.3 of this Chapter;
D — outside diameter of pipe, in mm;
$[\sigma]$ — permissible stress, in N/mm^2, obtained from Table 2.3.2.2;
e — efficiency factor, $e = 1$ for seamless copper pipes and for welded copper pipes delivered by manufacturers approved for making welded copper pipes which are considered an equivalent to seamless copper pipes. For copper pipes made by other methods, e will be specially considered.

Allowable stress of copper and copper alloy pipes [σ] **Table 2.3.2.2**

Materials	Material condition	Tensile strength (N/mm^2)	Allowable stress (N/mm^2)										
			Design temperature (℃)										
			50	75	100	125	150	175	200	225	250	275	300
copper	annealing	215	41	41	40	40	34	27.5	18.5	—	—	—	—
Aluminum brass	annealing	325	78	78	78	78	78	51	24.5	—	—	—	—
copper-nickel alloys CuNi5Fe1Mn CuNi10Fe1Mn	annealing	275	68	68	67	65.5	64	62	59	56	52	48	44
copper-nickel alloys CuNi30	annealing	365	81	79	77	75	73	71	69	67	65.5	64	62

Notes:
① If the metal temperature is between the values listed in the Table, allowable stress may be determined by linear interpolation.
② The allowable stresses of materials not covered by the Table are to submit detailed information.

2.3.2.3 Bending allowance b is not to be less than that determined by the following formula:

$$b = 0.4\frac{D}{R}\delta_0 \quad \text{mm}$$

where: R — radius of curvature of a pipe bend at the centre line of the pipe, in mm. In general, R is not to be less than $3D$;
D — outside diameter of pipe, in mm;
δ_0 — basic wall thickness, in mm, see 2.3.2.2 of this Section.

2.3.2.4 The minimum wall thickness δ mentioned in 2.3.2.1 above has not taken into account the negative manufacturing tolerance, where there is any negative tolerance allowable in manufacture, the nominal thickness of pipes is not to be less than that determined by the following formula:

$$\delta_m = \frac{\delta}{1 - \frac{a}{100}} \quad \text{mm}$$

where: a — percentage of negative manufacturing tolerance on thickness.

2.3.2.5 Where the minimum wall thickness calculated by the formula specified in 2.3.2.4 is less than that shown in Table 2.3.2.5, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used.
For threaded pipes, the thickness is to be measured at the bottom of the thread.

External diameter and minimum nominal thickness δ_m for copper and copper alloy pipes, in mm **Table 2.3.2.5**

Outside diameter (D)	Minimum nominal thickness (δ_m)	
	Copper	Copper alloys
8~10	1.0	0.8
12~20	1.2	1.0
25~44.5	1.5	1.2
50~76.1	2.0	1.5
88.9～108	2.5	2.0
133～159	3.0	2.5

Outside diameter (D)	Minimum nominal thickness (δ_m)	
	Copper	Copper alloys
193.7～267	3.5	3.0
273～470	4.0	3.5
508	4.5	4.0

Notes:
① The outside diameters and the thickness have been selected from ISO Standards.
② For pipes covered by other standards, slightly reduced thickness may be accepted.

Section 4 OTHER MATERIALS

2.4.1 Grey cast iron pipes, valves and fittings

2.4.1.1 Grey cast iron pipes, valves and fittings are not to be used in Class I and Class II piping systems. Grey cast iron valves and fittings may be used in Class II steam piping but the design temperature does not exceed 220℃.

2.4.1.2 Grey cast iron pipes, valves and fittings may, in general, be accepted in Class III piping systems, in cargo lines within cargo tanks of tankers , but grey cast iron is not to be used for the following:

(1) cargo oil pipelines having pressures exceeding 1.6 MPa on weather decks of oil tankers;
(2) pipes, valves and fittings intended for conveying media having temperatures above 220℃;
(3) piping may be subjected to pressure shock, excessive strains and vibration;
(4) ship-side valves and fittings and sea valves, pipes fitted on the ship sides and sea chest;
(5) valves fitted on the collision bulkhead;
(6) valves under static head fitted on the outside of fuel tank walls;
(7) boiler blow-off systems;
(8) pipes for steam, fire extinguishing, bilge and ballast systems.

Grey cast iron may be accepted for pressures up to 1.6 MPa for cargo oil pipe lines on weather decks of oil tankers except for manifolds and their valves and fittings connected to cargo handling hoses.

2.4.2 Nodular graphite cast iron pipes, valves and fittings

2.4.2.1 Ferritic nodular graphite iron castings for pipes, valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12% on a gauge length of $5.65\sqrt{S_0}$, where S_0 is the cross-sectional area of the test piece.

2.4.2.2 Ferritic nodular graphite iron pipes, valves and fittings may be accepted for bilge, ballast and cargo oil piping.

2.4.2.3 Ferritic nodular graphite cast iron pipes, valves and fittings are not to be used in piping systems for conveying media having temperatures exceeding 350℃.

2.4.2.4 Where ferritic nodular graphite iron castings are used for ship-side pipes, valves and fittings, the properties of this material are to comply with the relevant requirements of CCS Rules for Materials and Welding.

2.4.2.5 Where the elongation is less than the minimum required in 2.4.2.1 of this Section, the material is to be subject to the same limitations as grey cast iron.

2.4.3 Plastic pipes

2.4.3.1 The ranges and locations of plastic pipes used in ships are to comply with the provisions in Table 1 of Appendix I, and the plastic pipes are to comply with the fire endurance requirements in the Table.

2.4.3.2 Plastic pipes used on ships are to be selected in relation to their chemical composition, physical and mechanical properties, and temperature limits.

2.4.3.3 Plastic pipes are in general not to be used for media with a temperature above 60℃ or below 0℃.

2.4.3.4 Plastic pipes used on ships are to be designed, manufactured, used and test in accordance with the relevant requirements in Appendix 1 of this Chapter.

2.4.4 Flexible hoses

2.4.4.1 Flexible hoses mean short length of metallic or non-metallic hoses normally with prefabricated end fittings ready for installation.

2.4.4.2 Flexible hoses may be used for a permanent connection between a fixed piping system and items of machinery, as well as temporary connection between portable equipment and pipes.

2.4.4.3 Flexible hoses are to be designed, manufactured, used and tested in accordance with the relevant

requirements of Appendix 2 of this Chapter.

Section 5 CONNECTION OF PIPE LENGTHS, HEAT TREATMENT AND NON-DESTRUCTIVE TESTING

2.5.1 Connection of pipe lengths

2.5.1.1 Direct connection of pipe lengths may be obtained by:

(1) welded butt-joints between pipes or between pipes and valve chests or other fittings, the welded butt-joints are to be of full penetration type with or without special provisions for the quality of root side①;

(2) slip-on sleeve welded joints, the slip-on sleeve welded joints are to have sleeves and relative welding of adequate dimensions conforming to the recognized standard;

(3) threaded sleeve joints of approved type;

(4) mechanical joints.

2.5.1.2 The application of the aforesaid types of connection is as follows:

(1) Welded butt-joints and slip-on sleeve welded joints are to comply with the requirements specified in Table 2.5.1.2(1).

Connection of pipe length **Table 2.5.1.2(1)**

Type of connection	Allowed for classes	Allowed for outside diameter
Butt welded joints with special provision for a high quality of root side	I, II, III	No restriction
Butt welded joints without special provision for a high quality of root side	II, III	
Slip-on sleeve welded joints	III	
	I, II, except for piping systems conveying toxic media where fatigue, severe erosion or crevice corrosion is expected to occur	$D \leq 88.9$ mm

(2) Slip-on threaded joints are to comply with requirements of a recognized standard. Slip-on threaded joints may be used for outside diameters as stated below except for piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur. Slip-on threaded joints with outside diameters of maximum 25mm may be used for connecting small bore instrumentation equipment (e.g., pressure/temperature sensors) to piping systems conveying flammable media. Threaded joints in CO_2 systems are to be allowed only inside protected spaces and in CO_2 cylinder rooms.

① Threaded joints for direct connectors of pipe lengths with tapered thread may be allowed for Class I, outside diameter not more than 33.7 mm as well as Class II and Class III, outside diameter not more than 60.3 mm.

② Threaded joints for parallel thread may be allowed for Class III, outside diameter not more than 60.3 mm.

③ In particular cases, sizes in excess of those mentioned above may be accepted if they satisfy the requirements of recognized international or national standards.

2.5.2 Flange connections

2.5.2.1 Typical flange connections are indicated in Figure 2.5.2.1.

Slip-on joints, sleeve threaded joints and other types of direct connection of pipe lengths (e.g. bell and spigot joints) may be allowed in each particular case for small diameter and depending upon the service conditions.

2.5.2.2 The above-mentioned types of flange connections are to be selected in accordance with the requirements specified in Table 2.5.2.2.

Application of typical flange connections **Table 2.5.2.2**

Piping class	Toxic or corrosive media④, flammable media④, liquefied gas	Lubricating oil and fuel oil	Steam③ and hot oil	Other media①②③
I	A,B⑥	A,B	A,B⑥	A,B

① The expression "special provisions for the quality of root side" means that butt welds were accomplished as double welded or by use of a backing ring or inert gas back-up on first pass, or other similar methods accepted by CCS.

II	A,B,C	A,B,C,E⑦	A,B,C,D⑤,E⑤	
III		A,B,C,E	A,B,C,D,E	A,B,C,D,E,F②

Notes:
① Including water, air, other gases, hydraulic oil.
② Type F for water pipes and open ended lines only.
③ Only type A when design temperature exceeds 400℃.
④ Only type A when design pressure exceeds 1 MPa.
⑤ Types D and E are not be used when design temperature exceeds 250℃.
⑥ Type B for outside diameter < 150 mm only.
⑦ Type E for oil piping when design temperature < 150℃ and design pressure < 1.6 MPa only.

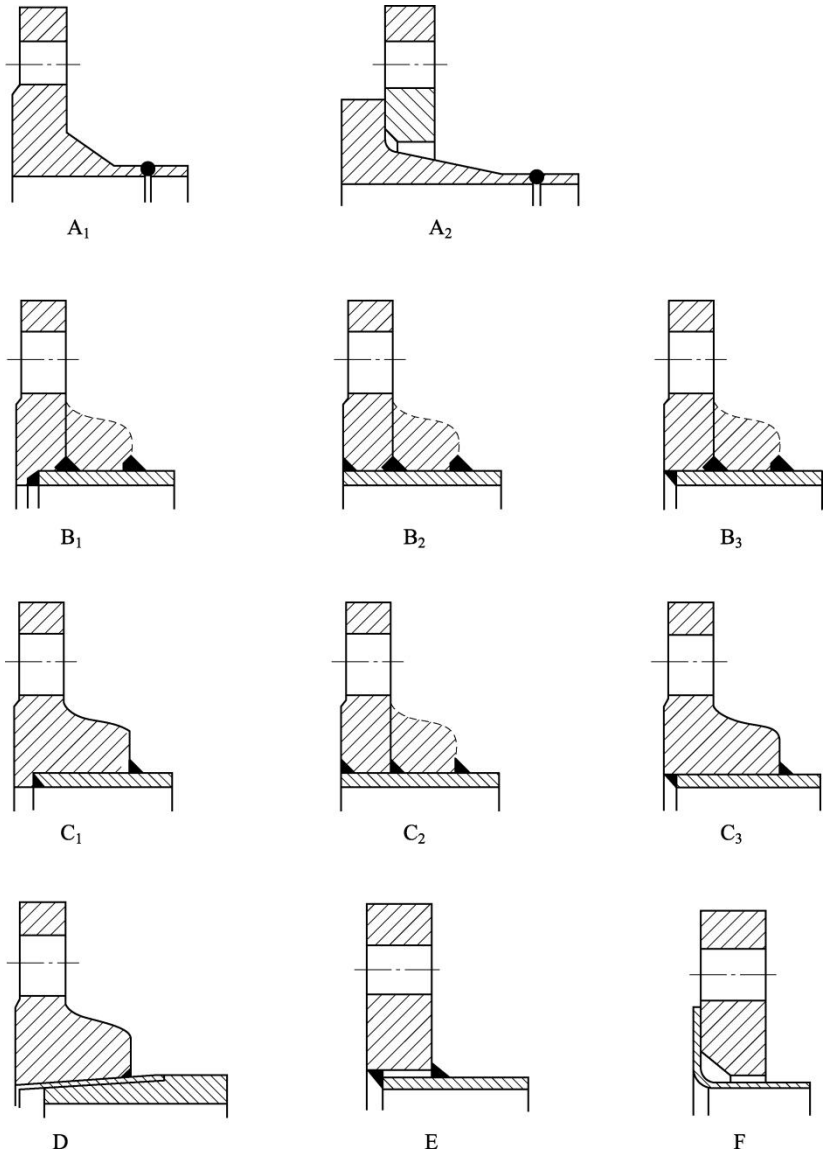


Figure 2.5.2.1 Typical flange connections

Notes: ① For type D, the pipe and flange are to be screwed with a tapered thread and the diameter of the screw portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unthreaded pipe. After the flange has been screwed hard home, the pipe is to be expanded into the flange.
② The leg length of the fillet weld and the penetration of the flange edge, as shown in the Figure, are in general to be 1.5 times the wall thickness of the pipe, but not less than 5 mm.

2.5.2.3 The dimensions of flanges and relative bolts are to be chosen in accordance with the national standards or acceptable standards. For special application, the dimensions of flanges and relative bolts are

to be subject to special consideration①.
Gaskets are to be suitable for the media being conveyed under design pressure and temperature conditions and their dimensions and configuration are to be in accordance with national or acceptable standards.
Flange connections are to be in accordance with national or international standards that are applicable to the piping system and are to recognize the boundary fluids, design pressure and temperature conditions, external or cyclic loading and location.

2.5.3 Mechanical joints

2.5.3.1 The different mechanical joints applicable to this paragraph are indicated in Table 2.5.3.1(1). The mechanical joints are to be subject to type approval based on different usage and location in accordance with the requirements of Appendix 3 of this Chapter.

2.5.3.2 Where appropriate, mechanical joints are to be of fire resistant type as required by Table 2.5.3.1(2). Fire endurance test is specified in 1.5.5(6), Appendix 3 of this Chapter.

2.5.3.3 Material of mechanical joints is to be compatible with the piping material and internal and external media.

2.5.3.4 Application of mechanical joints and their acceptable use for each service is indicated in Table 2.5.3.1(2); dependence upon the Class of piping and pipe dimensions is indicated in Table 2.5.3.1(3).
In particular cases, sizes in excess of those mentioned above may be accepted if in compliance with a recognized national and/or international standard.

2.5.3.5 Where the application of mechanical joints results in reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

2.5.3.6 Mechanical joints, which in the event of damage could cause flooding or fire, are not to be used in piping sections directly connected to the ship's side below the bulkhead deck of passenger ships (or freeboard deck of cargo ships) or tanks containing flammable fluids. The number of mechanical joints in flammable fluid systems is to be kept to a minimum. In general, flanged joints conforming to recognized standards are to be used.

2.5.3.7 Mechanical joints in bilge systems of machinery space and higher fire risk space (e.g. cargo pump room and vehicle space) are to be of fire resistant type. For the required fire resistant mechanical joints, see Table 2.5.3.1(2).

2.5.3.8 Mechanical joints are to be tested where applicable, to a burst pressure of 4 times the design pressure. When the design pressure exceeds 20 MPa, the burst pressure will be specially considered.

2.5.3.9 Piping in which a mechanical joint is fitted is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

2.5.3.10 Slip-on joints are not to be used in pipelines in cargo holds, tanks and other spaces which are not easily accessible (refer to MSC/Circ.734), except that these joints may be permitted in tanks that contain the same media.
Usage of slip type slip-on joints as the main means of pipe connection is not permitted except for cases where compensation of axial pipe deformation is necessary.

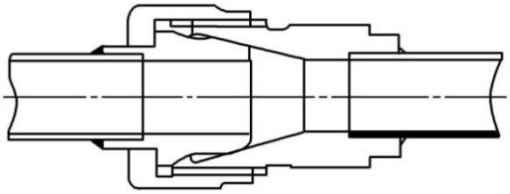
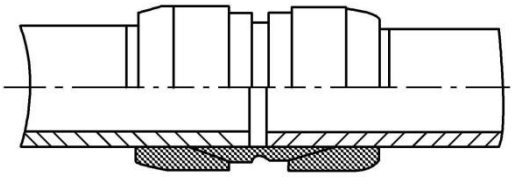
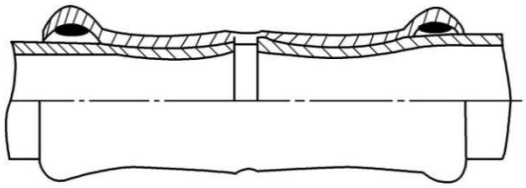
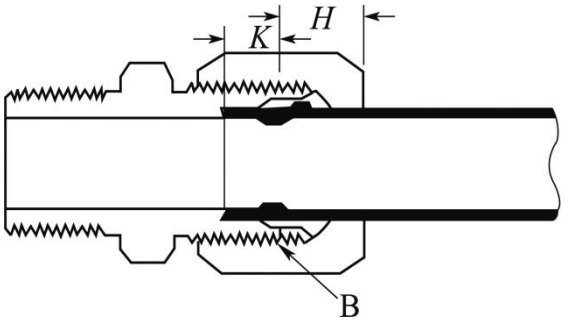
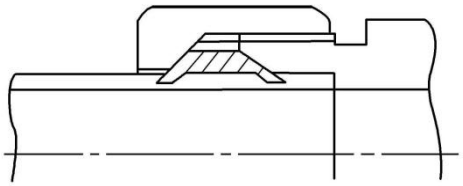
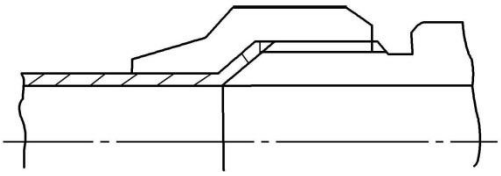
2.5.3.11 Mechanical joints are not to be used in the following cases:
(1) bilge piping through ballast tanks and fuel tanks;
(2) sea water and ballast piping (including air and overflow pipes) through cargo holds and fuel tanks;
(3) fuel and oil piping (including air and overflow pipes) through machinery spaces, cargo holds and ballast tanks.

2.5.3.12 The installation of mechanical joints is to be in accordance with the manufacturer's assembly instructions. Where special tools and gauges are required for installation of the joints, these are to be supplied by the manufacturer.

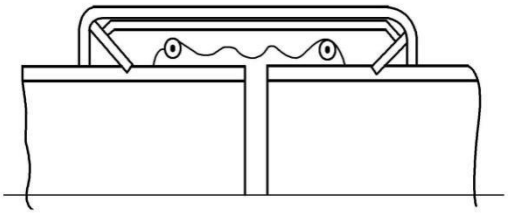
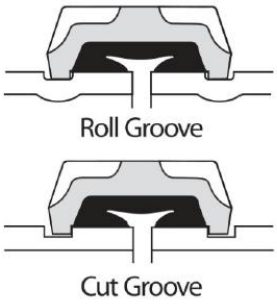
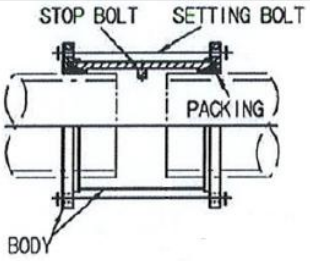
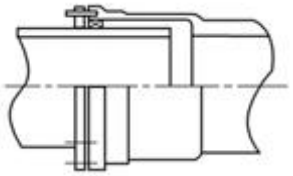
---

① For special applications where the fitting temperature, pressure and size of the flange exceed reliable limits, a complete calculation is to be carried out for bolts and flanges.

Examples of mechanical joints **Table 2.5.3.1(1)**

Pipe unions	
Welded and brazed types	
Compression	
Swage type	
Press type	
Typical Compression Type①	
Bite type	
Flared type	

① This requirement is applicable to any mechanical pipe joints submitted for approval from 1 January 2020 and to any renewal of type approval of existing design of mechanical pipe joint after 1 January 2020.

Slip-on joints	
Grip type	
Machine grooved type	
Slip type	 

Application of mechanical joints **Table 2.5.3.1(2)**

Systems		Kind of connections				
		Pipe Unions	Compression Couplings	Slip-on Joints	Classification of pipe system	Fire endurance test condition⑦
Flammable fluids (Flash point ≤ 60°C)						
1	Cargo oil lines①	×	×	×	dry	30 min dry (*)
2	Crude oil washing lines①	×	×	×	dry	
3	Vent lines③	×	×	×	dry	
Inert gas						
4	Water seal effluent lines	×	×	×	wet	30 min wet (*)
5	Scrubber effluent lines	×	×	×	wet	30 min wet (*)
6	Main lines①②	×	×	×	dry	30 min dry (*)
7	Distributions lines①	×	×	×	dry	30 min dry (*)
Flammable fluids (Flash point > 60°C)						

8	Cargo oil lines[①]	×	×	×	dry	30 min dry (*)
9	Fuel oil lines[②③]	×	×	×	wet	30 min wet (*)
10	Lubricating oil lines[②③]	×	×	×	wet	
11	Hydraulic oil[②③]	×	×	×	wet	
12	Thermal oil[②③]	×	×	×	wet	
Sea Water						
13	Bilge lines[④]	×	×	×	dry/wet	8 min dry + 22 min wet (*)
14	Permanent water filled fire extinguishing systems, e.g. fire main, sprinkler systems[③]	×	×	×	wet	30 min wet (*)
15	Non-permanent water filled fire extinguishing systems, e.g. foam, drencher systems and fire main[③]	×	×	×	dry/wet	8 min dry + 22 min wet (*) For foam systems FSS Code Chapter 6 to be observed
16	Ballast system[④]	×	×	×	wet	30 min wet (*)
17	Cooling water system[④]	×	×	×	wet	30 min wet (*)
18	Tank cleaning services	×	×	×	dry	Fire endurance test not required
19	Non-essential systems	×	×	×	dry dry/wet wet	Fire endurance test not required
Fresh Water						
20	Cooling water system[④]	×	×	×	wet	30 min wet (*)
21	Condensate return[④]	×	×	×	wet	30 min wet (*)
22	Non-essential system	×	×	×	dry dry/wet wet	Fire endurance test not required
Sanitary/Drains/Scuppers						
23	Deck drains (internal)[⑤]	×	×	×	dry	Fire endurance test not required
24	Sanitary drains	×	×	×	dry	
25	Scuppers and discharge (overboard)	×	×	-	dry	
Sounding/Vent						
26	Water tanks/Dry spaces	×	×	×	dry, wet	Fire endurance test not required
27	Oil tanks (f.p.>60℃) [②③]	×	×	×	dry	
Miscellaneous						
28	Starting/Control air[④]	×	×	-	dry	30 min dry (*)
29	Service air (non-essential)	×	×	×	dry	Fire endurance test not required
30	Brine	×	×	×	wet	
31	CO_2 system (outside protected space)	×	×	-	dry	30 min dry (*)
32	CO_2 system (inside protected space)	×	×	-	dry	Mechanical joints shall be constructed of materials with melting point above 925℃. Ref. to FSS Code Chapter 5.
33	Steam	×	×	×[⑥]	wet	Fire endurance test not required

Notes:
× Application is allowed.
– Application is not allowed.
* Fire endurance test as specified in 1.5.5(6) of Appendix 3 of this Chapter.
Fire resistance capability:
If mechanical joints include any components which readily deteriorate in case of fire, the following footnotes are to be observed:
① Fire endurance test shall be applied when mechanical joints are installed in pump rooms and open decks.
② Slip on joints are not accepted inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
③ Approved fire resistant types except in cases where such mechanical joints are installed on open decks, as defined in SOLAS Reg. II-2/9.2.3.3.2.2(10) and not used for fuel oil lines.
④ Fire endurance test shall be applied when mechanical joints are installed inside machinery spaces of category A.
General:
⑤ Only above bulkhead deck of passenger ships and freeboard deck of cargo ships.
⑥ Slip type slip-on joints as shown in Table 2.5.3.1(1) may be used for pipes on deck with a design pressure of 10 bar or less.
⑦ If a connection has passed the “30 min dry” test, it is considered suitable also for applications for which the "8 min dry+22 min wet" and/or "30 min wet " tests are required. If a connection has passed the "8 min dry+22 min wet" test, it is considered suitable also for applications for which the "30 min wet" test is required.

Application of mechanical joints depending upon the class of piping Table 2.5.3.1(3)

Types of joints	Classes of piping system		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	× (D_0≤ 60.3 mm)	× (D_0≤ 60.3 mm)	×
Compression couplings			
Swage type	×	×	×
Bite typ	×	×	×
Typical Compression Type①	×	×	×
Flared type	×	×	×
Press type	–	–	×
Slip-on joints			
Machine grooved type	×	×	×
Grip type	–	×	×
Slip type	–	×	×

Notes:
× Application is allowed.
– Application is not allowed.
D_0 Outside diameter of the pipe.

2.5.4 Heat treatment and non-destructive testing

2.5.4.1 The heat treatment and non-destructive testing of piping systems are to comply with the relevant requirements of CCS Rules for Materials and Welding.

Section 6 PUMPS, VALVES AND FITTINGS

2.6.1 Pumps

2.6.1.1 Pumps are to be designed and manufactured according to accepted standards.

2.6.1.2 Hydraulic tests

All components of pumps subject to pressure are to be subject to hydraulic tests in workshop prior to assembly. The hydraulic test pressure is to be 1.5 times the design pressure, but need not exceed the design pressure plus 7 MPa.

For centrifugal pumps, the design pressure is to be taken as the maximum pressure head on the performance curve. For displacement pumps, the design pressure is to be taken as the relief valve setting pressure.

For steam driven pumps, the test pressure at the steam side is to be 1.5 times the steam working pressure.

---

① This requirement is applicable to any mechanical pipe joints submitted for approval from 1 January 2020 and to any renewal of type approval of existing design of mechanical pipe joint after 1 January 2020.

2.6.1.3 Capacity tests
Pump capacities are to be checked with the pump operating at design conditions (rated speed and pressure head). For centrifugal pumps, the pump characteristic (head-capacity) design curve is to be verified to the satisfaction of the Surveyor.
Capacity tests may be waived if previous satisfactory tests have been carried out on similar pumps.
2.6.1.4 Relief valve capacity test
For positive displacement pumps with an integrated relief valve, the valve's setting and full flow capacity corresponding to the pump maximum rating is to be verified.
The operational test for relief valve capacity may be waived if previous satisfactory tests have been carried out on similar pumps.

2.6.2 Valves and fittings
2.6.2.1 Valves are to be designed and manufactured according to accepted standards. For other structurally new-type valves or non-standard valves, detailed drawings and information are to be submitted.
2.6.2.2 The strength of valves and fittings in piping system is to be appropriate to the strength required by the connected pipes and is to be able to work efficiently under the maximum working pressure. Valves are to be made of steel, cast iron, copper, copper alloy or other materials suitable for the intended service.
2.6.2.3 All valves are to be so constructed as to prevent the possibility of valve bonnets or glands being slackened back or loosened when the valves are operated. Screwed-on valve bonnets are not to be used for valves with nominal diameter exceeding 40 mm in Class I and Class II piping systems, sea valves, ship-side valves and valves in flammable liquid system.
2.6.2.4 Valves on board ships are to be of such construction that the closing of which is obtained by clockwise rotation of the hand wheel, and the opening by counter-clockwise rotation.
2.6.2.5 Indicators are to be provided to show the open and closing condition of the valves, unless this can be observed in some other way; for remotely controlled valves, the remote control position is also to show the open and closing condition of the valve.
2.6.2.6 Valves and cocks are to be fitted with nameplates to indicate their purposes. The casing of non-return valves is to be permanently marked with flow direction.
2.6.2.7 The welded necks on the valve bodies are to be long enough to ensure that the valves will not deform due to welding and subsequent heat treatment of the joints.
2.6.2.8 All valves are to be subject to hydraulic tests in workshop. The hydraulic test pressure is to be 1.5 times the design pressure.

2.6.3 Air pipe closing devices
2.6.3.1 Where air pipes are required by 1.12.7.5 of PART TWO of the Rules to be fitted with automatic closing devices, they are to be designed, manufactured and tested in accordance with the requirements of Appendix 4 of this Chapter.

Section 7 TESTS

2.7.1 Hydraulic tests for piping prior to installation on board
2.7.1.1 All Classes I and II pipes and their associated fittings and, all steam pipes, feed pipes, compressed air pipes and fuel oil pipes having a design pressure greater than 0.35 MPa together with their fittings are to be hydraulically tested after completion of manufacture and before insulating and coating.
2.7.1.2 The hydraulic test pressure P_s is not to be less than that determined by the following formula:

$$P_s = 1.5\,p \qquad \text{MPa}$$

where: p — design pressure, in MPa, see 2.1.3 of this Chapter.

2.7.1.3 For steel pipes and integral fittings for use in systems where the design temperature exceeds 300℃, test pressure P_s is to be determined by the following formula, but need not exceed 2 p.

$$P_S = 1.5\frac{[\sigma]_{100}}{[\sigma]_t}p \qquad \text{MPa}$$

where: p — as defined in 2.7.1.2;
$[\sigma]_{100}$ — permissible stress for 100℃, in N/mm^2;
$[\sigma]_t$ — permissible stress for the design temperature, in N/mm^2.

The test pressure may be reduced to 1.5 p where it is necessary to avoid excessive stress in way of bends

and T-connections. In no case is the membrane stress to exceed 90% of the yield stress at the testing temperature.
2.7.1.4 When the hydraulic test of piping is carried out on board, it may be carried out concurrently with the tightness tests required after assembly on board.
2.7.1.5 For pipes with an internal diameter less than 15 mm, the hydraulic test may be waived.
2.7.1.6 When, for technical reasons, it is not possible to carry out complete hydraulic test for all sections piping, prior to assembly on board, applications are to be submitted to CCS for approval for testing the closing lengths of piping, particularly in respect to closing seams.

2.7.2 Hydraulic tests for valves and fittings prior to installation on board

2.7.2.1 Valves and fittings non-integral with the piping system, intended for Classes I and II, are to be hydraulically tested in accordance with recognized standards, but the test pressure is not to be less than 1.5 times the design pressure.
Valves, cocks and distance pieces intended to be fitted on the ship side below the load waterline are to be tested by hydraulic pressure not less than 0.5 MPa.

2.7.3 Testing after assembly on board

2.7.3.1 All piping systems are to be checked for leakage under working conditions.
2.7.3.2 Liquid fuel piping, heating coils in tanks, bilge pipes in way of double bottom tanks or deep tanks and hydraulic piping are to be tested by hydraulic pressure in accordance with Table 2.7.3.2.

Hydraulic tests after assembly on board **Table 2.7.3.2**

Piping system	Test pressure
Liquid fuel piping	1.5 times design pressure, but not less than 0.4 MPa
Heating coils in tanks	
Bilge pipes in way of double bottom tanks or deep tanks	Not less than test pressure of the tank
Hydraulic piping	1.25 times design pressure, but no need to exceed design pressure plus 7 MPa

2.7.3.3 Where Classes I and II pipes are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of 2.7.1.1 to 2.7.1.4 after welding. During installation and before the hydraulic test is carried out, the pipe lengths may be insulated, except in way of the joints.
2.7.3.4 The hydraulic test required in 2.7.3.3 of this Section may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results.
2.7.3.5 Pneumatic leak testing may be carried out on water sensitive systems, in lieu of hydrostatic testing. In certain circumstances, a combined hydrostatic – pneumatic strength test may also be applied, where the system is partially filled with water and the free space above is pressurized with a test gas (typically air or nitrogen). When pneumatic tests cannot be avoided, the sufficient safety precautions are to be taken.

Section 8 ARRANGEMENT

2.8.1 Piping arrangement

2.8.1.1 All pipes are to be properly secured, and provision is to be made to avoid excessive stresses caused by thermal expansion in pipes or due to deflection of ship structure.
2.8.1.2 Penetration pieces or steel pads are to be provided for pipes passing through watertight or gastight structures. If pipes are fixed on watertight bulkhead by bolts, bolt holes are not to pass through bulkhead.
For pipes pass through deck or bulkhead with fire division, their arrangement is not to damage fire division of deck or bulkhead.
2.8.1.3 The pipe piercing the collision bulkhead below the freeboard deck (bulkhead deck for passenger ships) is to be fitted with a remotely controlled valve capable of being operated from above the freeboard deck (bulkhead deck for passenger ships). The valve is to be normally closed. If the remote control system should fail during operation of the valve, the valve is to close automatically or be capable of being closed manually from a position above the freeboard deck (bulkhead deck for passenger ships).
The above-mentioned valves are to be fitted on the forward or after side of the collision bulkhead provided that the space in which they are located is not a cargo space.

All valves are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.
2.8.1.4 The collision bulkhead may be pierced below the bulkhead deck by not more than one pipe for dealing with fluid in the forepeak tank. If the forepeak is divided to hold two different kinds of liquids, the collision bulkhead of each compartment may be allowed to be pierced below the bulkhead deck for passenger ships by one pipe.
2.8.1.5 For ships required for damage stability, the arrangement is to ensure that the continuing flooding will not extend to the compartments other than those with assumption of flooding , provided the piping system is fitted in the assumed flooding compartments.
2.8.1.6 Fresh water pipes are not to be led through oil tanks, nor oil pipes through fresh water tanks. Where it is impracticable to do so, the pipes are to be led inside an oil-tight pipe tunnel.

2.8.2 Separation of tanks
2.8.2.1 Where the following tanks are adjacent to each other, they are to be separated by cofferdams:
(1) lubricating oil tanks and fresh water tanks;
(2) boiler feed water tanks and fuel oil tanks;
(3) fresh water tanks and fuel oil tanks;
(4) boiler feed water tanks and lubricating oil tanks.
2.8.2.2 Where the fuel oil tank is directly adjacent to lubricating oil tank, the welding of the adjacent bulkhead is to be of full penetration type.

2.8.3 Corrosion protection
2.8.3.1 Steel pipes are to be protected against corrosion, and protective coatings are to be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

2.8.4 Fire protection
2.8.4.1 Air, overflow and sounding pipes for fuel oil tanks are not to be led through living quarters. Where this is not practicable, no detachable pipe joint is permissible in these spaces.
2.8.4.2 All steam, oil and water pipes as well as oil and other liquid tanks are not to be placed above or behind the switchboard. If this is not practicable, suitable protective means are to be provided.
In addition, oil pipes and oil tanks are not to be directly placed above the boilers, uptakes, steam pipes, exhaust gas pipes and silencers. If this is impracticable, effective means are to be made to prevent oil dropping onto the hot surfaces of the above-mentioned pipes or equipment.

2.8.5 Protection
2.8.5.1 Seawater pipes in cargo holds for dry cargoes, including cargo spaces of container ships, ro-ro ships, are to be protected from impact of cargo where they are liable to be damaged.
2.8.5.2 All pipes, fittings, pumps, filters and other equipment of piping systems are to be provided with drain valves or cocks where necessary.
2.8.5.3 The pipes which may be subject to a pressure greater than the design value are to be fitted with relief valves at the delivery side of pumps. The discharge from relief valves fitted in oil pipelines is to be led to the suction side of pumps or tanks. Heaters and air compressor coolers are also to be fitted with relief valves. The releasing pressure of relief valves is, in general, not to be greater than the design pressure of pipelines.
2.8.5.4 Where pressure-reducing valves are fitted in the pressure piping, a relief valve and a pressure gauge are to be fitted behind the pressure-reducing valve and a by-pass pipe fitted with a screw-down valve is to be provided. Or, at least an additional spare pressure reducing valve for replacement at any time is to be provided. The provision of pressure-reducing valves in the gas supply piping of the control system and relevant requirements are given in 2.2.2.2, PART SEVEN of the Rules.

2.8.6 Insulation
2.8.6.1 The insulation lagged on the machinery surfaces with a temperature over 220℃ is to comply with the provisions in 1.3.6.3 of this PART. The insulation in way of dismountable joints and valves is to be easily renewed.
2.8.6.2 Pipes passing through refrigerated spaces (including fish rooms), excluding those intended to serve such spaces, are to be well insulated to prevent freezing and from the steel structure.
2.8.6.3 Where the pipes pass through chambers intended for temperatures of 0℃ or below, they are in general to be insulated from the steel structure of these chambers.

2.8.7 Compensation for expansion

2.8.7.1 Suitable provision for compensation is to be made for all pipes subject to expansion, contraction or other strain, such as bends, loops, or expansion joints as required.
2.8.7.2 The adjoining pipes are to be suitably aligned and anchored. Where necessary, expansion pieces of bellows type are to be protected against mechanical damage.
2.8.7.3 In general, slip type expansion joints are only used for pipes in spaces accessible to operators for inspection during normal navigation. Slip type expansion joints are not to be used for pipes in spaces such as dry cargo tank and deep tank which are not easy to inspect. Slip type expansion joints may be used for pipes in tanks carrying the same liquid as that in the pipes.
Slip type expansion joints are not to be used in the systems listed below:
(1) class I Piping system;
(2) oil (such as fuel oil, lubricating oil, hydraulic oil, thermal oil) pipes of Class II piping system;
(3) steering gear hydraulic system;
(4) starting air and control air system;
(5) boiler feed water system;
(6) fixed gas fire extinguishing system;
(7) bilge pipelines located in cargo hold, deep tanks and double bottom tanks;
(8) cargo oil lines located in pipe duct keels;
(9) oil pipes, such as fuel oil, lubricating oil, hydraulic oil and thermal oil, of Class III systems located in machinery spaces of category A, accommodation spaces or non-mechanically ventilated pipe duct keels;
(10) pipes passing through other tanks;
(11) exhaust system.
For detailed requirements to slip type expansion joints, see relevant provisions in 2.5.3 of Section 5 and Appendix 3 of this Chapter.

2.8.8 Installation of valves and fittings

2.8.8.1 Valves, cocks, pipes or other fittings attached direct to the plating of tanks, and to bulkheads, flats or tunnels which are required to be of watertight construction, are to be secured by means of studs screwed into but not penetrating through the pads welded on the plating. Alternatively, the studs or the bulkhead piece may be welded to the plating.
2.8.8.2 The valves and fittings fitted in engine rooms, boiler rooms, pump rooms and shaft tunnels are to be easily accessible for operation. Where the valves and fittings are situated under the floor plate not easily accessible for operation, they are to be provided with extended operating rods or tools for operation. Furthermore, holes are to be cut in the floor plate under which the valves or fittings are located and to be provided with covers.
2.8.8.3 Where relief valves are fitted in sea water systems, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.
2.8.8.4 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism. Opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.
Sea valves, ship-side valves and valves on collision bulkhead are to be permanently arranged for local manual operation.

2.8.9 Installation of ship-side valves and fittings (other than those on scuppers and sanitary discharges)

2.8.9.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell plating, or to the plating of fabricated steel sea chests attached to the shell plating. The installation of the valves or cocks is to comply with the following requirements in (1) or (2):
(1) The valves or cocks are to be secured by means of studs screwed into but not penetrating through the pads welded on the shell plating or sea chests.
(2) The valves or cocks may be secured to the distance piece welded on the shell plating or sea chests. The wall thickness of the distance piece is to comply with the requirements in Table 5.3.4.2 of this PART, or may be same as that of the shell plating in way of its penetration into the distance piece. The distance piece is to be adequately strengthened as to ensure its rigidity.
2.8.9.2 All suction and discharge valves and cocks secured direct to the shell plating of the ship are to be fitted with spigots passing through the plating, but the spigots on the valves or cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the shell plating. Blow-off valves or cocks are also to be fitted with a protection ring through which the spigot is to pass, the ring being on the outside of the shell plating.

2.8.9.3 Blow-off valves or cocks on the ship's side are to be fitted in accessible positions above the level of the working platform, and are to be provided with indicators showing whether they are open or shut.
2.8.9.4 It is to be avoided to locate the overboard discharges in way of the areas where the lifeboats and accommodation ladders are lowered. Where this is not practicable, suitable means are to be provided to prevent any discharge of water into the lifeboats or onto the accommodation ladders.
2.8.9.5 Sea inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions and, so far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut. The operating position of hand wheel or manual operating device of main sea inlet valve is to be situated not less than 450 mm above the lower platform.
If an inlet or outlet pipeline passes through wing tank, the above-mentioned ship-side valve may be installed on inner bulkhead of wing tank. The wall thickness of pipes between inner bulkhead and shell plate of wing tank is to comply with the requirements in Table 5.3.4.2 of this PART, or may be same as that of the shell plating in way of its penetration into the pipes.
2.8.9.6 Gratings are to be fitted at all openings in the ship's side for sea inlet valves and sea chests. The direction of grating bars is to be in line with the length of the ship. The net area through the gratings is not to be less than twice that of the valves connected to the sea inlets, and provision is to be made for clearing the gratings by use of low pressure steam or compressed air.
2.8.9.7 Ship-side valves and fittings as well as sea chests, if made of steel, are to be suitably protected against wastage.
2.8.9.8 Sea chests are to be so arranged as to avoid the formation of air pocket. Where a vent pipe is fitted on the top of the sea chest, a screw-down valve is to be fitted at the root of the vent pipe. The open end of the vent pipe is to be extended to a position above the bulkhead deck or to be led overboard in the vicinity of the bulkhead deck and a ship-side screw-down valve is to be fitted.
2.8.9.9 For sea connections for ships having ice notations, see relevant provisions specified in Chapter 14 of this PART.

Appendix 1 PRODUCTION AND APPLICATION OF PLASTIC PIPING SYSTEMS ON SHIPS①

1.1 Terms and Definitions of this Appendix

1.1.1 "Plastic(s)" means both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fiber reinforced plastics − FRP. Plastic(s) includes synthetic rubber and materials of similar thermos/mechanical properties.

1.1.2 "Pipes/piping systems" means those made of plastics and include the pipes, fittings, system joints, method of joining and any internal or external liners, coverings and coatings required to comply with the performance criteria.

1.1.3 "Joint" means the location at which two pieces of pipe or a pipe and a fitting are connected together. The joint may be made by adhesive bonding, laminating, welding, flanges and mechanical joints listed in Table 2.5.3.1(1), Chapter 2 of this PART.

1.1.4 "Fittings" means bends, elbows, fabricated branch pieces etc. of plastic materials.

1.1.5 "Nominal pressure" means the maximum permissible working pressure which should be determined in accordance with the requirements in 1.3.1 of this Appendix.

1.1.6 "Design pressure" means the maximum working pressure which is expected under operation conditions or the highest set pressure of any safety valve or pressure relief device on the system, if fitted.

1.1.7 "Fire endurance" means the capability of piping to maintain its strength and integrity (i.e. capable of performing its intended function) for some predetermined period of time while exposed to fire.

1.1.8 "Essential to the safety of ship" means all piping systems that in event of failure will pose a threat to personnel and the ship (piping systems essential to the safety are provided by Table 1.4.1).

1.1.9 "Essential services" are those services essential for propulsion and steering and safety of the ship as specified in 1.1.2, Chapter 1, PART FOUR of the Rules.

1.2 Scope

1.2.1 This Appendix is applicable to piping systems on ships, including pipe joints and fittings, made predominately of other material than metal.

1.2.2 The use of mechanical joints approved for the use in metallic piping systems only are not applicable in this Appendix.

1.2.3 Piping systems intended for non-essential services are to meet only the requirements of recognized standards and 1.3.1(3)②, 1.4.2, 1.5.2~1.5.7 and 1.6 of this Appendix.

1.3 General Requirements

The specification of piping is to be in accordance with a recognized national or international standard acceptable to CCS. In addition, the following requirements apply:

1.3.1 Strength

(1) The strength of the pipes is to be determined by a hydrostatic test failure pressure of a pipe specimen under the standard conditions: atmospheric pressure equal to 0.1 MPa, relative humidity 30%, environmental and carried fluid temperature 298 K (25℃).

(2) The strength of fittings and joints is not to be less than that of the pipes.

(3) The nominal pressure is to be determined from the following conditions:

① Internal Pressure

For an internal pressure, the following is to be taken whichever is smaller:

$$Pn \text{ int } \frac{c}{\lambda} Psth/4 \quad \text{or} \quad Pn \text{ int } \frac{c}{\lambda} Plth/2.5$$

where: Psth — short-term hydrostatic test pipe failure pressure, in MPa;

Plth — long-term hydrostatic test pipe failure pressure (> 100,000 h), in MPa.

② External Pressure(for any installation which may be subject to vacuum conditions inside the pipe or a head of liquid acting on the outside of the pipe; and for any pipe installation required to remain operational in case of flooding damage, as per SOLAS II-1/8-1, or for any pipes that would allow progressive flooding to other compartments through damaged piping or through open ended pipes in the compartments)

For an external pressure:

---

① It is addressed by IACS according to the provisions of IMO resolution A.753(18), as amended by IMO Res. MSC.313(88) and IMO Res. MSC. 399(95).

$$P_{n\,ext} \le P_{col}/3$$

where: Pcol — pipe collapse pressure, in MPa.

In no case is the pipe collapse pressure to be less than 0.3 MPa.

The maximum working external pressure is a sum of the vacuum inside the pipe and a head of liquid acting on the outside of the pipe.

(4) Notwithstanding the requirements of (3)① or (3)② above as applicable, the pipe or pipe layer minimum wall thickness is to follow recognized standards. In the absence of standards for pipes not subject to external pressure, the requirements of (3)② above are to be met.

(5) The maximum permissible working pressure is to be specified with due regard for maximum possible working temperatures in accordance with manufacturer's recommendations.

1.3.2 Axial Strength

(1) The sum of the longitudinal stresses due to pressure, weight and other loads is not to exceed the allowable stress in the longitudinal direction.

(2) In the case of fiber reinforced plastic pipes, the sum of the longitudinal stresses is not to exceed half of the nominal circumferential stress derived from the nominal internal pressure condition (see 1.3.1 of this Appendix).

1.3.3 Impact Resistance

(1) Plastic pipes and joints are to have a minimum resistance to impact in accordance with recognized national or international standards.

(2) After testing, the specimen is to be tested to a hydraulic pressure equal to 2.5 times the design pressure for at least 1 h.

1.3.4 Temperature

(1) The permissible working temperature depending on the working pressure is to be in accordance with manufacturer's recommendations, but in each case it is to be at least 20℃ lower than the minimum heat distortion/deflection temperature of the pipe material, determined according to ISO 75-2 method A, or equivalent, e.g. ASTMD648-18.

(2) The minimum heat distortion/deflection temperature is not to be less than 80℃.

1.4 Requirements for Pipes/Piping Systems Depending on Service and/or Locations

1.4.1 Fire Endurance

(1) Pipes and their associated joints and fittings whose integrity is essential to the safety of ships, including plastic piping required by SOLAS II-2/21.4 to remain operational after a fire casualty, are required to meet the minimum fire endurance requirements of Appendix 1 or 2, as applicable, of IMO resolution A.753 (18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95).

(2) Unless instructed otherwise by the Administration, fire endurance tests are to be carried out with specimen representative for pipes, joints and fittings[①]:

① Pipes:

- for sizes with outer diameter < 200 mm the minimum outer diameter and wall thickness[②]
- for sizes with outer diameter ≥ 200 mm one test specimen for each category of t/d (D = outer diameter, t = structural wall thickness). A scattering of ±10% for t/D is regarded as the same group. Minimum size approved is equal to the diameter of specimen successfully tested.

② Joints

- Each type of joint applicable for applied fire endurance level tested on pipe to pipe specimen.

(3) Means are to be provided to ensure a constant media pressure inside the test specimen during the fire test as specified in Appendix 1 or 2 of the IMO Res.A.753(18), as amended by IMO Resolutions MSC.313(88) and MSC.399(95). During the test it is not permitted to replace media drained by fresh water or nitrogen.

(4) Depending on the capability of a piping system to maintain its strength and integrity, there exist five different levels of fire endurance for piping systems.

① Level 1: Piping having passed the fire endurance test specified in Appendix 1 of IMO resolution A.753(18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95) for duration of

---

① A test specimen incorporating several components of a piping system may be tested in a single test.

② Test conditions are most demanding for minimum wall thickness and thus larger wall thickness is covered. A key factor determining the fire performance of a pipe component variant is the thickness-to-diameter (t/D) ratio and whether it is larger or smaller than that of the variant which has been fire-tested. If fire-protective coatings or layers are included in the variant used in the fire test, only variants with the same or greater thickness of protection, regardless of the (t/D) ratio, are to be qualified by the fire test.

a minimum of one hour without loss of integrity in the dry condition is considered to meet level 1 fire endurance standard (L1).

② Level 1W: Piping systems similar to level 1 systems except these systems do not carry flammable fluid or any gas and a maximum 5% flow loss in the system after exposure is acceptable①, which is considered to meet level 1W fire endurance standard (L1W).

③ Level 2: Piping having passed the fire endurance test specified in Appendix 1 of IMO resolution A.753(18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95) for a duration of a minimum of 30 min in the dry condition is considered to meet level 2 fire endurance standard (L2).

④ Level 2W: Piping systems similar to level 2 systems except a maximum 5% flow loss in the system after exposure is acceptable①, which is considered to meet level 2W fire endurance standard (L2W).

⑤ Level 3: Piping having passed the fire endurance test specified in Appendix 2 of IMO resolution A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95) for a duration of a minimum of 30 min in the wet condition is considered to meet level 3 fire endurance standard (L3).

(5) Permitted use of piping depending on fire endurance, location and piping system is given in Table 1.4.1.

(6) For Safe Return to Port purposes (SOLAS II-2/21.4), plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to L1 standard.

1.4.2 Flame Spread

(1) All pipes, except those fitted on open decks and within tanks, cofferdams, pipe tunnels and ducts, if separated from accommodation, permanent manned areas and escape ways by means of an A class bulkhead, are to have low surface flame spread characteristics not exceeding average values listed in Appendix 3 of IMO resolution A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95).

(2) Surface flame spread characteristics are to be determined using the procedure given in the 2010 FTP Code, Annex 1, Part 5 with regard to the modifications due to the curvilinear pipe surfaces as listed in Appendix 3 of IMO Resolution A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95).

(3) Surface flame spread characteristics may also be determined using the test procedures given in ASTM D635, or in other national equivalent standards. Under the procedure of ASTM D635 a maximum burning rate of 60 mm/min applies. In case of adoption of other national equivalent standards, the relevant acceptance criteria are to be defined.

1.4.3 Fire Protection Coatings

Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance level required, it is to meet the following requirements:

① The pipes are generally to be delivered from the manufacturer with the protective coating on.

② The fire protection properties of the coating are not to be diminished when exposed to salt water, oil or bilge slops. It is to be demonstrated that the coating is resistant to products likely to come into contact with the piping.

③ In considering fire protection coatings, such characteristics as thermal expansion, resistance against vibrations, and elasticity are to be taken into account.

④ The fire protection coatings are to have sufficient resistance to impact to retain their integrity.

1.4.4 Electrical Conductivity

Where electrical conductivity is to be ensured, the resistance of the pipes and fittings is not to exceed 1×10^5 Ω/m.

① The flow loss must be taken into account when dimensioning the system.

Fire-resistance Requirements Table 1.4.1

N piping system		Parts										
		A	B	C	D	E	F	G	H	I	J	K
		Machinery space of category A	Other machinery space and pump tank	Cargo pump room	Ro-ro cargo hold	Other cargo hold	Cargo oil tank	Fuel oil tank	Ballast tank	Cofferdam, void, tunnel and duct	Accommodation and service spaces, control room	Open deck
1	2	3	4	5	6	7	8	9	10	11	12	13
Cargo oil (flammable cargo, with flash point ≤60℃)												
1 cargo oil pipeline		NA	NA	L1	NA	NA	O	NA	O[10]	O	NA	L1[2]
2 crude oil pipeline		NA	NA	L1	NA	NA	O	NA	O[10]	O	NA	L1[2]
3 gas venting pipeline		NA	NA	NA	NA	NA	O	NA	O[10]	O	NA	×
Inert gas												
4 water-sealed discharge pipeline		NA	NA	O[1]	NA	NA	O[1]	O[1]	O[1]	O[1]	NA	O
5 detergent discharge pipe		O[1]	O[1]	NA	NA	NA	NA	NA	O[1]	O[1]	NA	O
6 main pipe		O	O	L1	NA	NA	NA	NA	NA	O	NA	L1[6]
7 distribution pipe		NA	NA	L1	NA	NA	O	NA	NA	O	NA	L1[2]
Flammable liquid (flash point > 60℃)												
8 cargo oil pipe		×	×	L1	×	×	NA[3]	O	O[10]	O	NA	L1
9 fuel oil pipe		×	×	L1	×	×	NA[3]	O	O	O	L1	L1
10 lubricating oil pipe		×	×	L1	×	×	NA	NA	NA	O	L1	L1
11 hydraulic oil pipe		×	×	L1	×	×	O	O	O	O	L1	L1
Sea water[9]												
12 bilge main and branch pipes		L1[7]	L1[7]	L1	×	×	NA	O	O	O	NA	L1
13 fire main pipe and water spry pipe		L1	L1	L1	×	NA	NA	NA	O	O	×	L1
14 foam system		L1W	L1W	L1W	NA	NA	NA	NA	NA	O	L1W	L1W
15 automatic jet system		L1W	L1W	L3	×	NA	NA	NA	O	O	L3	L3
16 ballast system		L3	L3	L3	L3	×	O[10]	O	O	O	L2W	L2W
17 essential services of cooling water		L3	L3	NA	NA	NA	NA	NA	O	O	NA	L2W
18 fixed machinery system for cleaning tank		NA	NA	L3	NA	NA	O	NA	O	O	NA	L3[2]
19 non-essential system		O	O	O	O	O	NA	O	O	O	O	O
Fresh water												
20 essential services of cooling water		L3	L3	NA	NA	NA	NA	O	O	O	L3	L3
21 condensate back water		L3	L3	L3	O	O	NA	NA	NA	O	O	O
22 non-essential system		O	O	O	O	O	NA	O	O	O	O	O
Sanitary/drainage/discharge												
23 deck drainage (inside)		L1W[4]	L1W[4]	NA	L1W[4]	O	NA	O	O	O	O	O
24 sanitary drainage (inside)		O	O	NA	O	O	NA	O	O	O	O	O
25 scupper and discharge (overboard)		O[1][8]	O[1][8]	O[1][8]	L[1][8]	O[1][8]	O	O	O	O	O[1][8]	O
Sounding/air												
26 water tank / dry space		O	O	O	O	O	O[10]	O	O	O	O	O
27 oil tank (flash point > 60℃)		×	×	×	×	×	×[3]	O	O[10]	O	×	×
Miscellaneous												
28 air pipe for control		L1[5]	L1[5]	L1[5]	L1[5]	L1[5]	NA	O	O	O	L1[5]	L1[5]
29 service air pipe (non-essential service)		O	O	O	O	O	NA	O	O	O	O	O
30 salt water pipe		O	O	NA	O	O	NA	NA	NA	O	O	O
31 auxiliary low pressure steam pipe (≤ 0.7 MPa)		L2W	L2W	O[9]	O[9]	O[9]	O	O	O	O	O[9]	O[9]
32 central vacuum		NA	NA	NA	O	NA	NA	NA	NA	O	O	O
33 exhaust Gas Cleaning		L3[1]	L3[1]	NA	NA	NA	NA	NA	NA	O	L3[1], [11]	O

N piping system	Parts										
	A	B	C	D	E	F	G	H	I	J	K
	Machinery space of category A	Other machinery space and pump tank	Cargo pump room	Ro-ro cargo hold	Other cargo hold	Cargo oil tank	Fuel oil tank	Ballast tank	Cofferdam, void, tunnel and duct	Accommodation and service spaces, control room	Open deck
System Effluent Line										NA	
34 urea Transfer/Supply System (SCR installations)	L1⑫	L1⑫	NA	NA	NA	NA	NA	NA	O	L3⑪ NA	O

Notes:

L1—Fire endurance test (Annex 1 of IMO resolution A.753(18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95)) in dry conditions, 60 min;

L2—Fire endurance test (Annex 1 of IMO resolution A.753(18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95)) in dry conditions, 30 min;

L3—Fire endurance test (Annex 2 of IMO resolution A.753(18) , as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95)) in wet conditions, 30 min;

L1W—Fire endurance test (see 1.4.1(2) of this Appendix);

L2W—Fire endurance test(see 1.4.1(2) of this Appendix);

O — No fire endurance test required;

NA—Not applicable;

× — Metallic materials having a melting point greater than 925℃.

① Where non-metallic piping is used, remotely controlled valves to be provided at ship's side (valve is to be controlled from outside space).

② Remote closing valves to be provided at the cargo tanks.

③ When cargo tanks contain flammable liquids with f.p. > 60 ℃, "O" may replace "NA" or "×".

④ For drains serving only the space concerned, "O" may replace "L1W".

⑤ When controlling functions are not required in statutory requirements or guidelines, "O" may replace "L1".

⑥ For pipe between machinery space and deck water seal, "O" may replace "L1".

⑦ For passenger vessels, "×" is to replace "L1".

⑧ Scuppers serving open decks in positions 1 and 2, as defined in regulation 13 of the Protocol of 1988 relating to the International Convention on Load Lines, 1966, should be "×" throughout unless fitted at the upper end with the means of closing capable of being operated from a position above the freeboard deck in order to prevent down-flooding.

⑨ For essential services, such as fuel oil tank heating and ship's whistle, "×" is to replace "O".

⑩ For tankers where compliance with paragraph 3.6, regulation 19 of Annex I of MARPOL is required, "NA" is to replace "O".

⑪ L3 in service spaces, NA in accommodation and control spaces.

⑫ Type Approved plastic piping without fire endurance test (0) is acceptable downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire.

⑬ For Passenger Ships subject to SOLAS II-2, Reg.21.4 (Safe return to Port), plastic pipes for services required to remain operative in the part of the ship not affected by the casualty thresholds, such as systems intended to support safe areas, are to be considered essential services. In accordance with MSC Circular MSC.1/Circ.1369, interpretation 12, for Safe Return to Port purposes, plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to L1 standard.

Location Definition:

A —Machinery spaces of category A: Machinery spaces of category A as defined in SOLAS① II-2/3.31.

B—Other machinery spaces: Spaces, other than category A machinery spaces and cargo pump rooms, containing propulsion machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.

C—Cargo pump rooms: Spaces containing cargo pumps and entrances and trunks to such spaces.

D—Ro-ro cargo holds: Ro-ro cargo holds are ro-ro cargo spaces and special category spaces as defined in SOLAS① regulation II-2/3.41 and 3.46.

E—Other dry cargo holds: All spaces other than ro-ro cargo holds used for non-liquid cargo and trunks to such spaces.

F—Cargo tanks: All spaces used for liquid cargo and trunks to such spaces.

G—Fuel oil tanks: All spaces used for fuel oil (excluding cargo tanks) and trunks to such spaces.

H—Ballast water tanks: All spaces used for ballast water and trunks to such spaces.

I— Cofferdams, voids, etc.: Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments.

J—Accommodation and service spaces: Accommodation spaces, service spaces and control stations as defined in SOLAS①

① SOLAS Chapter II-2.

regulation II-2/3.1, 3.45, 3.18.
K—Open decks: Open deck spaces as defined in SOLAS① regulation II-2/9.2.2.3.2(5).

1.5 Material Approval and Quality Control During Manufacture

1.5.1 Except as required in 1.2.3 of this Appendix, Prototypes of pipes and fittings are to be tested to determine short-term and long-term design strength, fire endurance and low surface flame spread characteristics (if applicable), electrical resistance (for electrically conductive pipes), impact resistance in accordance with this Appendix.

1.5.2 For prototype testing, representative samples of pipes and fittings are to be selected to the satisfaction of CCS.

1.5.3 The manufacturer is to have quality system that meets ISO 9000 series standards or equivalent.

The quality system is to consist of elements necessary to ensure that pipes and fittings are produced with consistent and uniform mechanical and physical properties.

1.5.4 Each pipe and fitting is to be tested by the manufacturer at a hydrostatic pressure not less than 1.5 times the nominal pressure. Alternatively, for pipes and fittings not employing hand lay-up techniques, the hydrostatic pressure test may be carried out in accordance with the hydrostatic testing requirements stipulated in the recognized national or international standard accepted by CCS to which the pipe or fittings are manufactured, provided that there is an effective quality system in place.

1.5.5 Pipes and fittings are to be permanently marked with identification. Identification is to include pressure ratings, the design standards that the pipe or fitting is manufactured in accordance with, and the material of which the pipe or fitting is made.

1.5.6 In case the manufacturer does not have an approved quality system complying with ISO 9000 series or equivalent, pipes and fittings are to be tested in accordance with this Appendix to the satisfaction of the Surveyors for every batch of pipes.

1.5.7 Depending upon the intended application, CCS may require the pressure testing of each pipe and/or fitting.

1.6 Installation

1.6.1 Supports

(1) Selection and spacing of pipe supports in shipboard systems are to be determined as a function of allowable stresses and maximum deflection criteria. Support spacing is not to be greater than the pipe manufacturer's recommended spacing. The selection and spacing of pipe supports are to take into account pipe dimensions, pipe length, mechanical and physical properties of the pipe material, mass of pipe and contained fluid, external pressure, operating temperature, thermal expansion effects, loads due to external forces, thrust forces, water hammer, vibrations, maximum accelerations to which the system may be subjected. Combination of loads is to be considered.

(2) Each support is to evenly distribute the load of the pipe and its contents over the full width of the support. Measures are to be taken to minimize wear of the pipes where they contact the supports.

(3) Heavy components in the piping system such as valves and expansion joints are to be independently supported.

1.6.2 Expansion

(1) Suitable provision is to be made in each pipeline to allow for relative movement between pipes made of plastic and the steel structure, having due regard to:

① the difference in the coefficients of thermal expansion;

② deformations of the ship's hull and its structure.

(2) When calculating the thermal expansions, account is to be taken of the system working temperature and the temperature at which assembly is performed.

1.6.3 External Loads

(1) When installing the piping, allowance is to be made for temporary point loads, where applicable. Such allowances are to include at least the force exerted by a load (person) of 100 kg at mid-span on any pipe of more than 100 mm nominal outside diameter.

(2) Besides for providing adequate robustness for all piping including open-ended piping a minimum wall thickness, complying with 1.3.1 of this Appendix, may be increased taking into account the conditions encountered during service on board ships.

(3) Pipes are to be protected from mechanical damage where necessary.

1.6.4 Strength of Connections

(1) The strength of connections is not to be less than that of the piping system in which they are installed.

(2) Pipes may be assembled using adhesive-bonded, welded, flanged or other joints.

(3) Adhesives, when used for joint assembly, are to be suitable for providing a permanent seal between the

pipes and fittings throughout the temperature and pressure range of the intended application.
(4) Tightening of joints is to be performed in accordance with manufacturer's instructions.

1.6.5 Installation of Conductive Pipes

(1) In piping systems for fluids with conductivity less than 1,000 pS/m, such as refined products and distillates use is to be made of conductive pipes.
(2) Regardless of the fluid being conveyed, plastic piping is to be electrically conductive if the piping passes through a hazardous area. The resistance to earth from any point in the piping system is not to exceed 1×10^6 Ω/m. It is preferred that pipes and fittings be homogeneously conductive. Pipes and fittings having conductive layers are to be protected against a possibility of spark damage to the pipe wall. Satisfactory earthing is to be provided.
(3) After completion of the installation, the resistance to earth is to be verified. Earthing wires are to be accessible for inspection.

1.6.6 Application of Fire Protection Coatings

(1) Fire protection coatings are to be applied on the joints, where necessary for meeting the required fire endurance as for 1.4.3 of this Appendix, after performing hydrostatic pressure tests of the piping system.
(2) The fire protection coatings are to be applied in accordance with manufacturer's recommendations, using a procedure approved in each particular case.

1.6.7 Penetration of Divisions

(1) Where plastic pipes pass through A or B class divisions, arrangements are to be made to ensure that the fire endurance is not impaired. These arrangements are to be tested in accordance with Recommendations for fire test procedures for A, B and F bulkheads 2010 FTP Code, annex 1, part 3 (Res. MSC.307(88) as amended by Res.MSC.437(99)).
(2) When plastic pipes pass through watertight bulkheads or decks, the watertight integrity of the bulkhead or deck is to be maintained. For pipes not able to satisfy the requirements in 1.3.1(3)② of this Appendix, a metallic shut-off valve operable from above the freeboard deck should be fitted at the bulkhead or deck.
(3) If the bulkhead or deck is also a fire division and destruction by fire of plastic pipes may cause the inflow of liquid from tanks, a metallic shut-off valve operable from above the freeboard deck should be fitted at the bulkhead or deck.

1.6.8 Control during Installation

(1) Installation is to be in accordance with the manufacturer's guidelines.
(2) Prior to commencing the work, joining techniques are to be approved.
(3) The tests and examinations specified in this Appendix are to be completed before shipboard piping installation commences.
(4) The personnel performing this work are to be properly qualified and certified to the satisfaction of CCS.
(5) The procedure of making bonds is to include:

① materials used;
② tools and fixtures;
③ joint preparation requirements;
④ cure temperature;
⑤ dimensional requirements and tolerances;
⑥ tests acceptance criteria upon completion of the assembly.

(6) Any change in the bonding procedure which will affect the physical and mechanical properties of the joint is to require the procedure to be re-qualified.

1.6.9 Bonding Procedure Quality Testing

(1) A test assembly is to be fabricated in accordance with the procedure to be qualified and it is to consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint.
(2) When the test assembly has been cured, it is to be tested to a hydraulic pressure equal to 2.5 times the design pressure for at least 1 h. No leakage or separation of joints is allowed. The test is to be conducted so that the joint is loaded in both longitudinal and circumferential directions.
(3) Selection of the pipes used for test assembly, is to be in accordance with the following:

① When the largest size to be joined is 200 mm nominal outside diameter, or smaller, the test assembly is to be the largest piping size to be joined.
② When the largest size to be joined is greater than 200 mm nominal outside diameter, the size of the test assembly is to be either 200 mm or 25% of the largest piping size to be joined, whichever is greater.

(4) When conducting performance qualifications, each bonder and each bonding operator are to make up test assemblies, the size and number of which are to be as required above.

1.6.10 Testing after Installation on Board

(1) Piping systems for essential services are to be tested to a pressure equal to 1.5 times the design pressure or 0.4 MPa, whichever is greater. Notwithstanding the requirement above, the requirement in 1.6.10(2) may be applied to open ended pipes (drains, effluent, etc.).
(2) Piping systems for non-essential services are to be checked for leakage under operational conditions.
(3) For piping required to be electrically conductive, earthing is to be checked and random resistance testing is to be conducted.

1.7 Test specification for plastic pipes

1.7.1 General requirements

1.7 contains requirements for the type approval of plastic pipes. It is applicable to piping systems, including pipe joints and fittings, made predominately of other material than metal.

1.7.2 Documentation

The following information for the plastic pipes, fittings and joints is to be submitted for consideration and approval:

(1) General information:
- ① Pipe and fitting dimensions;
- ② Maximum internal and external working pressure;
- ③ Working temperature range;
- ④ Intended services and installation locations;
- ⑤ The level of fire endurance;
- ⑥ Electrically conductive;
- ⑦ Intended fluids;
- ⑧ Limits on flow rates;
- ⑨ Serviceable life;
- ⑩ Installation instructions;
- ⑪ Details of marking.

(2) Drawings and supporting documentation:
- ① Certificates and reports for relevant tests previously carried out;
- ② Details of relevant standards;
- ③ All relevant design drawings, catalogues, data sheets, calculations and functional descriptions;
- ④ Fully detailed sectional assembly drawings showing pipe, fittings and pipe connections.

(3) Materials(as applicable):
- ① The resin type;
- ② Catalyst and accelerator types, and concentration employed in the case of reinforced polyester resin pipes or hardeners where epoxide resins are employed;
- ③ A statement of all reinforcements employed where the reference number does not identify the mass per unit area or the tex number of a roving used in a filament winding process, these are to be detailed;
- ④ Full information regarding the type of gel-coat or thermoplastic liner employed during construction, as appropriate;
- ⑤ Cure / post-cure conditions. The cure and post-cure temperatures and times employ resin / reinforcement ratio;
- ⑥ Winding angle and orientation.
- ⑦ Joint bonding procedures and qualification tests results, see 1.6.8(5) of this Appendix.

1.7.3 Testing

Testing is to demonstrate compliance of the pipes, fittings and joints for which type approval is sought with the requirement of this Appendix.

Pipes, joints and fittings are to be tested for compliance with the requirements of standards① acceptable to CCS.

① For the list of standards refer to IACS Recommendation No.86.

Appendix 2 FLEXIBLE HOSES

1.1 Definition

1.1.1 Flexible hose assembly① means short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

Note: Flexible hose assemblies for essential services or containing either flammable or toxic media are not to exceed 1.5 m in length.

1.2 Scope

1.2.1 This Appendix applies to flexible hoses of metallic or non-metallic material intended for a permanent connection between a fixed piping system and items of machinery. This Appendix may also be applied to temporary connected flexible hoses or hoses of portable equipment.

1.2.2 Flexible hose assemblies satisfying the requirements of this Appendix may be accepted for use in oil fuel, lubricating, hydraulic and thermal oil systems, fresh water and sea water cooling systems, compressed air systems, bilge and ballast systems and Class III steam systems. Flexible hoses in high pressure fuel oil injection systems are not to be accepted.

1.2.3 This Appendix is not applicable to hoses intended to be used in fixed fire extinguishing systems.

1.3 Design and construction

1.3.1 Flexible hoses constructed of rubber materials and intended for use in bilge, ballast, compressed air, oil fuel, lubricating, hydraulic and thermal oil systems are to incorporate a single, double or more, closely woven integral wire braid or other suitable material reinforcement.

Flexible hoses of plastics materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable.

Where rubber or plastics materials hoses are to be used in oil supply lines to burners, the hoses are to have external wire braid protection in addition to the reinforcement mentioned above. Flexible hoses for use in steam systems are to be of metallic construction.

1.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. The end connections that do not have a flange are to comply with the requirements of 2.5.3 of this Chapter as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

1.3.3 The use of hose clamps and similar types of end attachments is not acceptable for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding.

In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 0.5 MPa and provided there are double clamps at each end connection.

1.3.4 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 1.5 of this Appendix are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

1.3.5 The following flexible hose assemblies constructed of non-metallic materials are to be of fire-resistant type②, except in cases where such hoses are installed on open decks, as defined in SOLAS regulation II-2/9.2.3.3.2.2(10) as amended by IMO resolutions up to MSC.421(98) and not used for fuel oil lines:

(1) used for flammable media;

(2) used for sea water systems where failure may result in flooding.

1.3.6 Flexible hose assemblies are to be selected for the intended location and application taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions.

1.4 Installation

1.4.1 In general, flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

---

① Flexible hoses are to be designed and manufactured according to the recognized national or international standards.

② Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

1.4.2 Flexible hose assemblies are not to be installed where they may be subjected to torsion deformation (twisting) under normal operating conditions.
1.4.3 The number of flexible hoses, in piping systems mentioned in 1.2.2 is to be kept to minimum and to be limited for the purpose stated in 1.2.1.
1.4.4 Where flexible hoses are intended to be used in piping systems conveying flammable fluids that are in close proximity of heated surfaces the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other similar protection.
1.4.5 Flexible hoses are to be installed in clearly visible and readily accessible locations.
1.4.6 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:
(1) orientation;
(2) end connection support (where necessary);
(3) avoidance of hose contact that could cause rubbing and abrasion;
(4) minimum bend radii.

1.5 Tests
1.5.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programs for flexible hose assemblies are to be submitted for approval and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.
1.5.2 The tests are, as applicable, to be carried out on different nominal diameters of hose type complete with end fittings for pressure, burst, impulse resistance and fire resistance in accordance with the requirements of the relevant standard①.
Note:
Prototype tests are to be carried out for each size of hose assembly. However, for ranges with more than 3 different diameters, the prototype tests are to be carried out for at least:
(1) the smallest diameter,
(2) the largest diameter,
(3) Intermediate diameters selected based on the principle that prototype tests carried out
for a hose assembly with a diameter D are considered valid only for the diameters ranging between 0.5 D and 2 D.
For fire resistance tests the specimens shall be selected in accordance with ISO 15540.
1.5.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an international standard② to demonstrate they are able to withstand a pressure not less than four times its design pressure without indication of failure or leakage.

1.6 Marking
1.6.1 Flexible hoses are to be permanently marked with the following details:
(1) hose manufacturer's name or trademark;
(2) date of manufacture (month / year);
(3) designation type reference;
(4) nominal diameter;
(5) pressure rating;
(6) temperature rating.
Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

---

① The following standards are to be used as applicable:
(1) ISO 6802 – Rubber and plastics hoses and hose assemblies with wire reinforcements – Hydraulic impulse test with flexing;
(2) ISO 6803 – Rubber or plastics hoses and hose assemblies with wire reinforcements 15 test without flexing;
(3) ISO 15540 – Ships and marine technology – Fire resistance of hose assemblies – Test methods;
(4) ISO 15541 – Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench;
(5) ISO 10380 – Pipework – Corrugated metal hoses and hose assemblies.

② The international standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 × MWP.

Appendix 3 TYPE APPROVAL OF MECHANICAL JOINTS

1.1 General

1.1.1 This Appendix describes the type testing condition for type approval of mechanical joints intended for use in marine piping systems. Conditions outlined in these requirements are to be fulfilled before Type Approval Certificates are issued.

Alternative testing in accordance with national or international standards may also be accepted.

1.2 Scope

1.2.1 This Appendix is applicable to mechanical joints defined in 2.5.3 of this Chapter, including compression couplings and slip-on joints of different types for marine use.

1.3 Documentation

1.3.1 Following documents and information are to be submitted by manufacturer for assessment and/or approval:

(1) product quality assurance system implemented;

(2) complete description of the product;

(3) typical sectional drawings with all dimensions necessary for evaluation of joint design;

(4) complete specification of materials used for all components of the assembly;

(5) proposed test procedure as required in 1.5 of this Appendix and corresponding test reports or other previous relevant tests;

(6) initial information:

① maximum design pressures (pressure and vacuum);

② maximum and minimum design temperatures;

③ conveyed media;

④ intended services;

⑤ maximum axial, lateral and angular deviation, allowed by manufacturer;

⑥ installation details.

1.4 Materials

1.4.1 The materials used for mechanical joints are to comply with the requirements of 2.5.3.3 of this Chapter.

1.4.2 The manufacturer has to submit evidence to substantiate that all components are adequately resistant to working the media at design pressure and temperature specified.

1.5 Testing, procedures and requirements

The aim of tests is to demonstrate ability of the pipe joints to operate satisfactory under intended service conditions. The scope and type of tests to be conducted (e.g. applicable tests), sequence of testing, and the number of specimen, is subject to approval and will depend on joint design and its intended service in accordance with the requirements of this Appendix.

Unless otherwise specified, the water or oil as test fluid is to be used.

1.5.1 Test program

Testing requirements for mechanical joints are to be as indicated in Table 1.5.1.

1.5.2 Selection of test specimen

Test specimens are to be selected from production line or at random from stock.

Where there is a variety of size of joints requiring approval, a minimum of three separate sizes, representative of the range, from each type of joint to be tested in accordance with Table 1.5.1 are to be selected.

1.5.3 Mechanical Joint Assembly

Assembly of mechanical joints should consist of components selected in accordance with 1.5.2 and the pipe sizes appropriate to the design of the joints.

Where pipe material would affect the performance of mechanical joints, the selection of joints for testing is to take the pipe material into consideration.

Where not specified, the length of pipes to be connected by means of the joint to be tested is to be at least five times the pipe diameter. Before assembling the joint, conformity of components to the design requirements, is to be verified. In all cases the assembly of the joint is to be carried out only according to he manufacturer’s instructions. No adjustment operations on the joint assembly, other than that specified by

the manufacturer, are permitted during the test.

Test Procedures of Mechanical Joints **Table 1.5.1**

Tests		Types of Mechanical Joints			Notes and references
		Compression couplings and pipes unions	Slip-on joints		
			Grip type & slip type machined grooved type	Slip type	
1	Tightness test	×	×	×	1.5.5(1)
2	Vibration (fatigue) test	×	×	–	1.5.5(2)
3	Pressure pulsation test①	×	×	–	1.5.5(3)
4	Burst pressure test	×	×	×	1.5.5(4)
5	Pull-out test	×	×	–	1.5.5(5)
6	Fire endurance test	×	×	×	1.5.5(6), if required by 2.5.3.7 of this Chapter
7	Vacuum test	×③	×	×	1.5.5(7), for suction lines only
8	Repeated assembly test	×②	×	–	1.5.5(8)

Abbreviations: × test is required
– test is not required

Notes:

① For use in all Class I and II systems and those Class III systems where pressure pulsation other than water hammer is expected.

② Except permanent joint type (e.g., press and swage type).

③ Except joints with metal-to-metal tightening surface.

1.5.4 Test results acceptance criteria

Where a mechanical joint assembly does not pass all or any part of the tests in Table 1.5.1, two assemblies of the same size and type that failed are to be tested and only those tests which mechanical joint assembly failed in the first instance, are to be repeated. In the event where one of the assemblies fails the second test, that size and type of assembly is to be considered unacceptable.

The methods and results of each test are to be recorded and reproduced as and when required.

1.5.5 Methods of tests

(1) Tightness test

In order to ensure correct assembly and tightness of the joints, all mechanical joints are to be subject to a tightness test, as follows:

① Mechanical joint assembly test specimen is to be connected to the pipe or tubing in accordance with the requirements of 1.5.3 and the manufacturer's instructions, filled with test fluid and de-aerated.
Mechanical joints assemblies intended for use in rigid connections of pipe lengths, are not to be longitudinally restrained.
Pressure inside the joint assembly is to be slowly increased to 1.5 times of design pressure. This test pressure is to be retained for a minimum period of 5 min.
In the event where there is a drop in pressure or there is visual indication of leakage, the test (including fire test) is to be repeated for two test pieces. Where one test piece fails in the repeat test, the coupling will be regarded as having failed.
Other alternative tightness test procedure, such as pneumatic test, may be accepted.

② For compression couplings, a static gas pressure test is to be carried out to demonstrate the integrity of the mechanical joints assembly for tightness under the influence of gaseous media. The pressure is to be raised to maximum pressure or 7.0 MPa, whichever is less.

③ Where the tightness test is carried out using gaseous media as permitted in ① above, then the static pressure test mentioned in ② above need not be carried out.

(2) Vibration (fatigue) test

In order to establish the capability of the mechanical joint assembly to withstand fatigue, which is likely to occur due to vibrations under service conditions, mechanical joints assembly is to be subject to the following vibration test.

Conclusions of the vibration tests should show no leakage or damage.

① Testing of compression couplings and pipe unions
Compression couplings and pipe unions intended for use in rigid pipe connections are to be tested in accordance with this method described as follows.
Rigid connections are joints, connecting pipe length without free angular or axial movement.
Two lengths of pipe is to be connected by means of the joint to be tested. One end of the pipe is to be rigidly fixed while the other end is to be fitted to the vibration rig. The test rig and the joint

assembly specimen being tested is to be arranged as shown in Figure 1.

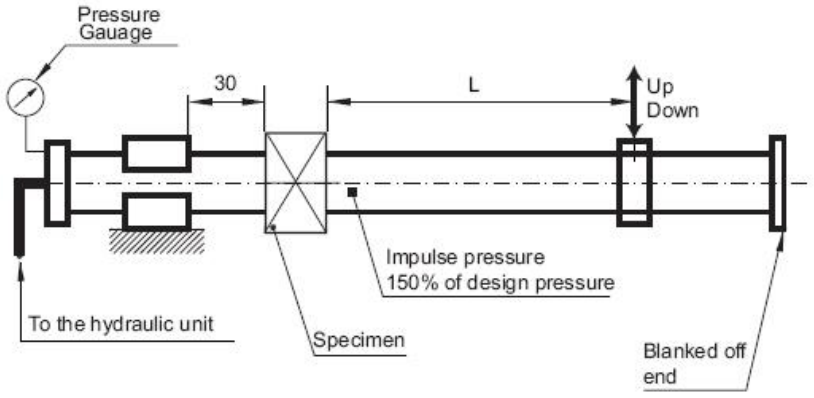


Figure 1

The assembly is to be filled with test fluid, de-aerated and pressurized to the design pressure of the joint.

Pressure during the test is to be monitored. In the event of drop in the pressure and visible leakage, the test is to be repeated as described in 1.5.4 of this Appendix.

Visual examination of the joint assembly is to be carried out.

Re-tightening may be accepted once during the first 1,000 cycles.

Vibration amplitude is to be within 5% of the value calculated from the following formula:

$$A = \frac{2SL^2}{3ED}$$

where: A – single amplitude, in mm;
L – length of the pipe, in mm;
S – allowable bending stress in N/mm^2 based on 0.25 of the yield stress;
E – modulus of elasticity of tube material (for mild steel, E = 210 kN/mm^2);
D – outside diameter of tube, in mm.

Test specimen is to withstand not less than 10^7 cycles with frequency 20 to 50 Hz without leakage or damage.

② Grip type and machine grooved type joints

Grip type joints and other similar joints containing elastic elements are to be tested in accordance with the following method.

A test rig of cantilever type used for testing fatigue strength of components may be used. The test specimen being tested is to be arranged in the test rig as shown in Figure 2.

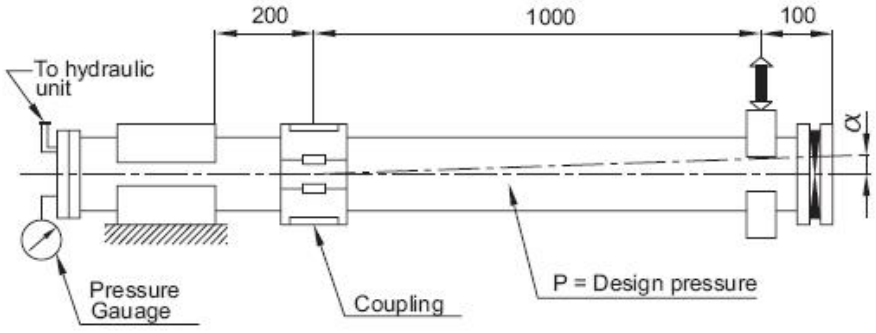


Figure 2

Two lengths of pipes are to be connected by means of joint assembly specimen to be tested. One end of the pipe is to be rigidly fixed while the other end is to be fitted to the vibrating element on the rig.

The length of pipe connected to the fixed end should be kept as short as possible and in no case exceeds 200 mm.

Mechanical joint assemblies are not to be longitudinally restrained.

The assembly is to be filled with test fluid, de-aerated and pressurized to the design pressure of the joint. Preliminary angle of deflection of pipe axis is to be equal to the maximum angle of deflection, recommended by the manufacturer. The amplitude is to be measured at 1 m distance from the center line of the joint assembly at free pipe end connected to the rotating element of the rig (see Figure 2). Parameters of testing are to be as indicated in the table below and to be carried out on the same assembly:

Number of cycles	Amplitude, in mm	Frequency, in Hz
3×10^6	± 0.06	100
3×10^6	± 0.5	45
3×10^6	± 1.5	10

Pressure during the test is to be monitored. In the event of a drop in the pressure or visible leakage, the test is to be repeated as described in 1.5.4 of this Appendix.

Visual examination of the joint assembly is to be carried out.

(3) Pressure pulsation test

In order to determine capability of mechanical joint assembly to withstand pressure pulsation likely to occur during working conditions, joint assemblies intended for use in rigid connections of pipe lengths, are to be tested in accordance with the following method.

The mechanical joint test specimen for carrying out this test may be the same as that used in the test in 1.5.5(1) provided it passed that test.

The vibration test in 1.5.5(2) and the pressure pulsation test are to be carried out simultaneously for compression couplings and pipe unions.

The mechanical joint test specimen is to be connected to a pressure source capable of generating pressure pulses of magnitude as shown in Figure 3.

Impulse pressure is to be raised from 0 to 1.5 times the design pressure of the joint with a frequency equal to 30 to 100 cycles per minute. The number of cycles is not to be less than 5×10^5.

The mechanical joint is to be examined visually for sign of leakage or damage during the test.

(4) Burst pressure test

In order to determine the capability of the mechanical joint assembly to withstand a pressure as stated by 2.5.3.8 of this Chapter, the following burst test is to be carried out.

Mechanical joint test specimen is to be connected to the pipe or tubing in accordance with the requirements of 1.5.3, filled with test fluid, de-aerated and pressurized to test pressure with an increasing rate of 10% per minute or test pressure. The mechanical joint assembly intended for use in rigid connections of pipe lengths is not to be longitudinally restrained.

Duration of this test is not to be less than 5 min at the maximum pressure. This pressure value is to be in compliance with the requirements of 2.5.3.8 of this Chapter.

Where considered convenient, the mechanical joint test specimen used in tightness test in 1.5.5(1) may be used for the burst test provided it passed the tightness test.

The specimen may have small deformation whilst under test pressure, but no leakage or visible cracks are permitted.

(5) Pull-out test

In order to determine ability of a mechanical joint assembly to withstand axial load likely to be encountered in service without the connecting pipe from becoming detached, following pull-out test is to be carried out.

Pipes of suitable length are to be fitted to each end of the mechanical joints assembly test specimen. The test specimen is to be pressurized to design pressure. When pressure is attained, an external axial load is to be imposed with a value calculated by the following formula:

$$L = \frac{\pi}{4} D^2 p$$

where: D – pipe outside diameter, in mm;

p – design pressure, in N/mm^2;

L – applied axial load, in N.

The pressure and axial load are to be maintained for a period of 5 min.

During the test, pressure is to be monitored and relative movement between the joint assembly and the pipe is to be measured.

The mechanical joint assembly is to be visually examined for drop in pressure and signs of leakage or damage.

There are to be no movement between mechanical joint assembly and the connecting pipes.

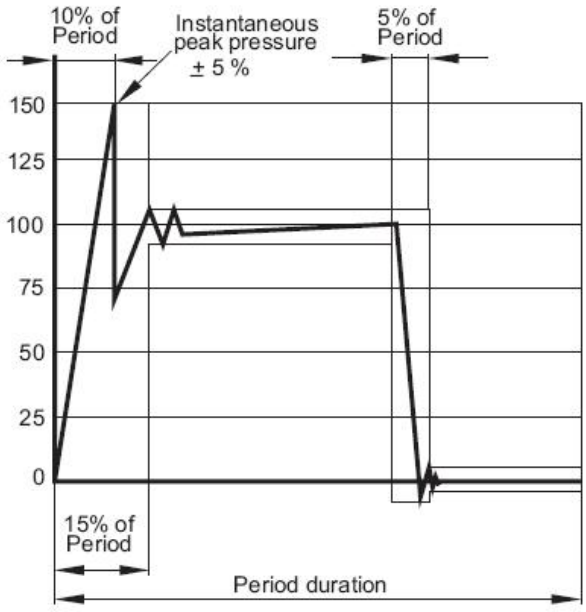


Figure 3 Impulse pressure diagram

(6) Fire endurance test

In order to establish capability of the mechanical joints to withstand effects of fire which may be encountered in service, mechanical joints are to be subjected to a fire endurance test. The fire endurance test is to be conducted on the selected test specimens as per the following standards.

ISO 19921: Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods.

ISO 19922: Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench.

Clarifications to the standard requirements in ISO19921, Paragraphs 7.2, 7.4, 7.6 and 7.7:

① If the fire test is conducted with circulating water at a pressure different from the design pressure of the joint (however of at least 5 bar), the subsequent pressure test is to be carried out to 1.5 times the design pressure.

② If the fire test is required in Table 2.5.3.1(2) to be “8 min dry + 22 min wet” or “30 min dry”, i.e. conducted for a period of time without circulating of water, the following test conditions apply:

a. Test condition “8 min dry + 22 min wet”

The test piece is not required to be rinsed with the test medium (water) in preparation for the test as required in Paragraph 7.2 of ISO 19921. The exposure to fire is to be started and continued for 8 minutes with the sample dry; after 8 minutes of dry test condition the piping system is to be filled with water and test pressure is to be increased up to at least 5 bar within 2 minutes, then maintained to at least 5 bar. After further 22 minutes (i.e. 30 minutes from initial exposure to fire) the exposure to fire is to be stopped and a hydrostatic pressure test as specified in ① is to be carried out.

b. Test condition “30 min dry”

The exposure to fire is to be started and continued for 30 minutes with the sample dry. After 30 minutes the exposure to fire is to be stopped and a hydrostatic pressure test as specified in ① is to be carried out.

Note:

For fire tests in dry condition the pressure inside the test specimen is to be monitored for a rise due to heating of the enclosed air. Means of pressure relief should be provided where deemed necessary.

High pressures created during this test can result in failure of the test specimen. Precautions shall be taken to protect personnel and facilities.

Paragraph 7.5 of ISO 19921 does not apply to the dry tests and no forced air circulation is to be arranged.

For fire endurance test requiring exposure time greater than 30 minutes test conditions are adjusted to meet the extended required total exposure time. In all cases for dry-wet test the minimum dry test exposure time is 8 minutes.

③ A selection of representative nominal bores may be tested in order to evaluate the fire resistance of a series or range of mechanical joints of the same design. When a mechanical joint of a given nominal bore (D_n) is so tested then other mechanical joints falling in the range D_n to $2 \times D_n$ (both inclusive) are considered accepted.

④ Alternative test methods and/or test procedures considered to be at least equivalent may be accepted in cases where the test pieces are too large for the test bench and cannot be completely enclosed by the flames.

⑤ Where thermal insulation is acceptable as a means of providing fire resistance, following requirements apply:

a. Thermal insulation materials applied on couplings are to be non-combustible according to ISO 1182 as required by the Fire Test Procedures Code defined in Regulation 3 of SOLAS Chapter II-2 as amended by IMO resolutions up to MSC.421(98).
Precautions are to be taken to protect the insulation from being impregnated with flammable oils.

b. At least the fire endurance and the vibration testing in Table 1.5.1 are to be carried out with thermal insulation in place.

c. A service restriction is to be stated on the type approval certificate that the mechanical joints are to be fitted with thermal insulation during the installation in cases where the mechanical joints are used where fire resistance is required, unless mechanical joints are delivered already fitted with thermal insulation before installation.

(7) Vacuum test

In order to establish capability of mechanical joint assembly to withstand internal pressures below atmosphere, similar to the conditions likely to be encountered under service conditions, following vacuum test is to be carried out.

Mechanical joint assembly is to be connected to a vacuum pump and subjected to a pressure 0.0170 MPa absolute. Once this pressure is stabilized, the test specimens under test are to be isolated from the vacuum pump and this pressure is to be maintained for a period of 5 min.

No internal pressure rise is permitted.

(8) Repeated assembly test

Mechanical joint test specimens are to be dismantled and reassembled 10 times in accordance with manufacturer’s instructions and then subject to a tightness test as defined in 1.5.5(1).

Appendix 4 AIR PIPE CLOSING DEVICES

1.1 General requirements

1.1.1 Where air pipes are required by the Rules or the International Convention on Load Lines, 1966 or the Protocol of 1988 relating to the International Convention on Load Lines, 1966 to be fitted with automatic closing devices, they are to comply with the following.

1.2 Design

1.2.1 Air pipe automatic closing devices are to be so designed that they will withstand both ambient and working conditions, and be suitable for use at inclination up to and including ±40°.

1.2.2 Air pipe automatic closing devices are to be constructed to allow inspection of the closure and the inside of the casing as well as changing the seals.

1.2.3 Efficient ball or float seating arrangements are to be provided for the closures. Bars, cage or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state and made in such a way that the ball or float is not damaged when subjected to water impact due to a tank being overfilled.

1.2.4 Air pipe automatic closing devices are to be self-draining.

1.2.5 The clear area through an air pipe closing device in the open position is to be at least equal to the area of the inlet.

1.2.6 An automatic closing device is to:

(1) prevent the free entry of water into the tank;

(2) allow the passage of air or liquid to prevent excessive pressure or vacuum coming on the tank.

1.2.7 In the case of air pipe closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim as specified in 1.2.1 of this Appendix.

1.2.8 The maximum allowable tolerances for wall thickness of floats are not to exceed ±10% of thickness.

1.2.9 The inner and the outer chambers of an automatic air pipe head is to be of a minimum thickness of 6 mm. Where side covers are provided and their function is integral to providing functions of the closing device as outlined in 1.2.6 of this Appendix, they are to have a minimum wall thickness of 6 mm. Where the air pipe head meets the tightness test in 1.4.1(2) of this Appendix without the side covers attached, such side covers are not considered to be integral to the closing device, in which case their wall thickness less than 6 mm may be acceptable.

1.3 Materials

1.3.1 Casings of air pipe closing devices are to be of approved metallic materials adequately protected against corrosion.

1.3.2 For galvanized steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 μm.

1.3.3 For areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, for example the inner chamber area above the air pipe, plus an overlap of 10° or more either side) an additional harder coating should be applied. This is to be an aluminum bearing epoxy, or other equivalent, coating, applied over the zinc.

1.3.4 Closures and seats made of non-metallic materials are to be compatible with the media intended to be carried in the tank and to seawater and suitable for operating at ambient temperatures between -25℃ and 85℃.

1.4 Type testing

1.4.1 Testing of air pipe automatic closing devices

Each type and size of air pipe automatic closing device is to be surveyed and type tested at the manufacturer's works or other acceptable location according to CCS' practice. The minimum test requirements for an air pipe automatic closing device are to include the following:

(1) Determination of the flow characteristics

The flow characteristics of the air pipe closing device are to be determined. Measuring of the pressure drop versus rate of volume flow is to be carried out using water and with any intended flame or insect screens in place.

(2) Tightness test during immersion/emerging in water

An automatic closing device is to be subject to a series of tightness tests involving not less than two immersion cycles under each of the following conditions:

① The automatic closing device is to be submerged slightly below the water surface at a velocity of approximately 4 m/min and then returned to the original position immediately. The quantity of leakage is to be recorded.

② The automatic closing device is to be submerged to a point slightly below the surface of the water. The submerging velocity is to be approximately 8 m/min and the air pipe vent head is to remain submerged for not less than 5 min. The quantity of leakage is to be recorded.

③ Each of the above tightness tests is to be carried out in the normal position as well as at an inclination of 40 degrees under the strictest conditions for the device. In cases where such strictest conditions are not clear, tests are to be carried out at an inclination of 40 degrees with the device opening facing in three different directions: upward, downward, sideways (left or right), see Figures 1 to 4.

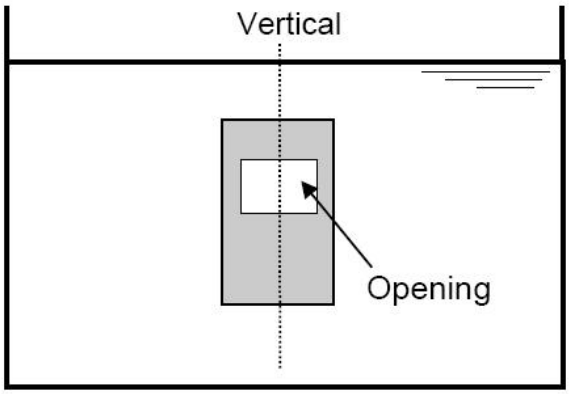


Figure 1 Example of normal position

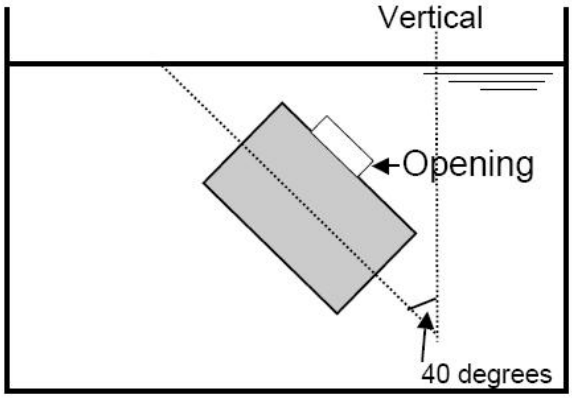


Figure 2 Example of inclination 40 degrees opening facing upward

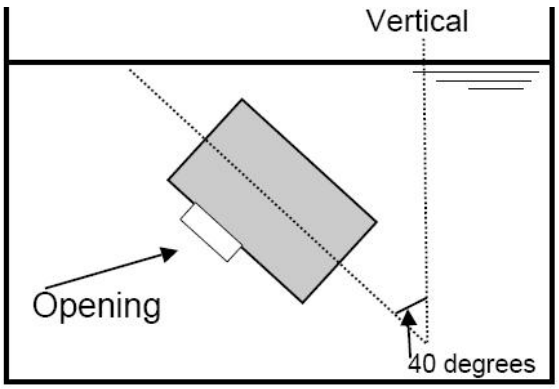


Figure 3 Example of inclination 40 degrees opening facing downward

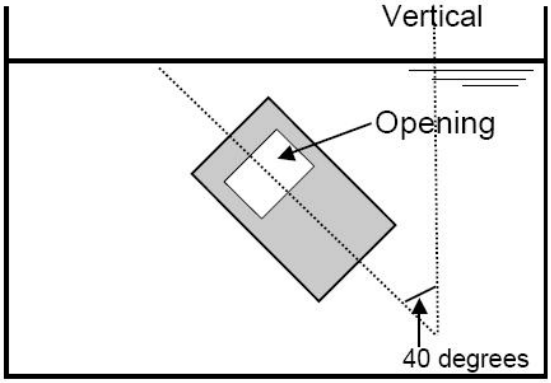


Figure 4 Example of inclination 40 degrees opening facing sideways

The maximum allowable leakage per cycle is not to exceed 2 m*l*/mm of nominal diameter of inlet pipe during any individual test.

(3) Discharge /reverse flow test

The air pipe head is to allow the passage of air to prevent excessive vacuum developing in the tank.

① Reverse flow test

a. A reverse flow is to be performed. A vacuum pump or another suitable device is to be connected to the opening of the air pipe leading to the tank. The flow velocity is to be applied gradually at a constant rate until the float gets sucked and blocks the flow.

b. The velocity at the point of blocking is to be recorded. 80% of the value recorded is to be stated in the certificate.

② Alternative to the reverse flow test

a. For pipe heads of 400 mm nominal diameter and above, as an alternative to the reverse flow test, a numerical simulation test based on computational fluid dynamics (CFD), to be carried out in conjunction with limited representative testing to establish the validity of the CFD modelling and results, may be accepted;

b. CFD predictions for air pipe heads can be validated against the available actual reverse flow test results of same size and type of air pipe heads;

c. The accuracy of the CFD modelling and the major assumptions used for the calculation are to be documented;

d. Mesh convergence studies are to be carried out and documented; and

e. The requirement as per the preceding ①b applies.

1.4.2 Testing of non-metallic floats

Impact and compression loading tests are to be carried out on the floats before and after pre-conditioning as shown in Table 1.4.2.

Pre-conditioning of test **Table 1.4.2**

Test condition \ Test temperature (℃)	-25	20	85
Dry	×	×	×
After immerging in water	×	×	×
After immerging in fuel oil	–	×	–
Immerging in water and fuel oil is to be for at least 48 h			

Abbreviations: × test is required
– test is not required

(1) Impact test

The test may be conducted on a pendulum type testing machine. The floats are to be subjected to 5 impacts of 2.5 Nm each and are not to suffer permanent deformation, cracking or surface deterioration at this impact loading.

Subsequently the floats are to be subjected to 5 impacts of 25 Nm each. At this impact energy level some localized surface damage at the impact point may occur. No permanent deformation or cracking of the floats is to appear.

(2) Compression loading test

Compression tests are to be conducted with the floats mounted on a supporting ring of a diameter and bearing area corresponding to those of the float seating with which it is intended that float is to be used.

For ball type float, loads are to be applied through a concave cap of the same internal radius as the test float and bearing on an area of the same diameter as the seating.
For a disc type float, loads are to be applied through a disc of equal diameter as the float.
A load of 350 kg is to be applied over one minute and maintained for 60 min. The deflection is to be measured at intervals of 10 min after attachment of the full load. The record of deflection against time is to show no continuing increase in deflection and, after release of the load, there is to be no permanent deflection.

1.4.3 Testing of metallic floats

Tests are to be conducted in accordance with 1.4.2(1). The tests are to be carried out at room temperature and in the dry condition.

CHAPTER 3 SHIP'S PIPING AND VENTILATING SYSTEMS

Section 1 GENERAL PROVISIONS

3.1.1 Application

3.1.1.1 The requirements of this Chapter apply to piping and ventilating systems on ships except where otherwise stated.

3.1.2 Materials

3.1.2.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

3.1.2.2 Materials sensitive to heat, such as aluminum, lead or plastics, are not to be used in systems essential to the safe operation of the ship, or in systems conveying combustible liquids or sea water where leakage or failure could result in fire or in flooding of watertight compartments. For the use of plastic pipes, see Section 4 of Chapter 2 of this PART.

3.1.3 Plans and documents

3.1.3.1 The plans and documents to be submitted as required in this Chapter are referred to in 2.1.2 of this PART.

Section 2 DRAINAGE OF COMPARTMENTS, OTHER THAN MACHINERY SPACES

3.2.1 General requirements

3.2.1.1 All ships are to be provided with efficient bilge pumping systems capable of pumping from and draining any watertight compartment, other than a space permanently appropriated for the carriage of fresh water, water ballast, oil fuel or liquid cargo, and any other space where efficient means of pumping are available under all practical conditions. For particular compartments, if the survival capability and the safety of the ship are not impaired by flooding of the compartments, bilge pumping arrangements may be dispensed with.

Efficient means are to be provided for draining water from insulated holds. For their particular requirements, see relevant provisions specified in Chapter 3 of PART FIVE of the Rules.

3.2.1.2 The suctions and means for drainage are to be so arranged that any water within any compartment of the ship, or any watertight section of any compartment, can be pumped out through at least one suction when the ship is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

3.2.1.3 In passenger ships, the bilge pumping plant is to be capable of draining any one watertight compartment which is neither a permanent oil compartment nor a permanent water compartment under all practicable conditions after a casualty, whether the ship is upright or listed.

3.2.2 Cargo holds

3.2.2.1 The bilge suctions in cargo holds are to be arranged in accordance with Table 3.2.2.1.

Bilge suction arrangements in cargo holds **Table 3.2.2.1**

Cargo holds condition		Suction arrangement in each cargo hold
Without double bottom	Bottom shell slopping down to the center line ≥ 5°	One near center line at after end
	Bottom shell slopping down to the center line < 5°	One on each side at after end
With double bottom	Inner bottom plating extending to ship's side and forming bilges at the wings	One on each side

Cargo holds condition		Suction arrangement in each cargo hold
	Inner bottom slopping down to the center line	One near center line
	Inner bottom plating extending to ship's side and not forming bilge	One bilge well with suction on each side
In ships having only one hold, and the length of the hold exceeds 35 m		Fitted in forward half-length and after half-length of the hold
In narrow holds at the ends of ships		One near center line

3.2.2.2 Enclosed cargo spaces situated on the bulkhead deck of a passenger ship and on the freeboard deck of a cargo ship

Drainage arrangement of enclosed cargo spaces situated on the bulkhead deck of a passenger ship and on the freeboard deck of a cargo ship may discharge in the form of gravity drainage by means of scupper according to the following requirements:

(1) Where the freeboard to the bulkhead deck or the freeboard deck, respectively, is such that the deck edge is immersed when the ship heels more than 5°, the drainage is to be by means of a sufficient number of scuppers of suitable size discharging directly overboard.

The arrangement of such scupper pipes is to be in accordance with the requirements of regulation 22, Annex I to Annex B of the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

(2) Where the freeboard is such that the edge of the bulkhead deck or the edge of the freeboard deck, respectively, is immersed when the ship heels 5° or less, the drainage of the enclosed cargo spaces on the bulkhead deck or on the freeboard deck, respectively, is to be led to a suitable space, or spaces, of adequate capacity, having a high water level alarm and provided with suitable arrangements for discharge overboard.

(3) Scuppers are to be provided at both port and starboard. The number and disposition of the scuppers are such as to prevent unreasonable accumulation of free water. Grills are to be provided at the open end of the scupper and the scuppers are not to be less than 100 mm in diameter.

(4) Where the enclosed cargo space is protected by a fixed pressure water-spraying fire-extinguishing system, the pumping arrangements are to take into account the requirements for any fixed pressure water-spraying fire-extinguishing system.

(5) Where the enclosed cargo space is protected by a carbon dioxide free-extinguishing system, the deck scuppers are fitted with means to prevent the escape of the smothering gas.

(6) Water contaminated with petrol or other dangerous substances is not drained to machinery spaces or other spaces where sources of ignition may be present.

3.2.3 Holds and deep tanks for alternative carriage of liquid or dry cargo

3.2.3.1 Where the inner bottom is slopping down to the centre line with an angle of not less than 5°, one centre suction only will be accepted and the wing suctions may be omitted.

3.2.3.2 In holds and deep tanks for alternative carriage of liquid or dry cargo, the liquid cargo and water ballast filling and suction pipes are to be provided with blanking flanges or other equivalent means, also the bilge suction pipes are to be provided with blanking flanges in way of the bulkheads, so as to isolate the filling and suction pipes when the hold or tank is being used for the carriage of dry cargo, and to isolate the bilge suction pipes when the hold or tank is being used for the carriage of liquid cargo or water ballast.

3.2.4 Fore peaks, after peaks and cofferdams

3.2.4.1 Where the peaks are used as dry compartments, the drainage of both peaks is to be effected either by a power pump branch bilge suction or a hand pump suction. In the latter case, the suction lift is in no case to exceed 7 m.

3.2.4.2 Suitable drainage arrangements are to be provided in cofferdams.

3.2.5 Spaces above fore peaks, after peaks and machinery spaces

3.2.5.1 The chain locker and the watertight compartments above the fore peak tank are to be drained by hand pump or power pump bilge suctions. Other effective means of drainage are also acceptable.

3.2.5.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be drained either by hand pump or power pump bilge suctions. Such compartments may also be drained by scuppers of not less than 38 mm bore, discharging to the shaft tunnels (or machinery space in the case of ships with machinery aft) and fitted with self-closing cocks or shut-off valves situated in well lighted and easily visible positions.

3.2.6 Shaft tunnel and pipe tunnel

3.2.6.1 The shaft or pipe tunnel is, in general, to be drained by a branch bilge suction at the after end of

the tunnel. Where water might accumulate at the forward end of the tunnel or the length of the tunnel is more than 35 m, additional bilge suction is required.

Section 3 BILGE DRAINAGE OF MACHINERY SPACES

3.3.1 General requirements

3.3.1.1 The bilge drainage arrangements in the machinery space are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the ship is on an even keel, and is either upright or has a list of not more than 5°. One of these suctions is to be branch bilge suction, and the other is to be direct bilge suction.

3.3.1.2 In passenger ships, the drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty, whether the ship is upright or listed.

3.3.2 Bilge suction arrangements in machinery spaces

3.3.2.1 The bilge suctions in machinery spaces are to be arranged in accordance with Table 3.3.2.1.

Bilge suction arrangements in machinery spaces **Table 3.3.2.1**

Condition of machinery spaces		Branch bilge suction	Direct bilge suction
Main engine room with single bottom	Bottom shell slopping down to the center line ≥ 5°	One near center line	One near center
	Bottom shell slopping down to the center line < 5° and all passenger ships	One near center line and one on each side	One near center
Main engine room with double bottom	Inner bottom extends the full length of the machinery space and forms bilges at the wings	One on each side	One on each side
	Inner bottom extends the full length and breadth of the machinery space	One bilge well with one suction on each side	One bilge well with one suction on each side
Ships with propelling machinery aft		One on each side at the fore end and one at central longitudinal plane at aft end	One on each side at the fore end of engine room
Boiler room or auxiliary engine room separated from the main engine room by watertight bulkheads; separate motor room of electrically propelled ships		Same as for cargo holds	At least one for each watertight compartment

3.3.2.2 Additional bilge suctions may be required for the drainage of depressions in the tank top formed by crank-pits, or other recesses, by tank tops having inverse camber or by discontinuity of the double bottom.

3.3.2.3 In ships propelled by electrical machinery, in addition to the branch bilge suctions and direct bilge suctions arranged appropriate to the conditions of machinery space, special means are to be provided to prevent the accumulation of bilge water under the main propulsion generators and motors.

3.3.2.4 In passenger ships, each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. Where two or more such suctions are provided, there is to be at least one suction on each side of the space.

3.3.3 Emergency bilge suctions of machinery spaces

3.3.3.1 In addition to the bilge suctions required in 3.3.2.1 to 3.3.2.4 of this Section, an emergency bilge suction is to be provided in each main machinery space. This suction is to be led to a main cooling water pump and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand wheel is 450 mm above the bottom platform.

3.3.3.2 In ships with steam propelling machinery, the emergency suction is to have a diameter of at least 2/3 that of the main circulating pump suction. In other ships, the diameter of suction is not to be less than the diameter of the pump suction.

3.3.3.3 Where main cooling water pumps are not suitable for bilge pumping duties, the emergency bilge suction is to be led to the largest power pump which is not a bilge pump. This pump is to have a capacity not less than that required for a bilge pump, and the bilge suction is at least to be the same size as that of the pump suction branch.

Where the pump to which the emergency bilge suction is connected is of the self-priming type, the direct bilge suction on the same side of the ship may be omitted, except in passenger ships.

3.3.3.4 Emergency bilge suction valves are to be provided with permanent nameplates clearly indicating

their purpose.

Section 4 BILGE PUMPS AND BILGE PIPING

3.4.1 Number of bilge pumps

3.4.1.1 The number of power bilge pumps for each ship is to comply with the requirements of Table 3.4.1.1.

Number of power bilge pumps **Table 3.4.1.1**

Ship type, navigation area and parameters			Independent power pump	Power pump driven by main engine or independent power pump
Passenger ship	Passenger ships engaged on international voyages; Passenger ships with service category 1 and upper than category 1; Passenger ships carrying more than 500 passengers with service category 2;	Bilge pump numeral ≥ 30	3	1
		Bilge pump numeral < 30	2	1
	Passenger ships other than those listed above		2	1
Ships other than passenger ship		Ship's length > 91.5m	2	–
		Ship's length ≤ 91.5m	1	1

3.4.1.2 Each bilge pump prescribed in 3.4.1.1 of this Section may be substituted by a pumping unit consisting of several pumps. The total capacity of each pumping unit is not to be less than the capacity of a bilge pump specified in 3.4.2.4 of this Section.

3.4.1.3 Independent power sanitary, ballast and general service pumps may be accepted as independent power bilge pumps, provided they are of the required capacity of the self-priming type or with the self-priming arrangement and connected to the bilge main.

3.4.1.4 For ships other than passenger ships, an ejector with an adequate pressure of water supply from a sea water pump and connected to the bilge piping may be accepted as an independent power bilge pump.

3.4.1.5 For passenger ships, the bilge pump numeral C is to be calculated as follows:

when P_1 is greater than P: $C = \frac{72(M + 2P_1)}{V + P_1 - P}$

in other cases: $C = \frac{72(M + 2P)}{V}$

where:

M — the volume of the machinery space, in m^3, as defined in SOLAS regulation II-1/2, that is below the bulkhead deck; with the addition thereto of the volume of any permanent oil fuel bunkers which may be situated above the inner bottom and forward of, or abaft, the machinery space;

V— the whole volume of the ship below the bulkhead deck, in m^3;

P— the whole volume of the passenger and crew spaces below the bulkhead deck, in m^3, which are provided for the accommodation and use of passengers and crew, excluding baggage, store, provision and mail rooms;

$$P_1 = KN$$

where:

N — the number of passengers for which the ship is to be certified; and

$K = 0.056L$

where:

L — the length of the ship, in m, as defined in SOLAS regulation II-1/2.

However, where the value of KN is greater than the sum of P and the whole volume of the actual passenger spaces above the bulkhead deck, the figure to be taken as P_1 is that sum or two-thirds KN, whichever is the greater.

3.4.2 Type and capacity of bilge pumps

3.4.2.1 All power bilge pumps are to be of the self-priming type, or with the self-priming arrangements.

3.4.2.2 Cooling water pumps having emergency bilge suctions need not be of the self-priming type, or with self-priming arrangements.
3.4.2.3 Each power bilge pump is to be capable of giving a speed of water through the required main bilge pipe of not less than 2 m per second.
3.4.2.4 The capacity of each bilge pump (Q) is not to be less than the value calculated by the following formula:

$$Q = 5.66\, d_1^2 \times 10^{-3} \quad \text{m}^3/\text{h}$$

where: d_1 — internal diameter of bilge main, obtained from the formula in 3.4.3.1 of this Section, in mm.
3.4.2.5 In ships other than passenger ships, where one bilge pump is of slightly less than the rule capacity, the deficiency may be made good by an excess capacity of the other pumps. In general, this deficiency is to be limited to 30%.

3.4.3 Bilge pipe systems

3.4.3.1 The internal diameter d_1 of the bilge main is to be calculated according the following formula. However, the actual internal diameter of the bilge main may be rounded off to the acceptable nearest standard size, but not less than the calculated value by 5 mm:

$$d_1 = 25 + 1.68\sqrt{L(B+D)} \quad \text{mm}$$

where: L — length of ship, in m (measured between perpendiculars taken at the extremities of the deepest subdivision load line).
Where the engine room bilge pumps are fitted primarily for serving the engine room and they do not serve cargo space bilges, L may be reduced by the combined length of the cargo tanks or cargo holds. In such cases, the cross sectional area of the main bilge line is not to be less than twice the required cross sectional area of the engine room branch bilge lines;
B — breadth of ship, in m (the extreme width from outside of frame to outside of frame at or below the deepest subdivision load line).
D — molded depth of ship to bulkhead deck, in m.
When the bilge of enclosed cargo spaces situated on the bulkhead deck or freeboard deck is drained by means of bilge system, D is to be selected according to following requirements:
(1) when the enclosed cargo space extends for the full length of the ship, D is to be measured to the next deck above the bulkhead deck;
(2) where the enclosed cargo spaces cover a lesser length, D is to be taken as the molded depth to the bulkhead deck plus lh/L, where l and h are the aggregate length and height respectively of the enclosed cargo spaces.

3.4.3.2 In no case is the internal diameter of the bilge main to be less than that required for the largest branch bilge line.
3.4.3.3 The internal diameter d_2 of branch bilge suction pipes fitted in cargo and machinery spaces is not to be less than the value determined by the following formula, but the actual internal diameter of branch bilge suction pipes may be rounded off to the acceptable nearest standard size, but not less than the calculated value by 5 mm:

$$d_2 = 25 + 2.15\sqrt{l(B+D)} \quad \text{mm}$$

where: l — length of compartment, in m;
B— breadth of ship, in m;
D— molded depth of ship to bulkhead deck, in m.
3.4.3.4 In general, no branch bilge suction pipe is to be less than 50 mm bore.
3.4.3.5 In no case is the internal diameter of the direct bilge suction to be less than that required for the main bilge line.
3.4.3.6 The branch bilge suction pipe to the tunnel well is, in general, not to be less than 65 mm bore.
3.4.3.7 The section area of each branch pipe connecting the bilge main to a distribution chest is not to be less than the sum of the areas required for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

3.4.4 Bilge pumps and pipe connections

3.4.4.1 The connections at the bilge pumps are to be such that at least one of the pumps may continue in operation when the other pumps are being opened up for overhaul.
3.4.4.2 The arrangements of pump and pipelines are such that the working of any of the pumps so

connected is unaffected by the other pumps being in operation at the same time.
3.4.4.3 All bilge suction pipes are to be independent of other piping up to the bilge pump suction valve chest.

3.4.5 Non-return arrangements

3.4.5.1 For the purpose of preventing the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks, screw-down non-return valves are to be provided in the following fittings:
(1) bilge valve distribution chests;
(2) bilge suction hose connection, whether fitted direct to the bilge pump or on the main bilge line;
(3) direct bilge suctions;
(4) bilge pump connections to main bilge line.

3.4.6 Blanking arrangements

3.4.6.1 In the case of deep tanks and cargo holds which may be used for either water ballast or dry cargo, provision is to be made for blank flanging the water ballast filling and suction pipes when the tank or hold is being used for the carriage of dry cargo, and for blank flanging the bilge suction pipes when the tank or hold is being used for the carriage of water ballast.
For arrangement when oil fuel or cargo oil (having a flash point above 60℃) is carried in deep tanks, see 4.2.9.1 of this PART.

3.4.7 Bilge pipes in way of deep tanks and double bottom tanks

3.4.7.1 In way of deep tanks, bilge pipes are preferably to be led through pipe tunnels but, where this is not done, the pipes are to have a wall thickness in accordance with Table 2.2.2.6(1) of this PART, with welded joints or other reliable joints. The number of joints is to be kept to a minimum.
3.4.7.2 Expansion bends, not glands, are to be fitted to these pipes within the deep tanks, and the open ends of the bilge suction pipes in the holds are to be fitted with non-return valves of the approved type.
3.4.7.3 Bilge suction pipes are not to be led through double bottom tanks as far as practicable. Bilge pipes which have to pass through these tanks are to have a wall thickness in accordance with Table 2.2.2.6(1) of this PART.
3.4.7.4 Expansion bends, not glands, are to be fitted to these pipes within the double bottom tanks.
3.4.7.5 The pipes are to be tested after installation, to a pressure not less than that required for the deep or double bottom tanks through which they pass.

3.4.8 Bilge fittings

3.4.8.1 Where the inner bottom plating in machinery spaces or cargo holds extends to the ship's side and does not form bilges, the bilge suctions are to be arranged in bilge wells. The bilge wells are to be formed of steel plates and are not to be less than 0.15 m^3 in capacity.
3.4.8.2 Each branch bilge suction and each direct bilge suction in machinery spaces and tunnels (excluding emergency suctions) are to be led from easily accessible mud boxes fitted with straight tail pipes to the wells or bilges. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency bilge suctions.
3.4.8.3 The open ends of bilge suctions in holds and other compartments outside machinery spaces and tunnels are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The strum boxes are to be so constructed that they can be easily removed and replaced for cleaning.
3.4.8.4 Bilge valves, cocks and mud boxes are as far as possible to be fitted at, or above, the machinery space and tunnel platforms. Where they are situated just below the platform, provided readily removable traps or covers are to be fitted, and nameplates are to be fitted to indicate the presence of these fittings.

3.4.9 Miscellaneous

3.4.9.1 The design, construction and arrangement of sludge tanks and standard discharge connections are to comply with the provisions of relevant international conventions.
3.4.9.2 Bilge piping systems are to be so arranged as to meet the relevant requirements for the prevention of pollution from ships.

Section 5 ADDITIONAL REQUIREMENTS FOR BILGE DRAINAGE FOR PASSENGER SHIPS

3.5.1 Arrangement of bilge pumps and bilge main

3.5.1.1 In passenger ships the required power bilge pumps are to be placed, if practicable, in separate watertight compartments. If the engines and boilers are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as is possible.

3.5.1.2 In passenger ships of 91.5 m or more in length, or having a bilge pump numeral of 30 or more, the arrangements are to be such that at least one of the power bilge pumps will be available for use in all ordinary circumstances in which the ship may be flooded at sea. This requirement will be satisfied if:

(1) one of the pumps is a reliable emergency pump of a submersible type having its source of power situated above the bulkhead deck;

(2) the pumps and their sources of power are so disposed throughout the length of the ship that, under any conditions of flooding which the ship is required to withstand, at least one pump in an undamaged compartment will be available.

3.5.1.3 The bilge main is to be so arranged that no part is situated nearer the side of the ship than $B/5$ (B being the breadth of ship), measured at right angles to the centreline at the level of the deepest subdivision load line.

3.5.1.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the $B/5$ line, then a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be so arranged that they are situated inboard of the $B/5$ line.

3.5.2 Arrangement of bilge pipes

3.5.2.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the ship than $B/5$ or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

3.5.2.2 All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be in positions which are accessible at all times under ordinary circumstances. They are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment. In addition, damage to a pump or its pipe connecting to the bilge main situated outboard of $B/5$ line is not to put the bilge system out of action. If there is only one system of pipes common to all the pumps, the necessary cocks or valves for controlling the bilge suctions must be capable of being operated from above the bulkhead deck. Where in addition to the main bilge pumping system an emergency bilge pumping system is provided, it is to be independent of the main system, and so arranged that a pump is capable of operating on any compartment under flooding conditions. In this case only the cocks and valves necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

3.5.2.3 All cocks and valves mentioned in 3.5.2.2 of this Chapter which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

Section 6 ADDITIONAL REQUIREMENTS FOR BILGE DRAINAGE

3.6.1 Additional requirements for bilge drainage for oil tankers

3.6.1.1 For the additional requirements for bilge drainage for oil tankers, see relevant provisions of Section 3, Chapter 5 of this PART.

3.6.2 Additional requirements for bilge drainage for spaces using fixed pressure water-spraying fire-extinguishing systems①

3.6.2.1 Pumping and drainage facilities are to be provided in spaces using fixed pressure water-spraying fire-extinguishing systems for draining large quantities of water accumulation on the deck or tank top on consequence of the operation of the fixed pressure water-spraying system, and following requirements are

① Refer to MSC.1/Circ.1320: Guidelines for the Drainage of Fire-fighting Water from Closed Vehicle and Ro-Ro Spaces and Special Category Spaces of Passenger and Cargo Ships.

to be complied with.

(1) For passenger ships:

① In the spaces above the bulkhead deck, scuppers complying with relevant requirements of MSC.1/Circ.1320 are to be fitted so as to ensure that such water is rapidly discharged overboard. Discharge valves for scuppers, fitted with positive means of closing operable from a position above the bulkhead deck in accordance with the requirements of regulation 22, Annex I to Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966, are to be kept open while the ships are at sea.

② In the spaces below the bulkhead deck, pumping and drainage facilities complying with relevant requirements of MSC.1/Circ.1320 may be required to be provided additional to the requirements of Section 2 to Section 5 of this Chapter. The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells are to be of sufficient holding capacity and are to be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment.

(2) For cargo ships:

The drainage and pumping arrangements are to be such as to prevent the build-up of free surfaces and comply with relevant requirements of MSC.1/Circ.1320. The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells are to be of sufficient holding capacity and are to be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment.

If this is not possible, the adverse effect upon stability of the added weight and free surface of water is to be taken into account in its approval of the stability information. Such information is to be included in the stability information supplied to the master as required.

3.6.2.2 On all ships, for closed vehicles and ro-ro spaces and special category spaces, where fixed pressure water-spraying systems are fitted, means are to be provided to prevent the blockage of drainage arrangements and relevant requirements of MSC.1/Circ.1320 are to be complied with.

3.6.3 Additional requirements for bilge drainage for periodically unattended machinery spaces

3.6.3.1 For the additional requirements of bilge drainage for periodically unattended machinery spaces, see relevant provisions of 3.9.2 of Chapter 3 in PART SEVEN of the Rules.

3.6.4 Additional requirements for bilge drainage for unattended other machinery spaces

3.6.4.1 Bilge level alarms are to be provided for unattended other machinery spaces below waterline (e.g. athwartship thruster space, emergency fire pump space, etc.).

Section 7 DRAINAGE ARRANGEMENTS AND BALLAST PIPING FOR NON-SELF-PROPELLED SHIPS

3.7.1 General requirements

3.7.1.1 Non-self-propelled ships are to be provided with means for drainage of all watertight compartments which give contribution to the vessel's buoyancy and floatability (except for compartments permanently used to carry liquid).

3.7.1.2 This Section is the additional requirements to drainage arrangements and ballast piping for non-self-propelled ships. With the exemption specified in the following, the rules and principles for drainage of ship with propulsion machinery are to be referred to.

3.7.2 Pierhead pontoon and non-self-propelled ships without auxiliary power

3.7.2.1 For pierhead pontoon and non-self-propelled ships without auxiliary power, at least two portable hand pumps are to be fitted to permit the efficient drainage of each compartment. Suitable access hatches for the pumping equipment are to be provided for each compartment.

3.7.2.2 The internal diameter d of the hand pump suction is not to be less than the value determined by the following formula:

$$d = 0.01T + 50 \quad \text{mm}$$

where: T — tonnage under upper deck, in t.

Where the ship is subdivided into small watertight compartments, 50 mm bore suction will be accepted. The internal diameter of the water cylinder of piston pumps is not to be less than twice the required diameter of the suction.

3.7.3 Manned non-self-propelled ships with auxiliary power

3.7.3.1 In non-self-propelled ships with auxiliary power, permanently installed bilge system with power bilge pumps are to be provided for dealing with the drainage of tanks and principal compartments.

3.7.3.2 Manned ships with auxiliary power for unlimited service are to be equipped with two power driven bilge pumps.

3.7.3.3 Manned ships with auxiliary power for limited service may have one power driven bilge pump, but in this case, the bilge pump is not to serve as fire pump.

3.7.3.4 All compartments required to be equipped with bilge drainage arrangements are to have branch bilge suction connected with bilge system.

3.7.3.5 In addition to branch bilge suction, a direct bilge suction to bilge pump is to be provided for the engine room.

3.7.3.6 Dry compartments in fore and aft peak may be drained by hand pumps.

3.7.3.7 Rooms situated on deck may be drained directly overboard.

3.7.4 Unmanned non-self-propelled ships with auxiliary power

3.7.4.1 Unmanned ships with auxiliary power are to be provided with a power driven bilge pump.

3.7.4.2 Any engine room or pump room is to have bilge suctions to power bilge pump.

3.7.4.3 Other compartments may be drained by portable pumps. Suitable access hatches for the pumping equipment are to be provided for each compartment.

3.7.5 Ballast system of non-self-propelled ships

3.7.5.1 For non-self-propelled ships fitted with ballast tank, each ballast tank is to be provided with ballast system connected by pipes.

3.7.5.2 Pierhead pontoon and non-self-propelled ships without auxiliary power may permit to use a portable pump as ballast pump.

3.7.5.3 Non-self-propelled ships with auxiliary power are to be provided with at least one power driven ballast pump.

Section 8 BALLAST AND SCUPPER SYSTEMS

3.8.1 Ballast piping

3.8.1.1 The arrangement of ballast piping and the number of suctions are to be such that any ballast tank can be filled or emptied under normal service conditions, whether the ship is upright or listed.

3.8.1.2 Where the ballast tanks exceed 35 m in length, they are normally to be fitted with bilge suctions at their forward and aft ends.

3.8.1.3 The arrangement of ballast piping is to be such as to prevent the possibility of water passing from the sea or from ballast tanks into dry cargo and machinery spaces or other dry compartments.

3.8.1.4 Ballast water pipes are not to pass through drinking water, boiler feed water or lubricating oil tanks. Where it is unavoidable, the wall thickness of ballast pipes in drinking water, feed water or lubricating oil tanks is to comply with the provisions of column 5 in Table 2.2.2.6(1) of this PART and welded joints are to be adopted. Ballast water pipes passing through a pipe tunnel may also be an option.

3.8.1.5 The ballast piping is not to be in connection with the bilge pipes from dry cargo and machinery spaces, nor with the pipes from oil tanks. However, this requirement need not be applied to the pipes located between distribution boxes and pump suctions or between pumps and overboard discharges, nor to the pipes described in 3.8.1.6 below.

3.8.1.6 Where the compartments (including deep tanks) are used for alternative carriage of dry cargo or oil or ballast water, provision is to be made for isolating or blank flanging the ballast lines. This requirement is also applicable to the drinking water tanks which may be used as ballast tanks, so as to avoid the interconnection of the two systems. The arrangement for the discharge of oily ballast water is to be in accordance with the relevant requirements for the prevention of pollution from ships.

3.8.1.7 Alternate loading of fuel oil and ballast water is to comply with the relevant requirements of 4.2.9, Chapter 4 of this PART.

3.8.1.8 For the requirements of ballast system in oil tankers, see the relevant provisions in Section 3, Chapter 5 of this PART.

3.8.2 Scuppers and sanitary discharges

3.8.2.1 For the requirements of scuppers and sanitary discharges, see the relevant requirements specified

in regulation 22, Annex I to Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.
3.8.2.2 The installation of all suction and discharge valves or side standpipes on scuppers and sanitary discharges that are secured direct to the shell plating of the ship is to be in compliance with the relevant requirements of 2.8.9.2 of this PART.

Section 9 REMOTELY CONTROLLED BILGE AND BALLAST SYSTEMS

3.9.1 Arrangement

3.9.1.1 If a main bilge line outside engine room is provided, its arrangement is to satisfy either of the following requirements:
(1) If there is only one main bilge line and a pipe tunnel is provided, it is to be placed in the pipe tunnel, and as high as possible in the pipe tunnel. Each branch bilge suction line connected to the main is to be fitted with remotely controlled valves.
(2) If there is only one main bilge line and a pipe tunnel is not provided, the main is to be placed in a space that is not prone to mechanical damage, such as double bottom ballast tanks and void tanks, etc. Each branch bilge suction line connected to the main is to be fitted with remotely controlled valves and the valves are to be located in an accessible dry compartment.
(3) If there are two main bilge lines, each cargo hold is provided with a branch bilge suction connected to each main bilge line respectively, and remotely controlled valves are fitted on each branch bilge suction line.
3.9.1.2 The main bilge line for cargo holds is to be dimensioned as the machinery spaces main bilge line.
3.9.1.3 The main bilge line for cargo holds is to be fitted with a shut-off valve in the machinery spaces.

3.9.2 Valves

3.9.2.1 The remotely controlled valves in branch bilge suction lines are to be screw-down non-return valves or shut-off and non-return valves connected in series.

3.9.3 Pumps

3.9.3.1 Operating indications of the remotely controlled bilge and ballast pumps are to be provided at the remote control panel.

Section 10 AIR, OVERFLOW AND SOUNDING PIPES

3.10.1 General requirements

3.10.1.1 The cargo mentioned in this Section is the oils having a flash point above 60℃(closed cup test).
3.10.1.2 Air, overflow and sounding pipes are to be made of steel or other approved material.
3.10.1.3 Nameplates are to be affixed to the upper ends of all air and sounding pipes.
3.10.1.4 In addition to complying with the requirements of this Section, air pipes are to be in compliance with the relevant provisions in 1.12.7.5 of PART TWO of the Rules.

3.10.2 Arrangement of air pipes

3.10.2.1 Air pipes are to be provided for tanks intended to carry water, oil fuel and lubricating oil, and also for cofferdams and pipe tunnels. The shaft tunnel is to be provided with air pipes if necessary. Air pipes are to be fitted at the highest part of the tanks and far apart from the filling pipes.
3.10.2.2 Tanks having top plates not less than 7 m either in length or in width are to be provided with two or more air pipes arranged suitably apart. Where such arrangements are impracticable due to special circumstances, one air pipe is acceptable provided that effective venting is guaranteed. Where the tank top is of unusual or irregular profile, the number and positions of the air pipes will be decided in each case.
3.10.2.3 Tanks with cathodic protection are to have air pipes fitted forward and aft.
3.10.2.4 All double bottom tanks are to be fitted with air pipes. The double bottom tanks extending from side to side of the ship are to be fitted with air pipes led from both sides. For the double bottom tanks with less breadth at the ship's bow and stern, however, only one vent pipe may be fitted, provided that this single pipe can ensure the effective venting.
3.10.2.5 Location and arrangement of vent pipes for fuel oil service, settling and lubrication oil tanks are

to be such that in the event of a broken vent pipe this will not directly lead to the risk of ingress of seawater splashes or rainwater.
3.10.2.6 The arrangement of the air piping is to be such that in the event of any one of the tanks being damaged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through combined air pipes.

3.10.3 Termination of air pipes

3.10.3.1 Air pipes to the following tanks and cofferdams are to be led to the open above the freeboard deck:
(1) fuel oil tanks;
(2) cargo tanks;
(3) heated lubricating oil tanks and hydraulic oil tanks;
(4) tanks, situated outside machinery spaces, which are not fitted with overflow pipes and can be pumped up;
(5) cofferdams adjacent to fuel oil tanks or cargo tanks.
3.10.3.2 Air pipes to the following tanks and cofferdams other than those prescribed in 3.10.3.1 of this Section are to be led to above the bulkhead deck:
(1) double bottom tanks;
(2) deep tanks extending to shell plating;
(3) tanks which can be directly flooded from the outboard and seawater case;
(4) other cofferdams.
3.10.3.3 Air pipes from lubricating oil tanks or fuel oil draining tanks with a volume less than 0.5 m^3 and which cannot be pumped up may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.
3.10.3.4 The open ends of air pipes to oil fuel and cargo tanks are to be situated on the open deck where no danger will be incurred from issuing oil or vapor.
3.10.3.5 The open ends of air pipes to oil fuel and cargo tanks are to be furnished with a wire gauze diaphragm of corrosion-resistant material which can be readily removed for renewal.
3.10.3.6 The wire gauze diaphragm at the open ends of air pipes is to have a clear area not less than the cross-sectional area required for the air pipe.

3.10.4 Size of air pipes

3.10.4.1 In the case of all tanks which can be pumped up, either by the ship's pumps or by shore pumps through a filling main, the total cross-sectional area of the air pipes to each tank is not to be less than 25% greater than the effective area of the respective filling pipes. In any case, the internal diameter of air pipes is not to be less than 50 mm. When an air pipe serves several tanks, the sectional area of the air pipe is to be at least the combined area of the largest air pipes for two tanks.
3.10.4.2 Where overflow pipes are fitted as specified in this Section, the sectional area of the air pipes is to be at least 20% of that of the filling pipes.
When an air pipe serves several tanks all having overflow pipes as specified in this Section, the sectional area of the air pipe is to be at least 20% of the combined area of the two largest filling pipes for the separate tanks.
3.10.4.3 For ships navigating in ice, the cross-sectional area of air pipes is to be adequately increased.
3.10.4.4 Where tanks form part of the structure of the ship, the wall thickness of air pipes is to comply with Table 2.2.2.6(1) of this PART.
3.10.4.5 Air pipes to shaft tunnels and pipe tunnels are to have an internal diameter not less than 75 mm.

3.10.5 Arrangement of overflow pipes

3.10.5.1 All tanks which can be pumped up are to be fitted with overflow pipes, when the liquid pressure head corresponding to the height of the air pipe is greater than that for which the tanks are suitable, or when the sectional area of the air pipe is less than that required in 3.10.4.1 of this Section. When an air pipe serves several tanks, the air pipe of one tank is not to be considered as the overflow pipe of another tank, except the shared overflow pipe connected to the overflow tank.
3.10.5.2 In the case of oil fuel and lubricating oil tanks, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes.
Overflow pipes from tanks, other than oil fuel and lubricating oil tanks, are to be led to the open or to suitable overflow tanks.
3.10.5.3 A well illuminated sight glass is to be provided in the overflow pipe, and placed on the vertical pipes in readily visible positions, or alternatively, an alarm device is to be provided to give warning either

when the tanks are overflowing or when the oil reaches a predetermined level in the tanks.
3.10.5.4 Shut-off valves or cocks are not allowed to be fitted to the overflow pipes.

3.10.6 Size of overflow pipes

3.10.6.1 The sectional area of overflow pipe(s) from each tank is not to be less than 1.25 times that of the filling pipe(s). When an overflow pipe serves several tanks, the sectional area of the overflow pipe is to be at least the combined area of the largest overflow pipes for two tanks.

3.10.7 Prevention of cross flow through the overflow pipes

3.10.7.1 Where overflows from deep tanks which are used for the alternative carriage of fuel oil, cargo oil, water ballast, or dry cargo are connected to an overflow main of other tanks, arrangements are to be made to prevent the overflowing of liquid, gases, etc. from other tanks into the deep tank carrying dry cargo, as well as to prevent the overflowing of liquid into other tanks from the deep tank carrying the liquid.

3.10.7.2 The arrangement of the overflow system is to be such that in the event of any one of the tanks being bilged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through the overflow main.

3.10.8 Sounding pipes

3.10.8.1 Sounding pipes are to be provided for all tanks, cofferdams and pipe tunnels as well as the bilges or bilge wells which are not at all times readily accessible. All sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible.
The sounding pipes are to be fitted as near the suctions as practicable.
3.10.8.2 Other sounding devices may be used in lieu of sounding pipes for sounding tanks. These devices are to be tested satisfactorily, after fitting on board.
3.10.8.3 All sounding pipes exposed to sea and weather are to be provided with permanently attached effective means of closing to prevent the free entry of water.
3.10.8.4 The bottom plating under open ended sounding pipes is to be protected by striking plates of adequate thickness and size.

3.10.9 Short sounding pipes

3.10.9.1 In machinery spaces and shaft tunnels where it is not practicable to extend the sounding pipes as mentioned in 3.10.8.1 of this Section, short sounding pipes extending to readily accessible positions above the platform may be fitted. The following requirements are to be complied with:
(1) Sounding pipes are to be easily accessible and are to be fitted with shut-off cocks or with screw caps attached to the pipes by chains.
(2) In passenger ships, short sounding pipes are permissible only for sounding cofferdams and double bottom tanks situated in the machinery space, and are in all cases to be fitted with self-closing devices.

3.10.10 Additional requirements to sounding pipes in fuel oil tanks

3.10.10.1 Safe and efficient means of ascertaining the amount of oil fuel contained in any fuel oil tank are to be provided. Where sounding pipes are used, they are not to terminate in any space where the risk of ignition of spillage from the sounding pipe might rise. In particular, they are not to terminate in passenger or crew spaces. As a general rule, they are not to terminate in machinery spaces. However, where it is impracticable to arrange, termination of sounding pipes in machinery spaces may be permitted on condition that the following requirements are met:
(1) an oil-level gauge is provided meeting the requirements of 3.10.10.3 of this Section;
(2) the sounding pipes terminate in locations remote from ignition hazards unless precautions are taken, such as the fitting of effective screens, to prevent the oil fuel in the case of spillage through the terminations of the sounding pipes from coming into contact with a source of ignition;
(3) the termination of sounding pipes are fitted with self-closing blanking devices and with a small-diameter self-closing control cock located below the blanking device for the purpose of ascertaining before the blanking device is opened that oil fuel is not present. Provisions are to be made so as to ensure that any spillage of oil fuel through the control cock involves no ignition hazard.
3.10.10.2 For fuel oil tanks other than double bottom tanks, if overflow pipes satisfying requirements are fitted, when the sounding pipes are terminated in machinery spaces, only above-mentioned requirements of 3.10.10.1(2) and (3) are to be met.
3.10.10.3 Other oil-level gauges may be used in place of sounding pipes subject to the following conditions:

(1) in passenger ships, such gauges are not to require penetration below the top of the tank and their failure or overfilling of the tanks is not to permit release of fuel;
(2) in cargo ships, the failure of such gauges or overfilling of the tank is not to permit release of fuel into the space. The use of oil-level gauges with flat glasses and self-closing valves between the gauges and fuel tanks is permitted. The use of cylindrical gauge glasses is prohibited.

3.10.11 Additional requirements to sounding pipes in lubricating oil tanks

3.10.11.1 In general, means of ascertaining the amount of lubricating oil contained in any lubricating oil tank are to comply with the requirements of 3.10.10 of this Section. However, the requirements of 3.10.10.1(1) and 3.10.10.1(3) need not be applied on condition that the sounding pipes terminating in machinery spaces are fitted with appropriate means of closure.

3.10.12 Additional requirements to sounding pipes in other flammable oil tanks

3.10.12.1 For flammable oil tanks in spaces where means of ignition are present, means of ascertaining the amount of flammable oil contained in any flammable oil tank are to comply with the requirements of 3.10.10 of this Section.
3.10.12.2 For flammable oil tanks in other locations, if oil-level gauges are used in place of sounding pipes, at least the requirements of 3.10.10.3(2) are to be complied with.

3.10.13 Size of sounding pipes

3.10.13.1 Sounding pipes are not to be less than 32 mm in bore and those of heavy fuel oil tanks are not to be less than 50 mm in bore. Sounding pipes passing through compartments or spaces where the temperatures contemplated are 0℃ or below, are not to be less than 65 mm in bore.

Section 11 VENTILATION

3.11.1 General requirements

3.11.1.1 Machinery spaces of category A are to be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions including heavy weather, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery.
Any other machinery space is to be adequately ventilated appropriate for the purpose of that machinery space.
Ventilators of machinery spaces required to be continuously ventilated are to be of a height of coaming complying with the relevant requirements of 1.12.7.4(6), PART TWO of the Rules without having to fit weathertight closing appliances, so that they can be used in all weather conditions. However, where due to vessel size and arrangement this is not practicable, lesser heights for ventilator coamings may be accepted with provision of weathertight closing appliances in accordance with the requirements of 1.12.7.4(7), PART TWO of the Rules in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.
3.11.1.2 All ventilator cowls for boiler rooms are to be fitted with rotating devices so that they may be turned and locked in any desired direction.
3.11.1.3 Effective means of ventilation are to be provided for all lamp-rooms, paint lockers and other compartments used for the storage of inflammable substances, explosives or where toxic or inflammable gases may accumulate.
3.11.1.4 When ventilation pipes pass through other compartments, relevant requirements on fire division and damage stability are to be complied with.
3.11.1.5 Ventilation system is to comply with the relevant requirements of PART SIX of the Rules.

3.11.2 Ventilators

3.11.2.1 The ventilators are to comply with the relevant requirements in 1.12.7.4, PART TWO of the Rules.

3.11.3 Ventilator cowls

3.11.3.1 Ventilator cowls are to be placed on the exposed deck and located as far from exhaust outlets, sky-lights and companionways as possible.

3.11.4 Ventilation of emergency generator rooms

3.11.4.1 The following requirements apply to ventilation louvers which can be closed for emergency generator rooms and to closing appliances where fitted to ventilators serving emergency generator rooms:

(1) Ventilation louvers and closing appliances may either be hand-operated or power-operated (hydraulic / pneumatic / electric) and are to be operable under a fire condition.

(2) Hand-operated ventilation louvers and closing appliances are to be kept open during normal operation of the vessel. Corresponding instruction plates are to be provided at the location where hand-operation is provided.

(3) Power-operated ventilation louvers and closing appliances are to be of a fail-to-open type. Closed power-operated ventilation louvers and closing appliances are acceptable during normal operation of the vessel. Power-operated ventilation louvers and closing appliances are to open automatically whenever the emergency generator is starting / in operation.

(4) It is to be possible to close ventilation openings by a manual operation from a clearly marked safe position outside the space where the closing operation can be easily confirmed. The louver status (open / closed) is to be indicated at this position. Such closing is not to be possible from any other remote position.

Section 12 ADDITIONAL REQUIREMENTS TO WATER LEVEL DETECTION AND DEWATERING OF FORWARD SPACES OF BULK CARRIERS

3.12.1 Application

3.12.1.1 This Section applies to classed bulk carriers of 500 gross tonnage and above and engaged on international voyages. The term bulk carrier referred to in this Section means a bulk carrier as defined in Chapter XII of the SOLAS Convention.

3.12.2 Plans and documents

3.12.2.1 The arrangement plan of dewatering system required by this Section is to be submitted for approval.

3.12.3 Water level detection

3.12.3.1 For water level detection and alarm system required to be installed in cargo hold, ballast tank and dry space, see the relevant requirements in Section 19, Chapter 2 of PART FOUR of the Rules.

3.12.4 Dewatering system

3.12.4.1 On bulk carriers, the means for drainage and pumping ballast tanks forward of the collision bulkhead, and bilges of dry spaces any part of which extends forward of the foremost cargo hold (excluding dry spaces the volume of which does not exceed 0.1% of the ship's maximum displacement volume and the chain locker), are to be capable of being brought into operation from a readily accessible enclosed space, the location of which is accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. Where pipes serving such tanks or bilges pierce the collision bulkhead, the remote control position of valves specified in 2.8.1.3 of this PART is to comply with the requirements of this regulation.

The detailed arrangements of dewatering system are to satisfy following requirements:

(1) The enclosed spaces which are required to control dewatering system are to be accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. A position which is accessible via an under deck passage, a pipe trunk or other similar means of access is not accepted.

(2) The dewatering arrangements are to be such that any accumulated water can be drained directly by a pump or ejector.

(3) Where the piping arrangements for dewatering closed dry spaces are connected to the piping arrangements for the drainage of water ballast tanks, two non-return valves are to be provided to prevent the ingress of water into dry spaces. One of these non-return valves is to be fitted with shut-off isolation arrangement. The non-return valves are to be located in readily accessible positions. The valve operation is to comply with all the requirements of this paragraph.

(4) The valve is not to move from the demanded position in the case of failure of the control system power or actuator power.

(5) Positive indication is to be provided at the remote control station to show that the valve is fully open or closed.
(6) Bilge wells are to be provided with gratings or strainers that will prevent blockage of the dewatering system with debris.
(7) The dewatering arrangements are to be such that when they are in operation, other systems essential for the safety of the ship including fire-fighting and bilge systems remain available and ready for immediate use. The systems for normal operation of electric power supplies, propulsion and steering are not to be affected by the operation of the dewatering systems. It must also be possible to immediately start fire pumps and have a ready available supply of fire-fighting water and to be able to configure and use bilge system for any compartment when the dewatering system is in operation.
(8) The enclosure of electrical equipment for the dewatering system installed in any of the forward dry spaces are to provide protection to IPX8① for a water head equal to the height of the space in which the electrical equipment is installed for a time duration of at least 24 h.

3.12.5 Dewatering capacity

3.12.5.1 The dewatering system is to be capable of quickly and efficiently removing water that may be accumulated in this space. The pump discharge capacity Q is not to be less than the value obtained from the following formula:

$$Q = 320A \quad \text{m}^3/\text{h}$$

where: A — the cross-sectional area of the largest ventilator pipe or air pipe serving this space and leading to the exposed deck, in m^2.

① See IEC Publication 60529.

CHAPTER 4 MACHINERY PIPING SYSTEMS

Section 1 GENERAL PROVISIONS

4.1.1 Application

4.1.1.1 Unless stated otherwise, the requirements of this Chapter apply to machinery piping systems for ships.

4.1.2 Materials

4.1.2.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

4.1.2.2 Materials sensitive to heat, such as aluminum, lead or plastics, are not to be used in systems essential for the safety of the ship, or in systems conveying combustible liquids or sea water where leakage or failure could result in fire or in flooding of watertight compartments. For the use of plastic pipes, see the relevant requirements of 2.4.3 of this PART.

4.1.3 Plans and documents

4.1.3.1 The plans and documents to be submitted as required in this Chapter are referred to in 2.1.2 of this PART.

Section 2 OIL FUEL SYSTEMS

4.2.1 General requirements

4.2.1.1 Oil fuels for use in ships are to comply with the relevant provisions contained in 1.2.9 of this PART.

4.2.1.2 Drip trays are to be provided under the oil tanks which do not form part of the hull structure, pumps, filters, boiler burners and all other oil fuel appliances which are required to be opened up frequently for cleaning or adjustment. Oils in the drip trays are to be drained to special sludge tanks, and if the sludge tanks are situated in double bottom tank, shut-off valves or other reliable means of isolation are to be fitted to the drain pipes to prevent sea water entering tank through drain pipes after double bottom tank is damaged. Drain pipes are to be mutual independent from the tank overflow system.

4.2.1.3 The gaskets used for joining covers and manholes of fuel oil tanks and for joining the flanges of fuel pipes are to be made of oil-proof or heat-resistant material.

4.2.1.4 For motor ships burning oil fuel which has to be purified by purifiers, two oil fuel purification units and heating units are to be provided, one of which is a standby.

4.2.1.5 The spaces in which the burning appliances of boilers and the oil fuel settling and service tanks are fitted are to be well ventilated and easy of access.

4.2.1.6 In addition to the local controls, the power supply to all independently driven oil fuel transfer pumps, boiler oil fuel pumps, diesel engine fuel pumps and oil separators is to be capable of being stopped from a readily accessible position outside the spaces in which they are situated.

4.2.1.7 The oil fuel systems of diesel engines for heavy oil are to be provided with immediate change-over devices for diesel oil.

4.2.1.8 Two fuel oil service tanks or equivalent arrangements, for each type of fuel used on board, necessary for propulsion and essential systems are to be provided. Each tank is to have a capacity for at least 8 h operation at sea, at maximum continuous rating of the propulsion plant and normal operating load of the generating plant associated with that tank.

The arrangement of oil fuel service tanks is to be such that one tank can continue to supply oil fuel when the other is being cleaned or opened up for repair.

4.2.1.9 A service tank is a fuel oil tank which contains only fuel of a quality ready for use, i.e. fuel of a grade and quality that meet the specification required by the equipment manufacturer. A service tank is to be declared as such and not to be used for any other purpose. Use of a settling tank with or without purifiers, or purifiers alone, and one service tank is not acceptable as an “equivalent arrangement” to two service tanks.

Examples of application for the most common systems are shown below:

(1) Example 1

① Requirement normally to be followed – main and auxiliary engines and boiler(s) operating with

heavy fuel oil (HFO) (one fuel ship)

HFO service tank Capacity for at least 8 h Main engine + Auxiliary engine + Auxiliary boiler	HFO service tank Capacity for at least 8 h Main engine + Auxiliary engine + Auxiliary boiler	MDO tank For initial cold starting or repair work of engines/boiler

② Equivalent arrangement

HFO service tank Capacity for at least 8 h Main engine + Auxiliary engine + Auxiliary boiler	MDO service tank Capacity for at least 8 h Main engine + Auxiliary engine + Auxiliary boiler

This arrangement only applies where main and auxiliary engines can operate with heavy fuel oil under all load conditions and, in the case of main engines, during manoeuvring.
For pilot burners of auxiliary boilers if provided, an additional marine diesel oil tank for 8 h may be necessary.

(2) Example 2

① Requirement normally to be followed – main engine(s) and auxiliary boiler(s) operating with HFO and auxiliary engine operating with marine diesel oil (MDO)

HFO service tank Capacity for at least 8 h Main engine + Auxiliary boiler	HFO service tank Capacity for at least 8 h Main engine + Auxiliary boiler	MDO service tank Capacity for at least 8 h Auxiliary engine	MDO service tank Capacity for at least 8 h Auxiliary engine

② Equivalent arrangement

HFO service tank Capacity for at least 8 h Main engine + Auxiliary boiler	MDO service tank Capacity for at least the highest of: • 4 h Main engine + Auxiliary engine + Auxiliary boiler, or • 8 h Auxiliary engine + Auxiliary boiler	MDO service tank Capacity for at least the highest of: • 4 h Main engine + Auxiliary engine + Auxiliary boiler, or • 8 h Auxiliary engine + Auxiliary boiler

The arrangements in (1)② and (2)② apply, provided the propulsion and vital systems which use two types of fuel support rapid fuel changeover and are capable of operating in all normal operating conditions at sea with both types of fuel (MDO and HFO).

4.2.2 Oil burning units of boilers

4.2.2.1 Auxiliary boilers for essential services in this Chapter are those for the purpose of supplying steam to auxiliary machineries as to ensure safe navigation of ships.

4.2.2.2 Main boilers and auxiliary boilers for essential services and for heating of heavy fuel oil are to have not less than two oil supply units, each unit generally comprising a pressure pump, a filter and a heater (if needed). The capacities and arrangements of the units are to be such that all the steam required for essential services can be maintained with any one unit out of action. Where an exhaust gas boiler is capable of supplying steam for essential purposes, a single oil supply unit may be accepted. For a composite boiler whose exhaust side can provide steam of essential services, a single oil supply unit may also be accepted.

4.2.2.3 Oil burning unit pressure pumps are to be entirely separate from the feed, bilge or ballast systems.

4.2.2.4 In systems where oil is fed to the burners by gravity, duplex filters are to be fitted in the supply pipeline to the burners.

4.2.2.5 A starting-up oil fuel unit, which does not require power from shore, is to be provided for main boilers.

4.2.2.6 Where boiler burners are provided with steam purging and/or atomizing connections, the arrangements are to be such that oil fuel cannot find its way into the steam system.

4.2.2.7 The burner arrangements are to be such that a burner cannot be withdrawn unless the oil fuel supply to that burner is shut out.

4.2.2.8 A quick-closing master valve is to be fitted to the oil supply to each boiler manifold, suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control. In the case of oil-fired boilers of automatic controls, the relevant requirements of PART SEVEN of the Rules are also to be complied with.

4.2.2.9 In the case of top-fired boilers, means are to be provided so that, in the event of flame failure, the oil fuel supply to the burners is shut off automatically, and audible and visual warnings are given. For small auxiliary top-fired boilers, this requirement may be dispensed with.
4.2.2.10 Provision is to be made, by suitable non-return arrangements, to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut off.
4.2.2.11 For alternately fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

4.2.3 Oil fuel pumps, filters and isolating valves

4.2.3.1 Where an oil fuel booster pump is fitted, one main supply pump of sufficient capacity is to be provided for the main engine at its maximum continuous output and one standby pump of sufficient capacity is to be provided for normal navigation of the ship. Such a standby pump is to be independently power driven and capable of being ready for immediate use. Where two or more main engines are fitted, each with its own booster pump, only one standby pump connected ready for immediate use is needed, or alternatively, a complete spare pump may be accepted, provided that it is readily accessible and can easily be installed.
4.2.3.2 Where pumps are provided for fuel valve cooling, the arrangements of standby ones are to be in accordance with 4.2.3.1 of this Section.
4.2.3.3 Oil fuel filters are to be fitted in the oil fuel supply lines to the diesel engines, and their arrangement are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.
4.2.3.4 Oil filters fitted in parallel for the purpose of enabling cleaning without distributing oil supply to engines (e.g. duplex filters) are to be provided with arrangements that will minimize the possibility of a filter under pressure being opened by mistake. Filters/filter chambers are to be provided with suitable means for venting when put into operation and depressurizing before being opened.
Valves or cocks with drain pipes led to a safe location are to be used for this purpose.
4.2.3.5 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided. Any suitable pump in connection with fuel transfer system may be accepted as the standby pump.
4.2.3.6 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be so arranged as to discharge back to the suction side of the pump or other appropriate tanks, and to effectively limit the pump discharge pressure to the design pressure of the system.
4.2.3.7 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.
4.2.3.8 In multi-engine installations which are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines are to be provided. The means of isolation are not to affect the operation of the other engines and are to be operable from a position not rendered inaccessible by a fire on any of the engines. The means of isolation are to be capable of reliable manual closing.
4.2.3.9 The redundancy requirements for fuel oil and hydraulic oil systems and electronic control system of electronically controlled diesel engine are to comply with the relevant requirements of paragraphs 2.1.3 and 2.2.3, Appendix 2, Chapter 9 of this PART.

4.2.4 Oil fuel piping

4.2.4.1 Oil fuel piping is to be entirely separate from other piping systems. The arrangements are to be such that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or into tanks which are used for the carriage of fresh water. Where it is necessary to connect the fuel pipes to ballast systems, they are to be fitted with blanking flanges or other effective isolating devices.
4.2.4.2 Every oil fuel suction pipe from a double bottom tank is to be fitted with a valve or cock.
4.2.4.3 All valves and cocks forming part of the oil fuel installation are to be capable of being controlled from readily accessible positions above the working platform.
4.2.4.4 Oil fuel lines are not to be located immediately above or near units of high temperature, including boilers, steam pipelines, exhaust manifolds, silencers or other equipment required to be insulated by 1.3.6.3, Chapter 1 of this PART. As far as practicable, oil fuel lines are to be arranged far apart from hot surfaces, electrical installations or other sources of ignition and are to be screened or otherwise suitably protected to avoid oil spray or oil leakage onto the sources of ignition. The number of joints in such piping systems is to be kept to a minimum.
4.2.4.5 Pipes conveying heated oil to boilers under pressure are to be of seamless steel or other approved material having flanged or welded joints, and are to be placed in sight above the platform in well lighted

parts. The number of flanged joints is to be kept to a minimum. The flanges are to be machined. The jointing material is to be oil proof and impervious to oil heated to 150℃, and is to be as thin as possible. The scantlings of the pipes and their flanges are to be suitable for a pressure of at least 1.37 MPa or design pressure, whichever is the greater.

4.2.4.6 The short joining lengths of pipes to the burners from the control valves at the boiler may have threaded cone unions of robust construction.

4.2.4.7 Flexible hoses may be used for the burner pipes, provided that spare lengths, complete with couplings, are carried on board. Flexible hoses are to comply with the relevant requirements of 2.4.4 of this PART.

4.2.4.8 Oil fuel pipes and their valves and fittings are to be of steel or other equivalent material. Nodular graphite cast iron may be used for valves under static head fitted on the outside of fuel tank walls. Grey cast iron valves may be used in oil fuel piping with design pressure of less than 0.7 MPa and design temperature of less than 60℃.

Restricted use of flexible pipes is permissible in some positions. Flexible hoses are to comply with the relevant requirements of 2.4.4 of this PART.

4.2.5 Oil fuel arrangements and fuel oil tanks

4.2.5.1 As far as practicable, parts of the oil fuel system containing heated oil under pressure exceeding 0.18 MPa are not to be placed in a concealed position so that defects and leakage cannot readily be observed. The machinery spaces in way of such parts of the oil fuel system are to be adequately illuminated.

4.2.5.2 Every oil fuel pipe, which, if damaged, would allow oil to escape from a storage, settling or daily service tank situated above the double bottom are to be fitted with a cock or valve directly on the tank or short pipe welded to the oil tank bulkhead with a length not exceeding the value obtained from the following formula. Such valves or cocks are to be capable of being closed locally as well as cable of being closed from safe and easily accessible positions outside the spaces where these tanks are situated. In the case of tanks having a capacity of less than 0.5 m^3, remotely controlled closing devices may be omitted.

$$L = 0.8D + 80 \quad \text{mm}$$

where: L — length of short pipe, in mm;

D— outside diameter of steel pipe, in mm.

Remote shut-off control of oil fuel valves for emergency generating set and emergency fire pump is to be separated from those of other valves.

In the special case of deep tanks situated in any shaft or pipe tunnel or similar space, valves on the tank are to be fitted but control in the event of fire may be effected by means of an additional valve on the pipe or pipes outside the tunnel or similar space. If such additional valve is fitted in the machinery space it is to be operated from a position outside this space.

4.2.5.3 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in 4.2.5.2 above.

4.2.5.4 Fuel oil tanks are not to be situated immediately above boilers or other highly heated surfaces. Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

4.2.5.5 As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A. Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is to preferably have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces are to be kept to a minimum.

Where such tanks are situated within the boundaries of machinery spaces of category A they are not to contain oil fuel having a flashpoint of less than 60℃ (closed cup test).

In general the use of free-standing fuel oil tanks is to be avoided. When such tanks are employed the use are to be prohibited in category A machinery spaces on passenger ships. Where permitted, they are to be placed in an oil-tight spill tray of ample size having a suitable drain pipe leading to a suitably sized spill oil tank.

4.2.5.6 Settling tanks are to be provided with means for draining water from the bottom of the tanks.

If settling tanks are not provided, the oil fuel bunkers or daily service tanks are to be fitted with water drains.

4.2.5.7 Drain valves or cocks fitted to the fuel oil tanks are to be of self-closing type, and suitable

provision is to be made for collecting the oily discharge.

4.2.5.8 In ships of 400 gross tonnage and above, oil is not to be carried in a forepeak tank or a tank forward of the collision bulkhead. All ships of less than 400 gross tonnage are to comply with the above mentioned provisions so far as it is reasonable and practicable.

4.2.5.9 Location of fuel tanks in cargo area on oil and chemical tankers

On oil and chemical tankers, carrying liquid cargoes having a flashpoint not exceeding 60℃ and/or toxic liquid cargoes[①] fuel tanks located with a common boundary to cargo or slop tanks are not to be situated within nor extend partly into the cargo tank block. Such tanks may, however, be situated aft and/or forward of the cargo tank block.

They may be accepted when located as independent tanks on open deck in the cargo area subject to spill and fire safety considerations.

The arrangement of independent fuel tanks and associated fuel piping systems, including the pumps, can be as for fuel tanks and associated fuel piping systems located in the machinery spaces. For electrical equipment, requirements to hazardous area classification must however be met.

Cargo tank block is the part of the ship extending from the aft bulkhead of the aftmost cargo or slop tank to the forward bulkhead of the forward most cargo or slop tank, extending to the full depth and beam of the ship, but not including the area above the deck of the cargo or slop tank as shown in Figure 4.2.5.9.

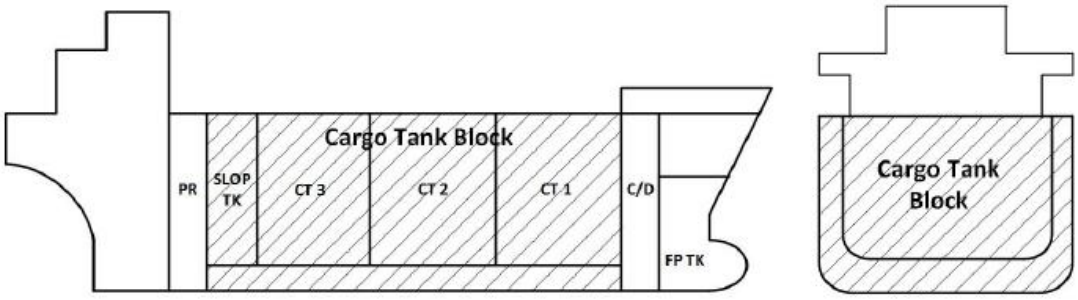


Figure 4.2.5.9

4.2.6 Filling piping

4.2.6.1 Fuel filling is to be effected by means of permanently installed lines. The filling pipes are to be led to a level as low as practicable inside the tank.

4.2.6.2 Where filling stations are fitted on board, they are to be isolated from other spaces and are to be efficiently drained and ventilated. Filling stations are to be so arranged that filling can be performed safely from both sides of the ship.

4.2.6.3 Provision is to be made against over-pressure in the filling pipelines, and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

4.2.7 Oil fuel (lubricating oil) heating

4.2.7.1 The heating media used for oil fuel (lubricating oil) tanks, heaters or oil separators are not to be more than 220℃ in temperature. Fuel oil (lubricating oil) in storage tanks is not to be heated to temperatures within 10℃ below the flash point of the fuel oil (lubricating oil), except that where oil fuel in service tanks, setting tanks and any other tanks in supply system is heated all of the conditions in 3.2.1.5(1) to (5) of Chapter 3 of PART SIX of the Rules are satisfied.

4.2.7.2 The exhaust drains from steam or hot water pipes used for heating the oil fuel (lubricating oil) are to be led to a separate observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil.

4.2.7.3 Relief valves are to be fitted on the oil side of heaters and the discharge from the relief valves is to be led to the suction of a related pump or to a safe position.

4.2.7.4 The oil fuel pipes and oil transfer pipes intended for conveying heated oil fuel are to be provided with suitable heating means if necessary.

4.2.7.5 Oil fuel (lubricating oil) tanks in which oil is heated and heaters are to be provided with suitable means for ascertaining the temperature of the oil.

4.2.7.6 Where steam heaters or heaters using other heating media are provided in fuel or lubricating oil

① Toxic liquid cargoes include those for which toxic vapour detection is specified in column “k” of the table of chapter 17 of the IBC Code.

systems, they are to be fitted with at least a high temperature alarm or low flow alarm in addition to a temperature control, except, where the temperature dangerous for the ignition of the medium cannot be reached.
4.2.7.7 Electric heating of fuel oil or lubricating oil are to be avoided as far as practicable.
When electric heaters are fitted, means are to be provided to ensure that heating elements are permanently submerged during operation. In order to avoid in any case element surface temperature of 220℃ and above, a safety temperature switch, independent from the automatic control sensor, is to be provided. The safety switch is to cut off the electrical power supply in the event of excessive temperature, and is to be provided with manual reset.
4.2.7.8 The exhaust gas of diesel engines is not to be directly used for heating oil fuel.

4.2.8 Alternative carriage of oil fuel and water ballast
4.2.8.1 In general, in oil tankers of 150 gross tonnage and above, all passenger ships and other ships of 4,000 gross tonnage and above, no ballast water is to be carried in fuel oil tanks. Where it is necessary to carry ballast water in fuel oil tanks, suitable means are to be provided for preventing pollution of the sea by oily-water ballast.
4.2.8.2 Where it is intended to carry oil fuel and water ballast in the same compartments alternatively, each settling or service tank fitted is to have a capacity sufficient to permit 12 h normal service, otherwise the suction lines of these compartments are to be so arranged that the oil may be pumped from any one compartment by the oil fuel pump at the same time as the ballast pump is being used on any other compartment.

4.2.9 Deep tanks for the alternative carriage of oil, water ballast or dry cargo
4.2.9.1 In the case of deep tanks which can be used for the carriage of oil fuel, cargo oil, water ballast or dry cargo, blank flange or other positive means of closing is to be provided for isolating the oil and water ballast filling and suction pipes, also the steam heating coils if retained in place, when the deep tank is used for dry cargo, and for isolating the bilge suction pipes when the deep tanks are used for oil or water ballast.
4.2.9.2 If the deep tanks are connected to an overflow system, the arrangements are to be such that liquid or vapor from other tanks cannot enter the deep tanks when dry cargo is carried in them.

4.2.10 Separation of cargo oils from oil fuel
4.2.10.1 Pipes conveying vegetable oils or similar cargo oils are not to be led through fuel oil tanks, nor are oil fuel pipes to be led through tanks containing these cargo oils.

4.2.11 Arrangements for other flammable oils
4.2.11.1 The arrangements for the storage, distribution and utilization of other flammable oils employed under pressure in power transmission systems, control and activating systems and heating systems are to be such as to ensure the safety of the ship and persons on board. In locations where means of ignition are present, such arrangements are at least to comply with the provisions of 4.2.4.8 and 4.2.5.4 of this Section, and with the relevant provisions contained in Section 10 of Chapter 3 of this PART.

Section 3 STEAM PIPING SYSTEMS

4.3.1 Arrangement
4.3.1.1 In general, steam pipes are not to be led through lamp rooms, paint lockers and cargo spaces, but where it is impracticable to avoid this arrangement, the pipes in way of cargo spaces are to be well protected from mechanical damage, and pipe joints are to be as few as practicable and preferably butt welded.
4.3.1.2 Where steam pipes subject to a working pressure exceeding 0.98 MPa are placed near to the fuel oil tank, the clearance space between the pipe and the external surface of the tank is in general to be at least 250 mm.
4.3.1.3 Steam pipes are to be arranged in visible and accessible positions in the machinery spaces. Steam pipes, except those used for preheating and sea chest blow-off services, are in general not to be led under the floor plates in machinery spaces.
4.3.1.4 Where two or more boilers are interconnected by steam pipe or pipes, a screw-down non-return valve is to be provided in the steam pipe of each boiler. Valves intended to drain condensate are to be fitted in the pipe length between these valves.

4.3.2 Condensate drainage

4.3.2.1 The slope of the pipes and the number and position of the drain valves or cocks are to be such that water can be efficiently drained from any portion of the steam piping system when the ship is in normal trim and is either upright or has a list of up to 5°. Arrangements are to be made for ready access to the drain valves or cocks.

A by-pass line is to be provided where the condensate trap is installed.

4.3.3 Thermal expansion stresses

4.3.3.1 For steam pipes subject to a working temperature exceeding 350℃, special consideration is to be given to stress due to thermal expansion and to technique of installation.

Section 4 FEED, BLOW-OFF AND CONDENSATE SYSTEMS

4.4.1 Feed pumps

4.4.1.1 Two or more power driven feed pumps are to be provided for main and auxiliary boilers for essential services or steam auxiliary boilers for heating heavy oil. These feed pumps are to be of sufficient capacity to supply the boilers under full load conditions with any one pump out of action.

4.4.1.2 Forced circulation boilers are to be provided with two independently driven circulating pumps, one of which is used as a stand-by pump. For auxiliary forced circulation boilers not used for essential services, one circulating pump will be accepted.

4.4.1.3 Where a harbor feed pump is provided, it may be used for other purposes, but in no case is it to be used for oil transferring or for discharging oily bilges. Furthermore, a suitable arrangement is to be provided to prevent the contamination of feed from sea water.

4.4.2 Feed piping

4.4.2.1 Two feed water systems are to be provided for main and auxiliary boilers for essential services, including feed pumps. The feed systems are to be of sufficient capacity to supply feed water to the boilers with any one system out of action. Only one feed water system may be provided for steam generators heated by steam where the steam for essential services is capable of being supplied simultaneously from another sources.

Feed water systems are to be so arranged that the feed water cannot be contaminated by oil or oily water.

4.4.2.2 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, so that any pump may be shut off and opened up for overhaul.

4.4.3 Reserve feed water

4.4.3.1 All ships fitted with main boilers and auxiliary boilers for essential services are to be provided with tanks of sufficient capacity for reserve feed water.

4.4.3.2 For main boilers in ships, one or more evaporators of adequate capacity are to be provided to cover the losses of feed water in the system. In the case of auxiliary boilers for essential services in ships, evaporators are to be installed as necessary.

4.4.4 Condensate pumps

4.4.4.1 At least two power driven condensate pumps, one of which is a standby pump, are to be provided for dealing with the condensate from the main and auxiliary condensers. Independent feed pumps may be accepted as stand-by condensate pumps.

4.4.5 Blow-off piping

4.4.5.1 The internal diameter of the blow-off pipes is to comply with the requirements of 6.3.7.2 of this PART. Valves or cocks in the blow-off piping, situated at the ship's bottom or ship's sides, are to be arranged and constructed according to the provisions contained in 2.8.9.2 and 2.8.9.3 of this PART.

4.4.5.2 The blow-off pipes of two or more boilers may be connected to a common discharge, but the blow-off pipe for each boiler is to be fitted with a non-return valve. It is recommended that a throttle washer be fitted to the blow-off pipe.

Section 5 COOLING WATER SYSTEMS

4.5.1 Cooling water pumps

4.5.1.1 For motor ships, where only one main engine is fitted, a main cooling pump of sufficient capacity to maintain supply of water at the maximum continuous output of the machinery and a standby cooling pump of sufficient capacity to supply cooling water under the normal navigating condition are to be provided. The standby pump is to be of independently power-driven type and to be connected ready for use. Where more than one main engine is fitted, each with its own cooling water pump, a complete spare pump may be accepted as a standby cooling water pump.

4.5.1.2 In steam ships, in addition to the main circulating pump for the condenser, there is to be an alternative supply from an emergency pump having a capacity sufficient to maintain the proper control of the ship (in general not to be less than 30% of that of the main circulating pump). If the main circulating pump unit consists of two independently power-driven pumps of approximately equal capacity, the emergency pump may be dispensed with.

Where a sea inlet scoop arrangement is fitted in lieu of the main circulating water pump, in addition to one independently power-driven circulating water pump having a capacity of at least 30% of that of the maximum required by circulation, a connection to the largest available pump suitable for circulation duties is to be fitted to provide the second means of circulation when the ship is maneuvering.

4.5.1.3 Where each essential auxiliary engine is fitted with a built-in cooling water pump, the standby pump may be dispensed with. If two or more auxiliary engines are supplied with cooling water from a common system, a standby cooling water pump is needed. The standby cooling water pump may be substituted by other pumps of sufficient capacity.

4.5.1.4 Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.

4.5.2 Piping and fittings

4.5.2.1 The cooling water piping for diesel engines is to be capable of effectively regulating the inlet cooling water temperature. For closed circuit fresh water cooling system, expansion tanks are to be provided and it is recommended that an alarm for high temperature be fitted.

4.5.2.2 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge. When discharge from the relief valves is to find its way into the bilge, the valves are to be fitted in readily visible positions above the floor. The arrangement is to be such that any discharge from the relief valves will also be readily visible.

4.5.2.3 Not less than two sea inlets, which are to be fitted on both sides of the ship as far as practicable, are to be provided for the cooling water pumps of sea water cooling system or circulating system. The suction of any cooling water pump or circulating pump under normal service conditions is to be supplied from either one of the sea inlets.

4.5.2.4 Provision is to be made for the protection of all equipment cooled by sea water against corrosion.

4.5.2.5 Strainers are to be provided to the suction pipes between the sea inlets and the suctions of sea water cooling pumps. The strainers are to be so arranged that they can be cleaned without interrupting the cooling water supply.

4.5.2.6 When it is necessary, the main diesel engine with closed circuit fresh water cooling system is to be provided with suitable means for warming the engine before starting. Alternatively, means to inter-connect the fresh water cooling system for main engine to that for auxiliary engines are acceptable.

Section 6 LUBRICATING OIL SYSTEMS

4.6.1 Lubricating oil pumps

4.6.1.1 Main engines and their transmission gearing are to be provided with a main lubricating oil pump of sufficient capacity to maintain supply of lubricating oil at the maximum continuous output of the machinery and a standby pump of sufficient capacity to supply lubricating oil under normal navigating condition are to be provided. The standby pump is to be of independently power-driven type and to be connected ready for use.

For ships fitted with more than one main engine, only one independently power-driven standby pump fitted is acceptable. Where each main engine and its transmission gearing is fitted with a built-in lubricating oil pump, a complete spare pump available for installation and connection may be accepted as an independently power-driven standby pump.

4.6.1.2 Where each essential auxiliary engine and its transmission gearing is fitted with a built-in lubricating oil pump, the standby pump may be dispensed with. If two or more auxiliary engines and their transmission gearing are connected to a common lubricating oil system, a standby pump is needed.

4.6.2 Piping and fittings

4.6.2.1 The lubricating oil piping is to be entirely separate from other piping systems. A common lubricating oil system is not to be in use for diesel engines and gear boxes.

4.6.2.2 Provision is to be made for the efficient filtration of the lubricating oil. For main propulsion machinery, the filters are to be capable of being cleaned without interrupting normal supply of filtered oil required in normal operation of ships. For generating sets, the filters are to be capable of being cleaned without interrupting normal supply of filtered oil required by generating sets under normal work load. Pressure gauges are to be fitted on both ends of lubricating oil filters or strainers. Proposals for fitting an emergency automatic by-pass device in high speed engines are to be submitted to CCS for special consideration.

Magnetic strainers are to be provided for high-powered main turbines and their reduction gears.

4.6.2.3 A relief valve is to be fitted on the lubricating oil pump discharge if the pump is capable of developing a pressure exceeding the design pressure of the system. The relief valve is to be such that the discharge oil can find its way to the suction of the pump and the pump discharge pressure is to be effectively limited to the design pressure of the system.

4.6.2.4 Visual and audible alarms are to be provided to give warning of an appreciable reduction in pressure of the lubricating oil.

4.6.2.5 Where two or more diesel engines are fitted, the drain pipes leading from the engine sumps to the lubricating oil drain tanks are to be independent to avoid intercommunication between crankcases.

4.6.3 Additional requirements for lubricating oil systems of main turbines and main turbo-generators

4.6.3.1 For main turbines and main turbo-generators in electrically propelled ships, a suitable emergency supply of lubricating oil is to be arranged. For this purpose, either one of the following will be accepted:

(1) The emergency supply may be obtained from a gravity tank holding sufficient lubricating oil to maintain adequate lubrication for not less than 5 min for main turbines, and, in the case of main turbo-generators, until the unloaded turbine comes to rest from the maximum rated running speed. The gravity tank is to be arranged to come automatically into use in the event of a failure of the lubricating oil pump. An alarm device is to be fitted to the gravity tank to give visual and audible warning when the oil in the tank falls to a predetermined level.

(2) The emergency supply may be obtained from a standby pump or an emergency pump. These pumps are to be so arranged that their availability is not affected by a failure in the main power supply and that they are capable of coming automatically into use.

4.6.3.2 Overflow pipes, which are to be led to the lubricating oil drain tanks, are to be fitted to the gravity tanks and the cross-sectional area of the overflow pipes is not to be less than 1.25 times that of the filling pipes from the lubricating oil pumps. The overflow pipes are to be fitted with illuminated sight glasses.

4.6.4 Lubricating oil arrangements and lubricating oil tanks

4.6.4.1 The separation of lubricating oil tanks from adjacent tanks is to be in compliance with the requirements of 2.8.2.1 of this PART.

4.6.4.2 The capacity of lubricating oil drain tanks is to be sufficient to hold the oil in the whole system.

Where an engine lubricating oil drain tank extends to the bottom shell plating in ships that are required to be provided with a double bottom, a shut-off valve is to be fitted in the drain pipe between the engine casing and the double bottom tank. This valve is to be capable of being closed from an accessible position above the level of the lower platform. If the drain tanks in the double bottom are separated from the shell plating by cofferdams, the shut-off valve mentioned above may be dispensed with.

The oil inlet pipe of the drain tank is to be extended to an adequate depth below the lowest working level and is to be located as wide apart from the outlet as practicable.

4.6.4.3 The pressure lubrication systems are to comply with the requirements of 4.2.4.4, 4.2.4.8, 4.2.5.1, 4.2.5.2, 4.2.5.4 and 4.2.6.3 of this Chapter and the relevant provisions contained in Section 10 of Chapter 3 of this PART.

In the case of tanks having a capacity of less than 0.5 m^3, consideration will be given to the omission of remote controls.

If the designers confirm that an unauthorized operation of the remotely controlled closing valves on the lubricating tanks will jeopardize safe running of the main or eventful auxiliary engines, the remotely

controlled device may be omitted.
4.6.4.4 All ships are to be provided with lubricating oil storage tank(s) having an adequate capacity.
4.6.4.5 Heating of lubricating oil is to comply with the relevant requirements of 4.2.7 of this Chapter.

Section 7 HYDRAULIC TRANSMISSION PIPING SYSTEMS

4.7.1 Materials

4.7.1.1 All components in the hydraulic transmission piping systems are to be made of materials which are not corrodible and have no chemical reaction with the hydraulic fluid.
4.7.1.2 The hydraulic fluid is to be of high chemical stability and of good viscosity-temperature property.
4.7.1.3 Main components in hydraulic power transmission system are to be generally made of steel materials. Material test is to be carried out according to the requirements of CCS Rules for Materials and Welding.

4.7.2 Piping

4.7.2.1 The hydraulic transmission piping is not to be used for the lubrication of other equipment.
4.7.2.2 The strength of hydraulic pipes and fittings is to be sufficient to withstand the pressure fluctuations which might occur in the system.
4.7.2.3 Strainers and relief valves are to be provided in the hydraulic transmission piping systems. The discharge from the relief valves is in general to be led to the hydraulic fluid tanks.
4.7.2.4 Provision is to be made for de-aeration in the hydraulic piping systems and the hydraulic fluid cylinders, etc. The hydraulic piping is to be so arranged as to avoid the formation of air pockets.
4.7.2.5 Where hydraulic accumulators are provided in the hydraulic systems, overflow valves are to be fitted on the liquid side. Unless otherwise specified, for hydro-pneumatic accumulators, safety valves or fuse plugs are to be fitted on the air side, otherwise they are to be fitted in the supply pipe line, and an isolation valve is not to be provided between the air side of the accumulator and the safety valve or fuse plug.
4.7.2.6 The use of flexible hoses is to comply with the relevant requirements of 2.4.4 of this PART. The flexible hoses are to be so arranged that abrupt bends and twisting will not occur in the laying of the hoses and they are to be far away from vibration and hot sources.
4.7.2.7 Hydraulic remote control valves for essential service are to be capable of being operated with a hand pump in emergency condition, and indicators showing whether the valves are open or closed are to be provided at their operating positions.
4.7.2.8 The hydraulic transmission piping system for essential services is to be provided with a standby power pump which is to be capable of immediate use.

4.7.3 Arrangement

4.7.3.1 Hydraulic units with working pressure above 1.5 MPa are to be placed in separate spaces. If it is impracticable to locate such units in a separate space, adequate shielding is to be provided.

Section 8 THERMAL OIL SYSTEM

4.8.1 General requirements

4.8.1.1 The thermal oil used in the thermal oil system is to be compatible with the oil being heated.
4.8.1.2 Heating of liquid cargoes with flash points below 60℃ is in general to be arranged by means of double circuit systems, with a secondary system located completely within the cargo area. However, a single circuit system may be accepted on the following conditions:
(1) System is so arranged that a positive pressure in the coil is to be at least 3 m water column above the static head of the cargo when circulating pump is not in operation.
(2) The thermal oil system expansion tank is to be fitted with high and low level alarms.
(3) Means are to be provided in the thermal oil system expansion tank for detection of flammable cargo vapors. Applicable portable equipment may be accepted.
(4) Valves for each heating coil are to be provided with locking arrangement to ensure that the coils are under static pressure at all times.
4.8.1.3 For details of heaters in thermal oil systems, see the relevant requirements of Section 5, Chapter 6 of this PART.

4.8.2 Plans and documents

4.8.2.1 The piping and pumping system plans of thermal oil systems are to be submitted for approval.

4.8.3 Design and manufacture

4.8.3.1 The installation is generally to comprise at least two circulation pumps and two filters for the thermal oil.

4.8.3.2 In addition to the local operations, the inlet and outlet valves of oil-fired thermal oil heaters and exhaust-fired thermal oil heaters are to be shut off from a readily accessible position outside the compartment where they are situated. As an alternative, an arrangement for quick gravity drainage of the thermal oil contained in the system into a collecting tank is acceptable.

4.8.3.3 Arrangements are to be provided to permit from inside and from outside the heater spaces a quick discharge by gravity of the expansion tank into a suitable tank.

4.8.3.4 The monitoring and protection of thermal oil heaters are to comply with the relevant requirements of 6.5.5, Chapter 6 of this PART.

4.8.3.5 Tubes and pipes for thermal oil are to be seamless steel tubes or welded steel tubes and pipes.

4.8.3.6 Casings of pumps, valves and similar components are to be made of steel or equivalent ductile material. Copper and copper alloys are not to be used for those parts the surface of which is in direct contact with thermal oil so as to prevent oxidation of thermal oil.

4.8.3.7 Thermal oil piping is to have welded connections except that flanges may be used to the limited number necessary for inspection and maintenance. If necessary, suitable devices are to be provided for avoiding oil splash in case of leakage in way of the flanges. Marine steel recess type or plane flanges having a nominal pressure not less than 1.6 MPa are to be used for inlet and outlet pipe connection of thermal oil heaters. In the case of steel plane flanges, wire-reinforced graphite gaskets or expanded graphite composite gaskets are to be used.

Screw joints are not to be used for thermal oil piping.

4.8.3.8 The piping system is to be designed and constructed to permit expansion and contraction without abnormal stressing.

4.8.3.9 Particular attention is to be paid to the insulation of thermal oil piping and heater. Flanges are not permitted to be protected by the insulation material. Insulation material of thermal oil heater and piping is to be of an approved type and, as far as possible, it does not lower than the auto-ignition point of the thermal oil when impregnated by it.

4.8.3.10 The thermal oil system is also to comply with the requirements contained in the relevant Chapters of the Rules.

4.8.4 Arrangement

4.8.4.1 Where the thermal oil heaters are located in main and auxiliary machinery spaces, effective means are to be provided to prevent dispersal of thermal oil after leakage, such as coaming plate, etc.

4.8.4.2 The thermal oil circulating pumps are to be arranged for emergency stopping from a position outside the space where they are situated.

4.8.4.3 Drip trays are to be installed under the components of the installation where leakage is liable to occur. These drip trays are to be drained to an appropriate sludge tank.

4.8.4.4 The thermal oil system is to be fitted with an expansion tank of sufficient capacity. The thermal oil expansion tank and pumping plants are to be located in the same space as the thermal oil heaters.

4.8.4.5 Vents from expansion tanks and thermal oil storage tanks of the thermal oil heating plants are to be led to open deck.

4.8.4.6 Thermal oil piping and pumping system are to comply with the relevant requirements of Section 2 of this Chapter. Only one pump supplying thermal oil to the thermal oil expansion tank is acceptable.

4.8.4.7 Thermal oil pipes are not to pass through accommodation spaces nor control stations. Thermal oil piping passing through main and auxiliary machinery spaces is to be restricted as far as possible.

4.8.4.8 Thermal oil heater rooms are to be suitably mechanically ventilated and illuminated.

4.8.4.9 Thermal oil heater rooms are to be fitted with approved automatic fire detection system or fire alarm system.

4.8.5 Additional requirements for exhaust-fired thermal oil heaters

4.8.5.1 Exhaust-fired thermal oil heaters are also to comply with the relevant requirements of 6.5.4.5 and 6.5.4.6, Chapter 6 of this PART.

4.8.6 Testing

4.8.6.1 Thermal oil system and installation are to be subject to hydraulic and tightness tests according to the relevant requirements contained in Chapters 2 and 6 of this PART.
4.8.6.2 On completion, working tests of the thermal oil system are to be carried out in accordance with the test program.

Section 9 REQUIREMENTS CONCERNING USE OF CRUDE OIL OR SLOPS AS FUEL FOR TANKER BOILERS

4.9.1 General requirements

4.9.1.1 The requirements of this section apply to tankers where crude oil or slops are used as fuel for boilers.When the flash point of the fuel is lower than 60℃, the relevant provisions in SOLAS regulations II-1/55,56 and 57 are to be complied with as a priority.
4.9.1.2 In tankers crude oil or slops may be used as fuel for main or auxiliary boilers according to the following requirements. For this purpose all arrangement drawings of a crude oil installation with pipeline layout and safety equipment are to be submitted for approval in each case.
4.9.1.3 Crude oil or slops may be taken directly from cargo tanks or flow slop tanks or from other suitable tanks. These tanks are to be fitted in the cargo tank area and are to be separated from non-gas-dangerous areas by means of cofferdams with gas-tight bulkheads.
4.9.1.4 The construction and workmanship of the boilers and burners are to be proved to be satisfactory in operation with crude oil.
The whole surface of the boilers is to be gas-tight separated from the engine room. The boilers are to be tested for gas-tightness before being used. The whole system of pumps, strainers, separators and heaters, if any, is to be fitted in the cargo pump room or in another room, to be considered as dangerous, and separated from engine and boiler room by gas-tight bulkheads. When crude oil is heated by steam or hot water the outlet of the heating coils is to be led to a separate observation tank installed together with above mentioned components. This closed tank is to be fitted with a venting pipe led to the atmosphere in a safe position according to the provisions for tankers and with the outlet fitted with a suitable flameproof wire gauze of corrosion resistant material which is to be easily removable for cleaning.
4.9.1.5 Electric, internal combustion and steam (when the steam temperature is higher than 220℃) prime movers of driving pumps, of separators (if any) are to be fitted in the engine room or in another non-dangerous room.
Where drive shafts pass through pump room bulkhead or deck plating, gas-tight glands are to be fitted. The glands are to be efficiently lubricated from outside the pump room.
4.9.1.6 Pumps are to be fitted with a pressure relief by-pass from delivery to suction side and it is to be possible to stop them by a remote control placed in a position near the boiler fronts or machinery control room and from outside the engine room.
4.9.1.7 When it is necessary to preheat crude oil or slops, their temperature is to be automatically controlled and a high temperature alarm is to be fitted.

4.9.2 Arrangement

4.9.2.1 The piping for crude oil or slops and the draining pipes for the tray defined in 4.9.2.3 are to have a thickness as shown in Table 4.9.2.1.

External diameter and thickness of crude oil, slops and draining pipes (mm)

Table 4.9.2.1

External diameter d_e	Wall thickness t
$d_e \leq 82.5$	≥ 6.3
$88.9 < d_e \leq 108$	≥ 7.1
$114.3 < d_e \leq 139.7$	≥ 8.0
$152.4 \leq d_e$	≥ 8.8

Their connections (to be reduced to a minimum) are to be of the heavy flange type. Within the engine room and boiler room these pipes are to be fitted within a metal duct, which is to be gas-tight and tightly connected to the fore bulkhead separating the pump room and to the tray. This duct (and the enclosed piping) is to be fitted at a distance from the ship's side of at least 1/5 of the vessel's beam (B) amidships and be at an inclination rising towards the boiler so that the oil naturally returns towards the pump room in the case of leakage or failure in delivery pressure. It is to be fitted with inspection openings with gas-tight doors in way of connections of pipes within it, with an automatic closing drain-trap placed on the pump room side, set in such a way as to discharge leakage of crude oil into the pump room.

In order to detect leakages, level position indicators with relevant alarms are to be fitted on the drainage tank defined in 4.9.2.3. Also a vent pipe is to be fitted at the highest part of the duct and is to be led to the open in a safe position. The outlet is to be fitted with a suitable flameproof wire gauze of corrosion-resistant material which is to be easily removable for cleaning.
The duct is to be permanently connected to an approved inert gas system or steam supply in order to make possible:
(1) injection of inert gas or steam in the duct in case of fire or leakage;
(2) purging of the duct before carrying out work on the piping in case of leakage.
4.9.2.2 In way of the bulkhead to which the duct defined in 4.9.2.1 is connected, delivery and return oil pipes are to be fitted on the pump room side, with shut-off valves remotely controlled from a position near the boiler fronts or from the machinery control room. The remote control valves are to be interlocked with the hood exhaust fans (defined in 4.9.3.1) to ensure that whenever crude oil is circulating the fans are running.
4.9.2.3 Boilers are to be fitted with a tray or gutterway with a suitable height and be placed in such a way as to collect any possible oil leakage from burners, valves and connections.
Such a tray or gutterway is to be fitted with a suitable flameproof wire gauze, made of corrosion resistant material and easily dismountable for cleaning. Delivery and return oil pipes are to pass through the tray or gutterway by means of a tight penetration and are then to be connected to the oil supply manifolds.
A quick closing master valve is to be fitted on the oil supply to each boiler manifold.
The tray or gutterway is to be fitted with a draining pipe discharging into a collecting tank in pump room. This tank is to be fitted with a venting pipe led to the open in a safe position and with the outlet fitted with wire gauze made of corrosion resistant material and easily dismountable for cleaning. The draining pipe is to be fitted with arrangements to prevent the return of gas to the boiler or engine room.

4.9.3 Other requirements

4.9.3.1 Boilers are to be fitted with suitable hood in such a way as to enclose as much as possible of the burners, valves and oil pipes, without preventing on the other side, air inlet to burner register.
The hood, if necessary, is to be fitted with suitable doors placed in such a way as to enable inspection of and access to oil pipes and valves placed behind it. It is to be fitted with a duct leading to the open in a safe position, the outlet of which is to be fitted with a suitable flameproof wire gauze, easily dismountable for cleaning. At least two mechanically driven exhaust fans having spark proof impellers are to be fitted so that the pressure inside the hood is less than that in the boiler room. The exhaust fans are to be connected with automatic change over in case of stoppage or failure of the one in operation.
The exhaust fan prime movers are to be placed outside the duct and a gas-tight bulkhead penetration is to be arranged for the shaft.
Electrical equipment installed in gas dangerous areas or in areas which may become dangerous (i.e. in the hood or duct in which crude-oil piping is placed) is to be of certified safe type as required by CCS.
4.9.3.2 When using fuel oil for delivery to and return from boilers, fuel oil burning units are to be fitted in the boiler room. Fuel oil delivery to, and returns from, burners are to be effected by means of a suitable mechanical interlocking device so that running on fuel oil automatically excludes running on crude oil or vice versa.
4.9.3.3 The boiler compartments are to be fitted with a mechanical ventilation plant and are to be designed in such a way as to avoid the formation of gas pockets.
Ventilation is to be particularly efficient in way of electrical plants and machinery and other plants which may generate sparks. These plants are to be separated from those for service of other compartments and are to be in accordance with relevant requirements of CCS.
4.9.3.4 A gas detector plant is to be fitted with intakes in the duct defined in 4.9.2.1 of this Section, in the hood duct (downstream of the exhaust fans in way of the boilers) and in all zones where ventilation may be reduced. An optical warning device is to be installed near the boiler fronts and in the machinery control room. An acoustical alarm, audible in the machinery space and control room, is to be provided.
4.9.3.5 Means are to be provided for the boiler to be automatically purged before firing.
4.9.3.6 Independent of the fire extinguishing plant as required in the Rules, an additional fire extinguishing plant is to be fitted in the engine and boiler rooms in such a way that it is possible for an approved fire extinguishing medium to be directed on to the boiler fronts and on to the tray defined in 4.9.2.3 of this Section. The emission of extinguishing medium is automatically to stop the exhaust fan of the boiler hood.
4.9.3.7 A warning notice is to be fitted in an easily visible position near the boiler front. This notice is to specify that when an explosive mixture is signaled by the gas detector plant defined in 4.9.3.4, the watchkeepers are to immediately shut off the remote controlled valves on the crude oil delivery and return

pipes in the pump room, stop the relative pumps, inject inert gas into the duct defined in 4.9.2.1 of this Section and turn the boilers to normal running on fuel oil.
4.9.3.8 One pilot burner in addition to the normal burning control is required.

Section 10 EXHAUST PIPELINES

4.10.1 Arrangement
4.10.1.1 Uptakes of boilers except exhaust gas boilers are not to be connected with exhaust pipelines of diesel engines.
4.10.1.2 Uptake governors or other means for closing the uptakes are not to be fitted within uptakes or funnels of oil-fired boilers.

4.10.2 Silencers
4.10.2.1 The structure of silencers is to be so designed that the internal cleaning and inspection can be carried out easily and these silencers are to be fitted with washing units with compressed air or steam or other cleaning appliances and drainage valves or cocks.
4.10.2.2 The external portion of silencers are to be packed with thermal insulation materials.

4.10.3 Water heaters
4.10.3.1 Water heaters fitted on the ducts for exhaust gas and smoke are, in general, to be of open type. If close type water heaters are fitted, the strength calculation is to be in accordance with the relevant requirements in Chapter 6 of this PART.
4.10.3.2 Close type water heaters are to be fitted with relief valves, pressure gauges, water level indicators, etc.
4.10.3.3 On construction, the close type water heaters are to be subject to a hydraulic test of 1.5 times the design pressure and the test pressure is not to be less than 0.4 MPa. The test of relief valves is to be carried out in accordance with the requirements in 6.3.5.3 of this PART.
4.10.3.4 Open type water heaters are to be fitted with a vent pipe of sufficient diameter and the vent pipe is not to be fitted with any closing appliances.

CHAPTER 5 PIPING SYSTEM FOR OIL TANKERS

Section 1 GENERAL PROVISIONS

5.1.1 Application

5.1.1.1 The requirements of this Chapter apply to oil tankers having the main propelling machinery aft which are intended to carry crude oil and petroleum products having a flash point (closed cup test) not exceeding 60℃.

Where ships are intended for the carriage of cargo oil having a flash point (closed cup test) exceeding 60℃, the relevant requirements in Section 8 of this Chapter are to be complied with.

5.1.1.2 In addition to the requirements of this Chapter, piping systems for oil tankers are to comply with the relevant provisions contained in Chapters 2, 3 and 4 of this PART, where applicable.

5.1.2 Arrangement of dangerous spaces

5.1.2.1 Diesel engines, or any other equipment which could constitute a possible source of ignition, are not to be situated within cargo tanks, pump rooms, cofferdams or other spaces liable to contain cargo oil or explosive vapors, or in spaces or zones immediately adjacent to cargo oil or slop tanks. The temperature of steam, or other fluid, in pipes (or heating coils) in these spaces is not to exceed 220℃.

5.1.3 Steam connections to cargo tanks

5.1.3.1 Where steaming out connections are provided for cargo tanks or cargo pipelines, they are to be fitted with valves of the screw-down non-return type. The main supply to these connections is to be fitted with a master valve placed in a readily accessible position clear of the cargo tanks.

The steaming pipes are to be so arranged that the steam can be supplied to the upper and lower parts of the tank separately as necessary.

5.1.4 Cargo pump room

5.1.4.1 Cargo pump rooms are to be situated within, or adjacent to, the cargo tank area and are to be provided with ready means of access on open deck.

Pump rooms are to be totally independent of and to have no direct communication with machinery spaces.

5.1.4.2 In cargo pump rooms any drain pipes from steam or exhaust pipes or from the steam cylinders of the pumps are to terminate well above the level of the bilges.

5.1.5 Slop tanks

5.1.5.1 In oil tankers, the venting arrangement, level sounding devices, heating systems and the piping for conveying oily water and cargo oil for the slop tanks designated for collecting and treating tank washings and dirty ballast from cargo tanks and other oily water are to comply with the relevant requirements for cargo tanks.

5.1.5.2 Discharge of oily water from slop tanks is to comply with the provisions for the prevention of pollution from ships.

5.1.6 Gas freeing equipment

5.1.6.1 Provision is to be made for the gas freeing of cargo tanks when the cargo has been discharged, and for the ventilation and gas freeing of all compartments adjacent to cargo tanks. For the purpose of monitoring flammable vapor, portable instruments are to be available on board for gas detection.

5.1.7 Earthing of cargo oil pipes

5.1.7.1 Earthing and bonding of cargo tanks and piping systems for the control of static electricity is to comply with the requirements in 1.3.4.11 of PART FOUR of the Rules.

5.1.8 Prevention and free of spark

5.1.8.1 The outlets of the exhaust gas pipes for main and auxiliary engines, boilers and other burner equipment are to be located at the sufficient height above the main deck. The horizontal distance of the outlets from cargo area is not to be less than 10 m. Where internal combustion engine is provided with approved spark arresters, as well as boilers and other burner equipment to be provided with spark arresters, their distance may be reduced to 5 m.

Section 2 CARGO HANDLING SYSTEM

5.2.1 General requirements

5.2.1.1 At least two independently power-driven cargo oil pumps are to be connected to the cargo oil system to pump cargo oil in each cargo tank. The arrangement is to ensure that the operation of other pumps is not affected if any one of the cargo oil pumps is inoperable.

5.2.1.2 If the cargo in cargo tank is lightered by a single deep well pump installed in each cargo tank, an emergency means for pumping out the tank is to be provided in case of failure of deep well pump.

5.2.2 Cargo pumps

5.2.2.1 Cargo pumps for the purpose of filling or emptying the cargo tanks are to be used exclusively for this purpose, except that they may be used for crude oil washing , cargo pump room drainage (see 5.3.2.1 of this Chapter) and filling or emptying water ballast in the cargo tanks. They are not to have any connections to compartments outside the range of cargo tanks.

5.2.2.2 Cargo pumps are to be installed in isolated pump rooms.

5.2.2.3 Where cargo pumps are driven by steam engines or turbines having a steam temperature not exceeding 220℃, the prime movers may be installed in the pump room.

5.2.2.4 Where cargo pumps are driven by shafting which passes through a pump room bulkhead or deck, gastight glands are to be fitted to the shaft at the pump room plating. the glands are to be efficiently lubricated from outside pump room and are to be so designed as to prevent overheating. The seal parts of the glands are to be of materials that will not initiate sparks. Where a bellows piece is incorporated in the design, it is to be hydraulically tested to 0.34 MPa before fitting.

5.2.2.5 Cargo pumps installed in cargo pump rooms and driven by shafts passing through pump room bulkheads are to be fitted with temperature sensing devices for bulkhead shaft glands and shaft bearings of cargo pumps from outside of pump room. Alarm is to be initiated for excessive temperature of the above-mentioned glands and bearings.

5.2.2.6 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be so arranged as to discharge back to the suction side of the pump, and to effectively limit the pump discharge pressure to the design pressure of the system.

5.2.2.7 Cargo oil pumps are to be capable of being stopped from a suitable position outside the pump room, as well as at the pumps.

5.2.2.8 A pressure gauge indicating the discharge pressure is to be fitted at the delivery side of each cargo oil pump. An additional gauge is to be fitted in the vicinity of the pump control station.

5.2.2.9 The safety requirements for stripping pumps fitted onboard and their piping systems are to be the same as those to cargo oil pumps and their piping systems.

5.2.2.10 Any integral hydraulic and/or electrical system used to drive both cargo and ballast pumps (integral cargo and ballast system) is to comply with the relevant provisions in 2.6.7, Chapter 2, PART FOUR of the Rules.

5.2.3 Cargo piping system

5.2.3.1 Cargo oil pipes are to be laid only within the cargo tank area, except for the bow or stern loading and unloading equipment outside cargo tank specified in the following 5.2.3.12.

5.2.3.2 Unless stated otherwise, cargo oil pipes are to be fully independent of other pipes.

5.2.3.3 Where Cargo tanks and slop tanks are provided with direct filling connections, the loading pipes are to be led to as low a level as practicable inside the tanks, so as to minimize the generation of static electricity.

5.2.3.4 Where it is necessary to fill the oil tanks by using the cargo oil suction pipes, a by-pass is to be provided to connect the suction and discharge ends of cargo oil pump. A stop valve is to be fitted on the by-pass.

5.2.3.5 Where the cargo oil piping system is used also as a ballast system for the cargo tanks, a blank flange or a removable spool piece is to be fitted between the sea chest valve and the cargo oil main, and a shut-off valve is to be fitted on each side of the blank flange or the removable spool piece.

The discharge of oily ballast water is to comply with the requirements for the prevention of pollution from ships.

5.2.3.6 Terminal pipes, valves and other fittings in the cargo loading and discharging lines to which shore installation hoses are directly connected, are to be of steel or ductile material. They are to be of robust construction and strongly supported.

A manually operated shut-off valve is to be fitted to each shore loading/discharging connection.
5.2.3.7 Expansion joints or bends are to be provided, where necessary, in the cargo pipelines.
5.2.3.8 For cargo piping system, means are to be provided to enable the contents of the cargo lines and pumps to be drained to a cargo tank or slop tank or to the shore facilities.
5.2.3.9 The operating rods for cargo valves in cargo tanks are to be extended to positions above the open deck. In the case of cargo tanks which are located adjacent to below-deck pump rooms or pipe tunnels, the operating rods may be located in these spaces at the bulkhead.
Stuffing boxes are to be fitted where the operating rod passes through the deck or bulkhead and to be so constructed that packing may be renewed from outside the cargo tanks. Indicators are to be provided at the operating hand wheels to show whether the valves are open or closed.
5.2.3.10 Materials used for the friction parts of the valves and operating rods of the cargo oil piping and of flexible couplings in shafts between the cargo pumps and the prime movers are to be such as to preclude the possibility of sparking while in operation.
5.2.3.11 Cargo oil pipelines are not to pass through ballast tanks. Where this can not be avoided, the pipes passing through ballast tanks are to have a wall thickness in accordance with the requirements in Table 5.3.4.2 of this Chapter and are to be provided with welded joints.
5.2.3.12 Bow or stern loading and unloading
Where bow or stern loading and unloading connections are provided outside cargo tank area, the arrangements are to be as follows:
(1) Cargo lines for bow or stern loading and unloading are to be installed outside accommodation spaces, service spaces, machinery spaces and control stations, and are to be clearly identified.
(2) Pipe joints outside the cargo area and used for bow or stern loading and unloading are to be welded.
(3) A spectacle flange or a removable spool piece is to be fitted at the connection line between the cargo loading and unloading line and cargo main line in cargo area, and a shut-off valve is to be fitted on each side of the blank flange or the removable spool piece.
(4) The loading and unloading connection is to be fitted with a shut-off valve and a blank flange. Spill containment is to be provided under the loading and unloading manifold.
(5) Arrangements are to be provided for cargo lines outside of the cargo area for easy draining to a slop tank or cargo tank.
(6) Space within 3 m from the oil spill containment boundary and connection mentioned in (4) above is considered to be gas hazardous area and is to be clearly identified.
(7) Fixed deck foam fire-extinguishing system required for cargo area is to effectively protect bow or stern loading and unloading area.

5.2.4 Remote control valves

5.2.4.1 Valves on deck and in pump rooms which are provided with remote control are to have local manual operating devices independent of the remote operating mechanism or emergency means for operating the valve actuators in the event of damage to the main hydraulic circuits on deck, such as connections, with isolating valves, fitted to the pipes near the valve actuators as far as possible for coupling to a standby portable pump carried on board.
5.2.4.2 Where the valves and their actuators are located inside the cargo tanks, two separate suctions are to be provided in each tank, or alternative means of emptying the tanks in the event of a defective actuator, are to be provided.
It is recommended that the lines to the valve actuators be led vertically inside the tanks from deck, and that connections, with isolating valves, be provided on deck lines for coupling to a standby portable pump carried on board for emergency operation of the valves in the event of damage to the main hydraulic circuits on deck.
5.2.4.3 Indication is to be provided at the remote control stations showing whether the valve is open or shut.
5.2.4.4 All actuators are to be of a type which will prevent the valves from opening inadvertently in the event of the loss of pressure in the operating medium. The design of the actuators is to be such that contamination of the operating medium with cargo oil cannot take place under normal operating conditions.
5.2.4.5 Compressed air is not to be used for operating actuators inside cargo tanks.
5.2.4.6 For the actuators in cargo tank, the supply tank is to be located as high as practicable above the level of the top of cargo tank, and all actuator supply lines are to enter the cargo tanks through the highest part of the tanks. Furthermore, the supply tank is to be of the closed type with an air pipe led to a safe space on the deck and fitted with a flameproof wire gauze diaphragm at its open end. This tank is also to be fitted with high and low level audible and visual alarms.

Section 3 BILGE, BALLAST AND OTHER PIPING SYSTEMS

5.3.1 Pumping arrangements at ends of ship outside ranges of cargo tanks

5.3.1.1 The pumping arrangements in machinery spaces and the forward end of the ship are to comply with the requirements for general cargo ships, unless otherwise specified in this Section.

5.3.1.2 The internal diameter d_1 of the bilge main and direct bilge suction in machinery spaces is to be calculated according to the requirements of 3.4.3.1 of this PART. L in the formula may be the ship's length reduced by the combined length of the cargo area. In such cases, the cross sectional area of the main bilge line is not to be less than twice the required cross sectional area of the engine room branch bilge lines.

5.3.1.3 The internal diameter d_2 of branch bilge suction pipes of machinery spaces is to be in accordance with the requirements in 3.4.3.3 of this PART.

5.3.1.4 Bilge, ballast and oil fuel lines, which are connected to pumps, tanks or compartments at the ends of the ship, are not to pass through cargo tanks or have any connections to cargo tanks or cargo lines, in general, no objection will be made to these lines being led through ballast tanks or void spaces within the range of the cargo tanks.

5.3.1.5 The arrangement of all pumps serving tanks directly adjacent to cargo tanks is also to comply with the requirements to cargo oil pumps in 5.2.2.2 to 5.2.2.5 of this Chapter, except for pumps and pipes serving fuel oil tanks located behind cargo tanks and directly adjacent to cargo tanks. Pumps and pipings serving above-mentioned fuel oil tanks may be located in engine room.

5.3.1.6 Unless specified otherwise, the piping system outside cargo area is to be mutual independent from the piping system within cargo area.

5.3.2 Cargo pump room drainage

5.3.2.1 Provision is to be made for the drainage of the cargo pump rooms by pump or bilge ejector suctions. Where cargo pumps or cargo stripping pumps are used for this purpose, the bilge suctions are to be fitted with screw-down non-return valves and, in addition, a stop valve is to be fitted on the pump connection to the bilge valve chest.

5.3.2.2 Cargo pump room suctions are not to enter machinery spaces.

5.3.2.3 The bilge drainage of the cargo pump rooms is to comply with the relevant requirements for the prevention of pollution from ships. It is recommended that cargo pump room bilge is to be drained into the slop tanks.

5.3.2.4 All the cargo pump rooms are to be provided with bilge level monitoring devices and suitable synchronous alarm devices.

5.3.3 Cofferdam drainage within the ranges of cargo tanks

5.3.3.1 The bilge suction equipment of cofferdam is to be installed within the ranges of cargo tanks. The requirements of 5.3.2.1 of this Section are to be complied with, where cargo pumps or cargo stripping pumps are used for drainage. Alternatively, cofferdams may be drained by bilge ejectors.

5.3.4 Ballast piping within the range of the cargo tanks

5.3.4.1 Ballast tanks within the range of cargo tanks and ballast pipelines in the double bottom tank are to be provided with separate ballast pumps and pipelines. The ballast pump is to be located in the cargo pump room or other suitable space within the range of the cargo tanks. The arrangement of ballast pumps is also to comply with the requirements for cargo oil pumps in 5.2.2.2 to 5.2.2.5 of this Chapter. However, If ballast pump is located in individual ballast pump tank, the requirements of 5.2.2.5 may be exempted.

5.3.4.2 The ballast lines are not to pass through cargo tanks. Where this cannot be avoided, the ballast lines passing through cargo tanks are to be heavy gauge steel, having welded or heavy flanged joints. The pipes in cargo tanks are not to be less than the value given in Table 5.3.4.2 in thickness. The number of joints is to be kept to a minimum. Where it is proposed to use material which is more resistant to corrosion than carbon steel, the pipe thickness may be suitably reduced.

Pipe thickness inside cargo tanks **Table 5.3.4.2**

Nominal diameter of pipe① (mm)	Minimum wall thickness (mm)
50	6.3
100	8.6
125	9.5
150	11.0
200 and above	12.5

Note: ① For nominal diameter with the value between those listed in the Table, the corresponding pipe thickness may be

calculated by insertion.

5.3.4.3 Expansion bends or bellows, not glands, are to be fitted to the ballast pipes in the cargo tanks.

5.3.4.4 For clean ballast piping, provision may be made for emergency discharge of water ballast by means of a portable spool connection to cargo oil pump and where this is arranged, a screw-down non-return valve is to be fitted in the ballast suction to the cargo oil pump and a screw-down valve is to be fitted to the cargo oil lines.

5.3.4.5 Where the clean ballast pumps are installed in a cargo pump room, the sea inlets of these pumps are to be entirely separated from the sea inlets of the cargo pumps.

5.3.4.6 Water supply of fire main may be used as dynamic water of eductors for discharging ballast water of ballast tank or for discharging bilge water of cofferdam in cargo area, and the following requirements are to be complied with:

(1) eductors are to be located in cargo area such as pump tank;

(2) water supply pipes from fire main for the above-mentioned purpose are to be led from upper deck in cargo hold area;

(3) a stop-check valve is to be fitted at appropriate position near deck before the water supply pipe passes through deck.

5.3.5 Air and sounding pipes for cofferdams

5.3.5.1 Deep cofferdams at the fore and aft ends of the cargo spaces and other tanks or cofferdams within the range of the cargo tanks, which are not intended for cargo, are to be provided with air and sounding pipes led to the open deck. The air pipes are to be fitted with renewable wire gauze diaphragms at their outlets. The height of air pipes from the deck to the point where water may have access below is not to be less than 760 mm.

5.3.5.2 So far as practicable, the air and sounding pipes required in 5.3.5.1 are not to pass through cargo tanks. Were side ballast tank or empty side tank are not provided on ship, the air and sounding pipes in way of the double bottom may pass through cargo tanks. But a wall thickness of the pipes passing through cargo tanks are to comply with the requirements in Table 5.3.4.2 of this Chapter and the pipes are to be completion or with welded joints.

5.3.6 Location and separation of spaces in combination carriers

5.3.6.1 The slop tanks are to be surrounded by cofferdams except where the boundaries of the slop tanks where slop may be carried on dry cargo voyages are the hull, main cargo deck, cargo pump-room bulkhead or fuel oil tank. These cofferdams are not to be open to a double bottom, pipe tunnel, pump-room or other enclosed space. Means are to be provided for filling the cofferdams with water and for draining them.

5.3.6.2 Means are to be provided for isolating the piping connecting the pump-room with the slop tanks referred to in 5.3.6.1. The means of isolation are to consist of a valve followed by a spectacle flange or a spool piece with appropriate blank flanges. This arrangement is to be located adjacent to the slop tanks, but where this is unreasonable or impracticable it may be located within the pump-room directly after the piping penetrates the bulkhead. A separate pumping and piping arrangement is to be provided for discharging the contents of the slop tanks directly over the open deck when the ship is in the dry cargo mode.

5.3.6.3 Hatches and tank cleaning openings to slop tanks are only permitted on the open deck and are to be fitted with closing arrangements. Except where they consist of bolted plates with bolts at watertight spacing, these closing arrangements are to be provided with locking arrangements which are to be under the control of the responsible ship's officer.

5.3.6.4 Where cargo wing tanks are provided, cargo oil lines below deck are to be installed inside these tanks. Where cargo wing tanks are not provided, cargo oil lines below deck are to be placed in special ducts which are capable of being adequately cleaned and ventilated.

Section 4 CARGO OIL HEATING

5.4.1 General requirements

5.4.1.1 The medium used for heating cargo oil is to have a temperature not exceeding 220℃.

5.4.2 Steam heating

5.4.2.1 The steam used for heating cargo oil is to be of saturated steam.

5.4.2.2 An observation tank is to be provided for the heating coil drains and is to be located in a well ventilated and well illuminated part of the machinery space remote from the boilers, diesel engine exhaust

pipes and electrical equipment. The upper drain pipe of the tank is to be led to a sludge tank.
5.4.2.3 The heating steam supply and return lines are not to penetrate the cargo tank plating, other than at the top of the tank, and these lines are to be run above the weather deck.
5.4.2.4 Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the heating circuit(s) of each tank. The heating coil exhaust pipes of the cargo oil heating systems for each tank are to be fitted with inspection valves or cocks on the open deck to check the heating coils for leakage.
5.4.2.5 Spectacle flanges or spool pipes are to be provided in the heating steam supply and return pipes to the cargo heating system, at a suitable position within the cargo area, so that the lines can be blanked off in circumstances where the cargo does not require to be heated or where the heating coils have been removed from the tanks. Alternatively, blanking arrangements may be provided for each tank heating circuit.

5.4.3 Thermal oil heating
5.4.3.1 Thermal oil heating of cargo oil is to comply with the relevant requirements of Section 8, Chapter 4 of this PART.
5.4.3.2 The heating oil supply and return lines are not to penetrate the cargo tank plating, other than at the top of the tank.
5.4.3.3 Isolating shut-off valves are to be provided at the inlet and outlet connections to the heating oil circuit(s) of each tank.
5.4.3.4 Spectacle flanges or spool pipes are to be provided in the heating oil supply and return pipes to the cargo heating system, at a suitable position within the cargo area, so that the lines can be blanked off in circumstances where the cargo does not require to be heated or where the heating coils have been removed from the tanks.

Section 5 CARGO TANK LEVEL SOUNDING

5.5.1 General requirements
5.5.1.1 Each cargo tank is to be fitted with suitable means for ascertaining the liquid level, and the requirements respectively in 5.5.2 to 5.5.4 below are to be complied with.

5.5.2 Closed sounding devices
5.5.2.1 In oil tankers fitted with a fixed inert gas system, the cargo tanks are to be fitted with closed sounding devices which do not permit the escape of cargo to the atmosphere when being used.

5.5.3 Limited sounding devices
5.5.3.1 Sounding pipes or other approved devices, which may permit a limited amount of vapor to escape to atmosphere when being used, would be accepted for those tanks which are not required to be fitted with closed sounding devices. The devices are to be so designed as to minimize the sudden release of vapor or liquid under pressure and the possibility of liquid spillage on deck. Means are also to be provided for relieving tank pressure before the device is operated.
Arrangements which permit the escape of vapor to the atmosphere are not to be fitted in enclosed spaces.

5.5.4 Open sounding devices
5.5.4.1 Separate ullage openings may be fitted as a reserve means for sounding cargo tanks.

Section 6 CARGO TANK VENTING ARRANGEMENTS

5.6.1 General requirements
5.6.1.1 Each cargo tank is to be fitted with venting arrangements which will limit the pressure or vacuum in the tanks. Vent pipes of cargo tanks are not to be in connection with the air pipes led from other tanks. Cargo tank venting arrangements are to be designed to provide:
(1) venting of large volumes of vapor/air mixtures during cargo handling and gas freeing operation;
(2) pressure/vacuum release of small volumes of vapor/air mixtures flowing during a normal voyage due to the change of temperature;
(3) a secondary means of allowing full flow relief of vapors, air or inert gas mixtures is to be provided in the event of failure of the arrangements in (1). The secondary means are to be capable of preventing over-pressure or under-pressure in the event of damage to, or inadvertent closing of, the means of isolation

required in the paragraph 5.6.2.2 of the Section. Alternatively, pressure sensors may be fitted in each tank protected by the arrangement required in 5.6.1.1 (1), with a monitoring system in the ship's cargo control room or the position from which cargo operations are normally carried out. Such monitoring equipment is also to provide an alarm facility which is activated by detection of over-pressure or under-pressure conditions within a tank.

5.6.2 Pressure/vacuum and venting systems

5.6.2.1 The pressure/vacuum system and venting system may be separate or combined and may be connected to an inert gas system.

5.6.2.2 The vent and/or pressure/vacuum valve stand pipes are to be connected to the highest part of each tank, and where combined systems are adopted, a means of isolation is to be provided between each tank and a common main. Any means of isolation must continue to permit the flow caused by thermal variations in a cargo tank in accordance with the provisions of 5.6.1.1(2). If cargo loading and ballasting or discharging of a cargo tank or cargo tank group is intended, which is isolated from a common venting system, that cargo tank or cargo tank group are to be fitted with a means for over-pressure or under-pressure protection as required in 5.6.1.1(3) of this Section. Any isolation is also to continue to permit the passage of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging.

5.6.2.3 In no case are shut-off valves to be fitted either above or in the pipe leading to a pressure/vacuum valves. However, by-pass valves may be fitted or provision may be made to enable the tank pressure/vacuum valves to be held in an open position. The arrangements are to be such that clear indication is given when the by-pass valve is open or the pressure/vacuum valve is secured in the open position.

5.6.2.4 The pressure/vacuum valve is to be located on open deck and means are to be provided to enable the functioning of the valve to be easily checked.

5.6.2.5 Pressure/vacuum valves are to be capable of preventing the cargo tanks from sustaining a positive pressure (generally not more than 0.021 MPa) which is greater than the testing pressure, and a negative pressure of less than 0.007 MPa.

5.6.2.6 The area of the venting system used during cargo loading is to be based on the maximum design loading rate and a gas evolution factor of 1.25.

5.6.2.7 Suitable drainage arrangements are to be provided in the vapor lines where condensate might collect.

5.6.3 Arrangement of vapor outlets

5.6.3.1 Outlets from vent pipes and, where necessary, outlets/inlets from pressure/vacuum valves are to be provided with readily renewable wire gauze①. Material of wire gauze is to be resistant to corrosion.

5.6.3.2 Vent outlets and pressure/vacuum valve, if used during loading, are to be arranged to discharge the vapor in an upward vertical direction. Vent outlets and pressure/vacuum valve inlets and outlets are to be arranged to prevent the entrance of water into the cargo tanks.

5.6.4 Height and location of cargo tank vent outlets

5.6.4.1 Vent outlets for cargo loading, discharging and ballasting required in 5.6.1.1(1) of this Section are to:

(1) permit the free flow of vapor mixtures; or

(2) permit the throttling of the discharge of the vapor mixtures to achieve a velocity of not less than 30 m/s.

They are also to be so arranged that the vapor mixture is discharged vertically upwards.

Where the method is by free flow of vapor mixtures, the arrangement is to be such that the outlet is not to be less than 6 m above the cargo tank deck or fore and aft gangway if situated within 4 m of the gangway and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard.

Where the method is by high-velocity discharge, the outlets are to be located at a height not less than 2 m above the cargo tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard.

---

① Refer to MSC/Circ.677 – Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers and MSC/Circ.450/Rev.1 – Revised Factors to be Taken into Consideration when Designing Cargo Tank Venting and Gas Freeing Arrangements.

5.6.4.2 Openings for pressure release required in 5.6.1.1(2) of this Section are to be arranged in accordance with 5.6.4.1 of this Section.

5.6.5 Preventive measures against liquid rising in the venting system

5.6.5.1 Provisions are to be made to guard against liquid rising in the venting system to a height which would exceed the design head of cargo tanks. This may be accomplished by high-level alarms or overflow control systems or other equivalent means, together with independent gauging devices and cargo tank filling procedures. For the purposes of this regulation, spill valves are not considered equivalent to an overflow system.

Section 7 REQUIREMENTS FOR DOUBLE HULL SPACES OF OIL TANKERS

5.7.1 Inerting, ventilation and gas measurement of double hull spaces

5.7.1.1 Double hull spaces are to be provided with suitable ventilation connections.

5.7.1.2 On tankers required to be fitted with inert gas systems:

(1) double hull spaces are to be fitted with suitable connections for the supply of inert gas;

(2) where such spaces are connected to an inert gas distribution system, means is to be provided to prevent flammable gases from the cargo tanks entering the double hull spaces through the system;

(3) where such are not connected to an inert gas distribution system, appropriate means is to be provided to allow connection to the inert gas main.

5.7.1.3 Tankers are to be provided with suitable portable instruments for measuring oxygen and flammable vapor concentrations. In selecting these instruments, due attention is to be given for their use in combination with the gas sampling systems referred to in 5.7.1.4 of this Section.

5.7.1.4 Where atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces are to be fitted with permanent gas sampling lines. The configuration of such line systems is to be adapted to the design of such spaces.

5.7.1.5 The materials of construction and the dimensions of gas sampling lines are to be such as to prevent restriction. Where plastic materials are used, they are to be electrically conductive.

Section 8 REQUIREMENTS FOR OIL TANKERS INTENDED FOR CARRIAGE OF CARGO OIL HAVING A FLASH POINT EXCEEDING 60℃

5.8.1 General requirements

5.8.1.1 For oil tankers intended for the carriage of cargo oil having a flash point above 60℃ (closed cup test) and where the maximum temperature heated for the cargo oil in cargo oil tanks is at least 10℃ below the flash point of the cargo oil, the requirements of this Chapter are to be complied with, but the following in this Chapter may not be applicable:

5.1.2, 5.1.4, 5.1.6, 5.1.8, 5.2.2.1 to 5.2.2.5, 5.2.3.1, 5.2.3.12, 5.2.4.5, 5.3.1.5, 5.3.3.1, 5.3.4.1, 5.3.4.6, 5.5.2.1, 5.6.1 to 5.6.5 and 5.7.1.

5.8.2 Vent pipes of cargo tanks

5.8.2.1 Vent pipes are to be led from the highest part of the tank to the open area above the freeboard deck and such pipes are not to be connected to those of other than cargo oil tank spaces.

5.8.2.2 Vent pipes required in 5.8.2.1 of this Section may be fitted for each cargo oil tank, vent pipes required for several cargo oil tanks may also be led to a common main, but it is proposed that a pressure/vacuum valves is to be fitted on the common main.

5.8.2.3 The height of the outlet ends of vent pipes (including branch and main) are not to be less than 760 mm above the freeboard deck.

5.8.2.4 The outlet ends of vent pipes are to be provided with a wire gauze diaphragm of corrosion-resistant material which can be readily removed for renewal.

CHAPTER 6 BOILERS AND PRESSURE VESSELS

Section 1 GENERAL PROVISIONS

6.1.1 General requirements

6.1.1.1 The requirements of this Chapter apply to the following devices or equipment of welded construction:

(1) boilers generating steam with a pressure above atmospheric pressure (0.103 MPa) or heating pressurized hot water above 120℃;

(2) thermal oil heaters;

(3) pressure vessels.

6.1.1.2 The certification requirements and product survey of boilers and pressure vessels are to comply with the relevant requirements in Chapter 3, PART ONE of the Rules.

6.1.2 Classification

6.1.2.1 For the purpose of the Rules, boilers and pressure vessels are classified in accordance with the design pressure p (MPa), thickness δ (mm) of cylindrical shell, working temperature t (℃) of cylindrical shell and inner diameter d (mm) of pressure vessel, see Table 6.1.2.1.

Classes of Boilers and Pressure Vessels **Table 6.1.2.1**

Type \ Class	Class I	Class II	Class III
Boilers or thermal oil heaters	$p > 0.35$	$p \leq 0.35$	–
Steam generators	$p > 1.15$, or $p.d > 1500$	Steam generators other than Class I	–
Pressure vessels or heat exchangers	$p > 4$, or $\delta > 40$, or $t > 350$	$4 \geq p > 1.57$, or $40 \geq \delta > 16$, or $350 \geq t > 150$	Pressure vessels and heat exchangers other than Classes I and II
Pressure vessels or heat exchangers for liquefied gases, toxic and corrosive substances	All	–	–

6.1.2.2 The small auxiliary boilers mentioned in this Chapter are the boilers having an evaporating capacity not exceeding 1,000 kg per hour and a design pressure not exceeding 0.78 MPa.

6.1.3 Definitions

6.1.3.1 For the purpose of this Chapter:

(1) Design pressure

The design pressure is the maximum permissible working pressure for boilers and pressure vessels. Strength calculations for boilers and pressure vessels are to be based on the design pressure and not to be less than the highest set pressure of safety valve.

The design pressure of economizers is the maximum working pressure of the medium in the economizer.

(2) Metal temperature

The metal temperature is to be taken as the actual metal temperature expected under operating conditions for the pressure part concerned, and is to be stated in the relevant plans of design.

(3) Boilers

Boilers include all closed vessels together with their fittings which receive the thermal energy released by burning fuel or any other thermal energy for the generation of steam or hot water.

(4) Pressure vessels

Pressure vessels are vessels together with their fittings which are subjected to an external or internal pressure.

(5) Heat exchangers

Heat exchangers are devices together with their fittings which are used for heat exchange between two or more media. Heat exchangers and their fittings are to be designed, manufactured and inspected in accordance with the requirements for pressure vessels.

(6) Steam generators

Steam generators are heat exchangers together with their fittings which are used to generate steam. Unless stated otherwise, the requirements for boilers in this Chapter apply to steam generators.

(7) Thermal oil heaters

Thermal oil heaters are devices in which thermal oil is heated and circulated.

6.1.4 Plans and documents

6.1.4.1 The following plans and documents of boilers are to be submitted for approval:
(1) General arrangement (the highest part of heating surfaces of the boiler is to be clearly indicated in the submitted drawing);
(2) Body construction (including details of welded connections, attachments and supports);
(3) Construction of pressure parts (cylindrical shell, steam and water drums, headers, combustion chamber, furnace, superheater, desuperheater, economizer, etc.);
(4) Arrangement of mountings and fittings;
(5) Safety valves with diameter calculation;
(6) Strength calculations;
(7) Heat treatment procedures of welded connections;
(8) Test pressure.

6.1.4.2 The following plans and documents of pressure vessels are to be submitted for approval:
(1) General arrangement;
(2) Body construction (including details of welded connections, attachments and supports);
(3) Construction of pressure parts (cylindrical shell, end plate, etc.);
(4) Arrangement of mountings and fittings;
(5) Strength calculations;
(6) Test pressure.

6.1.4.3 For thermal oil heaters, the following plans and information are to be submitted for approval or reference, in addition to those as required for boilers:
(1) Plan of monitoring and alarm system;
(2) Plan of fire-extinguishing system and relevant calculations (if applicable);
(3) Design temperature and pressure of the system, physical and chemical properties (e.g. viscosity, flash point, ignition temperature, decomposition temperature, self-ignition temperature) of thermal oil (for reference);
(4) Operation and maintenance instructions (for reference).

Section 2 DESIGN AND MANUFACTURE

6.2.1 Design

6.2.1.1 The design of boilers and pressure vessels is to comply with the relevant requirements in Appendix 1 to Appendix 6 of this Chapter. All the designs are to be submitted for approval prior to construction.

6.2.1.2 The metal temperature of boiler parts is, in any case, not to be less than the value given in Table 6.2.1.2, nor less than 250℃. The metal temperature of the pressure vessel parts in direct contact with hot medium is to be taken as the highest working temperature of the medium.

Metal temperature of boiler parts **Table 6.2.1.2**

Components \ Working condition	Not heated	Heated but well insulated	Subject to convective heat	Subject to radiant heat
Steam or water drum, header	t	t + 10℃	t + 50℃	–
Superheater cylinder or header	t + 15℃	t + 30℃	t + 50℃	–
Boiler generating tube	–	–	t + 25℃	t + 50℃
Superheater pipe	–	–	t + 35℃	t + 50℃
Economizer pipe	–	–	t + 30℃	–
Furnace, smoke duct and back tube sheet in dry back combustion chamber	–	–	–	t + 90℃
Wet back combustion chamber	–	–	–	t + 50℃

Note: t — working medium temperature, (℃).

6.2.1.3 Boilers are to be adequately insulated. The insulation is to have a metallic sheathing. When the boiler is under working conditions, the temperature of the sheathing is generally not to exceed 60℃.

6.2.1.4 Every shell type economizer is to be provided with removable lagging at the circumference of the tube end plates to enable ultrasonic examination of the tube plate to shell connection.

6.2.2 Materials

6.2.2.1 The materials used in the construction of boilers and pressure vessels are to be in compliance with the relevant provisions contained in CCS Rules for Materials and Welding. Where it is proposed to use materials other than those specified in the aforesaid, details of the mechanical properties (including mechanical property values used for the calculation of allowable stresses), chemical compositions and heat treatment are to be submitted for approval.

6.2.3 Plate cutting

6.2.3.1 Plates are to be cut to size and shaped by machine flame cutting and/or machining. Where the plate thickness does not exceed 25 mm, cold shearing may be used provided that the sheared edge is cut back by machining or chipping for a distance of 1/4 of the plate thickness, but in no case by less than 3 mm. After being cut and before further work is carried out upon them, all plate edges are to be examined for laminations and cracks.

6.2.4 Forming

6.2.4.1 Plates for shell sections and end plates are, so far as possible, to be hot and cold formed by machine. Forming by hammering is not to be employed. Forming is not to impair the quality of the material regardless of heating or not.

6.2.4.2 After forming, both shell plates and end plates are to be suitably heat treated. This heat treatment may be held concurrently with post-weld heat treatment.

6.2.5 Allowable stress

6.2.5.1 The allowable stress of boiler and pressure vessel parts is to be determined by the following formulae, and the lower value is to be taken:

(1) Metal temperature equal to or less than 50℃:

$[\sigma] = R_m/2.7$; $[\sigma] = R_{eH}/1.5$

(2) Metal temperature more than 50℃:

$[\sigma] = R_m/2.7$; $[\sigma] = R^T_{eH}/1.5$; $[\sigma] = R^T_{m100000}/1.5$

(3) Pressure vessels for stowage of liquid gas:

$[\sigma] = R_m/3.0$; $[\sigma] = R_{eH}/2.0$

where: R_m — specified tensile strength of material at room temperature, in N/mm^2;

R_{eH} — specified yield stress of material at room temperature, in N/mm^2;

R^T_{eH} — specified yield stress or proof stress of material at metal temperature, in N/mm^2;

$R^T_{m100000}$ — average stress to produce rupture in 10^5 h of material at metal temperature, in N/mm^2. In general, it is to be selected according to the relevant requirements of CCS Rules for Materials and Welding when the metal temperature is more than 350℃.

The allowable stress for steel castings is to be taken as 80% of the value determined by the method indicated above, using the appropriate value for cast steel.

6.2.6 Joint factor of welded seam

6.2.6.1 For welded seams welded on both side or on one side with a sealing run, the strength factor φ' used in the equations in this Chapter is given in Table 6.2.6.1 based on the method of examination employed.

Strength factor φ' of welded seam **Table 6.2.6.1**

Class	Strength factor of welded seam	Perspective inspection	Conventional welded seam test plate	Heat treatment
I	1	To be done, see Rules for Materials and Welding	To be done	See Rules for Materials and Welding
II	0.85	To be done, see Rules for Materials and Welding	To be done	See Rules for Materials and Welding
III	0.60	–	–	–

6.2.6.2 For boilers of Class II and pressure vessels of Classes II and III where higher joint factor of welded seam than that required for the respective class is selected, the welded seams are to be examined in accordance with the requirements for the higher joint factor of welded seam.

6.2.7 Welding and heat treatment

6.2.7.1 The welding, welds examination and post-welding heat treatment of all pressure parts of boilers and pressure vessels are to comply with the requirements of CCS Rules for Materials and Welding.

6.2.7.2 Cold-formed cylindrical shells of boilers and pressure vessels are to be subject to stress relief heat treatment, which may be carried out together with the post-welding heat treatment. For cylindrical shell having an inner diameter greater than or equal to 20 times the thickness of shell plate, the heat treatment may be dispensed with.

6.2.7.3 Hot formed parts of boilers or pressure vessels are to be normalized provided that hot forming is not carried out at a temperature within the normalizing range. Parts made of alloy steel are, in addition, to be tempered as necessary.

6.2.8 Pads

6.2.8.1 The pads for securing the mountings and fittings to boilers and pressure vessels are to be of sufficient thickness to permit the studs being screwed into them with a length not less than the diameter of the studs without penetrating the pads. The pads and cylindrical shell are to be tightly fitted.

6.2.9 Access arrangements

6.2.9.1 Boilers and pressure vessels are to be provided with manholes to facilitate internal examination and cleaning of the cylindrical shell and steam or water drums. In the case of boiler components and pressure vessels such as cylindrical shells, headers, which are too small to permit entry, sufficient number of sight holes for these purposes is to be provided.

Manholes in cylindrical shells are preferably to have their minor axes arranged longitudinally.

6.2.9.2 Doors for manholes and sight holes are to be made of steel plate or steel forgings. Doors of the internal type are to be provided with spigots which have a clearance of not more than 2 mm all round.

6.2.9.3 Holes of boilers and pressure vessels are in general to comply with the following:

(1) Boilers with an inside diameter of more than 1000 mm and vessels with an inside diameter of more than 800 mm are to be equipped at least with one manhole.

(2) In the case of boilers and their components (e.g. cylindrical shells, headers) which are too small to permit entry for internal examination and cleaning, and of pressure vessels on which no manhole is practicable, sufficient head holes or hand holes for these purposes are to be provided.

(3) Vessels with an inside diameter of up to 300 mm are not necessarily to be equipped with any inspection hole.

(4) The minimum dimensions of various holes are in general required as follows:

manholes: 300 × 400 mm (minimum diameter of 400 mm for circular ones);

head holes: 220 × 320 mm (minimum diameter of 320 mm for circular ones);

hand holes: 80 × 100 mm.

6.2.10 Structure attachment

6.2.10.1 Where cylindrical shell consists of shell plates and/or tube plates which differ in thickness, the shell plates and/or tube plates are to be so butt welded that their centerlines form a continuous circle (see Figure 6.2.10.1). At the welded joint, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than two times the difference in the thickness.

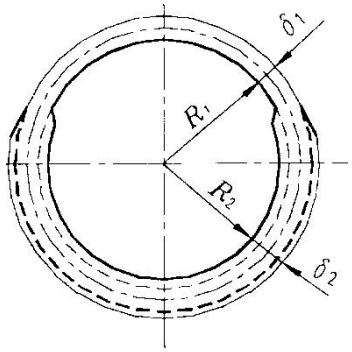


Figure 6.2.10.1

6.2.10.2 For the attachment of torispherical or ellipsoidal ends to cylindrical shells, see Figure 6.2.10.2. Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the

two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

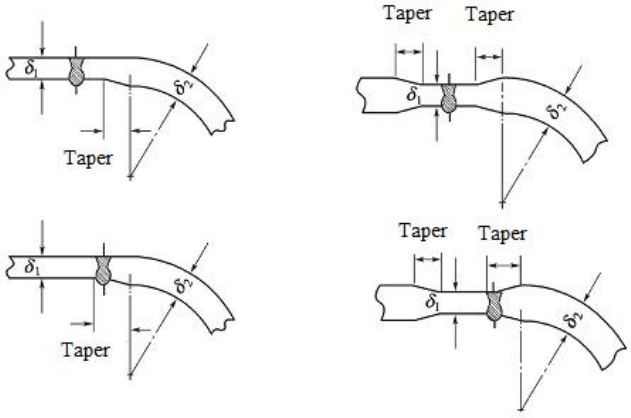


Figure 6.2.10.2

The thickness of the plates at the position of the circumferential weld is not to be less than that required for cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material.

6.2.10.3 Where hemispherical ends are butt welded to cylindrical shells, the thickness of the shell is to be tapered to that of the end, and the centre of the hemisphere is to be so located that the entire tapered portion of the shell and the butt weld are within the hemisphere, see Figure 6.2.10.3.

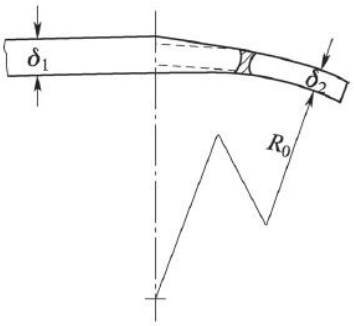
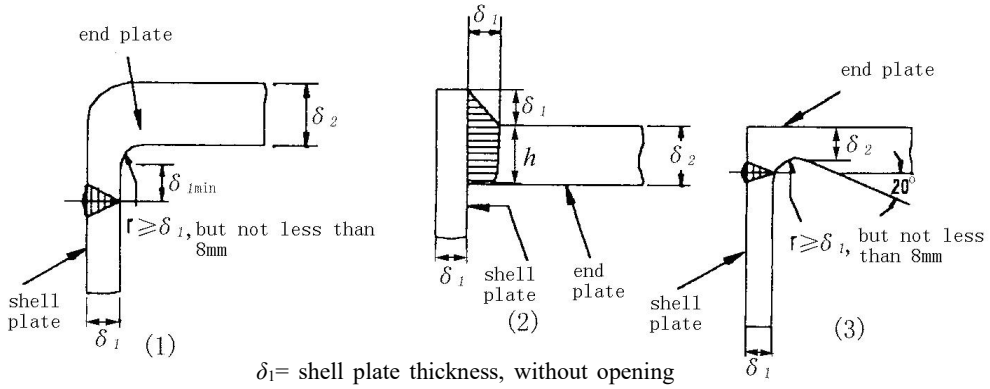


Figure 6.2.10.3

If the hemispherical end is provided with a parallel portion to be butt welded to the shell, the thickness of this portion is not to be less than that required for a seamless or welded shell.

6.2.10.4 The typical acceptable methods of attaching flat ends to cylindrical and rectangular headers are as shown in Figure 6.2.10.4.



δ_1= shell plate thickness, without opening weakening

δ_2= end plate thickness

$h = 2\delta_1$ or δ_2 -1.5mm, whichever is lesser

Figure 6.2.10.4

6.2.11 Fitting of tubes in water tube boilers

6.2.11.1 Where boiler tubes are expanded into the tube holes and are not normal to the tube plates, there is to be a neck having an effective depth h of not less than 13 mm (see Figure 6.2.11.1). Where the tubes are practically normal to their plates, this parallel seating is not to be less than 9.5 mm in depth.

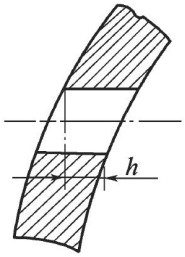


Figure 6.2.11.1

6.2.11.2 For tubes expanded into the tube holes in cylindrical shell or headers, they are to project through the neck or belt of parallel seating by at least 6 mm, but not more than 16 mm. Where the tube ends are secured from drawing out by means of bell mouthing, the included angle of belling is not to be less than 30°.

6.2.12 Design and construction of exhaust heating shell type economizers

6.2.12.1 Design and construction of shell type economizers are to pay particular attention to the welding, heat treatment and inspection arrangements at the tube plate connection to the shell.

6.2.13 Prevention of soot accumulation

6.2.13.1 Where the design (e.g. using boiler tubes with extended heat exchange surface) of exhaust gas boilers and economizers may lead to soot accumulation, resulting in fires or risks of excessive flow resistance, effective measures are to be taken to control soot accumulation, e.g. by fitting effective soot cleaning system, exhaust gas bypass, etc.

6.2.13.2 Unless specified otherwise by the flag States, the washing water generated during operation of the soot cleaning system is to be drained to appropriate tanks, and necessary measures are to be taken to prevent water from flowing into diesel engines.

Section 3 BOILER MOUNTINGS AND FITTINGS

6.3.1 General requirements

6.3.1.1 Boiler mountings are to be connected to pads or stand-pipes with flanges. Mountings under 20 mm in diameter may be fitted with screws on pads or stand-pipes.

Valves over 30 mm in diameter and the covers are to be secured by flange connections and valves having a diameter up to 30 mm and the covers may be secured by screw connections with stoppers.

6.3.1.2 Valve bodies for boilers are to be made of steel or other equivalent material. For boilers having a design pressure not exceeding 0.98 MPa and steam temperature not exceeding 220℃, the valve bodies may be made of cast iron with the exception of blow-off valves.

6.3.1.3 Boiler mountings are to be located in positions easily accessible for maintenance and operation.

6.3.2 Feed check valves

6.3.2.1 Each boiler is to be provided with two independent feed check valves. But for small vertical boilers and exhaust-gas boilers for non-essential service, one feed check valve may be accepted.

6.3.2.2 Each feed check valve is to consist of a screw-down valve and a non-return valve, the lift of non-return valve is to be adjustable. The screw-down valve is to be attached direct to the boiler. The non-return valve is to be adjacent to the screw-down valve wherever practicable. For boilers fitted with economizers, the screw-down valve may be attached direct to the economizer which forms an integral part of the boiler.

For water tube boilers, the feed check valves are to be fitted with efficient gearing, whereby they can be satisfactorily operated from the stoke hold floor or other convenient position.

6.3.2.3 For water tube boilers at least one of the feed water systems is to be fitted with an approved feed

water regulator whereby the water level in the boilers is controlled automatically.

6.3.3 Feed standpipes and internal pipes

6.3.3.1 For boilers having a design pressure more than 2.75 MPa, the standpipes for feed inlets are to be designed with an internal pipe with the object of minimizing thermal stresses where temperature differences occur between the feed pipe and boiler shell.

6.3.3.2 The internal pipes for feed inlets are to be so arranged that no feed water impinges directly on the inner surfaces of the boiler shell exposed to hot gases.

6.3.4 Water level indicators

6.3.4.1 Each boiler whose operation is designed at a specified water level is to be fitted with at least two water level indicators, one is to be a direct reading gauge glass, and the other may either be water gauge or other equivalent device (e.g. remote water level indicator).

6.3.4.2 The water gauges are to be readily accessible and so located that the water level is clearly visible. The lowest visible part of the glass water gauge is to be situated at the lowest safe working water level, but for water tube boilers, this level is to be situated at 50 mm below the lowest safe working water level.

In water tube boilers, where the steam and water drum exceeds 4 m in length and is fitted athwartships, one gauge glass is to be fitted in a suitable place at or near each end of the drum.

6.3.4.3 The water gauges are to be of flat glass type. Glass tube glass gauges with reliable protections may be used for boilers having a working pressure not exceeding 0.78 MPa.

Water gauge cocks are to be provided with operating gear if necessary and are to be so arranged that they can be easily operated without danger when the glass is damaged.

6.3.4.4 Water gauges are also to be provided with blow-off devices.

6.3.4.5 The water gauges may be fitted directly to the boiler shell or to columns, these columns are to be directly bolted or screwed to the boiler shells, or connected to the boiler by means of pipes. If they are connected by means of pipes, these pipes are to be fitted with cocks or screw-down valves with indicators showing whether the valves are open or shut. The internal diameter of the connecting pipes or columns is to be selected in accordance with Table 6.3.4.5.

Internal diameter of connecting pipes and columns **Table 6.3.4.5**

Internal dia. of boiler body (m)	Internal dia. of connecting pipes (mm)	Internal dia. of column (mm)
> 3	≥ 38	≥ 63
2.3~3	≥ 32	≥ 50
< 2.3	≥ 25	≥ 45

The connecting pipes which communicate with the steam space are to be so arranged that there is no pocket or bend where accumulation of condensate water can lodge. Connecting pipes are not to pass through the uptake; if, however, this requirement cannot be complied with, they may pass through the uptake by means of a pipe tunnel with at least 50 mm air gap clear of the pipe all round.

6.3.4.6 In general, the lowest water level in the boiler is to be as follows:

(1) For boilers with water tubes submerged when cold, the lowest water level is to be above the top row of tubes; for boilers with tubes not submerged when cold, the manufacturer is to submit the design information for the lowest level for consideration.

(2) The lowest water level in horizontal smoke tube boilers is not to be less than 75 mm above the top of combustion chambers or smoke tubes, but for multi-return flow smoke tube boilers, this level may be suitably lowered.

(3) The lowest water level in combined boilers is not to be less than 50 mm above the hot water tubes.

(4) The height of lowest water level in vertical boilers having vertical smoke tubes is not to be less than half the length of smoke tubes.

(5) The above mentioned heights of the lowest water level are to be still maintained when the ship has a list of 4°.

6.3.4.7 Water tube boilers serving turbine propulsion machinery are to be fitted with a high-water-level alarm.

6.3.4.8 Smoke tube exhaust gas boilers are to be provided with a low level alarm device and an exhaust gas bypass or a standby feed water pump. An alarm is to be given and exhaust gas automatically (or manually) bypassed or the standby feed water pump automatically started in a low water level condition.

6.3.4.9 Water tube exhaust boilers with forced circulation are to be provided with a low water flow or low pressure alarm device and a standby water circulating pump. An alarm is to be given and the standby water circulating pump automatically started in a low water flow or low pressure condition.

6.3.5 Safety valves

6.3.5.1 Boilers are to be fitted with not less than two safety valves. For small auxiliary boilers one safety valve may be accepted. For boilers with superheaters, at least one safety valve is to be fitted on the superheater.

Where a superheater is fitted as an integral part of a boiler, viz. there is no stop valve fitted between the superheater and the boiler, the area of superheater safety valve may be included in the total area of boiler safety valves; and where a stop valve is fitted between the superheater and the boiler, the area of superheater safety valve is not to be included in the area of boiler safety valves.

The area of the superheater safety valve is, in general, to be 25% of the total area of boiler safety valves required.

6.3.5.2 The diameter d of safety valve seatings is to be determined by the following formula:

(1) For saturated steam:

$$d = \sqrt{\frac{DA}{n(10.2p+1)}} \quad \text{mm}$$

where: n – number of valves;

p – design pressure of boiler, as specified in 6.1.3.1 of this Chapter, in MPa;

D – maximum design evaporation of boiler, in kg/h;

A – coefficient, as given in Table 6.3.5.2.

Coefficient A **Table 6.3.5.2**

Lift (mm)	d/24	d/20	d/16	d/12	d/4
Coefficient A	27	23	18.5	14	6.6

(2) For superheated steam:

$$d_1 = d\sqrt[4]{\frac{V_g}{V_B}}$$

where: d_1 — diameter of valve seating for superheated steam, in mm;

d — diameter of valve seating as obtained in the calculation for saturated steam, in mm;

V_g — specific volume of superheated steam, in m^3/kg;

V_B — specific volume of saturated steam, in m^3/kg.

(3) The diameter of full lift safety valves determined by the formula specified above is based on the area not including that of the guides or other obstructions. Then, for full lift safety valves with guides or other obstructions, the diameter of safety valves is to be determined by the total area of valve seatings and guides or other obstructions.

(4) In any case, the valve seating diameter of a safety valve is not to be greater than 100 mm, nor less than 25 mm.

(5) If the diameter of any safety valve fitted on the boiler is less than that required by the Rules, such valve is to be confirmed by testing. The designer is to ensure that safety valves fitted on boilers comply with the testing requirements for safety valves in the Rules.

6.3.5.3 Test of boiler safety valves

(1) For smoke tube boilers with all stop valves closed and under full firing conditions, for a duration of 15 min after the safety valve blows, the maximum pressure value attained is not to exceed 110% of the design pressure.

(2) For water tube boilers under the same conditions described above, for a duration of 7 min after the safety valve blows, the maximum pressure value attained is not to exceed 110% of the design pressure.

(3) The boiler is not to be supplied with water during the test unless it is necessary to maintain the safe working water level.

6.3.5.4 The construction of boiler safety valves is to comply with the following requirements:

(1) The safety valves are to be so locked or sealed that after setting to the working pressure, they cannot be tampered with or overloaded in service, and that they are to be so designed that in the event of fracture of springs they can not lift out of their seats.

(2) The waste steam is not to come into direct contact with the loading springs.

(3) The safety valves are to be so secured to the shell that the passage area is not to be less than the total area of the safety valves in the case of full lift valves (lift ≥ d/4), and one-half of that area in the case of other safety valves.

(4) Each safety valve chest is to be drained by a pipe led with a continuous fall to the bilge, and no valves or cocks are to be fitted to these drain pipes.
(5) Safety valves are to be provided with easing gear which is to be operable at a safe position from the boiler or engine room platforms.
(6) The spring casing of superheater safety valves are to be ventilated; or other arrangement provided to protect the springs from excessive temperature.
(7) Two safety valves may be fitted in one chest.
6.3.5.5 The safety valves are to be fitted directly to the boiler shell and superheater.
6.3.5.6 For full lift safety valves (lift $\geq d/4$), the passage area of the waste steam pipe is not to be less than twice the total area of safety valves, and for other type of safety valves. This passage area is not to be less than 1.1 times the total area of safety valves.
6.3.5.7 The setting pressure of boiler safety valves is not to be greater than the design pressure of the boiler. A setting pressure of safety valves to lift at not exceeding 103% of the design pressure is acceptable, taking into account the working tolerance.
The setting pressure of superheater safety valves is to be lower than that of the boiler safety valves.
6.3.5.8 It is desirable that there should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any relief valve is set to lift, to prevent unnecessary lifting of the relief valve.

6.3.6 Stop valves
6.3.6.1 The main and auxiliary stop valves are to be secured direct to the boiler shell. The number of auxiliary stop valves is to be minimized as far as practicable so as to minimize the unnecessary openings in the shell. Where the superheater is integral with the boiler, the main stop valve is to be fitted to the outlet of the superheater.
6.3.6.2 Where two or more main boilers or auxiliary boilers for essential services are connected together the following requirements are to be complied with:
(1) Essential services are to be capable of being supplied from at least two boilers.
(2) Stop valves of self-closing or non-return type are to be fitted.

6.3.7 Blow-off and scum valves
6.3.7.1 Each boiler is to be fitted with blow-off valves and, if necessary, scum valves. Both blow-off and scum valves (if fitted) are to be secured direct to the boiler shell. Where it is not practicable to attach the blow-off valve direct to water tube boilers, the valve may be placed immediately outside the boiler casing with a steel pipe of substantial thickness fitted between the boiler and valve.
6.3.7.2 Scum valves and blow-off valves are not to be less than 20 mm in diameter, nor to exceed 65 mm.
6.3.7.3 The top edge of scum pans for the surface blow-off is to be placed in the boiler within a range from 25 mm above the lowest water level to 25 mm below the working water level.
The number and arrangement of the scum pans are to be such as to ensure the possibility of blowing off the scum and oil from the entire evaporating surface.

6.3.8 Pressure gauges
6.3.8.1 Each boiler is to be fitted with at least one pressure gauge in an easily seen position.
6.3.8.2 The connecting tube for each pressure gauge is to be provided with a joint (including valve or cock) for check of the pressure gauge.
6.3.8.3 Pressure gauges are to be marked with a red line for indicating the working pressure of the boiler. The scale of pressure gauges is to be suitable for the hydraulic test pressure of boilers.

6.3.9 Sampling valve or cock
6.3.9.1 Each boiler is to be provided with a sampling valve or cock secured direct to the boiler shell. The valve or cock is not to be fitted on the water gauge standpipe.

6.3.10 Air cocks
6.3.10.1 An air valve or cock is to be fitted to the top of steam space of the boiler or drum and is to be, in general, 10 to 15 mm in diameter.

6.3.11 Superheater mountings
6.3.11.1 Superheaters are to be provided with the following mountings:
(1) safety valves as specified in 6.3.5.1 and 6.3.5.2 of this Section;
(2) stop valves as specified in 6.3.6.1 of this Section;
(3) drain valves;

(4) air cocks;
(5) thermometers.

6.3.12 Fittings of shell type exhaust gas heated economizer

6.3.12.1 All shell type exhaust gas heated economizers that may be isolated from the steam plant system in a flooded condition are to comply with the requirements 6.2.1.4, 6.2.12.1 and 6.3.12.2 to 6.3.12.6.

6.3.12.2 Where a shell type economizer is capable of being isolated from the steam plant system, it is to be provided with at least one safety valve, and when it has a total heating surface of 50 m^2 or more, it is to be provided with at least two safety valves.

6.3.12.3 To avoid the accumulation of condensate water on the outlet side of safety valves, the discharge pipes and/or safety valve housings are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the economizer where it will not pose threats to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements.

6.3.12.4 Every shell type economizer is to be provided with a means of indicating the internal pressure. A means of indicating the internal pressure is to be located so that the pressure can be easily read from any position from which the pressure may be controlled.

6.3.12.5 Every economizer is to be provided with arrangements for pre-heating and de-aeration, addition of water treatment or combination thereof to control the quality of feed water to within the manufacturer's recommendations.

6.3.12.6 The manufacturer is to provide operating instructions for each economizer which is to include reference to:

(1) feed water treatment and sampling arrangements;
(2) operating temperatures – exhaust gas and feed water temperatures;
(3) operating pressure;
(4) inspection and cleaning procedures;
(5) records of maintenance and inspection;
(6) the need to maintain adequate water flow through the economizer under all operating conditions;
(7) periodical operational checks of the safety devices to be carried out by the operating personnel and to be documented accordingly;
(8) procedures for using the exhaust gas economizer in the dry condition;
(9) procedures for maintenance and overhaul of safety valves.

Section 4 FITTINGS OF PRESSURE VESSELS

6.4.1 Fittings

6.4.1.1 Each pressure vessel is to be provided with the following fittings (for air receivers, see 6.4.1.2 of this Section):

(1) stop valves are to be fitted at the inlet and outlet of the pressure vessels, which are to be secured direct to the cylindrical shell as far as possible;
(2) drain devices including valves and internal pipes (where applicable);
(3) safety devices for preventing overpressure (safety valves are to comply with the requirements of 6.4.1.2(4) of this Section, if fitted);
(4) pressure gauges indicating the medium pressure (where applicable);
(5) level indicators showing the working level of medium (where applicable).

6.4.1.2 Each air receiver is to be provided with the following fittings:

(1) stop valves and pressure gauges as described in 6.4.1.1(1) and (4) of this Section;
(2) drain devices as specified in 6.4.1.1(2) of this Section, which are to be so arranged that they can drain completely the water from the lowest portion of the air receiver;
(3) safety valves. Where the air inlet pipe or the air compressor is fitted with a safety valve capable of preventing the pressure in the air receiver under charging conditions from exceeding the design pressure, the safety valve on the air receiver may be dispensed with, provided that a fusible plug with a melting point approximately at 100℃ and of a size capable of releasing the air in the event of fire is provided;
(4) the capacity of safety valves are to ensure that the air pressure is not to exceed 110% design pressure. Where outlet valves are closed, control valves are to be provided with safety valves.

6.4.1.3 Open drain system is normally to be taken for air receiver. Where closed drain system is taken, due consideration is to be given in design to the possibility of pressure accumulation within the system caused by the blockage of drainage outlet of port by oil/water, and the system has sufficient strength to

withstand the maximum pressure of air receiver.

Section 5 THERMAL OIL HEATERS

6.5.1 General provisions

6.5.1.1 This Section applies to thermal oil heaters in which thermal oils are heated to temperatures below their initial boiling point at atmospheric pressure.

6.5.1.2 The detailed requirements for thermal oil systems are given in Section 8, Chapter 4 of this PART.

6.5.2 Materials and welding

6.5.2.1 The materials and welding of thermal oil heaters are to comply with the requirements for boilers in this Chapter.

6.5.2.2 Copper and copper alloys are not to be used so as to prevent oxidation of thermal oil.

6.5.3 Design and manufacture

6.5.3.1 Thermal oil heaters are to be designed and manufactured in accordance with the requirements for boilers in this Chapter.

6.5.3.2 The surfaces which come into contact with the thermal oil are to be designed for the maximum allowable working pressure, subject to a minimum gauge pressure of 0.6 MPa.

6.5.3.3 Different thermal oil heaters are to be provided with inspection holes as follows:

(1) oil fired heaters are to be provided with inspection holes for examination of the combustion chamber;

(2) exhaust-gas thermal oil heaters are to be provided with manholes serving as inspection holes at the exhaust gas intake and outlet.

6.5.4 Fittings of thermal oil heaters

6.5.4.1 Each heater is to be equipped with at least one safety valve complying with the following:

(1) having a blow-off capacity at least equal to the increase in volume of the thermal oil at the maximum heating power. During blow-off, the pressure is not to exceed 110 % of the design pressure of the heater;

(2) the discharge pipe of safety valves is to be led to a thermal oil collecting tank with suitable capacity.

6.5.4.2 Thermal oil heaters are to be provided with means enabling the thermal oil to be completely drained.

6.5.4.3 Thermal oil heaters are to be provided with means to sample the thermal oil.

6.5.4.4 Thermal oil heaters are to be fitted with the following temperature and flow (or pressure) indicators:

(1) thermal oil temperature measuring devices are to be fitted at the thermal oil discharge line of both oil fired heaters and exhaust-gas thermal oil heaters;

(2) devices indicating the flow or pressure of the thermal oil are to be fitted in the thermal oil circulation system.

6.5.4.5 The gas outlet of exhaust-gas thermal oil heaters are to be provided with a temperature sensor and an alarm device for fire detection.

6.5.4.6 Thermal oil heaters are to be provided with means to monitor leakage in accordance with the following requirements:

(1) oil fired heaters are to be provided with a leakage detector which stops the burner and blocks the starting of burner when leakage of thermal oil is detected. If the thermal oil heater is ready to start, when leakage of thermal oil is detected, the starting of burner is to be blocked;

(2) exhaust-gas thermal oil heaters are to be provided with a leakage detector which triggers an alarm when leakage of thermal oil is detected.

6.5.4.7 Heating surfaces of exhaust-gas thermal oil heaters are to be provided with a fixed fire-extinguishing system and a cooling system. Where a pressure water spray system is fitted for this purpose, the following requirements are to be complied with:

(1) the flow rate of the water spraying system is to be at least 5.0 *l*/min for each square meter of the heating surface, and water supply is to be available for at least 20 min;

(2) nozzles are to be so arranged that the required amount of water is sprayed on the entire heating surface;

(3) suitable means for water collection and drainage are to be provided for the exhaust gas line below the heater so as to prevent water entering into engines;

(4) all means of starting valves and pumps necessary for the operation of the water spraying system are to be fitted in an easily accessible place at a safe distance from the heater so as to facilitate the operation by

the personnel in case of the heater catching fire;
(5) concise operating instructions are to be permanently displayed at the operating position of the system.

6.5.5 Monitoring and protection

6.5.5.1 Monitoring and protective measures are to be provided for thermal oil heaters according to Table 6.5.5.1.

Monitoring and Alarm Items for Thermal Oil Heaters **Table 6.5.5.1**

Items to be monitored	Local control			Remark
	Indication	Alarm	Automatic shutoff	
Thermal oil expansion tank level	×	Low	×	High alarm is also to be provided for single circuit thermal oil system
Thermal oil flow or pressure	×	Low	×	
Thermal oil outlet temperature	×	High	×	
Combustion air pressure or forced ventilation①		Low or shutoff	×	
Oil fuel pressure①	×	Low		Standby pumps to start automatically
Heavy oil fuel temperature or viscosity①	×	Low and great		For heavy oil fuel only
Uptake temperature①	×	High	×	
Burner flame or ignition①		Flameout/failure	×	Each burner to be monitored
Exhaust temperature②	×	High		

Notes:
× = functional requirement
① Applicable for oil-fired heaters.
② Applicable for exhaust gas heaters.

Section 6 INSTALLATION AND TEST

6.6.1 Installation of boiler

6.6.1.1 The boilers are to be securely fixed on board, and the boiler stools and upper part of cylindrical shell are to be secured in such a way as to be able to adapt the thermal expansion of the drums and headers.

6.6.2 Hydraulic tests

6.6.2.1 On completion of manufacture or assembly, boilers, boiler components and mountings, fittings, thermal oil heaters and pressure vessels are to withstand hydraulic tests in accordance with Table 6.6.2.1, but test pressure is not to exceed 90% yield force under test temperature.

Hydraulic Test **Table 6.6.2.1**

No.	Name		Test pressure (MPa)	
			On completion of manufacture or assembly	After installation of fittings
1	Drums, header, economizer header		1.5 p	–
2	Overheater header	Working temperature ≤ 350℃	1.5 p	–
		Working temperature > 350℃	$1.5p\frac{R_{eH}^{350}}{R_{eH}^{T}}$	–
3	Boiler, overheater, economizer, thermal oil heater		1.5 p	1.25 p
4	Pressure vessel	Working temperature ≤ 350℃	1.5 p	1.25p (air receiver may be used for gastight test under work pressure)
		Working temperature > 350℃	$1.5p\frac{R_{eH}^{350}}{R_{eH}^{T}}$	
5	Boiler gas pipe, water pipe, overheat pipe and economic pipe		2 p (after bending)	–
6	Overheat steam valve		2.5 p	1.5 p
7	Other boiler valves or fittings		2 p	1.25 p

Notes:
① p — design pressure, in MPa;

② R_{eH}^{350} — specified minimum yield point or 0.2 per cent proof stress of material at 350℃, in N/mm^2;

③ R_{eH}^{T} — specified minimum yield point or 0.2 per cent proof stress of material at the working temperature t (℃), in N/mm^2.

6.6.2.2 Where all components of a boiler, such as drums, headers, etc., have been satisfactorily tested to 1.5 times the design pressure or $1.5p\frac{R_{eH}^{350}}{R_{eH}^{T}}$, on completion of fabrication including attachment of standpipes and pads by welding and heat treatment (but before drilling the tube holes), the boiler may be tested only to 1.25 times the design pressure.

6.6.3 Shipboard trials

6.6.3.1 All boilers or thermal oil heaters are to be functionally tested in operation and safety devices after installation.

6.6.3.2 Pressure vessels are to be functionally tested with the systems in which they form a part.

Appendix 1 STRENGTH CALCULATION OF WATER TUBE BOILERS

1 Cylindrical shells

1.1 The minimum thickness of the cylindrical shell and tube plate of steam or water drums is to be determined by the following formula:

$$\delta = pD_0/(2\,[\sigma]\,\varphi - p) + 0.75 \quad \text{mm}$$

where: p — design pressure of boiler as specified in 6.1.3.1(1) of this Chapter, in MPa;

D_0 — inside diameter of cylindrical shell, in mm;

$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

φ — minimum strength factor of cylindrical shell, to be determined in accordance with 2.1 of this Appendix.

This formula is applicable only where the resulting thickness does not exceed 0.5 times the inner radius of cylindrical shell.

1.2 The minimum thickness of a cylindrical shell of boilers is not to be less than 6.0 mm.

1.3 For tube plates, such thickness as will give a minimum parallel seat of 9.5 mm, or such greater width as may be necessary to ensure tube tightness (see 6.2.11 of this Chapter).

2 Strength factor of cylindrical shell

2.1 The strength factor φ of the cylindrical shell is to be determined as follows:

(1) For welded cylindrical shell unweakened by the tube holes, the strength factor φ is to be the same as the joint factor φ' of the welded seam given in Table 6.2.6.1 of this Chapter. For seamless cylindrical shell, φ is equal to 1.

(2) Strength factor of cylindrical shell weakened by the tube holes is to be determined as follows:

① For tube holes of same diameter disposed with regular staggered spacing or regular drilling and having the same pitch in longitudinal direction as shown in Figure 2.1(2)① and Figure 2.1(2)③, the strength factor φ_1 of cylindrical shell is to be determined by the following formula:

$$\varphi_1 = \frac{t_1 - d}{t_1}$$

② For tube holes of same diameter disposed with regular staggered spacing (the holes in any row are shifted in relation to those in the adjacent row by half a pitch in longitudinal direction) and having the pitch both in longitudinal and transverse directions as shown in Figure 2.1(2)①, the strength factor φ_2 of cylindrical shell in longitudinal direction converted from that in diagonal direction is to be determined by the following formula:

$$\varphi_2 = K\varphi_k$$

where: $K = \dfrac{1}{\sqrt{1 - \dfrac{0.75}{(1+m^2)^2}}}$, or to be taken according to Figure 2.1(2)②;

where: $m = \dfrac{t_1}{t_2}$;

$$\varphi_k = \frac{t_k - d}{t_k}.$$

The strength factor φ of cylindrical shell is to be selected from either of the above two values obtained from ① and ②, whichever is the smaller.

③ For tube holes of same diameter disposed with regular drilling as shown in Figure 2.1(2)③, if the pitch t_2 in transverse direction is smaller than pitch $t_1/2$ in longitudinal direction, the strength factor of cylindrical shell is to be taken as $2\varphi_3$ instead of φ_1 as determined by 2.1(2)①. φ_3 is to be determined by the following formula:

$$\varphi_3 = \frac{t_2 - d}{t_2}$$

The tube pitch t_2 in transverse direction is to be the pitch in way of the centre surface of tube holes.

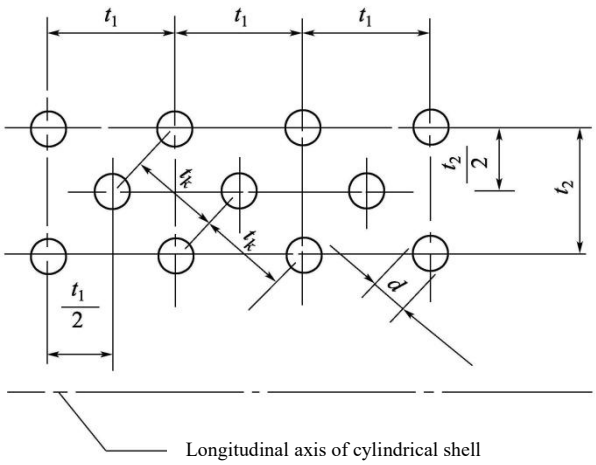


Figure 2.1(2)①

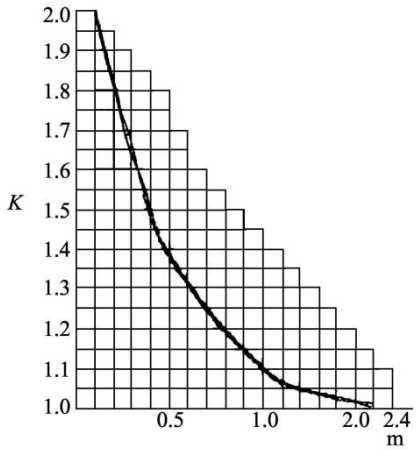


Figure 2.1(2)②

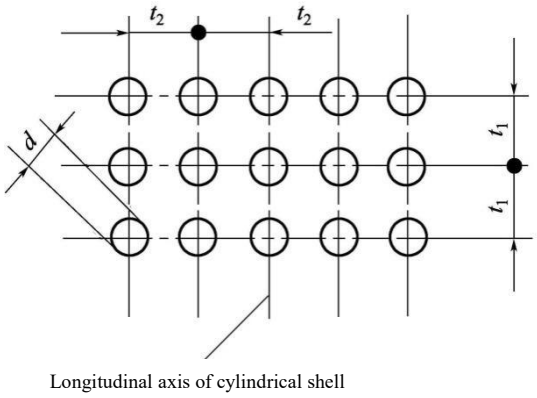


Figure 2.1(2)③

2.2 For tube holes of same diameter with distance between centres adjacent tube holes not constant, as shown in Figure 2.2, the strength factor φ_1 of cylindrical shell is to be determined by the following formula:

$$\varphi_1=\frac{t_1+t'-2d}{t_1+t_1'}$$

In such a case, the double pitch $t_1+t'_1$ chosen is to be that which makes a minimum φ_1, and in no case t'_1 is to be taken as greater than $2t_1$.

2.3 Where tube holes of two different diameters are alternately disposed, the diameter of tube holes is to be replaced by the mean value of the diameters.

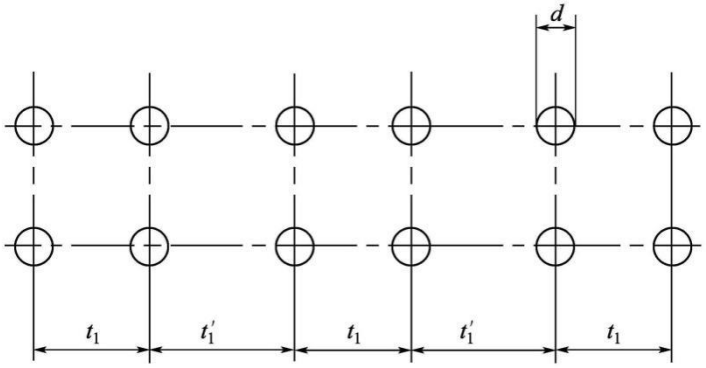


Figure 2.2

3 Compensating effect of tube stubs

3.1 Where a drum or header is drilled for tube stubs fitted by strength welding (see 1.3 of Appendix 5 of this Chapter), the effective diameter of holes used for calculation of the strength in hole line may be replaced by equivalent diameter dc of holes, which is to be taken as:

$$d_c = d - \frac{A}{\delta} \quad \text{mm}$$

where: d — the actual diameter of the hole, in mm;

δ — the thickness of the shell, in mm;

A — the compensating area provided by each tube stub and its welding filets, in mm^2 as shown in Figure 3.1(1) or (2), (the area in the shade line is a half compensating area A), in which:

δ_1 — actual thickness of the tube stub, in mm;

δ_3 — minimum thickness of the tube stub required in 9.1 of this Appendix, in mm;

$h = \sqrt{d\delta_1}$, in mm.

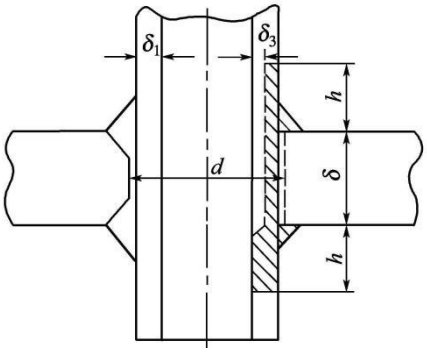


Figure 3.1(1)

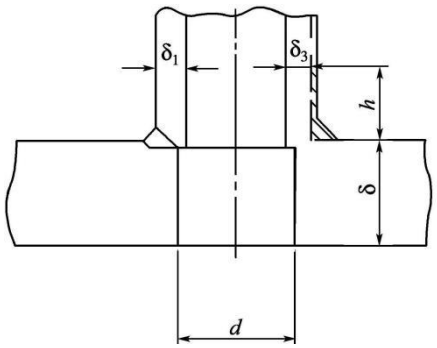


Figure 3.1(2)

3.2 Where the material of the tube stub has an allowable stress lower than that of the shell, the compensating cross-sectional area of the stub is to be multiplied by the following ratio for correction:

allowable stress of stub at design temperature;
allowable stress of shell at design temperature.

4 Spherical shells

4.1 The minimum thickness δ of spherical shells subject to internal pressure is to be determined by the following formula:

$$\delta = \frac{pD_0}{4[\sigma]\varphi - p} + 0.75 \quad \text{mm}$$

where: D_0 — inside diameter of the shell, in mm;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

[σ]— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter , in N/mm^2;

φ — strength factor of shell, to be taken in accordance with joint factor of welded seam given in Table 6.2.6.1 of this Chapter.

Spherical shells with openings are to be reinforced in accordance with 2.1 to 2.3 in Appendix 5 of this Chapter.

The above mentioned formula is applicable only where the resulting thickness does not exceed half the internal radius of the shell.

5 Dished ends

5.1 The minimum thickness δ of ellipsoidal, torispherical and hemispherical end plates subject to pressure on the concave side, as shown in Figures 5.1(1) to (3), is to be determined by the following formula:

$$\delta = \frac{pD_1 y}{2[\sigma]\varphi} + 0.75 \quad \text{mm}$$

where: D_1 — outside diameter of end plate, in mm;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

[σ]— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

φ — applying to joint factor of welded seam or the minimum strength factor of drum shell (see 2 in

this Appendix);

y — shape factor, to be obtained from Figure 5.1(4).

For ends without openings, the value of y is to be selected from the group of solid curves, dependent on the ratio of δ/D_1 and H/D_1.

For ends with unreinforced openings, the value of y is selected from the group of dotted curves, dependent on the ratio of $d/\sqrt{D_1\delta}$ and H/D_1, where: d – the diameter of the largest opening in the end plates, in mm (in the case of an elliptical opening, the major axis of the ellipse is to be taken).

For openings with effective reinforcement, the opening factor may be determined according to 2.1 in Appendix 5 of this Chapter. The location of openings and construction of dished ends are to comply with the requirements of 5.2 and 5.3 in this Appendix.

Where the ends are made from more than one plate and welded, the minimum thickness determined by above formula is to be modified by taking account of the joint factor according to 6.2.6.1 of this Chapter.

For ends which are butt welded to the drum shell, the thickness of the edge of the flange for connection to the shell is not to be less than the thickness of an unpierced seamless or welded shell, whichever is applicable, determined in 1.1 of this Appendix.

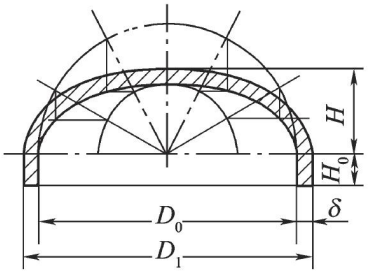


Figure 5.1(1) Ellipsoidal end

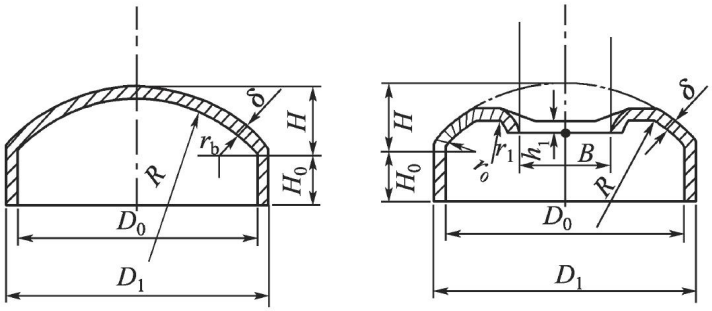


Figure 5.1(2) Torispherical end

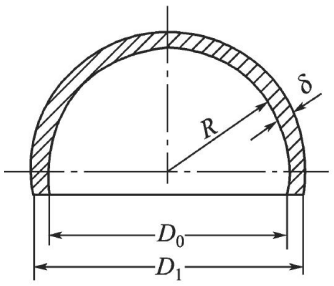


Figure 5.1(3) Hemispherical end

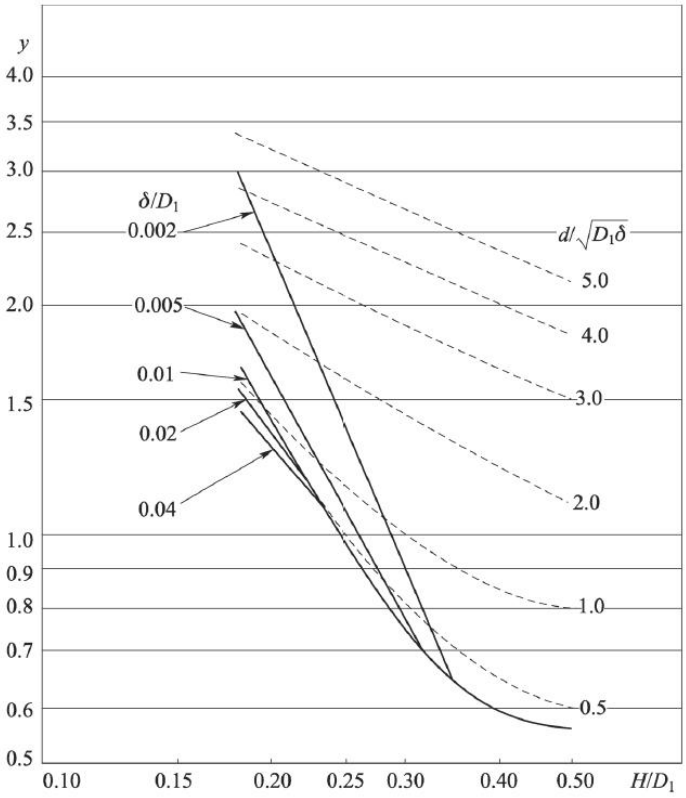


Figure 5.1(4)

5.2 Openings in ellipsoidal and torispherical ends are to be in accordance with the following requirements, as shown in Figure 5.2.

(1) The projectional distance from the edge of hole to the outside edge of the end plate is not to be less than $0.1D_1$.

(2) The projectional distance between two adjacent openings is not to be less than the diameter of the smaller opening.

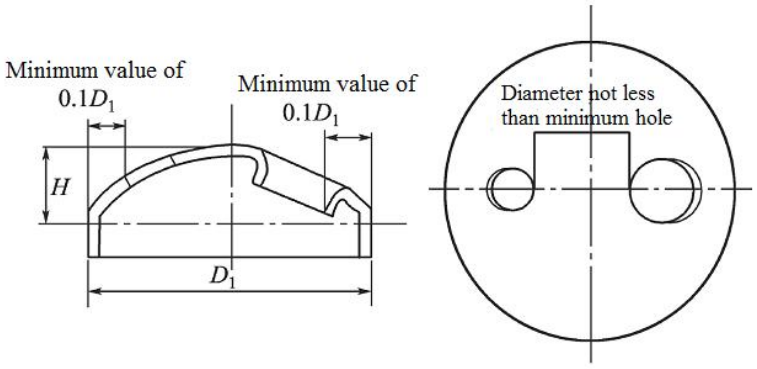


Figure 5.2

5.3 The construction of dished ends is to comply with the following requirements:

(1) For torispherical ends, see Figure 5.1(2) of this Appendix:

$r_b \geq 0.1D_1$ or $r_b \geq 3\delta$, whichever is the greater,

$R \leq D_1$; $H \geq 0.18D_1$ and $H_0 \geq 2\delta$.

(2) For ellipsoidal ends, see Figure 5.1(1) of this Appendix:

$H \geq 0.20D_1$; $H_0 \geq 2\delta$.

(3) For manhole flanges in ellipsoidal, torispherical and hemispherical ends, (in no case is the manhole flange to be taken as the opening reinforcement.), see Figure 5.1 (2) of this Appendix:

$h_1 \geq \sqrt{B\delta}$, where B is the minor axis of manhole;

r_1 = (1.5 to 2) δ .

5.4 The minimum thickness of a dished end is not to be less than 6.0 mm.

6 Conical ends subject to internal pressure

6.1 For the construction of conical ends and conical reducing sections, see Figures 6.1(1) to 6.1(4).

Connections between cylindrical shell and conical sections and ends are preferably to be by means of a knuckle transition radius. Alternatively, conical sections and ends may be butt welded to cylinders without a knuckle radius where the change in angle of slope ψ between the two sections under consideration does not exceed 30°C.

Conical ends may be constructed of several ring sections of decreasing thickness, as determined by the corresponding decreasing diameter.

The minimum thickness of conical ends or sections is to be determined by the formulae specified in 6.2 and 6.3 of this Appendix, but the thickness of plates at the knuckle and within the distance L from the knuckle is not to be less than the thickness of the section to which it is connected.

6.2 The minimum thickness δ of the cylinder, knuckle and conical end or section at the junction and within the distance L (see Figure 6.1 of this Appendix) from the junction is to be determined by the following formula:

$$\delta = \frac{pD_1K}{2[\sigma]\varphi'} + 0.75 \qquad \text{mm}$$

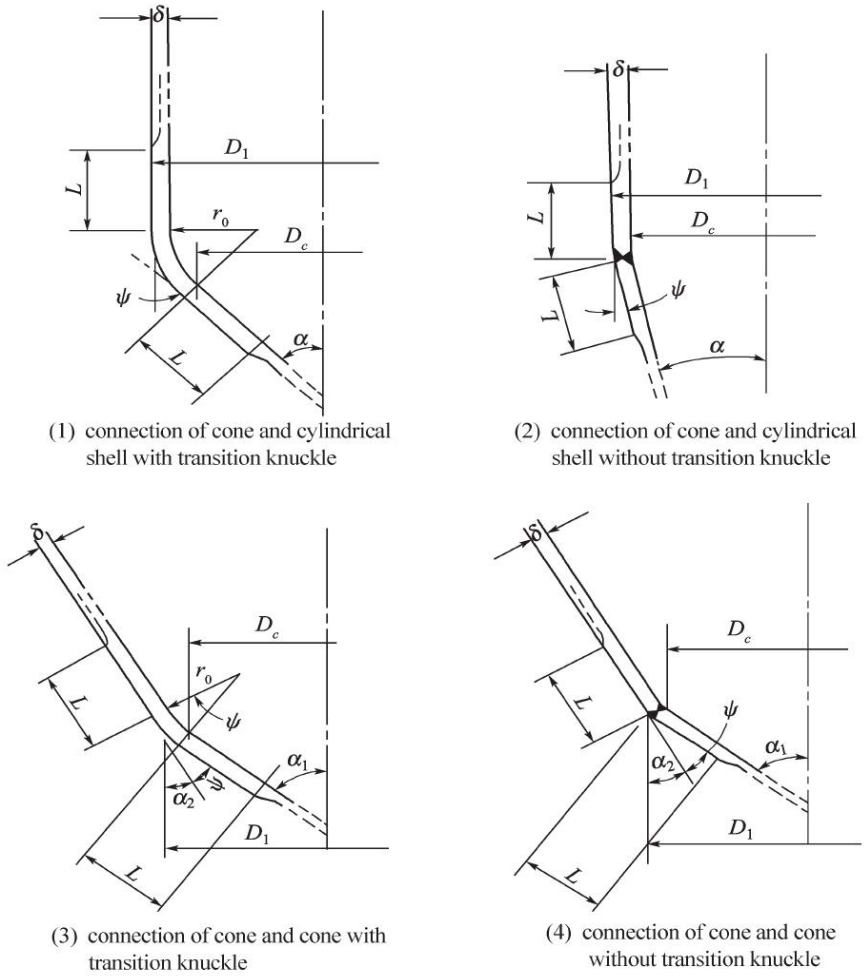
where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

D_1 — outside diameter of the cylinder, conical end or section, in mm, see Figures 6.1(1) to (4);

φ' — joint factor of welded seam, to be selected in accordance with Table 6.2.6.1 of this Chapter. Where the distance of a circumferential seam from the knuckle or junctions is not greater than L. φ' is to be taken 1.0, otherwise, φ' is to be taken as the weld factor appropriate to the circumferential seam;

K — a factor, see Table 6.2;

$[\sigma]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.



(1) connection of cone and cylindrical shell with transition knuckle

(2) connection of cone and cylindrical shell without transition knuckle

(3) connection of cone and cone with transition knuckle

(4) connection of cone and cone without transition knuckle

Figure 6.1

Factor *K* **Table 6.2**

r_0/D_1 / ψ	*K* corresponding to r_o / D_1											
	0.01	0.02	0.03	0.04	0.06	0.08	0.10	0.15	0.20	0.30	0.40	0.50
10°	0.70	0.65	0.60	0.60	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
20°	1.00	0.90	0.85	0.80	0.70	0.65	0.60	0.55	0.55	0.55	0.55	0.55
30°	1.35	1.20	1.10	1.00	0.90	0.85	0.80	0.70	0.65	0.55	0.55	0.55
45°	2.05	1.85	1.65	1.50	1.30	1.20	1.10	0.95	0.90	0.70	0.55	0.55
60°	3.20	2.85	2.55	2.35	2.00	1.75	1.60	1.40	1.25	1.00	0.70	0.55
75°	6.80	5.85	5.35	4.75	3.85	3.50	3.15	2.70	2.40	1.55	1.00	0.55

Note: r_0 — inside radius of transition knuckle, in mm, which is to be taken as 0.01 D_c in the case of conical sections without knuckle transition.

The distance L mentioned in this paragraph, as shown in Figures 6.1(1) to (4) of this Appendix, is to be determined by the following formula:

$$L = 0.5\sqrt{\frac{D_1\delta}{\cos\psi}} \qquad \text{mm}$$

where: ψ — difference between angle of slope of two adjoining conical sections, see Figure 6.1 of this Appendix.

6.3 The minimum thickness δ of those parts of conical sections not less than a distance L from the junction with a cylinder or other conical section is to be determined by the following formula:

$$\delta = \frac{pD_c}{2[\sigma]\varphi' - p} \cdot \frac{1}{\cos a} + 0.75 \qquad \text{mm}$$

where: D_c — inside diameter, in mm, of conical section or end at the position under consideration, see Figures 6.1(1) to (4) of this Appendix;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

φ' — joint factor of welded seam, to be selected in accordance with Table 6.2.6.1 of this Chapter;

$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

α — angle of slope of conical section to the vessel axis e.g. α, α_1, α_2, as shown in Figures 6.1(1) to (4). The thickness of conical sections having an angle of inclination to the vessel axis of more than 75° is to be determined as for a flat plate.

7 Headers

7.1 The minimum thickness for cylindrical shells of circular section headers is to be calculated in accordance with the requirements of 1.1 of this Appendix.

7.2 The minimum thickness of rectangular section headers is to be determined by the following formulae, the greater of two thicknesses obtained taken:

(1) thickness at the corner of the header:

$$\delta = \frac{p\sqrt{m^2 + l^2}}{2.6[\sigma]} + \sqrt{\frac{4.5M_k p}{[\sigma]}} \qquad \text{mm}$$

(2) thickness at flat surfaces of the header:

$$\delta = \frac{pl}{2.6[\sigma]\varphi} + \sqrt{\frac{4.5M_b p}{[\sigma]\varphi_1}} \qquad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

m — half the clear width of the header wall to which the strength calculations are made, in mm;

l — half the clear width of another wall of the header, in mm;

M_k — factor of bending moment at the corner of the header, in mm^2:

$$M_k = \frac{1}{3}\frac{m^3 + l^3}{m + l}$$

M_b — factor of bending moment at the flat surface of the header, in mm^2, use the absolute value for negative:

$$M_b = M_k - (m^2 - b^2)/2$$

b — distance measured from the center line of weaken holes to axis of header, in mm, see Figure 7.2(1);

φ, φ_1 — strength factor:

$$\varphi = \frac{t-d}{t}$$

$\varphi_1 = \varphi$ when $\frac{d}{m} < 0.6$

$\varphi_1 = 1 - 0.6\frac{m}{t}$ when $\frac{d}{m} \geq 0.6$

where: t — pitch between holes, in mm;

d — diameter of holes in the header, in mm. For elliptical holes, the value d adopted in $\varphi = (t\text{-}d)/t$ is to be replaced by the dimension a in a direction parallel to the longitudinal axis of the header, and value d in d/m is to be replaced by the dimension c in transverse direction, see Figure 7.2(2).

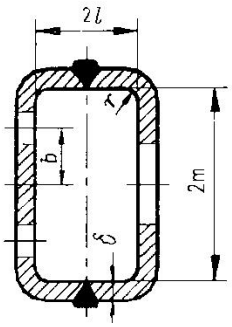


Figure 7.2(1)

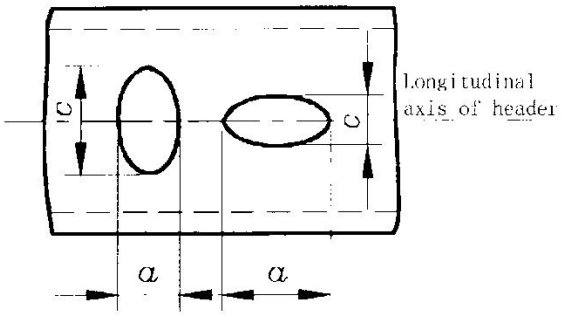


Figure 7.2(2)

7.3 Where the tube holes in the header are disposed with regular staggered spacing symmetrical to the center line of the header (see Figure 7.3), in addition to the calculation of header thickness in accordance with 7.1 or 7.2 of this Appendix, the thickness δ at the diagonal line of tube holes is to be calculated in accordance with the following formula:

$$\delta = \frac{pl}{2.6[\sigma]\varphi_k} + \sqrt{\frac{4.5M_b' p}{[\sigma]\varphi_k}} \quad \text{mm}$$

where: $M_b' = \left[\frac{m^3 + l^3}{3(m+l)} - \frac{m^2}{2}\right]\cos\alpha$;

$\varphi_k = \frac{t_k - d}{t_k}$;

α, t_k — see Figure 7.3.

Other symbols are as defined in 7.2 of this Appendix.

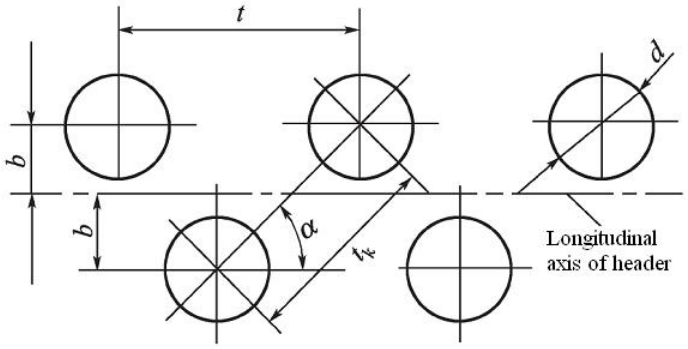


Figure 7.3

7.4 The radius r at the corner of the header, (as shown in Figure 7.2(1)) of this Appendix, is not to be less than 8 mm. Where the header wall is weakened by tube holes, the strength factor φ or φ_k is, as a rule, not to be less than 0.325. The minimum header wall thickness is not to be less than 8 mm, where tubes are fitted by expanding, the minimum header wall thickness is not to be less than 14 mm.

7.5 In welded headers, the distance measured from the center of tube holes to the edge of the welded

seam is not to be less than 0.9 times the diameter of hole, and openings in the welded zone are to be avoided as far as practicable.

8 Flat end plates

8.1 The minimum thickness δ of flat end plates is to be determined by the following formula:

$$\delta = CD\sqrt{\frac{p}{[\sigma]}} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;
D — calculated diameter of cylindrical shell, in mm;
c — constant, to be selected in accordance with Table 8.1.

In the case of rectangular flat end plates, the diameter D for calculations to be replaced by an equivalent diameter determined by the following formula:

$$D = a\sqrt{\frac{2}{1+(\frac{a}{b})^2}}$$

where: a — length of short side of rectangular end plate, in mm;
b — length of long side of rectangular end plate, in mm.

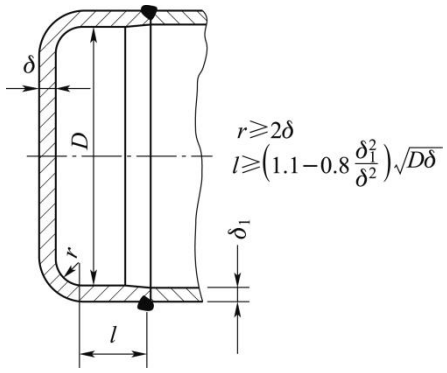


Figure 8.1(1)

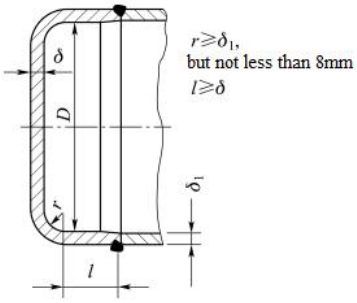


Figure 8.1(2)

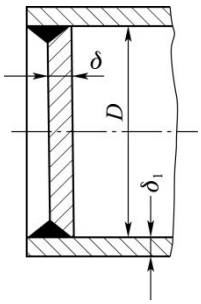


Figure 8.1(3)

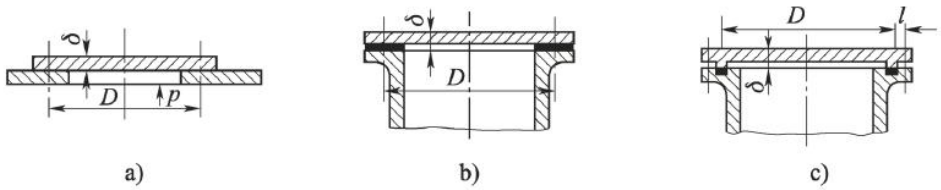


Figure 8.1(4)

Constant *C* **Table 8.1**

Type of end plate	Circular flat end plate *C*	Rectangular flat end plate *C*
Figure 8.1(1)	0.38	–
Figure 8.1(2)	0.43	0.50
Figure 8.1(3); Figure 8.1(4)(a); Figure 8.1(4)(b)	0.52	0.57
Figure 8.1(4)(c) *l*/D = 0.05 *l*/D = 0.10 *l*/D = 0.15	 0.57 0.62 0.67	 – – –

8.2 For circular flat end plates with openings, the minimum thickness of flat end plates is to be increased by 12% of the thickness required in 8.1 of this Appendix.

9 Boiler tubes subject to internal pressure

9.1 The minimum wall thickness δ of boiler tubes subject to internal pressure is to be determined by the following formula, but is in no case to be less than that required in 9.2 of this Appendix:

$$\delta = \frac{pD_1}{2[\sigma] + p} + 0.75 \quad \text{mm}$$

where: D_1 — outside diameter of tubes, in mm;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.

9.2 For boiler tubes calculated by 9.1 of this Appendix, the thickness is in no case to be less than the minimum thickness as given in Table 9.2, and in addition, provision is to be made for minus tolerances of tubes, bending allowances and abnormal corrosion which might be expected in service.

Minimum thickness of boiler tubes **Table 9.2**

Outside diameter of tubes	Minimum thickness	Outside diameter of tubes	Minimum thickness
≤ 38	1.75	> 75 ≤ 95	3.05
> 38 ≤ 50	2.16	> 95 ≤ 100	3.28
> 50 ≤ 70	2.40	> 100 ≤ 125	3.50
> 70 ≤ 75	2.67		

Note: For water tubes subject to internal pressure used for smoke tube boilers and vertical auxiliary boilers, the minimum thickness is not to be less than 3 mm.

Appendix 2 STRENGTH CALCULATION OF HORIZONTAL SMOKE TUBE BOILERS

1 Cylindrical shell

1.1 The minimum thickness of the cylindrical shell is to be determined in accordance with 1.1 in Appendix 1 of this Chapter.

1.2 Where the cylindrical shell is made of two sections, the longitudinal welded seams of the two sections are to be shifted for a distance at least 200 mm apart.

1.3 Where the steam dome is connected to the boiler shell by fillet welding, groove welding on both sides or groove welding on one side with sealing run is to be used.

2 Stayed flat surfaces

2.1 For flat plates supported by welded-in stays or by welded-in stays and flange connection, the minimum thickness δ is to be determined by the following formula:

$$\delta = Ct\sqrt{\frac{p}{[\sigma]}} + 0.75 \qquad \text{mm}$$

where: p – design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$– allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

C – constant, to be selected in accordance with Table 2.1 of this Appendix;

t – calculated pitch of points of support, in mm.

(1) Where the stays are regularly pitched, see Figure 2.1(1):

$$t = \sqrt{a^2 + b^2}$$

(2) Where the stays are irregularly pitched, or within the area enclosing the stays and flanges: When a circle is drawn through three points of support with a result of centre of the circle being situated inside the triangle formed by these three points, $t = d$, see Figure 2.1(2).

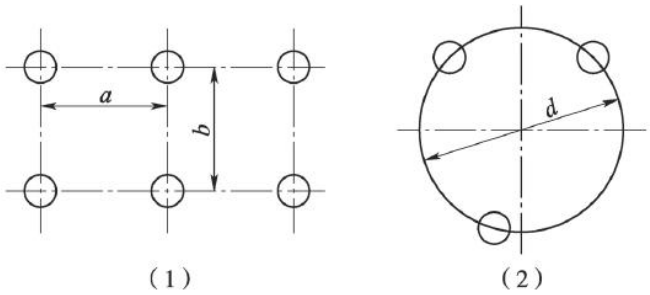


Figure 2.1

Constant *C* **Table 2.1**

Serial No.	Method of support	Constant C②	
		Not exposed to flame	Exposed to flame
1	Flange or fillet welding①	0.38	0.41
2	Stays, with gasket reinforcement, diameter of gasket ≥ 0.67 times stay spacing	0.36	—
3	Stays, with gasket reinforcement, diameter of gasket > 3.5 times diameter of stay	0.38	—
4	Stays, without gasket reinforcement, double-side welded	0.40	0.44
5	Stays, without gasket reinforcement, single-side welded	0.42	0.46
6	Stay tubes	0.46	0.51
7	Smoke tubes (within tube nests)	0.55	0.61

Notes: ① See 3.1(2), (3) and (4) of this Appendix.

② Where a flat plate is provided with two or more methods of support, the constant C is to be taken as the mean of the values for the respective methods adopted.

2.2 The minimum thickness δ of the flat tube plates within the tube nests is to be determined by the following formula:

$$\delta = Ct\sqrt{\frac{p}{[\sigma]}} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;
C — constant, to be selected in accordance with Table 2.1 of this Appendix, for methods of support, see Figure 4.2 (smoke tubes) and Figure 5.2 (stay tubes) of this Appendix;
t — mean pitch of stay tubes or smoke tubes, in mm.

(1) Where the stay tubes are welded to and the smoke tubes are expanded on the tube plates within the tube nests: t = mean pitch of stay tube supporting tube plates (equal to 1/4 the sum of the sides of a quadrangle formed by four tube centers).
(2) Where the smoke tube are all welded to the tube plates and without stay tubes within the tube nests: t = mean pitch of smoke tubes.
The minimum thickness of tube plates is in no case to be less than the following values:
(1) 10 mm where the tubes are welded to the tubes plates;
(2) 14 mm where the tubes are expanded on the plates; for auxiliary boilers with a design pressure not exceeding 0.78 MPa, 12 mm may be accepted.

2.3 The minimum thickness δ of the flat tube plates in the wide water spaces between tube nests or around tube nests is to be determined by the following formulae:
(1) For wide water spaces between tube nests:

$$\delta = Ct\sqrt{\frac{p}{[\sigma]}} + 0.75 \quad \text{mm}$$

(2) For flat tube plates around tube nests:

$$\delta = Cd\sqrt{\frac{p}{[\sigma]}} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;
C — constant, to be selected in accordance with Table 2.1 of this Appendix; for method of support of stay tubes, see Figures 5.2(1) and (2) of this Appendix;
t $= \sqrt{a^2 + b^2}$, in mm
where: a — horizontal pitch of stay tubes, in mm;
b — vertical pitch of stay tubes, in mm;
d — diameter of the maximum circle passing through three points of support of stay tubes and flanges, or of stay tubes and stays, or of stay tubes, stays and flanges, with a result of the centre of the circle being situated inside the triangle formed by these three points, in mm.

2.4 For tube plates the support afforded by the smoke tubes is not to be taken to extend beyond the line enclosing the outer surfaces of the tubes. If the distance between the outside of the wing row of smoke tubes and point of support of flanges is less than the width of margin of flat plate determined in accordance with 2.5 of this Appendix, stay tubes may not be fitted in the wing row.

2.5 For a plate supported by the flues, furnaces or shell, the range from the point of support (see 3 of this Appendix) to the width of margin b obtained by the following formula may be regarded as being supported by the flues, furnaces or shell to which the flat plate is attached:

$$b = \frac{C(\delta - 1)}{\sqrt{p}} \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
δ — thickness of flat plates, in mm;
C = 9.7 for plates not exposed to flame;
C = 9.1 for plates exposed to flame.

Where an unflanged flat plate is welded directly to the flues, furnaces or shell and it is not practicable to effect the full penetration weld from both sides of the flat plate, the constant C used in the formula mentioned above is to be:
C = 7.5 for plates not exposed to flame;
C = 7.1 for plates exposed to flame.

2.6 In addition to the requirements of 2.2 and 2.3 of this Appendix, the minimum thickness δ of combustion chamber tube plates under compression, due to the load on the top plates, is to be checked by the following formula:

$$\delta = \frac{pLt}{193(t-d)} \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
L — length at the top of combustion chamber along axis of the boilers, measured from the tube plate to the back chamber plate, in mm;
t — horizontal pitch of smoke tubes, in mm;
d — diameter of tube holes, in mm.

2.7 The minimum pitch t of the smoke tubes secured in tube plate is to be determined by the following formula:

expanded tubes:

$$t = 1.125\,d + 12.5 \quad \text{mm}$$

welded tubes:

$t = 1.125d + 7$ mm for gas smoke temperature ≤ 800℃
$t = 1.125d + 9$ mm for gas smoke temperature > 800℃

where: d — outside diameter of smoke tubes, in mm.

2.8 Where flat end plates are flanged for connection to the shell, the inside radius of flanging is not to be less than 1.75 times the thickness of plate, with a minimum of 38 mm.

Where tube plates or flat plates of combustion chambers are flanged for connection to the wrapper plates, the inside radius of flanging is not to be less than thickness of the plate, with a minimum of 25 mm.

3 Point of support

3.1 The points of support of boiler flat plates are to comply with the following:

(1) Long stays, short stays, stay tubes, welded-in smoke tubes (within the tube nests only) and flanges may be taken as points of support.

(2) Points of support of flanges:

① Where the inner radius of flange curvature does not exceed 2.5 times the thickness of the plate, the commencement of the flange curvature is to be taken as the point of support.

② Where the inner radius of flange curvature exceed 2.5 times the thickness of the plate, the point of support is to be taken at the position of 2.5 times the plate thickness measured from the inner surface of the flange.

(3) Where the furnace and front end plate are jointed by fillet welding, the outer surface of furnace is to be taken as a point of support.

(4) Where smoke tubes are fitted by means of roller expansion, the flanges of manholes or sight-holes are not to be taken as points of support.

3.2 Stay bars, stay tubes and welded-in smoke tubes, which are used as stays, are to be arranged as uniformly as possible to keep stayed areas as equal as practicable.

3.3 The area A supported by the stay is to be the area on the tube plate that is enclosed by the lines bisecting at right angles the lines joining the stay and the adjacent points of support. Such bisecting lines may approximately be taken as lines joining the center of a tangential circle for three or more adjacent points of support and the midpoint between two adjacent points of support, as shown in Figure 3.3. In respect to stay bars, stay tubes and plain smoke tubes, the stayed area is to be the above area less the area occupied by these stays, while the area occupied by diagonal stay bars are not to be deducted.

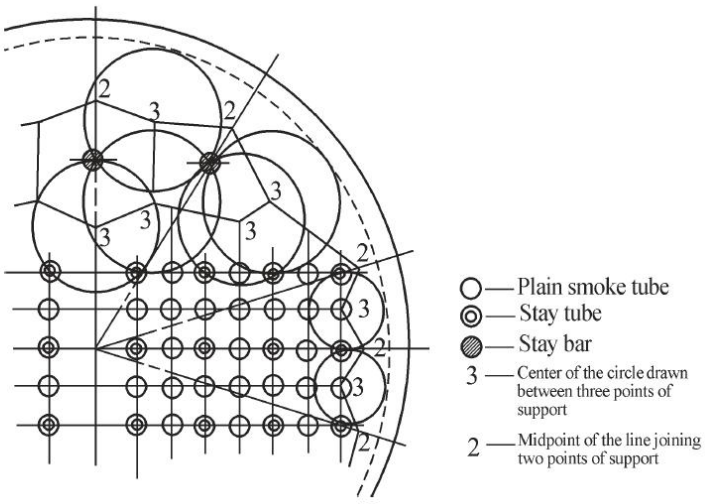


Figure 3.3

4 Plain smoke tubes

4.1 The minimum wall thickness δ of plain smoke tubes is to be determined by the following formula or is to be selected in accordance with Table 6.3.4.1, but in no case is to be less than 3 mm:

$$\delta = \frac{pd_1}{69} + 2 \qquad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

d_1 — outside diameter of smoke tubes, in mm.

Minimum wall thickness of smoke tubes **Table 4.1**

Outside diameter of tube, in mm	Wall thickness of tube, in mm				
	3	3.2	3.5	4.0	5.0
	Allowable design pressure, in MPa				
38	1.76				
44.5	1.52	1.81			
51	1.32	1.57	2.01		
57	1.18	1.42	1.77		
63.5	1.08	1.28	1.62	2.16	
70	0.98	1.18	1.47	1.96	
76	0.88	1.08	1.32	1.77	
83	0.78	0.98	1.23	1.62	
89		0.88	1.13	1.52	2.3

4.2 The smoke tubes may be fitted by means of roller expansion or by welding to the plates. Where the smoke tubes are fitted by welding, they are to be in compliance with Figure 4.2.

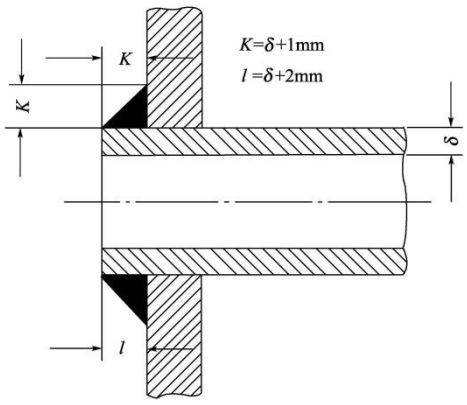


Figure 4.2

5 Stay tubes

5.1 The cross-sectional area F of welded-in stay tubes supporting tube plates is to be determined by the following formula, but in no case is the thickness of stay tubes to be less than 3.5 mm.

$$F = \frac{pA}{[\sigma]} \quad \text{mm}^2$$

where: p – design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

A – area of tube plate supported by one stay tube, in mm^2;

$[\sigma]$ – allowable stress, taken as 67 N/mm^2.

5.2 The stay tubes are to be welded to the tube plates in accordance with Figure 5.2(1) or (2).

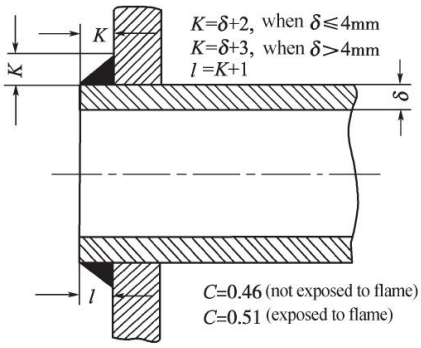


Figure 5.2(1)

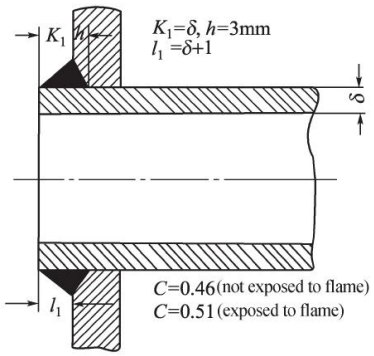


Figure 5.2(2)

6 Stays

6.1 The minimum cross-sectional area F of welded-in stays supporting the flat plates is to be determined by the following formula:

$$F = \frac{pA}{[\sigma]} \quad \text{mm}^2$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

A — maximum area of flat plate supported by one stay, in mm^2;

$[\sigma] = \frac{R_m}{5.3}$, in N/mm^2, for long stays;

R_m — specified tensile strength of materials, in N/mm^2;

$[\sigma]$ = 62, in N/mm^2, for short stays.

6.2 The structural details of welded-in stay bars are to comply with Figures 6.2. The structure shown in Figure 6.2(1) is to be used where the gas temperature is not over 600℃.

6.3 Where stay bars are connected to the flat tube plate and the shell as shown in Figure 6.3, the bar ends inserted into the flat tube plate are to be welded according to the requirements of 6.2. The minimum cross-sectional area F of the stay bar is to be calculated as follows:

$$F = \frac{pA}{[\sigma]\sin\alpha} \quad \text{mm}^2$$

where: α — angle between stay bar and flat tube plate, in degrees, not less than 60°.

Other symbols are the same as in 6.1.

6.4 In Figure 6.3, the throat thickness δ_h of the weld connecting stay bars and the shell is to comply with the following in respect to type I welds:

$$\delta_h \geq \frac{1.25F}{2L_h} \quad \text{mm}$$

where: F— minimum cross-sectional area of stay bars, in mm^2;

L_h — weld length, in mm.

In any case, the throat thickness δ_h is not to be less than 10 mm.

For type II welds, the throat thickness δ_h is to be taken as d/4.

The weld length is to comply with the following formula:

$$L_h \geq \frac{2.50F}{d} \quad \text{mm}$$

where: F— minimum cross-sectional area of stay bars, in mm^2;

d— diameter of stay bars, in mm.

6.5 The diameter of stay bars is in general not to be less than 25 mm.

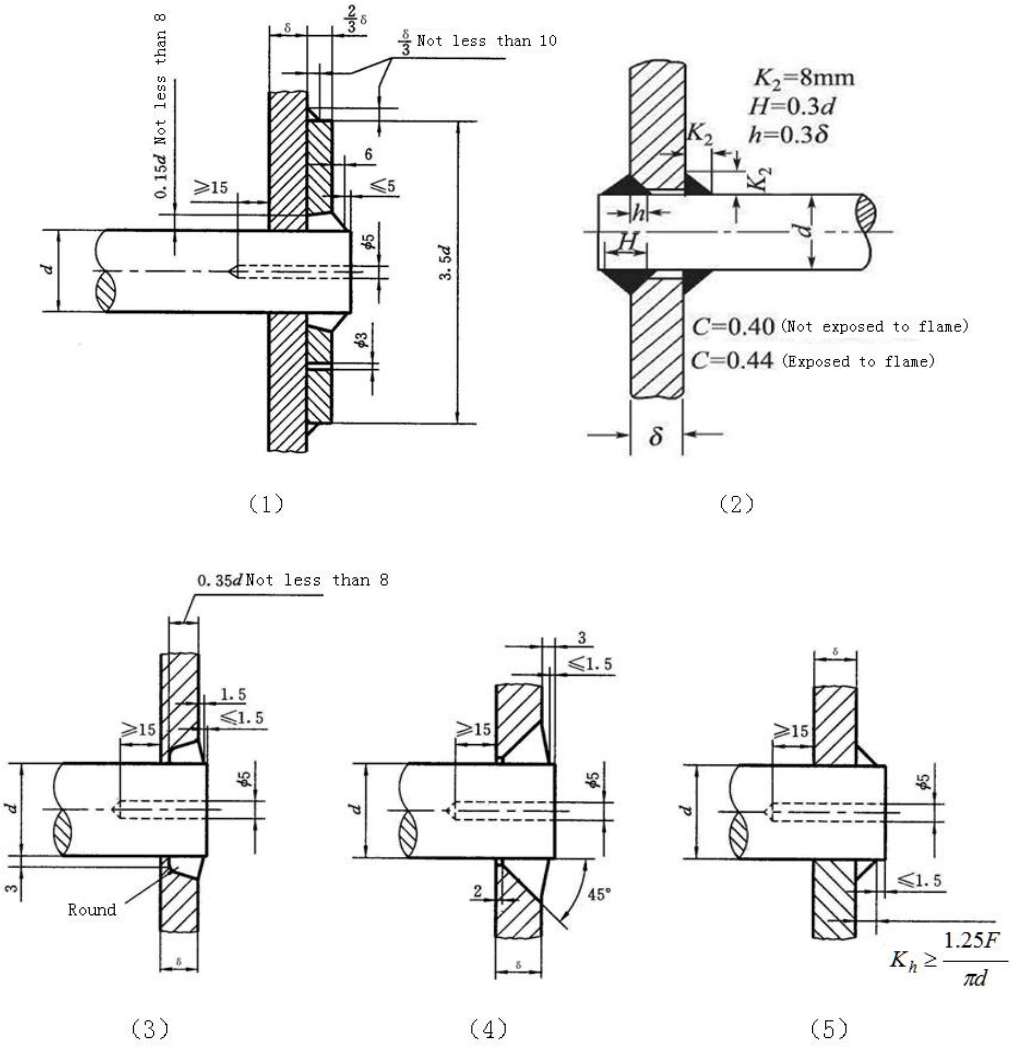


Figure 6.2

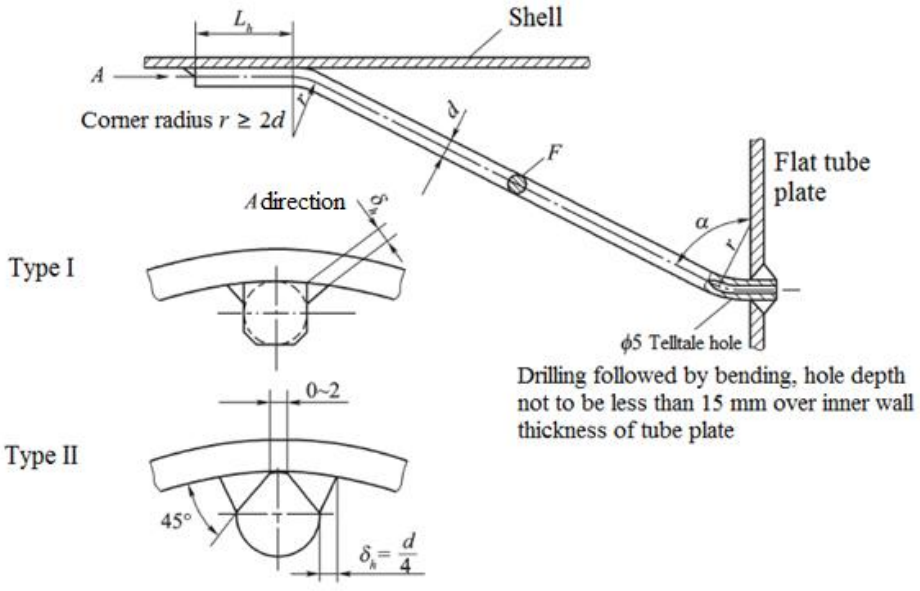


Figure 6.3

7 Furnaces

7.1 The minimum thickness δ of corrugated furnaces is to be determined by the following formula:

$$\delta = \frac{pD}{106} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

D — external diameter of the furnace measured at the bottom of the corrugations, in mm.

7.2 The minimum thickness δ of plain furnaces or of the cylindrical bottoms of combustion chambers is to be determined by the following formulae, whichever is the greater:

(1) $$\delta = \sqrt{\frac{pD(L+610)}{10300}} + 0.75 \quad \text{mm}$$

(2) $$\delta = \frac{KpD + 0.34L}{110} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

L — maximum length between two points of support of the plain furnace, or for the cylindrical bottom of combustion chamber, in mm. The bisecting plane perpendicular to the axis of reinforcing ring, the commencement of flange curvature of rear tube plate and the fillet welded seam of the front tube plate are to be taken as the point of support for the measurement of the length for calculation of the furnaces;

D — external diameter of the plain furnace or twice the external radius of the cylindrical bottom of combustion chamber, in mm;

$$K = \frac{X}{[R_{eH}^T]}$$

X — specified minimum proof stress ($\sigma_{0.2}$), in N/mm^2, for carbon and carbon-manganese steel with a specified minimum tensile strength of 400 N/mm^2, at a temperature of 90℃ above the saturated steam temperature corresponding to the design pressure;

$[R_{eH}^T]$ — specified minimum proof stress ($\sigma_{0.2}$), in N/mm^2, for the steel actually used, at a temperature of 90℃ above the saturated steam temperature corresponding to the design pressure .

7.3 The thickness of both plain and corrugated furnaces is in no case to be less than 8 mm, nor greater than 22 mm.

7.4 Where the sections of the plain furnace are jointed by reinforcing rings, the calculated length of each section is in general not to exceed 1000 mm. The reinforcing ring may be of two halves welded together, with an inner radius of curvature R = (3 to 4) δ, and a length of straight portion $l = 2\delta$ (see Figure 7.4).

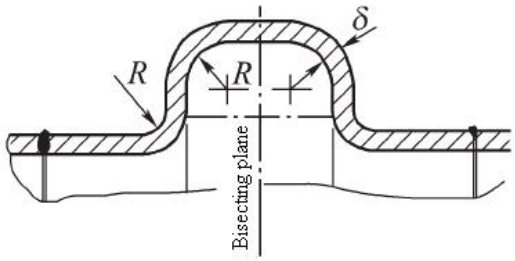


Figure 7.4

8 Crown plates and girders of combustion chambers

8.1 The crown plate and welded-on girders of combustion chambers (see Figure 8.1) are to comply with the following requirements:

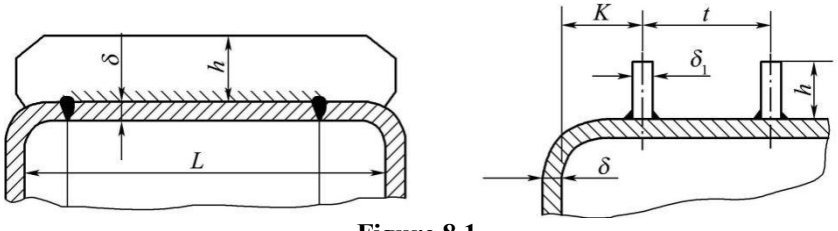


Figure 8.1

(1) The pitch t of the crown plate girders is in general not to be less than 10 δ, but not more than 25 δ.

(2) The thickness of girders δ_1 is not to be less than δ.

(3) The side girders are to be arranged at a distance K equal to or less than the pitch t from the commencement of curvature of the wrapper plates.
(4) The length of the girders is to be equal to the length of the combustion chamber L.
(5) Girders are to have semi-circular scallops above the welded seams of the crown plate, or to have the welds made flush.
(6) The crown plates of the wing combustion chambers are to be made inclined outward not less than 4°.
8.2 The minimum thickness δ of the crown plate of combustion chambers stiffened by welded-on girders is to be determined by the following formula:

$$\delta = 0.56t\sqrt{\frac{p}{[\sigma]}} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
t — pitch of girders, in mm;
$[\sigma]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.
8.3 The minimum depth (h) of welded-on girders on the crown plate of the combustion chambers is to be determined by the following formula:

$$h = \frac{L}{0.68}\sqrt{\frac{pt}{\delta_1 R_m}} \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
t — pitch of girders, in mm;
R_m — specified tensile strength of steel used for girders, in N/mm^2;
L — length at the top of combustion chamber measured internally from tube plate to back chamber plate, in mm;
δ_1 — thickness of girders, in mm.

Appendix 3 STRENGTH CALCULATION OF VERTICAL AUXILIARY BOILERS

1 Cylindrical shell

1.1 The thickness of the cylindrical shell of vertical auxiliary boilers is to be determined in accordance with 1.1 in Appendix 1 of this Chapter, but in no case is to be less than 5 mm.

2 Dished end plates subject to internal pressure

2.1 The minimum thickness of ellipsoidal, torispherical and hemispherical end plates without support subject to pressure on the concave side is to be determined in accordance with 5.1 in Appendix 1 of this Chapter. The construction and openings in dished end plates are to comply with the requirements of 5.2 and 5.3 in Appendix 1 of this Chapter.

2.2 The minimum thickness δ of torispherical end plates which are subject to pressure on the concave side and are supported by central uptakes is to be determined by the following formula:

$$\delta = \frac{pR}{1.3[\sigma]} + 0.75 \qquad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

R — inside radius of curvature of the end plate, in mm;

$[\sigma]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.

3 Flat crowns

3.1 The minimum thickness δ of flat crown plates of boilers which are supported by central uptakes is to be determined by the following formula:

$$\delta = cd\sqrt{\frac{p}{[\sigma]}} + 0.75 \qquad \text{mm}$$

where: p — design pressure of boiler, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2;

d — diameter of the largest circle drawn through two points of support by flanges, in mm;

c — constant:

c = 0.47, for plates not exposed to flame;

c = 0.51, for plates exposed to flame.

4 Tube plates

4.1 In addition to complying with the requirements of 2.2 to 2.6 in Appendix 2 of this Chapter, the minimum thickness of flat tube plates of vertical boilers having horizontal smoke tubes is to be determined by the following formula, whichever is the greater:

$$\delta = \frac{2pDt}{R_m(t-d)} + 0.75 \qquad \text{mm}$$

where: p — design pressure of boiler, as specified in 6.1.3.1(1) of this Chapter, in MPa;

D — twice the radial distance measured from the centre of cylindrical shell to the centre of tubes holes in the outer row, in mm;

t — vertical pitch of tubes, in mm;

d — diameter of tube holes, in mm.

R_m — specified tensile strength of tube plate material, in N/mm^2.

5 Horizontal shelves of tube plates

5.1 For vertical boilers having horizontal smoke tubes, the horizontal shelves of the tube plates are to be supported by gussets as follows:

(1) For the combustion chamber tube plate (rear tube plate) the minimum number of gussets is to be:

1 gusset, when 255,000 < $K \le$ 350,000;

2 gussets, when 350,000 < $K \le$ 420,000;

3 gussets, when $K >$ 420,000.

(2) For the smoke box tube plate (front tube plate) the minimum number of gussets is to be:

1 gusset when 250,000 < $K \le$ 470,000;

2 gussets when $K >$ 470,000.

Coefficient K is to be obtained from the following formula:

$$K = \frac{10.2ADp}{\delta}$$

where: A — maximum horizontal dimension of the shelf from the inside of the shell plate to the outside of the tube plate, in mm;

D — inside diameter of the boiler shell, in mm;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

□ — thickness of tube plates, in mm.

5.2 The shell plates to which the sides of the tube plates are connected are to be 1.6 mm thicker than that required in the formula applicable to shell plates. Where gussets are not fitted to the shelves, the strength of the parts of the circumferential seams at the top and bottom of these plates from the outside of one tube plate to the outside of the other is to be sufficient to withstand the whole load on the boiler end with a factor of safety of not less than 4.5 related to the specified minimum tensile strength of the shell plate material.

5.3 The minimum thickness δ of the vertical furnace or internal uptake of the vertical boiler is to be determined by the following two formulae, whichever is the greater:

(1) $$\delta = \sqrt{\frac{pD(L+610)}{10300}} + C \quad \text{mm}$$

(2) $$\delta = \frac{KpD + 0.34L}{110} + C \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

D — external diameter of the cylindrical furnace or internal uptake, in mm. Where the furnace is tapered, the diameter D is to be taken at the middle point of the calculated length L of the furnace;

L — calculated length of the cylindrical furnace or internal uptake, in mm, i.e. the length between two points of substantial support (see Figure 5.3, where H is the height of dished end). The symbol D is the same as above and Y is to be taken in accordance with Table 5.3. Where the furnace is supported by a circumferential row of regularly arranged stays with a diameter not less than 2.25 δ, and a pitch not exceeding 14 δ, these stays may be regarded as a point of support of calculated length;

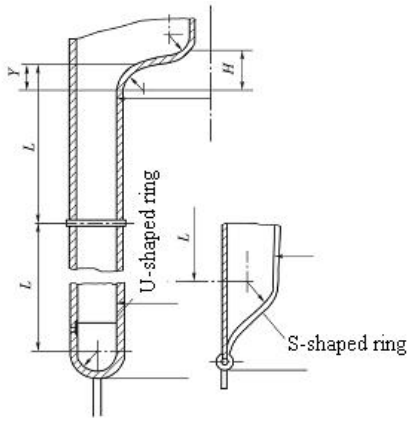


Figure 5.3

Value of *Y* **Table 5.3**

H/*D*	0.169	0.2	0.25	0.3	0.4	0.5
Y/*D*	0.07	0.08	0.10	0.12	0.16	0.20

Note: *Y*/*D* between two adjacent values is determined by means of arithmetic interpolation.

C — allowance:

C = 2 mm for furnace;

C = 4 mm for internal uptake;

$$K = \frac{X}{[R_{eH}^T]}$$

where: X and $[R_{eH}^T]$ are defined in 7.2 in Appendix 2 of this Chapter.

6 Hemispherical furnaces

6.1 The minimum thickness δ of unsupported hemispherical furnaces subject to pressure on the convex side is to be determined by the following formula:

$$\delta = \frac{KpR}{61} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

R — outside radius of curvature of the furnace, in mm;

$$K = \frac{X}{[R_{eH}^T]}$$

where: X and $[R_{eH}^T]$ are defined in 7.2 in Appendix 2 of this Chapter.

7 Torispherical furnaces subject to pressure on the convex side

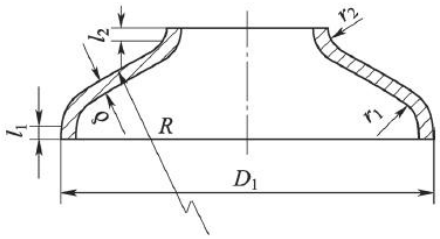
7.1 The minimum thickness δ of vertical furnace end plates which are subject to pressure on the convex side and are supported by central uptakes (see Figure 7.1 of this Appendix) is to be determined by the following formula:

$$\delta = \frac{pR}{[\sigma]} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

R — outside radius of curvature of the end plates, in mm;

$[\frac{L}{10}]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.



$R < D_1$;
$r_1 > 4\,\delta$, and > 50 mm;
$r_2 > 2\,\delta$, and > 25 mm;
l_1 and l_2, butt welding structure > 2 δ

Figure 7.1

7.2 The minimum thickness δ of dished and flanged ends for vertical boiler furnaces that are subject to pressure on the convex side and are without support from stays, is to be determined by the following formula, but is in no case to be less than the thickness determined by 5.3 of this Appendix:

$$\delta = \frac{KpR}{66} + 0.75 \quad \text{mm}$$

where: δ — the minimum thickness of flanged ends for boiler furnaces, in mm;

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

R — outside radius of curvature of the end plates, in mm;

$$K = \frac{X}{[R_{eH}^T]}$$

where: X and $[R_{eH}^T]$ are defined in 7.2 in Appendix 2 of this Chapter.

8 Ogee rings

8.1 The minimum thickness δ of the ogee ring which connects the bottom of the furnace to the boiler shell and sustains the whole vertical load on the furnace (see Figure 8.1) is to be determined by the following formula:

$$\delta = \sqrt{\frac{pD(D-d)}{990}} + 0.75 \quad \text{mm}$$

where: p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

D — internal diameter of boiler shell, in mm;

d — outside diameter of the furnace where it connects the ogee ring, in mm.

8.2 The minimum thickness of the U-shaped ring as shown in Figure 8.2 is to be 20% thicker than that obtained from the formula as specified 8.1 of this Appendix.

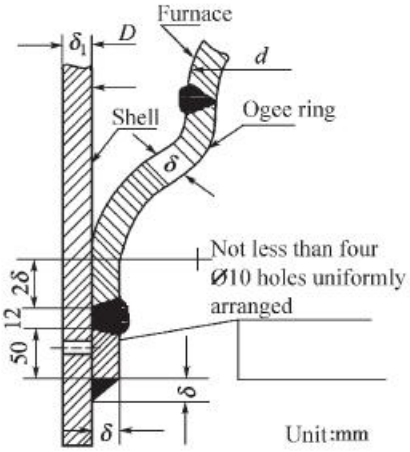


Figure 8.1

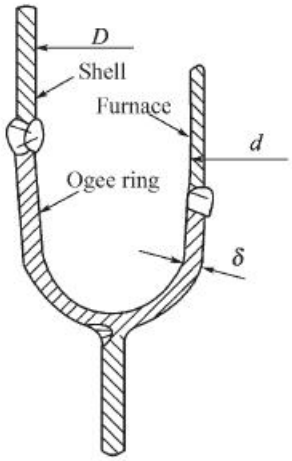


Figure 8.2

Appendix 4 STRENGTH CALCULATION OF PRESSURE VESSELS

1 Strength calculation

1.1 The strength calculation of pressure vessels is to comply with the strength calculation of relevant structure for water tube boilers, contained in Appendix 1 of this Chapter; however, the allowable stresses used in the calculation are to be determined in accordance with 6.2.5.1 of this Chapter. Where an accumulator works at frequently fluctuating working pressure, the allowable stress for its parts is to be appropriately lowered according to the fluctuation condition of pressure.

1.2 For the design pressure and allowable stress of pressure vessels, see 6.1.3.1(1) and 6.2.5.1 of this Chapter.

1.3 The minimum thickness δ of cylindrical shell of the pressure vessels is in no case to be less than that determined by the following formula:

$$\delta \geq 3 + \frac{D_0}{1500} \quad \text{mm}$$

where: D_0 — inside diameter of pressure vessels, in mm.

Appendix 5 OPENINGS AND COMPENSATION

1 Cylindrical shells

1.1 Any openings in cylindrical shells, including manholes, hand-holes, openings for standpipes or connecting branches and tube holes, having diameters exceeding those obtained from the formula in 1.2 of this Appendix, are to be reinforced in accordance with the requirements as specified in 1.3 of this Appendix.

1.2 The maximum diameter d of any unreinforced openings is to be determined by the following formula, but in no case is to exceed 200 mm:

$$d = 8.1\ \sqrt[3]{D_1\delta(1-K)} \qquad \text{mm}$$

where: δ — actual thickness of cylindrical shell, in mm;

D_1 — outside diameter of cylindrical shell, in mm;

$K = \dfrac{pD_1}{1.82[\sigma]\delta}$, but not more than 0.99

p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;

$[\sigma]$ — allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.

For elliptical holes arranged with their major axes in longitudinal direction, the major axes are to be taken as the diameter of the opening; for elliptical holes arranged with their minor axes in longitudinal direction, the mean of the major and minor axes are to be taken as the diameter of the openings.

1.3 Openings in cylindrical shells larger than those permitted by 1.2 of this Appendix are to be reinforced by the methods shown in the following Figures:

Figure 1.3(1): Reinforcement by stand-pipe or compensating ring;

Figure 1.3(2): Reinforcement by compensating plate; and

Figure 1.3(3): Combined reinforcement by standpipe or compensating ring together with compensating plate. Reinforcement will be considered adequate when the effective compensating sectional area is equal to or more than the sectional area in way of the openings.

(1) Half the effective compensating sectional area, shown in Figures 1.3(1) to (3) of this Appendix, is to be taken respectively as the total of the following relevant sectional areas:

① Surplus thickness of cylindrical shell multiplied by effective width, i.e. $A_1 = (\delta - \delta_0)\,B$ mm^2;

② Thickness of compensating plate multiplied by effective width, i.e. $A_2 = \delta_2 B$ mm^2;

③ Surplus thickness of standpipe or compensating ring multiplied by effective height, i.e. $A_3 = (\delta_1 - \delta_3)\,h_1$ mm^2;

④ Sectional area of that portion of the standpipe or compensating ring which projects inside the shell, i.e. $A_4 = \delta_1 \times h_2$ mm^2.

(2) Half the sectional area requiring compensating in way of the opening, i.e.:

$$\frac{d_1}{2} \times \delta_0 \qquad \text{mm}^2.$$

(3) The symbols used in (1) and (2) above are defined as follows:

δ — actual thickness of the shell, in mm;

δ_0 — thickness, in mm, to be determined in accordance with 1.1 in Appendix 1 of this Chapter, where the strength factor φ of the shell is equal to 1;

δ_1 — actual thickness of standpipes or compensating rings, in mm;

δ_2 — thickness of compensating plates, in mm;

δ_3 — thickness of standpipes, as determined by 9.1 in Appendix 1 of this Chapter, in mm;

d_1 — inside diameter of standpipes or compensating rings;

B = $\sqrt{D_0\delta}$, but not more than $0.5d_1$, in mm;

h_1 = $0.8\sqrt{d_1\delta_1}$, in mm;

h_2 — effective height above the inner side of the shell, in mm, taken as the actual one, but not greater than h_1;

D_0 — inside diameter of cylindrical shell, in mm.

(4) Where the material for the standpipe, compensating ring or compensating plate has an allowable stress lower than that of the shell, the effective compensating sectional area as prescribed in (1) above is to be corrected by multiplying the ratio of allowable stress of standpipe, compensating ring or compensating plate and the allowable stress of shell.

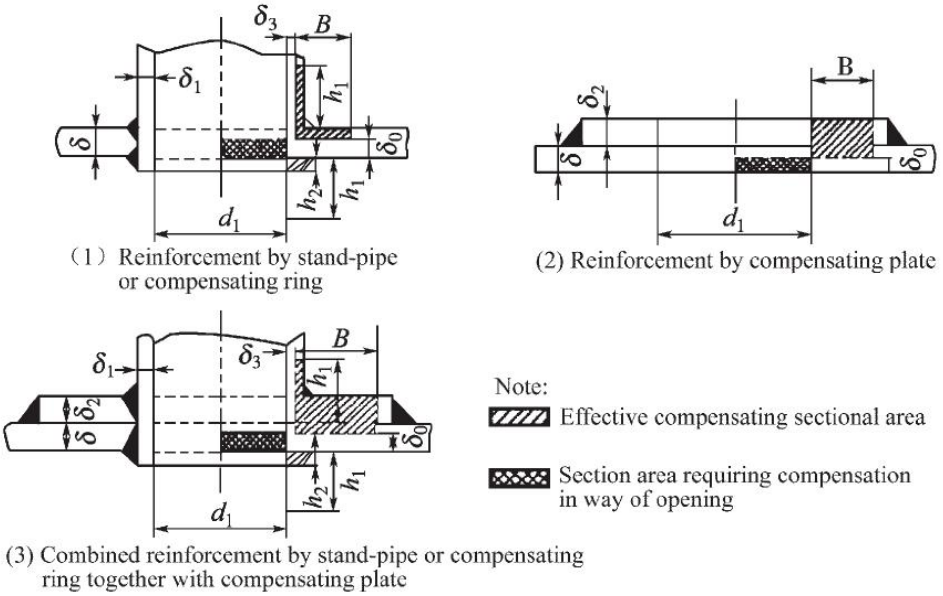


Figure 1.3

2 Dished end plates

2.1 For openings with effective reinforcement in dished end plates, the opening factor $d/\sqrt{D_1\delta}$ is to be calculated as described in 5.1 in Appendix 1 of this Chapter, but d in the formula is to be replaced by the equivalent diameter d' of openings, which is determined by the following formula:

$$d' = d - \frac{A}{\delta} \qquad \text{mm}$$

where: d — actual diameter of opening in dished end plate, in mm;

A — sectional area of the effective reinforcement, in mm^2, to be determined in accordance with 2.2 of this Appendix. The reinforcement is to be so arranged that the distance from its outer edge to the outside edge of dished end plate is not less than $0.1D$; the reinforcement is to be welded on the dished end plate in accordance with 2.3 of this Appendix.

2.2 Openings in dished end plates may be reinforced with standpipe, compensating ring or compensating plate, or with compensating ring combined with compensating plate, see Figure 2.2(1) of this Appendix.

The effective compensating sectional area A is to be taken as the total of the following sectional area:

(1) thickness of compensating plate multiplied by effective width, in mm^2 , i.e. $A_1 = 2\delta_2 B$ mm^2;

(2) surplus thickness of standpipe or compensating ring multiplied by effective height, i.e. $A_2 = 2\,(\delta_1 - \delta_3)h_1$ mm^2;

(3) thickness of standpipes or compensating ring multiplied by effective height of that portion of standpipe or compensating ring which projects inside the end, i.e. $A_3 = 2\,h_2\delta_1$ mm^2.

where: B — effective width, $B \le \sqrt{2R\delta}$ or $B \le 0.5d$, in mm, the smaller value being taken;

R — inside radius of the spherical portion of the torispherical end, or inside radius of the meridian of the ellipse at the center of the opening for ellipsoidal end, in mm, to be determined by the following formula:

$$R = \frac{[a^4 - x^2(a^2 - b^2)]^{3/2}}{a^4 b} \qquad \text{mm}$$

where: a, b and x are shown in Figure 2.2(2) of this Appendix;

h_1 — effective height, $h_1 = l + \delta + \delta_2$, in mm;

h_2 — effective height, $h_2 = l = \sqrt{d \cdot \delta_1}$, in mm;

δ — thickness of dished end plate, in mm;

δ_1 — thickness of standpipe or compensating ring, in mm;

δ_2 — thickness of compensating plate, in mm;

δ_3 — minimum thickness as required in 1.1 in Appendix 1 of this Chapter, in mm.

Where the reinforcement material for openings in dished end plates has an allowable stress lower than that of the end plate, the effective sectional area of compensating material is to be corrected by multiplying the ratio of allowable stress of compensating material and allowable stress of dished end plate.

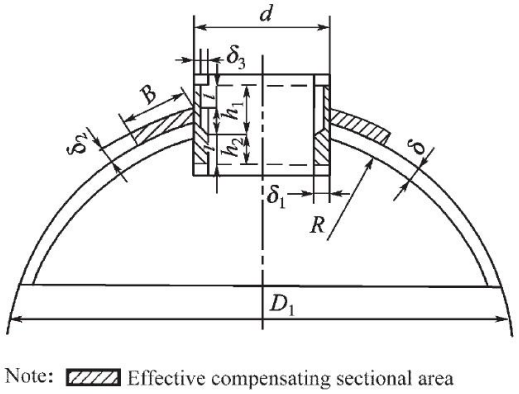


Figure 2.2(1)

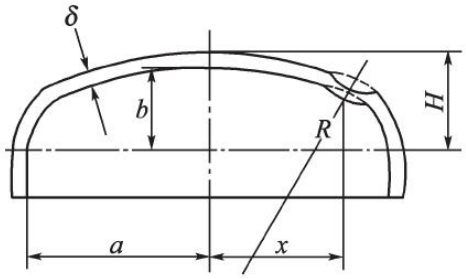


Figure 2.2(2)

2.3 Acceptable welded construction methods for compensating the openings are as shown in Figure 2.3 of this Appendix. Alternative methods of attachment by welding may be accepted provided that equivalent strength of welding is obtained.

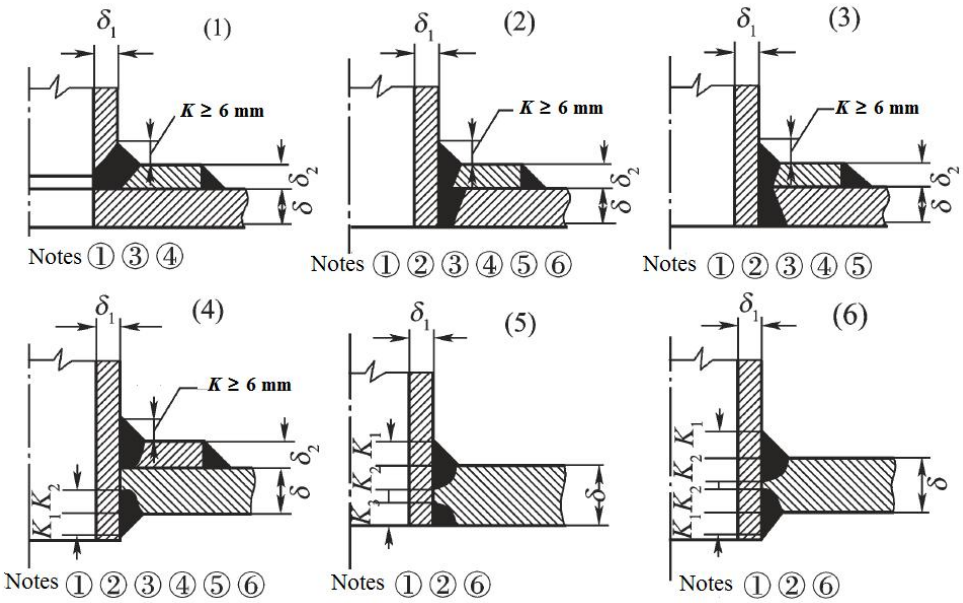


Figure 2.3

Notes:

① Where the thickness of standpipes or compensating rings is less than or equal to 10 mm, the ratio of δ_1/δ is in general not to be less than 1/5.

② There is to be a clearance between the inside of holes and outside of standpipes or compensating rings. This clearance is not to be more than 3 mm or $\delta_1/2$, whichever is the smaller.

③ There is to be no clearance between compensating plate and the shell plate.

④ Root of welds is to be gouged and a back sealing run is to be applied; where full penetration of welds can be ensured, the back sealing run may be dispensed with.

⑤ Care is to be taken that the welding stress is to be minimized as far as possible during welding.

⑥ Weld sizes:
$K \geq 6$ mm;
$K_1 + K_2 = 1.5\delta_1$, but K_1 is not to be more than 14 mm or $\delta_1/2$, whichever is lesser;
$K_3 = \delta_1$.

3 Furnaces

3.1 Calculations for the reinforcement of furnace openings are to be in accordance with the relevant requirements of Appendix 1.

3.2 In calculating the reinforcement of furnace openings, the furnace thickness is to be assumed as being determined according to 1.1 of Appendix 1, and the strength factor of the shell taken as $\varphi = 1$.

3.3 Furnace openings are not to be reinforced by compensating plates.

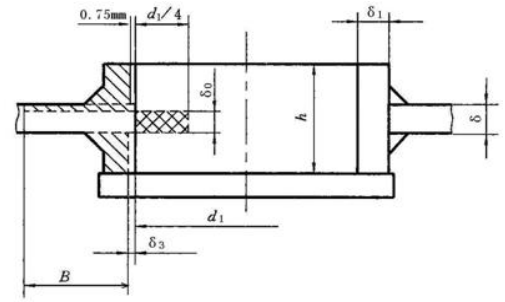
4 Flat plates

4.1 Where the actual thickness of flat plates complies with the following formula, no compensation of openings is necessary:

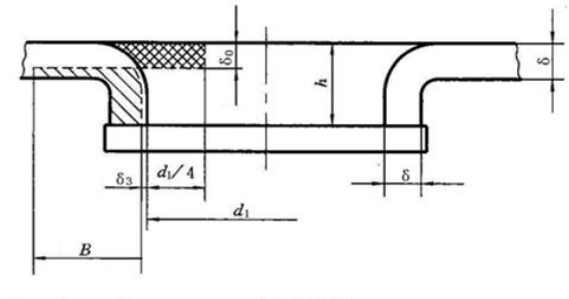
$$\delta \geq K_1\delta_0 \quad \text{mm}$$

where: K_1 = 1.5 (Figure 4.1(a), (b) and (d));

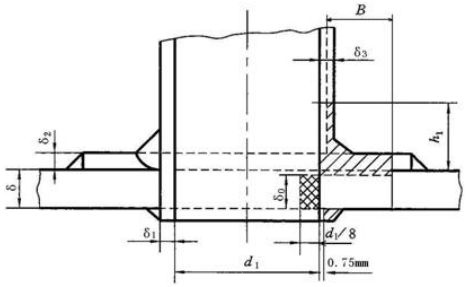
K_1 = 1.25 (Figure 4.1(c)).



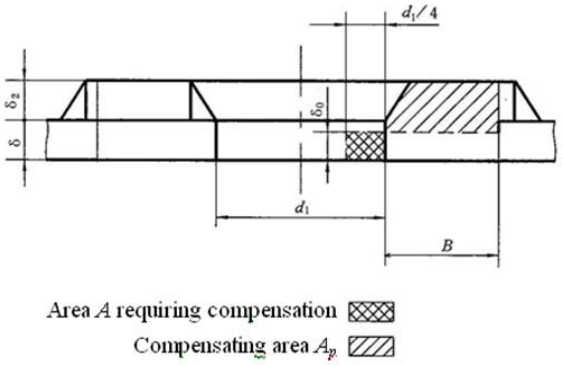
(a) Compensation of opening



(b) Compensation of flange opening



(c) Reinforcement by standpipe and compensating plate



(d) Reinforcement by compensating plate

Figure 4.1

Symbols in Figure 4.1:

- δ — actual thickness of flat plate, in mm;
- δ_0 — minimum thickness of flat plate, in mm, obtained according to the relevant requirements in Appendixes 1 and 2 of this Chapter;
- δ_1 — actual thickness of standpipe or reinforcing ring, in mm;
- δ_2 — thickness of compensating plate, in mm;
- δ_3 — thickness of standpipe, in mm, obtained according to 9.1, Appendix 1 of this Chapter;
- d_1 — inner diameter of opening, standpipe or opening ring, in mm;
- B — effective breadth of compensation, taken as $0.5d_1$, in mm;
- h_1 — effective height of compensation, taken as the lesser of $2.5\delta_1$ and 2.5δ, in mm;
- h — height of welded ring or flange height of flange opening, in mm.

4.2 Where the requirements of 4.1 are not complied with, the openings of flat plates are to be reinforced.

4.3 The effective cross-sectional area A_p of compensation and the cross-sectional area A requiring compensation, as shown in Figure 4.1, are to comply with the following formula:

$$A_P \geq A$$

4.4 In (a) and (b) of Figure 4.1, the height of welded ring or the flange height of flange opening is to comply with the following formula:

$$h \geq \sqrt{\delta d_1} \quad \text{mm}$$

In the case of an elliptical opening, the inner diameter d_1 of the opening or opening ring is to be the size of the shorter axis of the ellipse.

Appendix 6 STRENGTH CALCULATION OF STANDPIPES, DOORS FOR MANHOLES AND SIGHT HOLES

1 Standpipes

1.1 The minimum wall thickness δ of standpipes welded direct to the boilers and pressure vessels is not to be less than that determined by 9.1 in Appendix 1 of this Chapter, making such additions as may be necessary on account of bending, static loads and vibration. The wall thickness, however, is not to be less than:

$$\delta = 0.015D + 3.2 \quad \text{mm}$$

where: D — outside diameter of the standpipes, in mm.

1.2 In general, the wall thickness of the standpipes need not exceed that of the shell.
Where a standpipe is connected by screwing, the thickness is to be measured at the root of the thread.

2 Doors for manholes and sight holes

2.1 Doors for manholes and sight holes are to have sufficient strength, and the minimum thickness δ of which is to be determined by the following formula:

$$\delta = 0.8\, ab \sqrt{\frac{p}{(a^2 + b^2)[\sigma]}} + 0.75 \quad \text{mm}$$

where: a — length of major axis of the door, in mm, measured from the centre of jointing surface;
b — length of minor axis of the door, in mm, measured from the certre of jointing surface;
p — design pressure, as specified in 6.1.3.1(1) of this Chapter, in MPa;
$[\sigma]$— allowable stress, to be determined in accordance with 6.2.5.1 of this Chapter, in N/mm^2.

CHAPTER 7 STEAM TURBINES

Section 1 GENERAL PROVISIONS

7.1.1 Application

7.1.1.1 The requirements of this Chapter are applicable to steam turbines for main propulsion and to those for essential auxiliary services.

7.1.1.2 The certification requirements and product survey of steam turbines included in 7.1.1.1 of this Section are to comply with the requirements of Chapter 3, PART ONE of the Rules.

7.1.2 Critical speed

7.1.2.1 The steam turbines are to be so designed as to ensure freedom from critical speeds within the operating speed range.

7.1.3 Astern turbines

7.1.3.1 Main Propulsion turbines are to be installed with astern turbines or incorporated with reversing gears, and the astern power and astern speed are to comply with the relevant requirements in 1.2.4 of this PART.

7.1.4 Plans and documents

7.1.4.1 The following plans and documents are to be submitted for approval:

(1) General arrangement;

(2) Section of high-pressure and low-pressure cylinders;

(3) Rotor and shaft bearings;

(4) Nozzles and diaphragms;

(5) Moving blades;

(6) Quill shaft and couplings;

(7) Arrangement of steam turbine pipings (including steam, lub-oil and condensation water piping and indicating the material, size and rated working pressure of pipes);

(8) Technical performance of materials for principal component parts;

(9) Strength calculations for principal component parts;

(10) Welding specifications for principal component parts;

(11) Other plans and documents as deemed necessary by CCS.

7.1.4.2 The following plans and documents are to be submitted for information:

(1) Assembly sectional view of steam turbines;

(2) Specifications of steam turbines.

Section 2 MATERIALS

7.2.1 Testing of materials

7.2.1.1 The following parts are subject to testing in accordance with the relevant requirements for materials in CCS Rules for Materials and Welding:

(1) rotating parts such as rotors, discs, shafts, shrink rings, blades, toothed couplings and other dynamically loaded components as well as valve spindles and cones;

(2) stationary parts such as casings, diaphragms, nozzles and nozzle boxes, guide vanes, turbine casing bolts, bed frames and bearing seats;

(3) pipes and pipe plates of condenser.

7.2.1.2 For small auxiliary turbines with inlet steam temperature of 250℃ and below, the test of the material is to be limited only for the material of the blades and shafts.

7.2.2 Non-destructive test

7.2.2.1 Magnetic particle or liquid penetrant tests are required for rotating parts (including turbine rotor shafts, stiff and flexible couplings, bolts for couplings, blades (sample), gears and other dynamically stressed parts), and at the same time, ultrasonic examination is to be carried out to rotor shafts.

7.2.2.2 Magnetic particle or liquid penetrant tests are required for stationary parts (including castings and plates for casings) and the spots are to be agreed between the manufacturer and the surveyor.

7.2.2.3 Non-destructive tests to piping and associated fittings are to comply with the relevant requirements in Chapter 2 of this PART.

Section 3 DESIGN

7.3.1 Construction of rotors

7.3.1.1 Smooth fillets are to be provided at abrupt changes of section of blade roots, discs, rotors and bosses. Sharp edges of keyways and balancing holes are to be well rounded.

7.3.1.2 Any two among the wheel blade filling piece, balancing hole and keyway of a disc are not to be arranged on the same radial direction. Where the discs are shrunk on the rotor, the angle subtended between the keyways of any two adjacent discs is not to be less than 90°.

7.3.1.3 Under any working conditions, appropriate radial and axial clearances are to be provided between the moving parts and stationary parts, as well as in the gland sealing of turbines.

7.3.1.4 For propulsion turbines having astern stages, blades are to have sufficient strength to withstand the increased load arising from the counter-steam during reversing.

7.3.1.5 The vibration adjustment for the blading of prototype turbine is to be carried out so as to avoid resonance under service conditions and ensure safe running at any rating.

7.3.2 Construction of stators

7.3.2.1 Adequate provision is to be made for the relative thermal expansion of cylinders, diaphragms and nozzle boxes.

7.3.2.2 For the astern turbine, the built-in nozzle box or built-in casing is to be so arranged as to ensure the possibility of free axial or radial expansion relative to the turbine casing. The steam inlet pipe of the astern turbine is not to be rigidly connected to the casing.

7.3.2.3 Where carbon rings are used for outer gland sealing, they are to be capable of being repaired or renewed without opening the casing.

7.3.2.4 Turbine casings are to be provided with suitable drain devices.

7.3.3 Bearings

7.3.3.1 The journal bearings and thrust bearings of steam turbines are to be of plain type.

7.3.3.2 It is recommended that self-aligning types be adopted for both journal bearings and thrust bearings of propulsion turbines with high initial steam pressure and turbines designed for quick starting from cold condition. Alternatively, thrust bearings may be of such construction as to ensure uniform distribution of the thrust on the pads.

7.3.3.3 The oil well of the bearing seats is to be so constructed as to ensure that the lubricating oil system is capable of working free from troubles when the ship is under trim or list conditions as specified in 1.2.1.1 of this PART. The temperature of the bearing lubricating oil is not to exceed 70℃.

7.3.4 Piping

7.3.4.1 The design of steam piping is to comply with the relevant requirements in Section 3, Chapter 4 of this PART.

7.3.4.2 The design of lubricating oil piping is to comply with the relevant requirements in Section 6, Chapter 4 of this PART.

7.3.4.3 The design of cooling water piping is to comply with the relevant requirements in Section 5, Chapter 4 of this PART.

Section 4 FITTINGS

7.4.1 Overspeed protective devices

7.4.1.1 An overspeed protective device is to be provided for main and auxiliary turbines so as to shut off the steam supply automatically when the turbine speed exceeds 115% of the rated speed.

7.4.1.2 Where two or more turbines are coupled to the same gear wheel set, only one overspeed protective device may be provided for all the turbines.

7.4.1.3 Where exhaust steam from auxiliary systems is led to the main turbine, it is to be cut off at activation of the overspeed protective device.

7.4.1.4 Arrangement is to be provided for shutting off the steam to the main turbines by suitable hand trip

gear situated at the manoeuvring stand and at the turbine itself. Hand tripping for auxiliary turbines is to be arranged in the vicinity of the turbine overspeed protective device (The hand trip gear means any devices by hand manoeuvring, neglecting the executive action i.e. either by mechanical means or by external power means).

7.4.2 Low pressure protective devices for lubricating oil

7.4.2.1 Main ahead turbines are to be provided with a quick acting device which will automatically shut off the steam supply in the case of dangerous lowering of oil pressure in the bearing lubricating system. This device is to be so arranged as not to prevent the admission of steam to the astern turbine for braking purposes.

Where deemed necessary, appropriate means are to be provided to protect the turbines in case of:

(1) abnormal axial rotor displacement (see 7.4.4 Protective devices for axial displacement);

(2) excessive condenser pressure;

(3) high condensate level.

7.4.2.2 Auxiliary turbines having governors operated other than hydraulically in which the lubricating oil is inherent in the system, are to be provided with an alarm device and a means of shutting off the steam supply in the case of lowering of oil pressure in the bearing lubricating oil system.

7.4.2.3 Main steam turbines are to fitted with a satisfactory emergency supply of lubricating oil which will come into use automatically when the pressure drops below a predetermined value. Suitable arrangement for cooling the bearings after stopping is to be required. For emergency supply system of oil, see 4.6.3 of this PART.

7.4.3 Speed governors

7.4.3.1 Turbines for propulsion generators and auxiliary turbines intended for driving electric generators are to be provided with reliable governors.

7.4.3.2 The governor of a turbine installation incorporating electric transmission, controllable pitch propeller or reverse gear is to be capable of controlling the speed under various working conditions, without bringing the automatic overspeed protective device into action when full load is suddenly taken off.

7.4.3.3 The governors of auxiliary turbines intended for driving electric generators, in addition to the relevant requirements contained in Section 2, Chapter 3 of PART FOUR of the Rules, are to comply with the following:

Momentary variation is not to exceed 10% of the rated speed and permanent variation not to exceed 5% of the rated speed when full load is suddenly taken off.

Momentary variation is not to exceed 10% of the rated speed and permanent variation not to exceed 5% of the rated speed when 50% of the rated load of the generator is suddenly put on from no-load condition, followed by the remaining 50% load after an interval sufficient to restore the speed to steady state. The recovery time for the engine speed (i.e. the time for speed fluctuation ratio to return to ±1%) is not to exceed 5 s.

7.4.4 Protective devices for axial displacement

7.4.4.1 All propulsion turbines are to be equipped with devices indicating the axial position of the rotor relative to the stator.

7.4.4.2 A protective device is to be provided for main turbines so as to shut off the steam automatically when axial displacement of the turbine rotor is in excess of the specified value.

7.4.5 Gland sealing and condensate systems

7.4.5.1 In the arrangement of the gland sealing system, the pipes are to be made self-draining and every precaution is to be taken against the possibility of condensate entering the turbines. In the air ejector re-circulating water system, the connection to the condenser is to be so located that water can not impinge on the rotor or casing.

7.4.6 Safety devices for manoeuvring

7.4.6.1 Screw-down non-return valves or other approved means are to be fitted in steam bleeding-off pipes to prevent any steam and water from returning to the turbines.

7.4.6.2 Propulsion turbines are to be provided with power-driven turning gear. An interlock device is to be provided between turbine and turning gear to prevent the turbine from being started until the turning gear is disengaged.

7.4.6.3 An interlock device is to be provided for the ahead and astern manoeuvring valves of propulsion turbines. A screw-down valve is also required between those valves.

7.4.6.4 Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or alternatively at the inlets to manoeuvring valves.

7.4.7 Alarm devices

7.4.7.1 Propulsion turbines are to be fitted with alarm devices giving both audible and visible warnings when the vacuum in the condenser is lower than the specified value.

7.4.7.2 To provide a warning to personnel in the vicinity of the exhaust end steam turbines of excessive pressure, a sentinel valve or equivalent is to be provided at the exhaust end of all turbines. The valve discharge outlets are to be visible and suitably guarded if necessary. When, for auxiliary turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to exhaust valve are designed, means to relieve the excess pressure are to be provided.

7.4.8 Emergency arrangements

7.4.8.1 In single screw ships fitted with cross compound steam turbines, the arrangements are to be such as to enable safe navigation when the steam supply to any one of the turbines is required to be isolated. For this emergency operation purpose, the steam may be led directly to the L.P. turbine and either the H.P. or M.P. turbine can exhaust direct to the condenser. Adequate arrangements and controls are to be provided for these operating conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.

7.4.8.2 The necessary pipes and valves for these arrangements are to be readily available and properly marked. A fit up test of all combination of pipes and valves is to be performed prior to the first sea trials.

7.4.8.3 The permissible power/speeds when operating without one of the turbines (all combinations) is to be specified and information provided on board.

7.4.8.4 The operation of the turbines under emergency conditions is to be assessed for the potential influence on shaft alignment and gear teeth loading conditions.

Section 5 TESTS AND TRIALS

7.5.1 General requirements

7.5.1.1 Turbines covered in 7.1.1.1 of this Chapter are to be subject to following tests and surveys.

7.5.2 Material test and non-destructive test

7.5.2.1 All components of turbines are to be subject to material test and non-destructive test according to the relevant requirements of 7.2.1 and 7.2.2 of this Chapter in the presence of the Surveyor.

7.5.3 Test pressure

7.5.3.1 All components of turbines together with associated equipment are to be tested to the hydraulic pressures as given in Table 7.5.3.1.

Hydraulic test pressure **Table 7.5.3.1**

Name	Test pressure (MPa)
Cylinder, steam receiver, nozzle box	1.5 p, but not less than 0.2
Operating valve	2 p
Steam jacket space of condenser	0.1
Cooling water jacket space of condenser	1.5 p

Note: p – working pressure, in MPa.

7.5.4 Thermal stability test of rotors

7.5.4.1 Where the inlet steam temperature exceeds 400℃, the solid forged rotors or welded rotors of propulsion turbines are to be subject to a thermal stability test after heat treatment and rough machining of the forging.

7.5.5 Dynamical balance test of rotors

7.5.5.1 Rotors together with the half-coupling are to be dynamically balanced on completion of final assembly.

7.5.6 Maximum load test of diaphragm

7.5.6.1 All diaphragms of the first turbine of the same type are to be subject to a maximum load test for checking their deflections.

7.5.7 Safety relief valve test

7.5.7.1 Safety relief valves required by Section 4 of this Chapter are to be subject to opening and closing test according to the design pressure of manufacturer.

7.5.8 Workshop trials

7.5.8.1 Upon completion of fabrication and assembly, each steam turbine is to be subject to a shop trial in accordance with manufacturer's test schedule, which is to be submitted for review before the trial.

7.5.8.2 The test schedule is to specify the duration of tests and to include full load test, half load response test, etc.

7.5.8.3 The overspeed protective device is to be tested.

7.5.9 Shipboard trials

7.5.9.1 After installation on board, each steam turbine, including all control and safety systems, is to be operated to satisfactorily demonstrate its function.

7.5.9.2 Freedom of steam turbine from harmful vibration at speeds within the operating range is to be demonstrated.

7.5.9.3 The reversing characteristics of propulsion turbine plants are to be demonstrated.

7.5.9.4 The function of governor is to be demonstrated.

CHAPTER 8 GAS TURBINES

Section 1 GENERAL PROVISIONS

8.1.1 Application

8.1.1.1 This Chapter applies to gas turbines for main propulsion and to those for essential and auxiliary services.

8.1.1.2 The certification requirements and product survey of gas turbines included in 8.1.1.1 of this Section are to comply with the relevant requirements of Chapter 3, PART ONE of the Rules.

8.1.2 Rating

8.1.2.1 The rated output is defined as the maximum continuous power developed by gas turbines for continuous running under the following reference conditions:

(1) air at compressor inlet:

① temperature of 15℃;

② absolute pressure of 101.325 kPa;

③ relative humidity of 60%.

(2) cooling water inlet temperature is of 15℃(if applicable);

(3) static pressure of the exhaust in way of turbine exhaust flange (or heat recuperator outlet) is of 101.325 kPa.

The rated speed is defined as the speed corresponding to the rated output.

8.1.3 Correction curves

8.1.3.1 Correction curves are to be submitted by the manufacturers indicating the variation in major performance of gas turbines relating to ambient conditions.

8.1.4 Astern running

8.1.4.1 The astern power of the main propulsion gas turbines is to comply with the requirements of 1.2.4 of this PART.

8.1.5 Miscellaneous

8.1.5.1 The construction and arrangement of the components and systems of gas turbines are to be in compliance with the provisions as specified in 1.2.1.1 of this PART.

8.1.5.2 The welding of gas turbine components is to comply with the relevant provisions as specified in CCS Rules for Materials and Welding.

8.1.5.3 Automation systems of gas turbines are to comply with the relevant provisions as specified in PART SEVEN of the Rules.

8.1.5.4 Lubricating oil systems of gas turbines are to comply with the relevant provisions of Section 6, Chapter 4 of this PART.

8.1.6 Plans and documents

8.1.6.1 The following plans and documents are to be submitted for approval:

(1) Sectional assembly of gas turbines and compressors;

(2) Rotors, including blades;

(3) Combustion chambers and heat exchangers;

(4) Fuel oil systems;

(5) Lubricating oil systems;

(6) Details of high temperature characteristics of the materials, including(at the working temperatures) the associated creep rate and rupture strength for the designed service life (where applicable), fatigue strength, corrosion resistance and scaling properties. Particulars of heat treatment, including stress relief;

(7) Calculations of the critical speeds;

(8) Calculations of strength for major components;

(9) Details of the automatic safety devices;

(10) Specifications of gas turbines, including but not limited to the following:

① essential parameters, e.g. mass, time between overhaul, maximum continuous power, maximum air mass flow rate, temperature at main sections, pressure at main sections, revolving speed of gas

generator, revolving speed of power turbine, maximum allowable rate of load increase/reduction and maximum allowable rate of revolving speed increase /reduction;

② Usage limitations, e.g., maximum allowable heel and trim, maximum allowable roll and pitch, maximum allowable axial force of output shaft, maximum allowable shear force and bending moment of output shaft, maximum allowable acceleration load, maximum allowable salt content in inlet air and fuel type, etc.

(11) Other plans and documents as deemed necessary by CCS.

8.1.6.2 The following plans and documents are to be submitted for information:

(1) Principal particulars of gas turbines, characteristics of compressors (including surge margin in various operation conditions), overall performance curves of gas turbines, performance curves indicating power and speed dependency on ambient temperature, gas turbine performance or power loss as a function of operation time, and expected recovery performance after a complete overhaul, etc.;

(2) General section of gas turbines and compressors;

(3) The failure mode and effect analysis (FMEA) of the automatic safety devices;

(4) Operation and maintenance manuals of gas turbines;

(5) Other plans and documents as deemed necessary by CCS.

Section 2 MATERIALS

8.2.1 General requirements

8.2.1.1 Materials used for the construction of gas turbine components are to comply with the relevant provisions as specified in CCS Rules for Materials and Welding. Where materials other than those mentioned above are used, relevant documents are to be submitted for approval.

8.2.2 High temperature properties

8.2.2.1 Gas turbine components working under high temperature are to have high temperature characteristics consistent with the working temperature (such as creep rate, rupture strength, fatigue strength, corrosion resistance and scaling properties).

8.2.3 Testing of materials

8.2.3.1 The following parts of gas turbines are to be in accordance with the relevant requirements for testing of materials in CCS Rules for Materials and Welding:

(1) shafts, turbine and wheel of compressor, guide vanes and blades;

(2) turbine and casing of compressor, combustion chambers and heat exchangers.

For low-power gas turbines, materials of shafts, turbines and wheels of compressors are also to be subject to material tests.

8.2.4 Non-destructive testing

8.2.4.1 Non-destructive tests are required for rotating parts (including welded joints),including compressors and turbine rotor shafts, stiff and flexible couplings, bolts for couplings, blades, discs, integral pinions and gears and other dynamically stressed parts. Details including test methods and results are to be assessed in accordance with acceptable recognized standards.

8.2.4.2 Non-destructive tests are required for stationary parts (including castings for casings intended for a temperature exceeding 230℃ and plates for casings intended for a temperature exceeding 370℃ or pressure exceeding 4 MPa). Details including test methods and results are to be assessed in accordance with acceptable recognized standards.

8.2.4.3 Non-destructive tests to piping and associated fittings are to comply with the relevant requirements in Chapter 2 of this PART.

Section 3 DESIGN AND CONSTRUCTION

8.3.1 General requirements

8.3.1.1 All parts of gas turbines, compressors, etc., are to have clearances and fits appropriate to and consistent with their respective thermal expansion.

8.3.1.2 Gas turbine bearings are to be so disposed and supported that lubrication cannot be impaired by

hot gas. Effective means are to be provided to prevent leakage oil coming into contact with hot parts.
8.3.1.3 Gas turbines are to be so designed that escape of fragments due to burst of rotors can be avoided as far as practicable.

8.3.2 Stress analysis
8.3.2.1 Stress analysis to each rotor including rotor discs, blades and shafts at maximum designed working condition is to be submitted by the manufacturers.

8.3.3 Vibration
8.3.3.1 Gas turbine and compressor rotor discs and blades are to be designed and manufactured to be free from undue vibration within the operating speed range. Calculations of the critical speed are to be submitted. Where critical speeds are found by calculation to occur within the operating speed range, vibration tests may be required.

8.3.4 Air inlet and exhaust gas systems
8.3.4.1 The air-inlet system is to be designed to minimize the entrance of harmful foreign matter into the compressors and gas turbines.
8.3.4.2 Appropriate means is to be provided to prevent icing of air inlet pipes.
8.3.4.3 The air-inlet pipelines are to be designed to minimize the risk of loose parts entering the gas turbines due to air flow or corrosion.
8.3.4.4 The air-inlet system is to be provided with appropriate filtering equipment to keep water, particulate matters and corrosive sea salt within the limits specified by gas turbine manufacturers.
8.3.4.5 Where multiple turbines are arranged, each gas turbine is to be provided with separate inlet pipes and exhaust pipes, so that simultaneous operation of turbines is not to harm the operation condition of any turbine and induced circulation through a stopped gas turbine is prevented.
8.3.4.6 Pressure drop of inlet and exhaust systems is not to exceed the range specified by gas turbine manufacturers.
8.3.4.7 The arrangement of the turbine exhaust system is to be such as to prevent exhaust gas being drawn into the compressors.

8.3.5 Fuel and salt deposits
8.3.5.1 Where it is intended to burn non-distillate fuels forming harmful deposits, adequate provision is to be made for periodic removal of the deposits.
8.3.5.2 Means for preventing the accumulation of salt deposits in the compressors and turbines are to be provided.

8.3.6 Turning gear
8.3.6.1 Gas turbines are to be equipped with turning gear. Where gas turbines are provided with remotely controlled starting or automatic starting function, in order to prevent the starting of gas turbines during engagement of turning gear, the turning gear is to be interlocked with starting arrangements. If gas turbines are not provided with remotely controlled starting or automatic starting function, at least safe operation instructions with a warning notice are to be provided, indicating that “Starting of gas turbines during engagement of turning gear is prohibited”.

8.3.7 Starting system
8.3.7.1 The starting arrangements and starting air pipe systems are to comply with the relevant provisions as stated in Section 5, Chapter 9 of this PART, where applicable.
8.3.7.2 Automatic or interlocked means are to be provided for clearing all parts of the main gas turbine of the accumulation of liquid fuel or for purging gaseous fuel, before ignition commences on starting or recommences after failure to start. Where means are provided for automatic starting, a purging program is to be included in the starting sequence.
8.3.7.3 Starting devices are to be so arranged that firing operation is discontinued and main fuel valve is closed within pre-determined time, when ignition is failed.

8.3.8 Inspection openings
8.3.8.1 It is recommended that inspection openings be provided to permit inspection of rotors of the compressors and gas turbines and the inside of the burner with bore scope or other instrument without dismantling the gas turbines.

8.3.9 Instrumentation

8.3.9.1 Main propulsion gas turbines are to be provided with monitoring device fitted on the control platforms to display and/or record various principal parameters such as temperature, pressure, speed, etc.

8.3.9.2 Monitoring devices are at least to indicate the following:

(1) air pressure and temperature at compressor inlet;

(2) gas temperature at burner outlet;

(3) lubricating oil pressure and temperature;

(4) rotor speed.

8.3.10 Installation

8.3.10.1 Pipes and ducts connected to the turbine casings are to be so designed that no excessive thrust loads or moments are applied to the gas turbines.

8.3.10.2 Platform gratings and fittings in way of the supports are to be so arranged that free expansion of casing can not be restricted.

Section 4 FITTINGS

8.4.1 Overspeed protection

8.4.1.1 An overspeed protective device is to be provided near the burners for each shaft of gas turbines to shut off the fuel supply automatically in order to prevent dangerous overspeed.

The overspeed protection values of main gas turbine and auxiliary gas turbine to drive an electric generator are to be 110% and 115% of the rated speed respectively.

8.4.2 Speed governors

8.4.2.1 Where a main propulsion gas turbine incorporates a reverse gear, controllable pitch propeller, electric transmission gear or other clutches, a speed governor independent of the overspeed protective device is to be fitted and is to be capable of controlling the speed of the power turbine without bringing the overspeed protective device into action when suddenly unloaded.

8.4.2.2 Where an auxiliary gas turbine is intended for driving an electric generator, a speed governor, independent of the overspeed protective device, is to be fitted and is to comply with the following requirements:

When the maximum step load is added or taken off, instantaneous frequency variation of the power grid is not to exceed ±10% of the rated frequency, and the recovery time for the engine speed (i.e. the time for the speed fluctuation ratio to return to ±1%) is not to exceed 5 s. When the rated load is suddenly taken off, instantaneous speed variation exceeding 10% of the rated speed is allowed provided this does not cause the intervention of the over-speed device as specified in 8.4.1 of this Chapter.

Under various load conditions from no-load to the rated load, variation of speed after being stable is not to exceed ±5% of the rated speed.

The permanent speed variations of A.C. generating sets intended for parallel operations are to be equal as far as possible.

8.4.3 Low oil pressure protection

8.4.3.1 Gas turbines are to be provided with low oil pressure protective devices capable of shutting off the fuel supply automatically when lubricating oil pressure is lower than the specified value.

8.4.4 High gas temperature alarm

8.4.4.1 Gas turbines are to be provided with high gas temperature alarms to give warning when the gas temperature at burner outlet exceeds the permissible value.

8.4.5 Flame failure protection

8.4.5.1 Gas turbines are to be provided with flame failure protective devices capable of shutting off the fuel supply automatically in the event of flame failure in the combustion chambers.

8.4.6 High temperature alarm for bearings

8.4.6.1 The bearings of gas turbines are to be provided with high temperature alarms to give warning when the lub oil is going up excessively.

8.4.7 Hand trip gear

8.4.7.1 Hand trip gear for shutting of the fuel supply in an emergency is to be provided at the manoeuvring platform of the gas turbines.

8.4.8 Temperature control

8.4.8.1 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the main gas turbine:
(1) lubricating oil supply;
(2) oil fuel supply (or automatic control of oil fuel viscosity as alternative);
(3) exhaust gas.

8.4.9 Safety protection

8.4.9.1 Main gas turbines are to be equipped with a quick closing device (shut-down device) which automatically shuts off the fuel supply to the turbines at least in case of:
(1) overspeed;
(2) unacceptable lubricating oil pressure drop;
(3) loss of flame during operation;
(4) excessive vibration;
(5) excessive axial displacement of each rotor (except for gas turbines with rolling bearings);
(6) excessive high temperature of exhaust gas;
(7) unacceptable lubricating oil pressure drop of reduction gear;
(8) excessive high vacuum pressure at the compressor inlet.

8.4.10 Alarming devices

8.4.10.1 Unless the FMEA required in item 8.1.6.2(3) proves otherwise, main gas turbines are to be provided with alarming and safeguards devices in accordance with the requirements of Table 8.4.10.1, they can be added or omitted, taking into account the result of FMEA specified in item 8.1.6.2(3).
8.4.10.2 Suitable alarms are to be operated by the activation of shutdown devices.

Alarms and Safeguards for Main Gas Turbines **Table 8.4.10.1**

Monitoring parameter	Alarm	Shutdown
Turbine speed	Overspeed	Overspeed
Lubricating oil pressure	Low*	Too low
Lubricating oil pressure of reduction gear	Low*	Too low
Differential pressure across lubricating oil filter	Large	
Lubricating oil temperature	High	
Oil fuel supply pressure	Low	
Oil fuel temperature	High	
Cooling medium temperature	High	
Bearing temperature	High	
Flame and ignition	Failure	Failure
Automatic starting	Failure	
Vibration	Large*	Too large
Axial displacement of rotor	Large	Large
Exhaust gas temperature	High*	Too high
Vacuum pressure at the compressor inlet	High*	Too high
Control system	Loss	

Note: Alarms marked with "*" are to be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices.

Section 5 TESTS AND TRIALS

8.5.1 General requirements

8.5.1.1 Turbines covered in 8.1.1.1 of this Chapter are to be subject to following tests and surveys.

8.5.2 Material test and non-destructive test

8.5.2.1 All components of turbines are to be subject to material test and non-destructive test according to the relevant requirements of 8.2.3 and 8.2.4 of this Chapter.

8.5.3 Balance tests

8.5.3.1 For compressors and gas turbines, all rotors as finished-bladed and complete with half-coupling are to be dynamically balanced.

8.5.4 Hydraulic tests

8.5.4.1 All casings (including compressors casings) are to be tested to a hydraulic pressure equal to 1.5 times the maximum working pressure. For test purposes, if necessary, the casings may be subdivided with temporary diaphragms for distribution of test pressure.

Where hydraulic tests can not be carried out, the manufacturers are to submit for approval, alternative proposals for determining the soundness of the component.

8.5.4.2 Heat exchangers and intercoolers are to be tested to a hydraulic pressure equal to 1.5 times the maximum working pressure on each side.

8.5.5 Overspeed tests

8.5.5.1 Before installation, all complete rotors of the gas turbines are at least to be tested at 115% of the rated speed for 5 min.

8.5.6 Workshop trials

8.5.6.1 Gas turbines are to be subject to a workshop trial, and the manufacturer’s test program is to be submitted to CCS for approval.

8.5.7 Shipboard trials

8.5.7.1 After installation on board, each gas turbine, including all starting, control and safety systems, is to be operated to satisfactorily demonstrate its function.

8.5.7.2 Freedom of gas turbine from harmful vibration at speeds within the operating range is to be demonstrated.

8.5.7.3 The reversing characteristics of propulsion turbine plants are to be demonstrated.

8.5.7.4 The function of governor is to be demonstrated.

CHAPTER 9 DIESEL ENGINES

Section 1 GENERAL PROVISIONS

9.1.1 Application

9.1.1.1 The design, construction, installation as well as testing and trial of marine diesel engines, including main propulsion diesel engines，diesel engines for driving generators and other diesel engines related to classification, are to comply with the requirements of this Chapter.

9.1.1.2 The certification requirements and product survey of marine diesel engines are to comply with the requirements of Chapter 3, PART ONE of the Rules.

9.1.2 Definitions

9.1.2.1 For the purpose of this Chapter:

(1) A type of engine is defined by:

① bore and stroke;

② injection method (direct or indirect);

③ valve and injection operation (by cams or electronically controlled);

④ kind of fuel (oil fuel, gaseous/low flashpoint, dual fuel);

⑤ working cycle (4-stroke, 2-stroke);

⑥ turbo-charging system (pulsating or constant pressure);

⑦ the charging air cooling system (e.g. with or without intercooler);

⑧ cylinder arrangement (in-line or V)[①];

⑨ cylinder power, speed and cylinder pressures[②];

Notes:

① Requirements for type test of diesel engines with different cylinder arrangement are given in 9.10.2.3.

② Relevant provisions for cylinder power, speed and cylinder pressures are given in 9.10.2.4 and 9.10.2.5.

(2) Low-Speed Engines mean diesel engines having a rated speed of less than 300 rpm.

(3) Medium-Speed Engines mean diesel engines having a rated speed of 300 rpm and above, but less than 1,400 rpm.

(4) High-Speed Engines mean diesel engines having a rated speed of 1,400 rpm and above.

(5) The rated output is defined as the maximum continuous output developed by diesel engines (i.e. the maximum shaft power for which the machinery is to be classed) based on the ambient conditions specified in 1.2.1.3 or 1.2.1.4 of Chapter 1 of this PART. The rated speed is defined as the speed corresponding to the rated output.

9.1.3 Overload power

9.1.3.1 Main propulsion diesel engines，diesel engines for driving generators and other diesel engines related to classification are to be capable of running at 110% of the rated output.

9.1.4 Astern

9.1.4.1 Main engines are to be reversible except those coupled with variable pitch propellers, reversing gears or electric propulsion generators.

9.1.4.2 Main engines are to have sufficient astern capability to ensure proper control of the ship under normal conditions.

9.1.5 Minimum steady speed

9.1.5.1 Main engines are to have good performance at low speeds. In general, the minimum steady speed of diesel engines is to satisfy the following provisions:

(1) for low-speed engines, not more than 30% rated speed;

(2) for medium-speed engines: not more than 40% rated speed;

(3) for high-speed engines: not more than 45% rated speed.

9.1.6 Manoeuvring

9.1.6.1 The time required for reversing main engines is not to exceed 15 s. The time for reversal is defined as, when the main engine is running at the minimum steady speed, the time elapsed from the beginning of manoeuvring till starting of running in the opposite direction.

9.1.6.2 An index indicating the “Ahead” and “Astern” directions of the handle or the hand-wheel is to be fitted to the control station. As a common practice, for navigating the ship ahead, the handle is to be pushed forward, or the hand-wheel is to be turned clockwise.
9.1.6.3 An indicator showing the crankshaft rotational direction is to be fitted to the control station, but it may be dispensed with provided the tachometer is of a dual-rotation type.
9.1.6.4 For ships propelled by multiple engines geared on one shaft or more, a centralized control station for main engines is to be installed in the engine room, and is to be provided with interlocking device ensuring the correct operation sequence of main engines, clutches, etc. while manoeuvring. If the centralized control station is installed in the bridge, another control gear is to be provided in the engine room and is to be interlocked with that in the bridge.
9.1.6.5 Devices for quickly cutting off oil fuel supply or other effective arrangements for emergency stopping are to be provided near the main engine control station.

9.1.7 Interlocking of turning gear
9.1.7.1 For diesel engine arranged to be remotely controlled or automatically started, a safety interlocking device is to be fitted between the turning gear and the starting arrangement of the main engine in order to prevent the diesel engine being started when the turning gear is under engagement condition.
9.1.7.2 For diesel engine not arranged to be remotely controlled or automatically started, instructions for safety operations or warning notice are at least to be provided in order to prevent the diesel engine being started by mistake when the turning gear is under engagement condition. The warning notice is to specify that diesel engine is not to be started when the turning gear is under engagement condition.

9.1.8 Vibration and alignment
9.1.8.1 The vibration and alignment of marine diesel engine shafting are to comply with the relevant requirements as specified in Chapter 12 of this PART.

9.1.9 Gas/low flash-point fuel engines
9.1.9.1 In addition to the relevant provisions of this Chapter, gas fuel engines are to comply with the applicable requirements of Appendix 1[①] of this Chapter, CCS Rules for Ships Using Natural Gas Fuels and CCS Guidelines for Design and Installation of Gas Fuel Engine Systems of Liquefied Gas Carriers.
9.1.9.2 In addition to the relevant provisions of this Chapter, methanol/ethanol fuel engines are to comply with the applicable requirements of Appendix 10 of this Chapter and CCS Guidelines for Ships Using Methanol/Ethanol Fuel.
9.1.9.3 In addition to the relevant provisions of this Chapter, ammonia fuel engines are to comply with the applicable requirements of Appendix 11 of this Chapter and CCS Guidelines for Ships Using Ammonia Fuel.

9.1.10 Electrically controlled diesel engines
9.1.10.1 Electrically controlled diesel engines are to comply with the relevant requirements of Appendix 2 of this Chapter.

9.1.11 Turbochargers[②]

---

① (1) Appendix 1 applies to gas fuel engines for which the date of an application for type approval certification is dated on or after 1 July 2019.
(2) The “date of application for type approval” is the date of documents accepted by CCS as request for type approval certification of a new engine type or of an engine type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate.
(3) Engines with an existing type approval on 1 July 2019 are not required to be re-type approved in accordance with the new requirements until the current type approval becomes invalid. For the purpose of certification of these engines, the current type approval and related submitted documentation will be accepted.

② (1) The requirements of 9.1.11, 9.1.12.3, 9.6.2, 9.6.6.2, 9.6.10 and 9.6.11 apply to turbochargers with the date of an application for certification of the new turbocharger type or of a turbocharger type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate on or after 1 January 2023. Turbochargers with an existing type approval on 1 January 2023 are not required to be re-type approved in accordance with the requirement until the current Type Approval reaches its expiry date. The requirements of 9.6.12 apply to turbochargers with the date of application for certification of an individual turbocharger on or after 1 January 2023.
(2) The “date of application for certification” is the date of whatever document CCS requires/accepts as an application or request for certification of a new turbocharger type or of a turbocharger type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate.

9.1.11.1 The turbochargers are to be designed to operate under conditions given in 1.2.1, Chapter 1 of this PART. The component lifetime and the alarm level for speed are to be based on 45℃ air inlet temperature.

9.1.11.2 Turbochargers are categorized in three groups depending on served power by cylinder groups (e.g. for a V-engine with one turbocharger for each bank, the size is half of the total engine rated power) with:

(1) Category A: ≤ 1,000 kW;

(2) Category B: > 1,000 kW and ≤ 2,500 kW;

(3) Category C: > 2,500 kW.

9.1.11.3 The requirements for turbochargers with regard to design, approval, type testing and certification escalate with the size of the turbochargers. For details, see Section 6 of this Chapter.

9.1.11.4 Turbochargers are to be type approved, either separately or as a part of an engine.

9.1.11.5 The requirements relating to turbochargers in this Chapter are written for exhaust gas driven turbochargers, but apply in principle also for engine driven chargers.

9.1.12 Plans and documents

9.1.12.1 The following engine plans and documents are to be submitted for approval:

No.	Item
1	Bedplate and crankcase of welded design, with welding details and welding instructions[1,2]
2	Thrust bearing bedplate of welded design, with welding details and welding instructions[1]
3	Bedplate/oil sump welding drawings[1]
4	Frame/framebox/gearbox of welded design, with welding details and instructions[1,2]
5	Frame/framebox/gearbox, with welding drawings[1,2]
6	Crankshaft, details, each cylinder No.
7	Crankshaft, assembly, each cylinder No.
8	Crankshaft calculations (for each cylinder configuration) according to Appendix 3 of this Chapter
9	Thrust shaft or intermediate shaft (if integral with engine)
10	Shaft coupling bolts
11	Material specifications of main parts (see Table 9.2.2.1) with information on non-destructive material tests and pressure tests[3]
12	Schematic layout or other equivalent documents on the engine of starting air system, fuel oil system, lubricating oil system, cooling water system, hydraulic system (including hydraulic system for valve lift), control and safety system
13	Shielding of high pressure fuel pipes, assembly[4]
14	Construction and strength of accumulators (for electronically controlled engine)
15	Arrangement and details of the crankcase explosion relief valve (see 9.7.4)[5]
16	Calculation results for crankcase explosion relief valves (see 9.7.4)
17	Details of the type test program and the type test report[7]
18	High pressure parts for fuel oil injection system[6]
19	Oil mist detection and/or alternative alarm arrangements (see 9.7.6 and 9.7.7)
20	Details of mechanical joints of piping systems (see 2.5.3, Chapter 2 of this PART)
21	Documentation verifying compliance with inclination limits (see 1.2.1, Chapter 1 of this PART)
22	Documents as required in Section 6, Chapter 2, PART SEVEN of the Rules, as applicable

Notes:

1. For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
2. For each cylinder for which dimensions and details differ.
3. For comparison with rules requirements for material, NDT and pressure testing as applicable.
4. All engines.
5. Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m^3 or more.
6. The documentation to contain specifications for pressures, pipe dimensions and materials.
7. The type test program is to be submitted before the type test, and the type test report may be submitted after the conclusion of the type test.

9.1.12.2 The following engine plans and documents are to be submitted for information:

No.	Item
1	Engine particulars (e.g. Data sheet with general engine information (see Annex 3 to Appendix 5 of this Chapter), Project Guide, Marine Installation Manual)

2	Engine cross section
3	Engine longitudinal section
4	Bedplate and crankcase of cast design
5	Thrust bearing assembly[1]
6	Frame/framebox/gearbox of cast design[2]
7	Tie rod
8	Connecting rod
9	Connecting rod, assembly[3]
10	Crosshead, assembly[3]
11	Piston rod, assembly[3]
12	Piston, assembly[3]
13	Cylinder jacket/ block of cast design[2]
14	Cylinder cover, assembly[3]
15	Cylinder liner
16	Counterweights (if not integral with crankshaft), including fastening
17	Camshaft drive, assembly[3]
18	Flywheel
19	Fuel oil injection pump
20	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
21	For electronically controlled engines, construction and arrangement of control valves, high-pressure pumps and drive for high pressure pumps
22	Operation and service manuals[4]
23	FMEA (for engine control system)[5]
24	Production specifications for castings and welding (sequence)
25	Evidence of quality control system for engine design and in service maintenance
26	Quality requirements for engine production
27	Type approval certification for environmental tests, control components of electrical system[6]
28	Fatigue analysis of high pressure fuel oil piping and hydraulic oil piping (where applicable)
29	Other plans and documents as deemed necessary by CCS

Notes:

1. If integral with engine and not integrated in the bedplate.
2. Only for one cylinder or one cylinder configuration.
3. Including identification (e.g. drawing number) of components.
4. Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.
5. Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, a failure mode and effects analysis (FMEA) is to be submitted to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine.
6. Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions per CCS Guidelines for Type Approval Test of Electric and Electronic Products.

9.1.12.3 For turbochargers, the following plans and documents are to be submitted for approval:

(1) Category A:

① Containment test report;

② Cross sectional drawing with principal dimensions and names of components;

③ Test program.

(2) Category B and C:

① Cross sectional drawing with principal dimensions and materials of housing components for containment evaluation;

② Documentation of containment in the event of disc fracture (see 9.6.10);

③ Operational data and limitations, including maximum permissible operating speed (rpm), alarm level for overspeed, maximum permissible exhaust gas temperature before turbine, alarm level for exhaust gas temperature before turbine, minimum lubrication oil inlet pressure, lubrication oil inlet pressure low alarm set point, maximum lubrication oil outlet temperature, lubrication oil outlet temperature high alarm set point, maximum permissible vibration levels (i.e. self- and externally generated vibration);

Note: Alarm levels may be equal to permissible limits but are not to be reached when operating the

engine at 110% power or at any approved intermittent overload beyond the 110%.

④ Arrangement of lubrication system, all variants within a range;

⑤ Type test reports;

⑥ Test program.

(3) In addition to the provisions of (2) above, the following plans and documents for category C turbochargers are to be submitted:

① Drawings of the housing and rotating parts including details of blade fixing;

② Material specifications (chemical composition and mechanical properties) of all parts mentioned above;

③ Welding details and welding procedure of above mentioned parts, if applicable;

④ Documentation* of safe torque transmission when the disc is connected to the shaft by an interference fit, see 9.6.6.2;

⑤ Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue;

⑥ Operation and maintenance manuals*.

Note: * Applicable to two sizes in a generic range of turbochargers.

Section 2 INSPECTION, TEST AND CERTIFICATION OF DIESEL ENGINE PARTS

9.2.1 General requirements

9.2.1.1 The engine manufacturer is to have a quality control system that is suitable for the actual engine types. The quality control system is also to apply to any sub-suppliers. CCS reserves the right to review the system or parts thereof.

9.2.1.2 Materials and components are to be produced in compliance with all the applicable production and quality instructions specified by the engine manufacturer.

9.2.1.3 Certain parts are to be verified and documented by means of CCS Marine Product Certificate (C), Manufacturer's document (W) or Test Report (TR). For the definitions of CCS Marine Product Certificate (C), Manufacturer's document (W) or Test Report (TR), see Chapter 3, PART ONE of the Rules.

9.2.1.4 The documents above are used for product documentation as well as for documentation of single inspections such as crack detection, dimensional check, etc. If agreed to by CCS, the documentation of single tests and inspections may also be arranged by filling in results on a control sheet following the component through the production.

9.2.1.5 The TR and W issued by the manufacturer are to be submitted to CCS for review to ensure compliance with the agreed or approved specifications. CCS Marine Product certificate (C) means that the Surveyor also witnesses the testing, batch or individual, unless Alternative Certification Scheme (ACS) provides other arrangements.

9.2.1.6 The manufacturer is not exempted from responsibility for any relevant tests and inspections of those parts for which documentation is not explicitly requested by CCS. The manufacturing works process and equipment is to be set up and maintained in such a way that all materials and components can be consistently produced to the required standard. This includes production and assembly lines, machining units, special tools and devices, assembly and testing rigs as well as all lifting and transportation devices.

9.2.1.7 The extent of parts to be documented depends on the type of engine, engine size and criticality of the part. Requirements for inspection, test and documentation of diesel engine parts are listed in Table 9.2.2.1.

9.2.1.8 For components and materials not specified in Table 9.2.2.1, consideration will be given by CCS upon full details being submitted and reviewed.

9.2.1.9 Symbols used in Table 9.2.2.1 are listed below.

Symbol	Description
CC	Chemical composition
CH	Crosshead engines
D	Cylinder bore diameter (mm)
M	Mechanical properties
MT	Magnetic particle testing
PT	Dye penetration testing
UT	Ultrasonic testing
VT	Visual examination of accessible surfaces by the Surveyor

9.2.2 Inspection, test and certification

9.2.2.1 Diesel engine parts are to be subject to material test, NDT, hydraulic test, dimensional inspection and visual examination as given in Table 9.2.2.1.

9.2.2.2 Turbochargers are to be subject to inspection, test and certification in accordance with the relevant requirements of Section 6 of this Chapter.

9.2.2.3 Crankcase explosion relief valves are to be subject to inspection, test and certification in accordance with the requirements of 9.7.4 of this Chapter.

9.2.2.4 Oil mist detection system is to be subject to inspection, test and certification in accordance with the requirements of 9.7.6 and 9.7.7 of this Chapter.

9.2.2.5 Speed governor and overspeed protection device are to be subject to inspection and test in accordance with the requirements of 9.7.8, 9.7.9 and 9.7.10 of this Chapter.

9.2.2.6 Diesel engine control, alarm and safety protection system (including computer system) are to be subject to inspection and test in accordance with the relevant requirements of PART SEVEN of the Rules.

9.2.2.7 Material test and non-destructive testing are to be carried out in accordance with the relevant requirements of CCS Rules for Materials and Welding.

9.2.2.8 Hydraulic testing is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, relevant documents are to be submitted for confirmation.

Summary of inspection, test and certification of diesel engine parts Table 9.2.2.1

Item	Parts [5]	Material properties [1]	Non-destructive examination [2]	Hydraulic testing	Dimensional inspection (including surface condition)	Visual inspection (surveyor)	Applicable to engines
1	Welded bedplate	CC+M	UT+MT/PT			VT(fit-up and post-welding)	All
2	Bearing transverse girders (cast steel)	CC+M	UT+MT/PT			VT	All
3	Welded frame box	CC+M	UT+MT/PT			VT(fit-up and post-welding)	All
4	Cylinder block (cast iron)			X[4]			>400 kW/cyl
5	Welded cylinder frames	CC+M	UT+MT/PT			VT(fit-up and post-welding)	CH
6	Engine block (grey cast iron)			X[4]			>400 kW/cyl
7	Engine block (nodular graphite cast iron)	M		X[4]			>400 kW/cyl
8	Cylinder liner	CC+M		X[4]			D>300mm
9	Cylinder head (cast iron)			X			D>300mm
10	Cylinder head (cast steel)	CC+M	UT+MT/PT	X		VT	D>300mm
11	Forged cylinder head	CC+M	UT+MT/PT	X		VT	D>300mm
12	Piston crown (cast steel)	CC+M	UT+MT/PT			VT	D>400mm
13	Forged piston crown	CC+M	UT+MT/PT			VT	D>400mm
14	Crankshaft: made in one piece	CC+M	UT+MT/PT		X	VT (random, of fillets and oil bores)	All
15	Semi-built crankshaft (Crank throw, forged main journal and journals with flange)	CC+M	UT+MT/PT		X	VT (random, of fillets and shrink fittings)	All
16	Exhaust gas valve cage			X			CH
17	Piston rod	CC+M	UT+MT/PT			VT (random)	D>400mm CH
18	Cross head	CC+M	UT+MT/PT			VT (random)	CH
19	Connecting rod	CC+M	UT+MT/PT		X	VT (random,	All

Item	Parts [5]	Material properties [1]	Non-destructive examination [2]	Hydraulic testing	Dimensional inspection (including surface condition)	Visual inspection (surveyor)	Applicable to engines
	with cap					of all surfaces, in particular those shot peened)	
20	Coupling bolts for crankshaft	CC+M	UT+MT/PT		X	VT (random, of interference fit)	All
21	Bolts and studs for main bearings and cylinder heads	CC+M	UT+MT/PT				D>300mm
22	Bolts and studs for connecting rods	CC+M	UT+MT/PT		X (thread making)		D>300mm
23	Tie rod	CC+M	UT+MT/PT		X (thread making)	VT (random)	CH
24	High pressure fuel injection pump body	CC+M		X			All
25	High pressure fuel injection valves (only for not autofretted)			X			All
26	High pressure fuel injection pipes including common fuel rail	CC+M		X for those that are not autofretted			All
27	High pressure common servo oil system	CC+M		X			All
28	Cooler, both sides [3]	CC+M		X			D>300mm
29	Accumulator	CC+M		X			All engines with accumulators with a capacity of >0.5 l
30	Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable	CC+M		X			>800 kW/cyl
31	Engine driven pumps (oil, water, fuel, bilge) other than pumps referred to in item 24 and 30			X			>800 kW/cyl
32	Bearings for main, crosshead, and crankpin	CC	UT (full contact between basic material and bearing metal)		X		>800 kW/cyl

Notes:

(1) Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force).

(2) Non-destructive examination means e.g. ultrasonic testing, crack detection by MT or PT. When certain NDE method on the finished component is impractical (for example UT for items 10/11), the NDE method can be performed at earlier appropriate stages in the production of the component, see 3.1.5.2, PART ONE of the Rules.

(3) Charge air coolers need only be tested on the water side.

(4) Hydraulic testing is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner.

(5) Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. The certification requirements for relevant components are to comply with the requirements of Chapter 3, PART ONE of the Rules.

Section 3 DESIGN AND CONSTRUCTION

9.3.1 Design

9.3.1.1 Design and construction of diesel engines are to comply with relevant requirements relating to ambient condition, properties and availability specified in Section 2, Chapter 1 of this PART.

9.3.1.2 Fatigue strength calibration or diameter calibration may be adopted in calculating crankshafts of diesel engines. For details, see Appendix 3 of this Chapter.

9.3.2 Materials

9.3.2.1 The specified tensile strength of forgings and castings for crankshafts is in general to be selected within the following limits, and the materials used are to comply with the relevant requirements contained in CCS Rules for Materials and Welding:

(1) carbon and carbon-manganese steel 400 to 600 N/mm^2;

(2) alloy steel 600 to 1,000 N/mm^2;

(3) nodular graphite cast iron 490 to 780 N/mm^2.

9.3.2.2 Where it is proposed to use alloy steel forgings for crankshafts, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

9.3.3 Structure

9.3.3.1 Frames and bedplates of diesel engines are to be stress-relieved. Where valid documentation and evidence are provided by the manufacturer or the designer, the stress-relieved treatment is unnecessary. In the case of welded structure, they are to meet, furthermore, the relevant requirements in CCS Rules for Materials and Welding.

Section 4 PIPING SYSTEMS

9.4.1 Lubricating oil systems

9.4.1.1 The lubricating oil systems of diesel engines are to be so designed and installed as to maintain operation when the ship is under a list or trim up to that as given in 1.2.1.1 of Chapter 1 of this PART.

9.4.1.2 Diesel engines greater than 37 kW are to be provided with an audible and visible alarm device giving an indication of failure of lubricating oil systems.

9.4.1.3 Lubricating oil drain pipes from the engine sump to the drain tank are to be submerged at their outlet ends.

9.4.1.4 In addition, the lubricating oil systems are to comply with the relevant requirements of Section 6, Chapter 4 of this PART.

9.4.2 Cooling water systems

9.4.2.1 For large low-speed diesel engine having oil-cooled or water-cooled pistons, a thermometer and a device for observing the circulation of cooling oil or cooling water are to be fitted to each outlet pipe led from the inside of the piston. If there is no outlet pipe led from the inside of the piston, other means of arrangement may be adopted.

9.4.2.2 Cooling water systems of diesel engines are to be provided with alarm devices for indicating the excess temperature.

9.4.2.3 In addition, the cooling water systems are to comply with the relevant requirements of Section 5, Chapter 4 of this PART.

9.4.3 Oil fuel systems

9.4.3.1 For cargo ships of 500 gross tonnage and over and all passenger ships, high-pressure fuel delivery lines are to meet the relevant requirements of PART SIX of the Rules.

For cargo ships of less than 500 gross tonnage, where the cylinder bore of main and auxiliary diesel engines is 250 mm and above, the fuel injection piping is to be effectively secured and shielded so as to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any oil fuel leakage.

9.4.3.2 Where, on V-type engines, the fuel system is located between the rows of cylinders, suitable shielding and drainage ducts for leaking fuel are to be provided.

9.4.3.3 Leaking fuel is to be safely drained away at zero excess pressure. Care is to be taken to ensure that

leaking fuel cannot become mixed with the engine lubricating oil.
9.4.3.4 Where the engine is installed on elastic mountings, the approved flexible joints are to be fitted in way of connection between the diesel engine and fuel oil supply pipes. The flexible joints are to comply with relevant requirements of Section 5, Chapter 2 of this PART.
9.4.3.5 In addition, the oil fuel systems are to comply with the relevant requirements of Section 2, Chapter 4 of this PART.

9.4.4 Exhaust systems

9.4.4.1 An instrument for measuring the exhaust gas temperature is to be fitted to each cylinder of diesel engines with cylinder bore 200 mm and over.
9.4.4.2 The exhaust pipes of diesel engines are to be provided with effective silencers or other equivalent silencing measures.
9.4.4.3 Each diesel engine is to have a separate exhaust pipe to prevent the backflow of the exhausts. Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economizer, an isolating device is to be provided in each exhaust pipe.
9.4.4.4 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the diesel engine.
9.4.4.5 For alternatively fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.
9.4.4.6 In addition, the exhaust systems are to comply with the relevant requirements of Section 10, Chapter 4 of this PART.

9.4.5 Starting air systems

9.4.5.1 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.
9.4.5.2 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system.
9.4.5.3 The starting air piping system is to be protected against the effects of explosions due to the improper function of the starting valve by providing an isolating non-return valve or equivalent at the starting air supply to each engine.
9.4.5.4 In diesel engines having cylinders exceeding 230 mm, bursting discs or flame arresters or other equivalent means are to be fitted in the starting air systems, such devices are to be fitted at the starting valves on each cylinder for direct reversing engines and at the supply inlet to the starting air manifold for non-reversing engines.

9.4.6 Compressed air systems for essential services

9.4.6.1 Compressed air systems for essential services mean compressed air systems provided for the proper operation of SCR purging systems (if applicable), gas fuel double-wall duct ventilation systems (if applicable) etc. on board ships, other than those used for engine starting.
9.4.6.2 The arrangements for the supply of compressed air to essential services are to ensure that sufficient compressed air to satisfy the total demand of the essential services is available at all times during normal operation, during maintenance, and in the event of a failure of the compressed air system.
9.4.6.3 Where compressed air is supplied from the engine starting air system, either continuously in normal operation, or periodically during maintenance or in the event of a failure of the compressed air system, the required compressed air demand is not to reduce the capacity and availability of the engine starting air.

Section 5 STARTING ARRANGEMENTS

9.5.1 Mechanical starting arrangements

9.5.1.1 The arrangement for air starting is to be such that the necessary air for the first charge can be produced on board without external aid.
9.5.1.2 Where the main engine is arranged for starting by compressed air, two or more air compressors are to be fitted. At least one of the compressors is to be driven independent of the main propulsion unit. The capacity of one of the said independently driven compressors or the combined capacity of independently driven compressors is not to be less than 50% of the total required.

The total capacity of air compressors is to be sufficient to supply within one hour the quantity of air needed to satisfy 9.5.1.6 by charging the receivers from atmospheric pressure. The capacity is to be approximately equally divided between the number of compressors fitted, excluding an emergency compressor which may be installed to satisfy the requirements of 9.5.1.1.

9.5.1.3 Pressure gauges and safety valves are to be fitted to air compressors. The safety valves are to be set at a pressure not more than 1.1 times the working pressure. Casings of the cooling water space of compressed air coolers are to be provided with relief valves or bursting discs.

9.5.1.4 Relief valves are to be fitted to the crankcase of air compressors when the crankcase has a volume exceeding 0.6 m^3.

9.5.1.5 The design and construction of air receivers are to comply with the relevant requirements contained in Section 4 and Appendix 4, Chapter 6 of this PART.

9.5.1.6 Where the main engines are arranged for starting by compressed air, at least two starting air receivers of about equal capacity are to be fitted, which can be used independently. The total capacity of air receivers is to be sufficient to provide, without their being replenished, not less than 12 consecutive starts alternating between ahead and astern of each main engine of the reversible type, and not less than 6 starts of each main non-reversible type engine connected to a controllable pitch propeller or other device enabling the start without opposite torque. When other consumers such as auxiliary engines starting systems, control systems, whistle, SCR purging systems (if applicable), gas fuel double-wall duct ventilation systems (if applicable), etc., are to be connected to starting air receivers, their air consumption is also to be taken into account. Regardless of the above, for multi-engine installations the number of starts required for each engine may be reduced to 3 times, the total number of starts is not to be less than 12 times, but unnecessarily exceed 18 times.

9.5.1.7 The air receivers are to be so fitted with drain arrangement as to permit effective drainage when the ship is under normal inclination conditions.

9.5.2 Electric starting installations

9.5.2.1 Where the main engine is arranged for electric starting, two separate batteries are to be fitted. The arrangement is to be such that the batteries cannot be connected in parallel. Each battery is to be capable of starting the main engine when in cold and ready to start conditions. The combined capacity of the batteries is to be sufficient without recharging to provide within 30 min the number of starts of main engines as required in 9.5.1.6 of this Section in case of air starting.

9.5.2.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or may be supplied by separate circuits from the main engine batteries when such are provided. In the case of a single auxiliary engine only one battery may be required. The capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

9.5.2.3 The starting batteries are to be used for starting and the engines own monitoring purposes only. Provisions are to be made to maintain continuously the stored energy at all times.

9.5.3 Starting arrangements for emergency generating sets

9.5.3.1 The prime mover of emergency generating sets is to be capable of being started in cold condition at a temperature of 0℃. If this is impracticable, or if lower temperatures are likely to be encountered, an accessory heating arrangement may be fitted so as to ensure low-temperature starting of the emergency generating sets.

9.5.3.2 Each emergency generating set arranged to be automatically started is to be equipped with starting devices with a stored energy capability of at least three consecutive starts. The source of stored energy is to be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. In addition, a second source of energy is to be provided for an additional three starts within 30 min unless manual starting can be demonstrated to be effective.

9.5.3.3 The stored energy is to be maintained at all times as follows:

(1) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.

(2) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers through a suitable non-return valve or by an emergency air compressor which, if, electrically driven, is supplied from the emergency switchboard.

(3) All of these starting, charging and energy storing devices are to be located in the emergency generator space; these devices are not to be used for any purpose other than the operation of the emergency generating set. This does not preclude the supply to the air receiver of the emergency generating set from the main or auxiliary compressed air system through the non-return valve fitted in the emergency generator space.

9.5.3.4 Where automatic starting is not required, manual starting is permissible, such as manual cranking,

inertia starts, manually charged hydraulic accumulators, or powder charge cartridges, where they can be demonstrated as being effective.
When manual starting is not practicable, the requirements of 9.5.3.2 and 9.5.3.3 are to be complied with except that starting may be manually initiated.
9.5.3.5 Where the emergency generating sets are provided with electronic speed governors (or other auxiliary facilities which are only able to start after being supplied with electric power), two sets of power supply which are independent from each other are to be provided.
9.5.3.6 The emergency generator used to restore operation from the dead ship condition is to comply with the provisions of 1.2.6, Chapter 1 of this PART.

Section 6 SCAVENGING AND SUPERCHARGING ARRANGEMENTS

9.6.1 Lubricating oil systems
9.6.1.1 The lubricating oil system of exhaust gas turbochargers may be separate from, or in common with, that of the main engine. If lubricating oil pumps are not directly driven by turbochargers, an independent standby lubricating oil pump is to be provided. And in addition, large low-speed diesel engines are to be provided with lubricating oil gravity tanks for emergency. Lubricating oil systems are to be arranged according to the requirements of 1.2.1.1 of this PART.

9.6.2 Alarm and monitoring
9.6.2.1 For all turbochargers of Categories B and C, indications and alarms as listed in Table 9.6.2.1 are required.
9.6.2.2 Indications may be provided at either local or remote locations.

Requirements for alarm and indication of turbochargers of categories B and C

Table 9.6.2.1

Pos.	Monitored Parameters	Category of Turbochargers				Remark
		B		C		
		Alarm	Indication	Alarm	Indication	
1	Speed	High (4)	X (4)	High (4)	X (4)	
2	Exhaust gas at each turbocharger inlet, temperature	high (1)	X (1)	high	X	High temp. alarms for each cylinder at engine is acceptable (2)
3	Lub. oil at turbocharger outlet, temperature			high	X	If not forced system, oil temperature near bearings
4	Lub. oil at turbocharger inlet, pressure	low	X	low	X	Only for forced lubrication systems (3)

Notes:
(1) For Category B turbochargers, the exhaust gas temperature may be alternatively monitored at the turbocharger outlet, provided that the alarm level is set to a safe level for the turbine and that correlation between inlet and outlet temperatures is substantiated.
(2) Alarm and indication of the exhaust gas temperature at turbocharger inlet may be waived if alarm and indication for individual exhaust gas temperature is provided for each cylinder and the alarm level is set to a value safe for the turbocharger.
(3) Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the diesel engine or if it is separated by a throttle or pressure reduction valve from the diesel engine lubrication oil system.
(4) On turbocharging systems where turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the sequence, provided all turbochargers share the same intake air filter and they are not fitted with waste gates.

9.6.3 Air filters and silencers
9.6.3.1 Turbochargers are to be fitted with inlet air filters and silencers.

9.6.4 Rotor shaft locking devices
9.6.4.1 Turbocharger rotor shafts are to be provided with locking devices. If not, by-pass connections or other suitable devices are to be fitted to the pipes before and after the turbines to ensure the normal operation of main engines in case of turbocharger breakdown.

9.6.5 Critical speeds

9.6.5.1 Critical speeds of the turbocharger rotor are to be determined by calculation. In the case of rigid rotor shafts, critical speeds are not to be less than 1.3 times the rated speed.

9.6.6 Rotors and rotor shafts

9.6.6.1 Where rotor shafts are of welded construction, they are to meet the relevant requirements in CCS Rules for Materials and Welding.

9.6.6.2 For turbochargers of category C, in cases where the disc is connected to the shaft with interference fit, calculations is to substantiate safe torque transmission during all relevant operating conditions such as maximum speed, maximum torque and maximum temperature gradient combined with minimum shrinkage amount.

9.6.6.3 After assembly, rotors are to be dynamically balanced.

9.6.7 Protection

9.6.7.1 For two-stroke loop-scavenged and cross-scavenged diesel engines, grids or other suitable devices are to be fitted before turbine nozzles to prevent broken piston rings from entering into the turbine casings.

9.6.7.2 It is undesirable to connect vent pipes of crankcase with turbocharger inlets. Otherwise, effective oil vapor separating devices are to be fitted before the turbocharger inlets.

9.6.8 Emergency blowers

9.6.8.1 Two-stroke turbocharged diesel engines not equipped with scavenge pumps are to be provided with independent emergency blowers, except that the scavenging air systems arranged in series are available.

9.6.9 Relief valves of scavenging air receivers and fire extinguishing devices

9.6.9.1 Scavenging air receivers of two-stroke diesel engines are to be fitted with relief valves as well as devices for removing dirty oil and condensate. Relief valves are to be set generally at a pressure not more than 1.1 times the maximum scavenging air pressure.

9.6.9.2 Crosshead type engine scavenge spaces in open connection with cylinders are to be provided with independent fire extinguishing arrangements which are to be independent of the fire extinguishing system of the engine room.

9.6.10 Containment

9.6.10.1 Turbochargers are to fulfil containment in the event of a rotor burst. This means that at a rotor burst no part may penetrate the casing of the turbocharger or escape through the air intake. For documentation purposes (test/calculation), it is to be assumed that the discs disintegrate in the worst possible way.

9.6.10.2 For category B and C, containment is to be documented by testing. Fulfilment of this requirement can be awarded to a generic range of turbochargers based on testing of one specific unit. Testing of a large unit is preferred as this is considered conservative for all smaller units in the generic range. In any case, it must be documented (e.g. by calculation) that the selected test unit really is representative for the whole generic range.

9.6.10.3 The minimum test speeds, relative to the maximum permissible operating speed, are:

— for the compressor: 120%;

— for the turbine: 140% or the natural burst speed, whichever is lower.

9.6.10.4 Containment tests are to be performed at a temperature which is not lower than the maximum allowable temperature of the turbocharger to be specified by the manufacturer.

9.6.10.5 Manufacturers are to determine whether cases more critical than those defined in 9.6.10.3 and 9.6.10.4 exist with respect to containment safety. Where such a case is identified, evidence of containment safety is also to be provided for that case.

9.6.10.6 A numerical analysis simulation such as Finite Element Method (FEM) of sufficient containment integrity of the casing based on calculations by means of a simulation model may be accepted in lieu of the practical containment test, provided that:

(1) the numerical simulation model has been tested and its suitability/accuracy has been proven by direct comparison between calculation results and the practical containment test for a reference application (reference containment test). This test is to be performed at least once by the manufacturer for acceptance of the numerical simulation method in lieu of tests;

(2) the corresponding numerical simulation for the containment is performed for the same speeds as specified for the containment test;

(3) material properties for high-speed deformations are to be applied in the numeric simulation. The

correlation between normal properties and the properties at the pertinent deformation speed are to be substantiated;
(4) the design of the turbocharger regarding geometry and kinematics is similar to the turbocharger that was used for the reference containment test. In general, totally new designs will call for a new reference containment test.
Note: A generic range means a series of turbocharger which are of the same design, but scaled to each other.
9.6.10.7 In cases where a totally new design is adopted for a turbocharger for which an application for type approval certification has been requested, new reference containment tests are to be performed.
Note: Totally new design means the principal differences between a new turbocharger and previous ones are related to geometry and kinematics. The turbochargers are to be regarded as having a totally new design if the structure and/or material of the turbocharger casings are changed, or any of, but not limited to, the following items is changed from the previous design.
(1) Maximum permissible exhaust gas temperature;
(2) Number of bearings;
(3) Number of turbine blades;
(4) Number of turbine wheels and/or compressor wheels;
(5) Direction of inlet air and/or exhaust gas (e.g., axial flow orientation, radial flow orientation);
(6) Type of the turbocharger drive (e.g., axial turbine type, radial turbine type, mixed flow turbine type).

9.6.11 Type testing
9.6.11.1 Type testing is applicable to categories B and C. The type test for a generic range of turbochargers may be carried out either on an engine (for which the turbocharger is foreseen) or in a test rig.
9.6.11.2 Turbochargers for the low, medium, and high-speed engines are to be subjected to at least 500 load cycles at the limits of operation. This test may be waived if the turbocharger together with the engine is subjected to this kind of low cycle testing, see Appendix 4 of this Chapter.
9.6.11.3 The suitability of the turbocharger for such kind of operation is to be preliminarily stated by the manufacturer.
9.6.11.4 The rotor vibration characteristics are to be measured and recorded in order to identify possible sub-synchronous vibrations and resonances.
9.6.11.5 The type test is to be completed by a hot running test at maximum permissible speed combined with maximum permissible temperature for at least one hour. After this test, the turbocharger is to be opened for examination, with focus on possible rubbing and the bearing conditions.
9.6.11.6 The extent of the surveyor's presence during the various parts of the type tests is left to the discretion of each Society.

9.6.12 Certification
9.6.12.1 The manufacturer is to adhere to a quality system designed to ensure that the designer's specifications are met, and that manufacturing is in accordance with the approved drawings.
9.6.12.2 For category C, this is to be verified by means of periodic product audits of Alternative Certification Scheme (ACS, see Section 10, Chapter 3, PART ONE of the Rules).
9.6.12.3 These audits are to focus on:
(1) chemical composition of material for the rotating parts;
(2) mechanical properties of the material of a representative specimen for the rotating parts and the casing;
(3) UT and crack detection of rotating parts, or other non-destructive testing as applicable;
(4) dimensional inspection of rotating parts;
(5) rotor balancing;
(6) hydraulic testing of cooling spaces to 0.4MPa or 1.5 times the maximum working pressure, whichever is higher;
(7) overspeed test of all compressor wheels for a duration of 3 min at either 20% above alarm level speed at room temperature or 10% above alarm level speed at 45℃ inlet temperature when tested in the actual housing with the corresponding pressure ratio. The overspeed test may be waived for forged wheels that are individually controlled by an approved non-destructive method.
9.6.12.4 The certification requirements for turbochargers are to be in compliance with Chapter 3, PART ONE of the Rules.
9.6.12.5 The requirements of 9.6.12.1 to 9.6.12.4 also apply to replacement of rotating parts and casing.
9.6.12.6 Alternatively to the above periodic product audits, individual certification of a turbocharger and its parts may be made. However, such individual certification of category C turbocharger and its parts are to be based on test requirements specified in 9.6.12.3.

Section 7 FITTINGS

9.7.1 Indicator valves

9.7.1.1 An indicator valve is to be fitted to each cylinder cover of diesel engines having cylinder bore over 200 mm.

9.7.2 Cylinder Safety valves

9.7.2.1 A safety valve or equivalent means to prevent overpressure in the cylinders is to be fitted to each cylinder cover of diesel engines having cylinder bore over 230 mm. The safety valve is to be set at a pressure not more than 1.40 times the maximum combustion pressure and is to be so arranged that personal injury will not be caused by the outburst gas. For auxiliary engines, consideration will be given to the replacement of the relief valve by an efficient warning device of overpressure in the cylinder.

9.7.3 Crankcases

9.7.3.1 Crankcases and their doors are to be of robust construction and the doors are to be securely fastened so that they will not be readily displaced by an explosion.

9.7.3.2 The total volume of the stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components are to be included in the gross volume).

9.7.4 Crankcase relief valves

9.7.4.1 In engines having cylinders not less than 200 mm bore or having a crankcase gross volume not less than 0.6 m^3, relief valves are to be installed according to the requirements of 9.7.4.2 to 9.7.4.6 of this Section.

9.7.4.2 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least one relief valve is to be fitted near respectively each end of crankcase and an additional relief valve is to be fitted near the middle of the engine, where crank throws exceed eight.

9.7.4.3 In engine having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. Relief valves are to be arranged from each end, where the cranks are of odd number.

9.7.4.4 In engines having cylinders exceeding 300 mm bore at least one relief valve is to be fitted in way of each main crank throw.

9.7.4.5 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces exceeds 0.6 m^3.

9.7.4.6 The structural design of crankcase relief valves are to satisfy following requirements:

(1) The combined free area of the crankcase relief valves fitted on an engine is not to be less than 115 cm^2 per m^3 of the volume of the crankcase. The free area of each relief valve is not to be less than 45 cm^2.

(2) Crankcase explosion relief valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self-closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent the inrush of air thereafter.

(3) The valve discs in crankcase explosion relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

(4) Crankcase explosion relief valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0.02 MPa.

(5) Crankcase explosion relief valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.

(6) Where crankcase relief valves are provided with arrangements for shielding emissions from the valve following an explosion, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valves.

(7) Crankcase explosion relief valves are to be provided with a copy of manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:

① description of valve with details of function and design limits;
② copy of type test certification;
③ installation instructions;
④ maintenance in service instructions to include testing and renewal of any sealing arrangements;
⑤ actions required after a crankcase explosion.

(8) A copy of the installation and maintenance manual required by 9.7.4.6(7) of this Section is to be

provided on board ship.
(9) Valves are to be provided with suitable markings that include the following information:
① name and address of manufacturer;
② designation and size;
③ month/Year of manufacture;
④ approved installation orientation.
(10) Crankcase explosion relief valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine in accordance with Appendix 7 of this Chapter.

9.7.5 Vent pipes

9.7.5.1 Ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase, are in principle not permitted except for gas fuel engines where crankcase ventilation is to be provided in accordance with the applicable requirements of Appendix 1 of this Chapter, CCS Rules for Ships Using Natural Gas Fuels and CCS Guidelines for Design and Installation of Gas Fuel Engine Systems of Liquefied Gas Carriers. Vent pipes, where provided, are to be as small as practicable to minimise the inrush of external air after a crankcase explosion.

9.7.5.2 In order to avoid the interconnection between crankcases and the possible spread of fire following an explosion, interconnection of ventilating pipes of two or more engines is not permitted nor that of oil drain pipes of crankcase.

9.7.5.3 If provision is made for the extraction of gases from within the crankcase, e.g. for smoke detection purpose, the vacuum within the crankcase is not to exceed 25 mm of water column.

9.7.6 Alarms①

9.7.6.1 Oil mist detection arrangements (or engine bearing temperature monitors or equivalent devices) are required for alarm and slowdown purposes for low speed diesel engines of 2,250 kW and above or having cylinders of more than 300 mm bore.

9.7.6.2 Oil mist detection arrangements (or engine bearing temperature monitors or equivalent devices) are required for alarm and automatic shutoff purposes for medium and high speed diesel engines of 2,250 kW and above or having cylinders of more than 300 mm bore.

9.7.6.3 Oil mist detection arrangements are to be of a type approved by classification societies and tested in accordance with Appendix 8 of this Chapter and comply with the requirements of 9.7.7 of this Section. Engine bearing temperature monitors or equivalent devices used as safety devices have to be of a type approved by classification societies for such purposes.

9.7.7 Crankcase oil mist detection/monitoring system

9.7.7.1 Crankcase oil mist detectors are to comply with the relevant requirements of PART SEVEN of the Rules in addition to 9.7.7.2 to 9.7.7.13 of this Section.

9.7.7.2 The oil mist detection/monitoring system and arrangements are to be installed in accordance with the engine designer's and oil mist manufacturer's instructions/recommendations. The following particulars are to be included in the instructions:
(1) Schematic layout of engine oil mist detection/monitoring and alarm system showing location of engine crankcase sample points and piping or electrical cable arrangements together with pipe dimensions to detector/monitor.
(2) Evidence of study to justify the selected location of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate.
(3) The manufacturer's maintenance and test manual.
(4) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist monitoring equipment.

9.7.7.3 A copy of the oil mist detection/monitoring equipment maintenance and test manual required by 9.7.7.2 is to be provided on board ship.

9.7.7.4 Oil mist monitoring and alarm information is to be capable of being read from a safe location away from the engine.

9.7.7.5 Each engine is to be provided with its own independent oil mist detection arrangement and a dedicated alarm.

---

① For equivalent devices for high speed engines, refer to UI SC133.

9.7.7.6 Oil mist detection/monitoring and alarm systems are to be capable of being tested on the test bed and board under engine at standstill and engine running at normal operating conditions in accordance with accepted test procedures.
9.7.7.7 The oil mist detection/monitoring arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.
9.7.7.8 The oil mist detection/monitoring system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.
9.7.7.9 Where oil mist detection/monitoring equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with relevant requirements of PART SEVEN of the Rules.
9.7.7.10 The equipment together with detectors/monitors is to be tested when installed on the test bed and on board ship to demonstrate that the detection/monitoring and alarm system functionally operates. The testing arrangements are to be submitted to CCS for approval.
9.7.7.11 Where sequential oil mist detection arrangements are provided for each crankcase, the sampling frequency and time is to be as short as reasonably practicable.
9.7.7.12 Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, the following information is to be included in the details to be submitted for approval:
(1) Engine particulars – type, power, speed, stroke, bore and crankcase volume;
(2) Details of arrangements prevent the build-up of potentially explosive conditions within the crankcase, e.g. bearing temperature monitoring, oil splash temperature, crankcase pressure monitoring, recirculation arrangements;
(3) Evidence to demonstrate that the arrangements are effective in preventing the build-up of potentially explosive conditions together with details of in-service experience;
(4) Operating instructions and the maintenance and test instructions.
9.7.7.13 Where it is proposed to use the introduction of inert gas into the crankcase to minimize a potential crankcase explosion, details of the arrangements are to be submitted for approval.

9.7.8 Governors
9.7.8.1 Main engines are to be provided with efficient governors to ensure that the speed of main engines does not exceed 115% of the rated speed.
9.7.8.2 When electronic speed governors of main engines form part of a remote control system, they are to comply with the following conditions:
(1) If lack of power to the governor may cause major and sudden changes in the present speed and direction of thrust of the propeller, back-up power supply is to be provided.
(2) Local control of the engines is always to be possible even in the case of failure in any part of the automatic or remote control systems, and to this purpose, from the local control position it is to be possible to disconnect the remote signal. A separate governor may be additionally fitted to satisfy the requirements for speed control specified in 9.7.8.1.
(3) Electronic speed governors and their actuators are to be type tested in accordance with CCS Guidelines for Type Approval Test of Electric and Electronic Products.

9.7.9 Overspeed protective devices
9.7.9.1 For each main engine developing 220 kW and above which drives a controllable pitch propeller or which can be declutched from the transmission shafting, an overspeed protective device is to be provided in addition to the governor prescribed in 9.7.8.1, so as to prevent the speed of main engines exceeding 120% of the rated speed. Equivalent arrangements may also be accepted subject to special consideration. Overspeed protective devices (including the driving mechanism) are to be independent of governors required by 9.7.8.1.

9.7.10 Governors for generating sets
9.7.10.1 Diesel engines intended for driving electric generators are to be provided with governors, which are to meet the following requirements:
They will prevent transient frequency variations in the electrical network in excess of ±10% of the rated frequency with a recovery time to steady state conditions not exceeding 5 s, when the maximum electrical step load is switched on or off. When the rated load is suddenly taken off, a transient speed variation in excess of 10% of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device as required by 9.7.10.3.
In various load conditions between no load and rated load, the permanent speed variation is not to exceed ±5% of the rated speed.
The selected prime mover is to satisfy the load demand within the ship's mains.
Two step application of electrical load is to be achieved with the following method:

When 50% of the rated load is suddenly applied from no-load condition to the prime mover, followed by the remaining 50% load after an interval sufficient to restore the speed to steady state, the momentary variation in speed is not to exceed 10% of the rated speed, the recovery time for the engine speed (i.e. the time for speed fluctuation ratio to return to ±1%) is not to exceed 5 s.

Note: Steady state conditions are those at which the envelope of speed variation does not exceed ±1% of the declared speed at the new power.

For a prime mover for which only more than 2 load steps can be achieved, such load steps may be permitted provided that the use of such prime movers is permitted by the condition of ship's electrical network and such prime mover has been considered and approved for use at the design stage. Verification is to be carried out at ship's trials. When a four-stroke diesel engine with high supercharge is used as the prime mover for driving generator, application of electrical load in more than 2 load steps can be permitted in its governing characteristics tests (see Figure 9.7.10.1). Thus, the power necessary electrical installations being automatically switched on after block-out and the sequence in which it is connected are to be sufficiently considered in designing the load of ship's electric power station. This also applies analogously for generators to be operated in parallel and where the power has to be transferred from one generator to another in the event of any one generator has to be switched off.

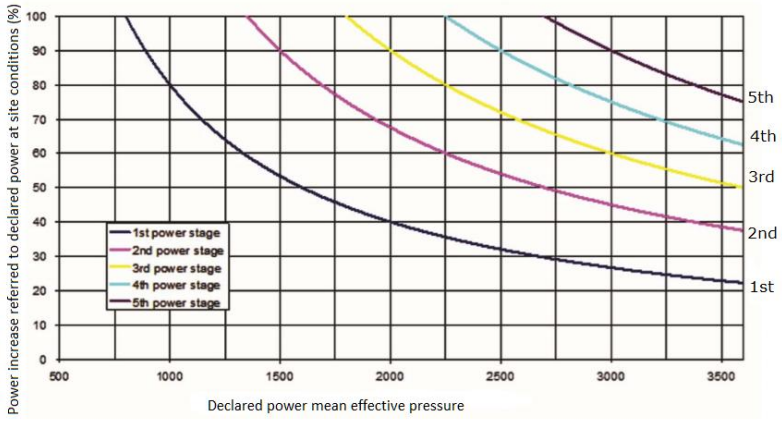


Figure 9.7.10.1①

9.7.10.2 Emergency generator sets must satisfy the governor conditions as per 9.7.10.1 even when their total consumer load is applied suddenly or in steps, subject to:

(1) the total load is supplied within 45 seconds since power failure on the main switchboard;

(2) the maximum step load is declared and demonstrated;

(3) the power distribution system is designed such that the declared maximum step loading is not exceeded;

(4) the compliance of time delays and loading sequence with the above is to be demonstrated at ship's trials.

9.7.10.3 For diesel engines driving electric generators and having a rated power of 220 kW and above, separate overspeed protective devices are to be provided in addition to the governors prescribed in 9.7.10.1, so as to prevent the speed of diesel engines exceeding 115% of the rated speed.

9.7.10.4 The construction and performance of governors for diesel engines intended for driving electric generators are to be in accordance with the relevant provisions specified in Chapter 3, PART FOUR of the Rules. If the generating sets are arranged to operate in parallel, their permanent speed variations are to be the same as far as possible.

9.7.11 Instrumentation

9.7.11.1 Tachometers and other necessary measuring instruments are to be fitted to diesel engines. Restricted speed ranges are to be marked red on tachometers.

---

① (1) The newly revised figure of multiple load steps of four-stroke diesel engines applies to speed governors for which an application for certification is dated on or after 1 January 2020 or which are installed in new ships contracted for construction on or after 1 January 2020.

(2) The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and shipbuilder

(3) The "date of application for certification" is the date of whatever document CCS requires/accepts as an application or request for certification of a speed governor.

9.7.12 Warning notice

9.7.12.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

Section 8 INSTALLATION

9.8.1 Bedplates

9.8.1.1 Bedplates of main engines are to be reasonably rigid, and are to be securely fixed to the engine seatings of reasonable rigidity by means of holding-down bolts, or bolts and chocks, or bolts and thrust sleeves.

When holding-down bolts only are used, the number of fitting bolts is in general not to be less than 15% of the total number.

9.8.1.2 For installation of main engines, consideration is to be given to the effects of the engines on crankshaft deflection in cold or hot condition. The crankshaft deflection of an installed engine is to be in accordance with the manufacturer's requirements for installation.

Section 9 ALARMS AND SAFEGUARDS FOR EMERGENCY DIESEL ENGINES

9.9.1 General requirements

9.9.1.1 Emergency diesel engines mainly include:

(1) a diesel engine generator used as the emergency source of electrical power;

(2) a diesel engine used to power the emergency fire pump;

(3) a diesel engine generator used as the independent source of power required for steering gear;

(4) other diesel engines used in an emergency.

9.9.1.2 This Section applies to diesel engines, which use distillate marine fuels covered by ISO 8217:2017, required to be immediately available in an emergency and capable of being controlled remotely or automatically operated.

9.9.2 Alarms and safeguards

9.9.2.1 The safety and alarm systems are to be designed to "fail safe" and satisfy the requirements of 2.1.3, PART SEVEN of the Rules.

9.9.2.2 Regardless of the engine output, shutdowns other than the overspeed shutdown specified in Table 9.9.2.5 are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

9.9.2.3 The alarm system is to function in accordance with the relevant requirements of PART SEVEN of the Rules, with additional requirements that grouped alarms are to be arranged in the bridge.

9.9.2.4 In additional to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.

9.9.2.5 Emergency diesel engines are to be fitted with alarms and safeguards in accordance with the requirements of Table 9.9.2.5. Local indications of at least those parameters listed in Table 9.9.2.5 are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

Alarms and Safeguards for Emergency Diesel Engines **Table 9.9.2.5**

Parameter	Alarm activation	Shutdown with alarm
Lubricating oil pressure	Low	
Lubricating oil temperature①	High	
Temperature of cooling water or cooling air	High	
Pressure or flow of cooling water①	Low	
Overspeed activated①	Overspeed	Shutdown
Fuel oil leakage from high pressure pipes (fuel	Oil leakage	

injection pipes and common rails)		
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: - the engine main and crank bearing oil outlet; or - the engine main and crank bearing)②	High	

Note: ① for engines having a power of or more than 220 kW.
② only for engines having a power of not less than 2,250 kW or a cylinder bore of more than 300 mm.

Section 10 SURVEY AND CERTIFICATION

9.10.1 Approval and certification of diesel engines①

9.10.1.1 The type approval of diesel engines consists of drawing and specification approval, conformity of production, approval of type testing program, type testing of engines, review of the obtained type testing results, evaluation of the manufacturing arrangements and issue of a type approval certificate.

9.10.1.2 For each type of engine that is required to be approved, a Type Approval Certificate is to be obtained by the engine designer, and the maximum period of validity of a Type Approval Certificate is for 5 years. The process details for obtaining a Type Approval Certificate are given in Appendix 5 of this Chapter.

9.10.1.3 Each diesel engine intended for installation onboard a ship classed with CCS is to have a CCS marine product certificate. The certification process details for obtaining the engine certificate are in Appendix 5 "Approval and Certification of Diesel Engines" of this Chapter.

9.10.2 Type testing①

9.10.2.1 Type testing is required for every new engine type intended for installation onboard ships subject to classification in accordance with the requirements of Appendix 4 of this Chapter.

9.10.2.2 A type test carried out for a particular type of engine at any place of manufacture will be accepted for all engines of the same type built by licensees or the licensor, subject to each place of manufacture being found to be acceptable to CCS.

9.10.2.3 One type test will be considered adequate to cover a range of different numbers of cylinders. However, a type test of an in-line engine may not always cover the V-version. Subject to CCS' discretion, separate type tests may be required for the V-version. On the other hand, a type test of a V-engine covers the in-line engines, unless the bmep is higher.

Items such as axial crankshaft vibration, torsional vibration in camshaft drives, and crankshafts, etc. may vary considerably with the number of cylinders and may influence the choice of engine to be selected for type testing.

9.10.2.4 The engine is type approved up to the tested ratings and pressures (100% corresponding to MCR). Provided documentary evidence of successful service experience with the classified rating of 100% is submitted, an increase (if design appraisal is obtained ①②) may be permitted without a new type test if the increase from the type tested engine is within:

(1) 5% of the maximum combustion pressure, or
(2) 5% of the mean effective pressure, or
(3) 5% of the rpm.

Providing maximum power is not increased by more than 10%, an increase of maximum approved power may be permitted without a new type test provided engineering analysis and evidence of successful service experience in similar field applications (even if the application is not classified) or documentation of internal testing are submitted if the increase from the type tested engine is within:

(1) 10% of the maximum combustion pressure; or
(2) 10% of the mean effective pressure, or
(3)10% of the rpm.

---

① (1) The new requirements of type approval and type testing (including Appendix 4 and Appendix 5 of this Chapter) apply to engines for which the date of an application for type approval certification is dated on or after 1 July 2016.
(2) The "date of application for type approval" is the date of documents accepted by CCS as request for type approval certification of a new engine type or of an engine type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate.
(3) Engines with an existing type approval on 1 July 2016 are not required to be re-type approved in accordance with the new requirements until the current type approval becomes invalid. The certification of such engines may be carried out in accordance with the current type approval and related submitted documentation.

Notes:

①Where those engine data increase from the approved engine type, the crankshaft strength is to be reappraised, and the modified calculations and documents are to be submitted for approval.

② In this Chapter, design appraisal means evaluation of all drawings, information and calculations related to the design. See Glossary in Annex 1 of Appendix 5 of this Chapter.

9.10.2.5 If an engine has been subject to design appraisal, and internal testing per Stage A is documented to a rating higher than the one type tested, the Type Approval may be extended to the increased power/mep/rpm upon submission of an Extended Delivery Test Report at:

(1) test at over speed (only if nominal speed has increased);

(2) rated power, i.e. 100% output at 100% torque and 100% speed corresponding to load point 1, 2 measurements with one running hour in between;

(3) maximum permissible torque (normally 110%) at 100% speed corresponding to load point 3 or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a., 0.5 h;

(4) 100% power at maximum permissible speed corresponding to load point 2, 0.5 h.

9.10.2.6 An integration test demonstrating that the response of the complete mechanical, hydraulic and electronic system is as predicted maybe carried out for acceptance of sub-systems (Turbo Charger, Engine Control System, Dual Fuel, Exhaust Gas treatment, etc.) separately approved. The scope of these tests is to be proposed by the designer/licensor taking into account of impact on engine.

9.10.3 Works acceptance test and shipboard trials

9.10.3.1 Factory acceptance test and shipboard trials of diesel engines are to be carried out in accordance with Appendix 6 of this Chapter.

9.10.3.2 The scope of test loads for various engine applications given in Appendix 6 may be expanded depending on the engine application, service experience, or other relevant reasons.

9.10.3.3 Alternatives to the detailed tests may be agreed between the manufacturer and CCS when the overall scope of tests is found to be equivalent to the provisions of Appendix 6.

Appendix 1 SAFETY OF NATURAL GAS FUEL ENGINES

1 General Requirements

1.1 Application and scope

1.1.1 This Appendix applies to marine reciprocating engines supplied with natural gas as fuel. This appendix also applies to engines using similar fuels with main component methane such as bio-methane or synthetic methane. This Appendix only specifies relevant requirements for the use of natural gas fuel, and in addition, gas fuel engines are to comply with relevant provisions of this Chapter. It is to be ensured by the gas supply system that the gas supplied to the engine is always in gaseous state. This Appendix does not cover requirements for liquid or cryogenic gas. The engines can be dual fuel engines (hereinafter referred to as DF engines), gas fuel only engines (hereinafter referred to as GF engines), or any variations thereof including fuel sharing capability. DF engines and GF engines may not be permitted for emergency applications.

1.1.2 This Appendix is only supplementary to the rules. Gas fuel engines intended for gas carriers are to comply with relevant provisions of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. Gas fuel engines intended for ships other than gas carriers are to comply with relevant provisions of CCS Rules for Ships Using Natural Gas Fuels.

1.1.3 Specific requirements of CCS Rules for Ships Using Natural Gas Fuels as referenced in this Appendix are to be applied to gas fuel engines installed on any ship, regardless of type, size and trading area, as long as CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk is not referenced or explicitly specified otherwise.

1.2 Definitions

(1) Certified safe type means electrical equipment that is certified by an independent national testing institution or a competent authority and complies with the recognized standards for electrical equipment in hazardous areas.

Note: Refer to IEC 60079 series, Explosive gases; IEC 60092-502:1999 Electrical installations in ships -Part 502: Tankers - Special features.

(2) Double block and bleed valves means the set of valves referred to in 16.4.5 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and 1.1.2.10 and 6.2.1.5 of CCS Rules for Ships Using Natural Gas Fuels.

(3) Dual fuel engine ("DF engine") means an engine that can burn natural gas as fuel simultaneously with liquid fuel, either as pilot oil or bigger amount of liquid fuel (gas mode), and also has the capability of running on liquid diesel fuel oil only (Diesel mode).

(4) Explosion relief device means a device to protect personnel and component against a determined overpressure in the event of a gas explosion. The device may be a valve, a rupture disc or other, as applicable.

(5) Gas means natural gas used as fuel consisting primarily of methane.

Note: Gas may also be bio-methane or synthetic methane etc. with methane as main component.

(6) Gas fuel injection (admission) valve is a valve or injector on the engine, which controls gas supply to the cylinder(s) according to the engine's gas demand.

(7) Gas fuel engine means a gas fuel only engine, a dual fuel engine or any variations thereof.

(8) Gas fuel only engine means an engine capable of operating on gas fuel only and not able to switch over to oil fuel operation.

(9) Gas piping means piping containing gas or air / gas mixtures, including venting pipes.

(10) High pressure gas means gas with a maximum working pressure greater than 1.0MPa.

(11) IGC Code means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended.

(12) IMO means the International Maritime Organisation.

(13) IGF Code means the International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IMO Resolution MSC.391(95), as amended).

(14) Low pressure gas means gas with a maximum working pressure lower or equal to 1.0 MPa.

(15) Lower Heating Value ("LHV") means the amount of heat produced from the complete combustion of a specific amount of fuel, excluding latent heat of vaporization of water.

(16) Methane Number is a measure of resistance of a gas fuel to knock, which is assigned to a test fuel based upon operation in knock testing unit at the same standard knock intensity.

Note: Pure methane is used as the knock resistant reference fuel, that is, methane number of pure methane is 100, and pure

hydrogen is used as the knock sensitive reference fuel, methane number of pure hydrogen is 0.
(17) Pilot fuel means the fuel oil that is injected into the cylinder to ignite the main gas-air mixture on DF engines.
(18) Pre-mixed engine means an engine where gas is supplied in a mixture with air through a common manifold for all cylinders, e.g. mixed before or after the turbocharger.
(19) Recognized standards means applicable international or national standards acceptable to CCS or standards laid down and maintained by an organisation which complies with the standards adopted by IMO and which are recognized by the Classification Society.
(20) Safety Concept is a document describing the safety philosophy with regard to gas as fuel. It describes how risks associated with this type of fuel are controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures. The results of the risk analysis, see 1.4, are to be reflected in the safety concept.
Note: A detailed evaluation regarding the hazard potential of injury from a possible explosion is to be carried out and reflected in the safety concept of the engine.

1.3 Plans and documents

1.3.1 The following plans and documents are to be submitted for approval with regard to the approval of gas fuel engines, in addition to those required in 9.1.12.1 of this Chapter:

No.	Plans and documents
(1)	Schematic layout or other equivalent documents of gas system on the engine
(2)	Gas piping system (including double-walled arrangement where applicable)
(3)	Parts for gas admission system②
(4)	Arrangement of explosion relief valves (crankcase①, charge air manifold, exhaust gas manifold and exhaust gas system on the engine) as applicable
(5)	List of certified safe equipment and evidence of relevant certification
(6)	Schematic layout or other equivalent documents of pilot fuel systems (only for DF engine)
(7)	Shielding of high pressure fuel pipes for pilot fuel system, assembly (only for DF engine)
(8)	High pressure parts for pilot fuel oil injection system②(only for DF engine)
(9)	Schematic layout or other equivalent documents of the ignition system (only for GF engine)

Notes:

① If required by 9.1.12 of this Chapter and 2.2.5.1 of this Appendix.
② The documentation to contain specification of design pressures, working pressure, pipe dimensions and materials.

1.3.2 The following plans and documents are to be submitted for information with regard to the approval of gas fuel engines, in addition to those required in 9.1.12.2 of this Chapter:

No.	Plans and documents
(1)	Safety concept
(2)	Report of the risk analysis①
(3)	Gas specification
(4)	Other plans and documents as deemed necessary by CCS

Note:
① see 1.4 of this Appendix.

1.4 Risk analysis

1.4.1 The risk analysis is to address:
(1) a failure or malfunction of any system or component involved in the gas operation of the engine;
(2) a gas leakage downstream of the double block and bleed valve;
(3) the safety of the engine in case of emergency shutdown or blackout, when running on gas;
(4) the inter-actions between the gas fuel system and the engine.
Note: With regard to the scope of the risk analysis it shall be noted that failures in systems external to the engine, such as fuel storage or fuel gas supply systems, may require action from the engine control and monitoring system in the event of an alarm or fault condition. Conversely failures in these external systems may, from the vessel perspective, require additional safety actions from those required by the engine limited risk analysis.
1.4.2 The risk analysis is to be carried out in accordance with international standard IEC 31010:2019 Risk management - Risk assessment techniques, or other recognized standards.
The required analysis is to be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.

1.4.3 The risk analysis is to:
(1) Identify all the possible failures in the concerned equipment and systems which could lead:
① to the presence of gas in components or locations not designed for such purpose, and/or
② to ignition, fire or explosion.
(2) Evaluate the consequences (see 2.1.2 of this Appendix).
(3) Where necessary, identify the failure detection method.
(4) Where the risk cannot be eliminated, identify the corrective measures, e.g. in the system design such as redundancies or safety devices, monitoring or alarm provisions which permit restricted operation of the system; in the system operation, such as initiation of the redundancy or activation of an alternative mode of operation.
The results of the risk analysis are to be documented.
1.4.4 The risk analysis required for engines is to cover at least the following equipment and systems
(1) failure of the gas-related systems or components, in particular gas piping and its enclosure, where provided and gas admission valves. Failures of the gas supply components not located directly on the engine, such as block-and-bleed valves and other components of the gas supply system, are not to be considered in the analysis;
(2) failure of the ignition system (oil fuel pilot injection for DF engines, sparking plugs, glow plugs for GF engines);
(3) failure of the air to fuel ratio control system (charge air by-pass, gas pressure control valve, etc.);
(4) for engines where gas is supplied upstream of the turbocharger compressor, failure of a component likely to result in a source of ignition (hot spots);
(5) failure of the gas combustion or abnormal combustion (misfiring, knocking);
(6) failure of the engine monitoring, control and safety systems;
Note: Where engines incorporate electronic control systems, a failure mode and effects analysis (FMEA) is to be carried out in accordance with 9.1.12.2(23) and Note 5 of this Chapter.
(7) presence of gas in engine components (e.g. air inlet manifold or scavenge space and exhaust manifold) and in the external systems connected to the engines (e.g. exhaust duct, cooling water system, hydraulic oil system, etc.);
(8) changes of operating modes for DF engines, including fuel oil mode, gas fuel mode and other working mode;
(9) hazard potential for crankcase fuel gas accumulation, for trunk piston engines, refer to 7.2.1.6 of CCS Rules for Ships Using Natural Gas Fuels and Section 7 of this Chapter;
(10) risk of crankcase explosion in connection with active crankcase ventilation which produces a flow of external air into the crankcase.

2 Design Requirements

2.1 General principles

2.1.1 The manufacturer is to declare the allowable gas composition limits for the engine and the minimum and (if applicable) maximum methane number.
2.1.2 Components containing or likely to contain gas are to be designed to:
(1) minimise the risk of fire and explosion so as to demonstrate an appropriate level of safety commensurate with that of an oil-fuelled engine;
(2) mitigate the consequences of a possible explosion to a level providing a tolerable degree of residual risk, due to the strength of the component(s) to withstand the overpressure due to the ignition of leaked gas in the most severe condition or the fitting of suitable explosion relief devices of an approved type.
The strength of the component(s) of arrangement of explosion relief devices is to be documented (e.g., as part of risk analysis) or otherwise demonstrated to be sufficient for a worst-case explosion.
Also refer to Section 1 and Section 2, Chapter 7 of CCS Rules for Ships Using Natural Gas Fuels.
2.1.3 Discharge from explosion relief devices is to prevent the passage of flame to the machinery space and be arranged such that the discharge does not endanger personnel or damage other engine components or systems.
2.1.4 Relief devices are to be fitted with a flame arrester.

2.2 Design requirements

2.2.1 For gas carriers, engine-mounted gas piping is to be designed and manufactured in accordance with 5.1 to 5.9 of Chapter 5 and Chapter 16 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For ships other than gas carriers, the piping is to be designed in accordance with the criteria for gas piping (design pressure, wall thickness, materials, piping fabrication and joining details

etc.) as given in Chapter 3 of CCS Rules for Ships Using Natural Gas Fuels. Requirements for pipe class are as follows:
(1) All single walled or high-pressure gas pipes are to be considered as Class I.
(2) Low pressure double walled gas pipes are to be considered as Class II.
(3) All secondary enclosures for gas pipes are to be considered as Class II.
(4) Single walled gas vent pipes, if permitted, should be considered as Class I, except it is justified that the maximum built up pressure is less than 5 bar gauge, in which case it should be considered as Class II.
(5) Gas vent pipes protected by a secondary enclosure are to be considered as Class II.
(6) Secondary enclosure for vent pipes is to be considered as Class III.

Design pressure for gas pipes Table 1

	Design pressure	
Gas pipe, low pressure	See 3.2.3.1 of CCS Rules for Ships Using Natural Gas Fuels	See 5.4.1 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
Gas pipe, high pressure	See 3.2.3.1 of CCS Rules for Ships Using Natural Gas Fuels	See 5.4.1 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
Out pipe, low pressure	See 6.4.1.3 of CCS Rules for Ships Using Natural Gas Fuels	See 5.4.4 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
Out pipe, high pressure	See 6.4.1.3 of CCS Rules for Ships Using Natural Gas Fuels	See 5.4.4 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
Open ended pipes	See 3.2.3.2 of CCS Rules for Ships Using Natural Gas Fuels	See 5.4.1 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk

Flexible bellows used in the fuel gas system on the engine are to be approved based on the requirements of 13.7.2 of CCS Rules for Ships Using Natural Gas Fuels, and 5.13.1.2 of Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as applicable.
The number of cycles, pressure, temperature, axial movement, rotational movement and transverse movement which the bellow will encounter in actual service on the engine should be specified by the engine designer.
Endurance against high cycle fatigue due to vibration loads shall be verified by testing or alternatively be documented by the Expansion Joint Manufacturers Association, Inc. (EJMA) calculation or equivalent (i.e., more than 10^7 cycles).
Note: The fatigue test due to ship deformations in 13.7.2.4 of CCS Rules for Ships Using Natural Gas Fuels is considered not relevant for bellows which are an integral part of the engine.

2.2.2 Arrangement of the gas piping system on the engine
(1) Pipes and equipment containing fuel gas are defined as hazardous area Zone 0 (refer to 9.2.2.1 of CCS Rules for Ships Using Natural Gas Fuels).
(2) The space between the gas fuel piping and the wall of the outer pipe or duct is defined as hazardous area Zone 1 (refer to 9.2.2.2(6) of CCS Rules for Ships Using Natural Gas Fuels).
(3) For gas carriers, the gas fuel piping system on the engine is to be arranged in accordance with 16.4.3 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For ships other than gas carriers, the piping is to be arranged in accordance with the principles and requirements of 6.4.1.1 and 6.4.1.2 of CCS Rules for Ships Using Natural Gas Fuels.
The double pipe or duct is to be designed in accordance with 3.3.1.4, 6.4.1.3 and 6.4.1.4 of CCS Rules for Ships Using Natural Gas Fuels.
In case of a ventilated double wall, for gas carriers, the ventilation inlet is to be arranged in accordance with 16.4.3.2 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. For ships other than gas carriers, the ventilation inlet is to be arranged in accordance with 10.6.1.3 of CCS Rules for Ships Using Natural Gas Fuels.
The pipe or duct is to be pressure tested at 1.5 times of design pressure to ensure gas tight integrity and to show that it can withstand the expected maximum pressure at gas pipe rupture.
(4) Single walled gas piping is only acceptable:

① for engines supplied with low pressure gas and installed in ESD protected machinery spaces, as defined in 2.3.1.1(2) of CCS Rules for Ships Using Natural Gas Fuels and in compliance with other relevant requirements of CCS Rules for Ships Using Natural Gas Fuels (e.g. 2.3.3);

② in the case as per 6.4.1.2(1) of CCS Rules for Ships Using Natural Gas Fuels.

For gas carriers, the requirements of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk apply.

In case of gas leakage in an ESD-protected machinery space, which would result in the shutdown of the engine(s) in that space, a sufficient propulsion and manoeuvring capability including essential and safety systems is to be maintained. Therefore the safety concept of the engine is to clearly indicate application of the "double wall" or "alternative" arrangement.

Note: The minimum power to be maintained is to be assessed on a case-by-case basis from the operational characteristics of the ship.

2.2.3 Charge air system and exhaust gas system on the engine

(1) The charge air system and exhaust gas system on the engine are to be designed in accordance with 2.1.2 above.

(2) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the explosion relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.

Note: Load reduction is to be considered on a case by case basis, depending on engine configuration (single or multiple) and relief mechanism (self-closing valve or rupture disk).

2.2.4 Continuous relief of exhaust gas (through open rupture disc) into the engine room or other enclosed spaces is not acceptable.

Suitable explosion relief system for air inlet manifolds, scavenge spaces and exhaust system should be provided unless designed to accommodate the worst-case overpressure due to ignited gas leaks or justified by the safety concept of the engine. A detailed evaluation regarding the hazard potential of overpressure in air inlet manifolds, scavenge spaces and exhaust system should be carried out and reflected in the safety concept of the engine.

Explosion relief devices for air inlet and exhaust manifold are to be type approved.

The necessary total relief area and the arrangement of the explosion relief devices are to be determined taking into account:

- The worst-case explosion pressure depending on initial pressure and gas concentration,
- the volume and geometry of the component, and
- the strength of the component.

The arrangement shall be determined in the risk analysis (see 1.4.4(7)) and reflected in the safety concept.

2.2.5 Protection of crankcase

(1) Crankcase explosion relief valves are to be installed in accordance with 9.7.4 of this Chapter. Refer also to 7.2.1.6 of CCS Rules for Ships Using Natural Gas Fuels. For engines not covered by 9.7.4 of this Chapter, the detailed evaluation as required in 1.4.4(7) of this Appendix is to determine if crankcase explosion relief valves are necessary.

(2) For maintenance purposes, a connection, or other means, are to be provided for crankcase inerting and ventilating and gas concentration measuring.

(3) Ventilation of crankcase (either supply or extraction), if arranged, is to comply with 10.3.1 of CCS Rules for Ships Using Natural Gas Fuels. Relevant evidence is to be documented in Safety Concept. The ventilation systems for crankcase, sump and other similar engine spaces are to be independent from the systems on the other engines.

2.2.6 With regard to gas ignition in the cylinder, for gas carriers, the requirements of 16.7 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk apply; for ships other than gas carriers, the requirements of Section 2 of Chapter 7 of CCS Rules for Ships Using Natural Gas Fuels apply.

2.2.7 Control, monitoring, alarm and safety systems

(1) The engine control system is to be independent and separate from the safety system.

(2) The gas admission valves are to be controlled by the engine control system or by the engine gas demand.

(3) Combustion is to be monitored on an individual cylinder basis.

(4) In the event that poor combustion is detected on an individual cylinder, gas operation may be allowed in the conditions specified in 7.2.1.13 of CCS Rules for Ships Using Natural Gas Fuels.

(5) If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.

(6) Unless the risk analysis required by 1.4 of this Appendix proves otherwise, the monitoring and safety system functions for DF or GF engines are to be provided in accordance with Table 2 of this Appendix in

addition to the general monitoring and safety system functions given by the Rules.
Note: For DF engines, Table 2 applies only to the gas mode.

Monitoring and Safety System Functions for Gas Fuel Engines Table 2

Parameter	Alarm	Automatic activation of the double block-and bleed valves	Automatic switching over to oil fuel mode①	Engine shutdown
Abnormal pressures in the gas fuel supply line	×	×	×	×⑤
Gas fuel supply systems - malfunction	×	×	×	×⑤
Pilot fuel injection or spark ignition systems - malfunction	×	×②	×	×②⑤
Exhaust gas temperature after each cylinder - high	×	×②	×	×②⑤
Exhaust gas temperature after each cylinder, deviation from average – low③	×	×②	×	×②⑤
Cylinder pressure or ignition - failure, including misfiring, knocking and unstable combustion	×	×②④	×④	×②④⑤
Oil mist concentration in crankcase or bearing temperature⑥ - high	×	×		×⑨
Pressure in the crankcase – high⑧	×	×	×	
Engine stops - any cause	×	×		
Failure of the control-actuating medium of the block and bleed valves	×	×	×	
Failure of crankcase ventilation system, if applicable	×	×⑦	×⑦	

Symbol: × Applicable
Note:
① DF engine only, when running in gas mode.
② For GF engines, the double block-and-bleed valves and the engine shutdown may not be activated in case of specific failures affecting only one cylinder, provided that the concerned cylinder can be individually shutoff and the safe operation of the engine in such conditions is demonstrated by the risk analysis.
③ Required only if necessary for the detection of misfiring.
④ In the case where the failure can be corrected by an automatic mitigation action, only the alarm may be activated. If the failure persists after a given time, the safety actions are to be activated.
⑤ GF engine only.
⑥ Where required by 9.7.6 of this Chapter.
⑦ Automatic safety actions to be activated as specified by the engine manufacturer, see 9.7.6 of this Chapter.
⑧ Only for trunk piston engines. This pressure sensor cannot replace or substitute a gas detector.
⑨ Only for trunk piston engines. For crosshead engines slow down is to apply (see Table 3.10.1.1, Chapter 3, PART SEVEN of the Rules).

2.2.8 Electrically operated gas admission valves are to be certified safe as follows:
(1) The inside of the valve contains gas and is therefore to be certified for Zone 0.
(2) When the valve is located within a pipe or duct in accordance with 2.2.2(2), the outside of the valve is to be certified for Zone 1.
(3) When the valve is arranged without enclosure in accordance with the “ESD-protected machinery space” (see 2.2.2(4)) concept, no certification is required for the outside of the valve, provided that the valve is de-energized upon gas detection in the space.
However, if they are not rated for the zone they are intended for, it is to be documented that they are suitable for that zone. Documentation and analysis are to be based on IEC 60079-10-1 or IEC 60092-502.
Gas admission valves operated by hydraulic oil system are to be provided with sealing arrangement to prevent gas from entering the hydraulic oil system.

3 Specific Design Requirements

3.1 DF Engines

3.1.1 The maximum continuous power that a DF engine can develop in gas mode may be lower than the approved MCR of the engine (i.e. in oil fuel mode), depending in particular on the gas composition and its

quality or the engine design. This maximum continuous power available in gas mode and the corresponding conditions are to be stated by the engine manufacturer.

3.1.2 DF engines are to be arranged to be started using either oil fuel or gas fuel with pilot oil fuel for ignition. The engines are to be arranged for rapid changeover from gas use to fuel oil use. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply without interruption to the power supply.

Changeover to gas fuel operation is to be only possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing.

Changeover from gas fuel operation mode to oil fuel operation mode is to be possible at all situations and power levels.

The changeover process itself from and to gas operation is to be automatic but manual interruption is to be possible in all cases.

If the power level or other conditions do not allow safe and reliable gas operation, changeover to oil fuel mode is to be automatically performed.

In case of shut-off of the gas supply, the engines are to be capable of continuous operation by oil fuel only.

3.1.3 Gas supply to the combustion chamber is not to be possible without operation of the pilot oil injection.

Note: Pilot injection is to be monitored for example by fuel oil pressure and combustion parameters.

3.2 GF Engines

3.2.1 In case of failure of the spark ignition, the engine is to be shut down except if this failure is limited to one cylinder, subject to immediate shut off of the cylinder gas supply and provided that the safe operation of the engine is substantiated by the risk analysis and by tests.

3.3 Pre-Mixed Engines

3.3.1 Inlet manifold, turbo-charger, charge air cooler, etc. are to be regarded as parts of the fuel gas supply system. Failures of those components likely to result in a gas leakage are to be considered in the risk analysis (see 1.4 of this Appendix).

3.3.2 Flame arresters are to be installed before each cylinder head, unless otherwise justified in the risk analysis, considering design parameters of the engine such as the gas concentration in the charge air system, the path length of the gas-air mixture in the charge air system, etc.

3.4 Two-stroke engines

3.4.1 The risk analysis required in 1.4 is to cover the possible gas accumulation in a scavenge space.

3.4.2 The risk analysis required in 1.4 is to cover the possible failure of a piston rod stuffing box.

4 Type Testing, Factory Acceptance Tests and Shipboard Trials

4.1 Type Testing

4.1.1 Type approval of DF and GF engines is to be carried out in accordance with 9.10.1 and 9.10.2 of this Chapter, taking into account the additional requirements below.

4.1.2 In addition to the criteria given in 9.1.2.1(1) of this Chapter, the type of engine is defined by the following:

(1) gas admission method (cylinder injection after compression stroke, cylinder individual injection before compression stroke or pre-mixed);

(2) gas admission valve operation (mechanical or electronically controlled);

(3) ignition system (pilot injection, spark ignition, glow plug or gas self-ignition);

(4) ignition system (mechanical or electronically controlled).

Note: Cylinder-individual injection before compression stroke may be port injection into the air inlet channel before the cylinder inlet valve, injection into the cylinder before or during compression stroke, or similar arrangements.

4.1.3 In addition to the safety precautions mentioned in 1.2, Appendix 4 of this Chapter, measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.1.4 The type testing of the engine is to be carried out in accordance with 1.3, Appendix 4 of this Chapter, taking into account the additional requirements of this Section.

The influence of the methane number and LHV of the fuel gas is not required to be verified during the Stage B type tests. It is however to be justified by the engine designer through internal tests or calculations and documented in the type approval test report.

4.1.5 In addition to the measurements and records required in 1.4, Appendix 4 of this Chapter, the following engine data are to be measured and recorded:

(1) Each fuel index for gas and diesel as applicable (or equivalent reading).
(2) Gas pressure and temperature at the inlet of the gas manifold.
(3) Pilot fuel temperature and pressure (supply or common rail as appropriate).
(4) Gas concentration in the crankcase.
Note: The gas concentration in the crankcase is normally to be measured inside the crankcase or at the crankcase outlet (crankcase vent pipe).
Gas concentration measurements may be carried out as part of Stage A if the method and the results are properly documented.
Additional measurements may be required in connection with the design assessment.
4.1.6 Stage A – internal tests. In addition to internal tests required in 2.1, Appendix 4 of this Chapter, the following conditions are to be tested:
(1) DF engines are to run the load points in both gas and diesel modes (with and without pilot injection in service) as found applicable for the engine type.
(2) For DF engines with variable liquid / gas ratio, the load tests are to be carried out at different ratios between the minimum and the maximum allowable values.
(3) For DF engines, switch over between gas and diesel modes are to be tested at different loads.
(4) The influence of the methane number and LHV of the fuel gas on the engine's maximum continuous power available in gas mode is to be verified.
4.1.7 Stage B – witnessed tests. Witnessed tests are to be carried out in accordance with 2.2, Appendix 4 of this Chapter. The following requirements are to be considered:
(1) The following test conditions are to be considered for DF engine during the load test:
① All load points must be run in both gas and diesel modes that apply for the engine type as defined by the engine designer. The independent overspeed protection device has to be tested both in gas and diesel mode.
② For engines with variable liquid / gas ratio, selected load tests are to be carried out at different ratios between the minimum and the maximum allowable value. (most relevant and critical loads and ratios should be selected for the test)

The maximum continuous power available in gas mode (see 3.1.1) is to be demonstrated. Overload testing is not required in gas mode for DF engines, provided that changeover to oil fuel mode is automatically performed in case of overload. For load tests of DF engines in gas mode, the test loads are taken as the different percentages of maximum continuous power in gas mode.
(2) The following items are to be carried out for functional test:
① For DF engines, the lowest specified speed is to be verified in diesel mode and gas mode.
② For DF engines, switch over between gas and diesel modes are to be tested at different loads.
③ For DF engines, verification of automatic changeover to diesel mode when the load demand exceeds the maximum continuous power available in gas mode (see 3.1.1 and 3.1.2).
④ The efficiency of the ventilation arrangement or other approved principal of the double walled gas piping system is to be verified.

Engines intended to produce electrical power are to be tested as follows:
① Capability to take sudden load and loss of load in accordance with the provisions of 9.7.10.1 of this Chapter.
② For GF and premixed engines, the influences of LHV, methane number and ambient conditions on the dynamic load response test results are to be theoretically determined and specified in the test report. Referring to the limitations as specified in 2.1.1 of this Appendix, the margin for satisfying dynamic load response is to be determined.

Notes:
1. For DF engines, switchover to oil fuel in accordance with the requirements of 3.1.2 under the extreme power during the test is acceptable.
2. Application of electrical load in more than 2 load steps can be permitted in the conditions stated in 9.7.10.1 of this Chapter.

(3) GF and DF engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes. The scope of these tests is to be agreed with CCS for selected cases based on the risk analysis, and is at least to include the following incidents:
① Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;
② Failure of a gas admission valve;
③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);

④ Abnormal gas pressure;
⑤ Abnormal gas temperature*.

Note*: This test may be carried out using a simulation signal of the temperature.

4.1.8 Stage C – Component inspection. Component inspection is to be carried out in accordance with the provisions of 2.3, Appendix 4 of this Chapter. The components to be inspected after the test run are to include also:

(1) gas admission valve including pre-chamber as found applicable;
(2) spark igniter (for GF engines);
(3) pilot fuel injection valve (for DF engines).

4.1.9 Engine type approval certificate

For DF engines, the maximum continuous power available in gas mode is to be specified on the type approval certificate in addition to the maximum continuous rating in diesel mode if differing.

4.2 Factory acceptance test

4.2.1 Factory acceptance tests are to be carried out in accordance with Appendix 6 of this Chapter, taking into account the additional requirements below.

For DF engines, the load tests referred to in 2.3, Appendix 6 of this Chapter are to be carried out in diesel engine mode and in gas mode at the different percentages of the engine's MCR.

Maximum continuous power available in gas mode is to be demonstrated (see 3.1.1 of this Appendix).

4.2.2 In addition to the safety precautions mentioned in 1.1, Appendix 6 of this Chapter, measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.2.3 In addition to the records required in 2.2, Appendix 6 of this Chapter, the following engine data are to be recorded:

(1) Fuel index, both gas and diesel as applicable (or equivalent reading);
(2) Gas pressure and temperature;
(3) Pilot fuel temperature and pressure (supply or common rail as appropriate).

4.2.4 Test loads for various engine applications are given in 2.3, Appendix 6 of this Chapter. DF engines are to be tested in both diesel and gas mode as found applicable. In addition the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

4.2.5 Gas fuel engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes.

The scope of these tests is to be agreed with CCS for selected cases based on the risk analysis and is at least to include the following incidents:

① Failure of ignition (spark ignition or pilot injection systems), for one cylinder unit;
② Failure of a gas admission valve;
③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);
④ Abnormal gas pressure;
⑤ Abnormal gas temperature.

Note: The above tests may be carried out using simulation or other alternative methods, subject to special consideration by CCS.

4.3 Shipboard trials

4.3.1 A leak test is to be carried out for the gas piping system after assembly on board.

4.3.2 Shipboard trials are to be carried out in accordance with the provisions of Appendix 6 of this Chapter, considering the additional requirements below.

(1) For DF engines, the test loads are to be carried out in all operating modes (gas mode, diesel mode, etc.), as applicable (see 3.1.1). The maximum continuous power available in gas mode is to be demonstrated.

Note: If a test load is performed in all applicable operation modes without interruption (direct changeover at same power and speed), the duration may be considered as the total duration demonstrated in all fuel modes. However, demonstration at each mode shall not be less than one hour.

(2)The starting maneuvers are to be carried out in diesel mode and gas mode, if applicable.

(3) For DF engines, automatic switching over to oil fuel mode is to be tested. Further, manual change over from diesel to gas mode and vice versa is to be tested.

(4) The efficiency of the ventilation arrangement, or other approved principle, of the double walled gas piping system is to be verified.

5 Certification of Engine Components

5.1 General requirements

5.1.1 Section 2 of this Chapter applies. In addition to those components specified in Table 9.2.2.1, the engine components listed in Table 3 are to be documented as listed in the table.

Required documentation for engine components **Table 3**

No.	Part	Material properties	Nondestructive examination	Pressure testing	Visual inspection of welds	
1	Gas pipe Low-pressure double walled	W(CC+M)	W ②, ⑥	W④	VT	
2	Single walled Gas pipes	W(CC+M)	W ①	W④	VT	C
3	High-pressure gas pipes	W(CC+M)	W①	W④	VT	C
4	Secondary enclosure for gas pipes	W(CC+M)	W ②	W③	VT	
5	Gas pipe Low-pressure, Flanges *	W(CC+M)	W ②, ⑥		VT	
6	Gas pipe High-pressure, Flanges *	W(CC+M)	W ①		VT	C
7	Gas pipe Low-pressure, Fittings and other components	W(CC+M)		W④	VT	
8	Gas pipe High-pressure, Fittings and other components	W(CC+M)		W④	VT	C
9	Gas pipe Low-pressure Bodies of valves⑦	W(CC+M)		W④		
10	Gas pipe High-pressure Bodies of valves⑦	W(CC+M)		W④		C
11	Gas venting pipes and flanges*, build up pressure less than 5.0bar	TR(CC+M)	W②	W④	VT	
12	Gas venting pipes and flanges*, build up pressure at 5.0bar or more with secondary enclosure	TR(CC+M)	W②	W④	VT	
12	Gas venting pipes and flanges*, build up pressure at 5.0bar or more	W(CC+M)	W①	W④	VT	C
13	Gas venting pipes Secondary enclosure			W⑤	VT	

Footnotes:

① 100 % radiographic or ultrasonic inspection of all butt-welded joints in accordance with CCS Rules for Materials and Welding

② 10 % radiographic or ultrasonic inspection of butt-welded joints in accordance with CCS Rules for Materials and Welding

③ Pressure test at 1.5 × design pressure to ensure gas tight integrity, not less than the expected maximum pressure at gas pipe rupture

④ Pressure test at 1.5 × design pressure

⑤ Leak test.

⑥ If inside diameter > 75 mm or wall thickness > 10 mm: 100 % radiographic or ultrasonic inspection of all butt-welded joints in accordance with CCS Rules for Materials and Welding

⑦ If nominal diameter > 25 mm

⑧ (*) “Flanges” limited to the final connection to the engine.

Appendix 2 GUIDELINES FOR ELECTRONICALLY CONTROLLED DIESEL ENGINES

1 General Provisions

1.1 Application

1.1.1 The Guidelines apply to electronically controlled diesel engines.

1.1.2 In addition to the requirements of the Guidelines, electronically controlled diesel engines are to comply with other requirements of this Chapter.

1.1.3 With the advancement of the electronic control technology of diesel engines and the development of intelligent diesel engines, the Guidelines will not limit the progress and development of this new technology.

1.1.4 Where a single electronic control system is used in diesel engines, the applicable requirements of the Guidelines may be referred to.

1.2 General requirements

1.2.1 The safety required and functions of electronically controlled diesel engines are not to be inferior to those of non-electronically controlled diesel engines.

1.2.2 The electronic control system is to operate safely and reliably under operating conditions of diesel engines.

1.2.3 The guaranteed working period and the maintenance of the electronic control system are in general to be indicated in product instructions.

1.3 Definitions

1.3.1 For the purpose of the Guidelines:

(1) **Electronically controlled diesel engine** means a diesel engine with an electronic control system where system parameters can be adjusted flexibly by control equipment such as ECU to further improve the flexibility and adaptability of individual systems to match the diesel engine, and to optimize its operation and performance.

(2) **Non-electronically controlled diesel engine** means a diesel engine without an electronic control system.

(3) **Intelligent diesel engine** generally means a diesel engine where a comprehensive electronic control is applied to individual systems of fuel oil injection, air intake and exhaust, oil or water cooling, cylinder lubricating, exhaust turbocharging and vibration balance so as to fully optimize system parameters, lower consumption, decrease environmental pollution (low harmful discharge, low noise, low vibration), and automatically monitor its operation and failures.

(4) **Electronic control system of diesel engine:** According to different objects, methods and parameters, an electronic control system of diesel engines has various options and forms, of which the most important is the electronically controlled fuel oil system. It controls parameters such as fuel injection pressure, time, amount and mode. The electronic control system which can flexibly adjust parameters of each system of a diesel engine is called electronic control system of diesel engine, composed of sensors, electronic control units (ECU) and actuators.

(5) **Sensor** means a device or an apparatus which detects ambient conditions, working conditions and various operating parameters of the diesel engine. There are mainly crankshaft speed sensor, pressure sensor, temperature sensor, humidity sensor, gas composition sensor, TDC position sensor, massflow sensor and vibration sensor, which are selected according to electronic control systems of various diesel engines.

(6) **Electronic control unit (ECU)** deals with input information, outputs the results and drives actuators. ECU is mainly composed of a microcomputer, an interface circuit, a drive circuit and necessary software.

(7) **Actuator means a mechanism which** receives control orders from ECU and initiates actions to operate relevant components of the diesel engine. An actuator is mainly composed of an electromagnetic valve, a step motor, electrohydraulic equipment and pipes. The driving power of actuators includes electric power and hydraulic power. Electric drive is operated by the step motor and generally used in cases with less driving power and less strict real-time requirements, such as electronic speed governor, control of variable nozzles of small turbochargers, control of adjustable valves of cooling and lubricating systems. Hydraulic drive is operated by hydraulic power controlled by the electromagnetic valve, such as used in injection systems and air intake and exhaust systems where power transmission is without camshaft.

(8) **Common rail (pressure accumulator)** means a pressure vessel used to supply high pressure fuel oil or

hydraulic oil within the fuel oil or hydraulic oil system of an electronically controlled diesel engine.

2 Design and Installation

2.1 Fuel oil and hydraulic oil systems

2.1.1 Fuel oil and hydraulic oil systems are to comply with the applicable requirements of Chapters 2, 4 and 9 of this PART.

2.1.2 The strength of fuel oil and hydraulic oil pressure accumulators is to comply with the relevant requirements of Chapter 6 of this PART.

2.1.3 For electronically controlled diesel engines intended for single main engine propulsion systems, at least two fuel oil and two hydraulic oil pressure pumps are to be provided for their respective service. The capacity of all pumps are to ensure maximum continuous rating of main propulsion diesel engine, and in case of failure of any one fuel oil and/or hydraulic oil pressure pump, the capacity of other pumps are to ensure that the main propulsion diesel engine can output power necessary for normal navigation. All pumps are to be arranged ready for immediate use. For electronically controlled diesel engines intended for multiple main engines propulsion systems, each diesel engine is at least to be provided with one fuel oil pressure pump and one hydraulic oil pressure pump to ensure maximum continuous rating of diesel engines. One common standby pump connected ready for immediate use is needed, or alternatively, a complete spare pump may be accepted, provided that it is readily accessible and can easily be installed.

2.1.4 The fuel oil pressure piping between the high pressure fuel oil pumps and the fuel oil injectors is to be protected with a jacketed piping system or other equivalent means capable of preventing fuel oil leakage from splashing onto sources of ignition.

2.1.5 The piping between the high pressure hydraulic oil pumps and the hydraulic actuators is to be protected with a jacketed piping system capable of preventing hydraulic oil leakage from splashing onto sources of ignition.

2.1.6 Isolating valves and cocks are to be located as near as practicable to the equipment to be isolated. All valves forming part of the fuel oil and hydraulic oil installations are to be capable of being controlled from readily accessible positions above the working platform.

2.1.7 High pressure fuel oil and high pressure hydraulic oil piping systems are to be provided with high pressure alarms with set points that do not exceed the system design pressures.

2.1.8 High pressure fuel oil and high pressure hydraulic oil piping systems are to be provided with suitable relief valves on any part of the system that can be isolated and in which pressure can be generated. The settings of the relief valves are not to exceed the design pressures. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressures.

2.1.9 Equipment fitted for monitoring pressures and temperatures in the high pressure fuel oil and high pressure hydraulic oil systems is to comply with the requirements of CCS Guidelines for Type Approval Test of Electric and Electronic Products in respect to the anticipated vibration and temperature conditions.

2.1.10 In general, dual high pressure fuel oil and high pressure hydraulic oil piping systems are to be provided. Where a fatigue analysis has been carried out (all anticipated pressure, pulsation and vibration loads are to be addressed), single systems may be accepted.

2.1.11 Means are to be provided to prevent continuous injection of fuel oil into cylinders due to failure of control valves.

2.2 Electronic control systems

2.2.1 The design, manufacture and inspection of the electronic equipment used for electronic control systems, including software design, are to comply with the relevant requirements in PART SEVEN of the Rules and CCS Guidelines for Type Approval Test of Electric and Electronic Products.

2.2.2 Electronic control systems are to have the functions of failure self-diagnosis and fail-safe protection. In case of failure, the system is to immediately perform a self-diagnose and initiate appropriate fail-safe protection to maintain operation of the diesel engine.

2.2.3 Those devices in the electronic control system which will affect normal operation of the main propulsion engine in case of functional failure, such as ECUs and crankshaft rotation angle indicators, are to be provided as dual systems. The type and function of such dual systems are to be fully identical. When one system fails, the other will automatically take over so as to maintain normal operation of the engine and an alarm will be given at the same time. For electronically controlled diesel engines intended for ships with two or more main propulsion diesel engines, if risk analysis indicates that in case of failure of electronic control system of any one diesel engine, the others remain capable of outputting power necessary for normal navigation, dual electronic control systems are not necessary for each diesel engine. The electronic control system out of order is to be readily replaced and put into service.

2.2.4 The power for the electronic control system is to be supplied by two independent feeders from two independent power sources.
2.2.5 Local controls and a central control room or bridge control system are to be provided.
2.2.6 The monitoring performed by the electronic control system is to be able to initiate alarms when main functions of sensors, ECUs and actuators fail.
2.2.7 The electronic control system is to be able to monitor the working condition of diesel engines, automatically adjust individual system parameters, and automatically detect and given alarms for failures of systems and components.
2.2.8 Components and parts of the electronic control system are to be changeable considering functional characteristics and structural dimensions, and capable of being disassembled, replaced and installed quickly.
2.2.9 For corrosive materials, anticorrosive coating is to be provided. Where parts made of different metals contact directly each other, means are generally to be provided to prevent electrolytic corrosion.
2.2.10 Electronic control systems are to be provided with test ports to facilitate test and maintenance.

2.3 Failure Mode and Effects Analysis (FMEA)
2.3.1 A Failure Mode and Effects Analysis (FMEA) is to demonstrate that a failure of the functioning of any device or circuit of fuel oil, lubricating oil, hydraulic, starting air, cooling water, and control and safety systems of the electronically controlled diesel engine will not result in the failure or deterioration of the function of other devices or circuits.
2.3.2 An FMEA analysis report is in general to address the following issues:
(1) the standards used for analysis and system design;
(2) the objectives of the analysis;
(3) any assumptions made in the analysis;
(4) the equipment, system or sub-system, mode of operation;
(5) potential failure modes and their causes;
(6) evaluation of the effects of each failure mode;
(7) measures for reducing the risks associated with each failure mode.
2.3.3 Failures of components of the equipment itself need not be taken into account for the analysis.

2.4 Installation
2.4.1 The installation of components of an electronic control system is to comply with the requirements for installation positions on the diesel engine, interface dimension, joints, screening, heat and shock resistance. The components are to be capable of being easily installed and fixed on the diesel engine. The wiring of all electronic circuits is to be secure and reliable to prevent loosening during operation.
2.4.2 When installing components with vibration dampers, sufficient spacing is to be left around to avoid collision with adjacent components or structures.

3 Tests

3.1 General requirements
3.1.1 Electronically controlled diesel engines are to be subjected to type tests, trials at the manufacturer's works and shipboard trials in accordance with the relevant requirements of this Chapter.
3.1.2 For test items related to electronic control systems, refer to the applicable requirements of the Guidelines.

3.2 Type tests
3.2.1 Main components of the electronic control system are to be type tested.
3.2.2 The type test of the electronic control system may also be carried out with the type test of the diesel engine at the same time.
3.2.3 The purpose of the type test of an electronically controlled diesel engine is to confirm normal function of the electronic control system after switch-in. Prior to test, piping, electrical circuits, sensors and actuators of the electronic control system are to be functionally verified and the installation of the system software into each module according to respective downloading instructions is to be confirmed.
3.2.4 Test scope:
(1) functions in respect to safe operation of the diesel engine;
(2) functions which can only be tested together with the diesel engine;
(3) verification of functions of the system software.
3.2.5 The effective functions of an electronic control system are to be verified during tests, generally

including the following items (if applicable):
(1) one crankshaft rotation angle indicator failing;
(2) one control module failing;
(3) one power supply unit failing;
(4) failure of fuel oil injection control valve of one cylinder;
(5) one communication network failing;
(6) main operation panel failing;
(7) earth failure;
(8) failure of action control station;
(9) one stop signal failing;
(10) other applicable failure and function tests.

3.3 Works trials

3.3.1 Prior to test, piping, electrical circuits, sensors and actuators of the electronic control system are to be functionally verified.

3.3.2 During testing of electronically controlled diesel engines, control parameters are to be checked.

3.3.3 The effective functions of an electronic control system are to be verified during tests, generally including the following items (if applicable):
(1) confirmation of software version;
(2) function of fuel oil injection control valve;
(3) function of exhaust control valve;
(4) power supply failure of control module of one cylinder;
(5) function of arrangements for emergency stopping;
(6) one crankshaft rotation angle sensor failing;
(7) other applicable failure and function tests.

3.4 Shipboard trials

3.4.1 Prior to trial, the examination of the items of control and remote control systems of diesel engines in respect to electronic control is to be confirmed.

Appendix 3 APPRAISAL OF CRANKSHAFT STRENGTH OF DIESEL ENGINES

1 General Provisions

1.1 Scope

1.1.1 The calculation methods in this Appendix are to be applied to diesel engines for propulsion and auxiliary purposes, where the engines are capable of continuous operation at their rated power when running at rated speed.

1.1.2 Where the calculation methods in this Appendix cannot be directly used for check in design, detailed design calculations or measurements are to be submitted for approval.

1.1.3 Where a crankshaft design involves the use of surface treated fillets, or when fatigue parameter influences are tested, or when working stresses are measured, the relevant documents with calculations/analysis are to be submitted in order to demonstrate equivalence to the calculation methods in this Appendix.

1.2 Requirements for calculation

1.2.1 This Appendix provides two calculation methods, i.e. the Calibration of Crankshaft Fatigue Strength (IACS) in Section 2 and the Calibration of Crankshaft Diameter in Section 3.

1.2.2 Steel crankshafts are to be subjected to the calibration of their fatigue strength in accordance with Section 2 of this Appendix.

1.2.3 Crankshafts, which are made of nodular graphite cast iron or to which Section 2 of this Appendix is not applicable, may be subjected to the calibration of their diameters in accordance with Section 3 of this Appendix.

1.3 Drawings and particulars

1.3.1 Drawings and particulars to be submitted

(1) When the calculation method for crankshaft fatigue strength check (IACS) is adopted, drawings and particulars are to be submitted according to the requirements of Table 1.3.1.

Data Sheet for Calculation of Crankshafts for Diesel Engines **Table 1.3.1**

1	Engine builder		
2	Engine type designation		
3	Stroke – Cycle ☐2 SCSA ☐4 SCSA		
4	Kind of engine ☐In-line engine ☐V-type engine with adjacent connecting-rods ☐V-type engine with articulated-type connecting-rod ☐V-type engine with forked/inner connecting rod ☐Crosshead engine ☐Trunk piston engine		
5	Combustion method ☐Direct injection ☐Precombustion chamber ☐Others		
6	For designation of cylinders, see Figure 1.3.1(1) of this Appendix		
7	Sense of rotation ☐Clockwise ☐Counterclockwise		
8	Firing order		
9	Firing intervals [deg]		
10	Rated power		kW
11	Rated engine speed		r/min
12	Mean effective pressure		MPa
13	Mean indicated pressure		MPa
14	Maximum cylinder pressure (gauge)		MPa
15	Charge air pressure (gauge, before inlet valves or scavenge ports, whichever applies)		MPa
16	Nominal compression ratio		–
17	Number of cylinders		–
18	Diameter of cylinders		mm

19	Length of piston stroke		mm
20	Length of connecting rod (between bearing centres)		mm
21	Oscillating Mass of one cylinder (mass of piston, rings,pin, piston rod,crosshead, oscillating part of connecting rod)		kg
22	Digitized gas pressure curve presented at equidistant intervals [MPa/crank angle] (intervals not more than 5° CA)		
	Additional Data of V-type Engines		
23	V-angle α_v (see Figure 1.3.1(1) of this Appendix)		deg
	For the Cylinder Bank with Articulated-type Connecting Rod (see Figure 1.3.1(2) of this Appendix)		
24	Maximum cylinder pressure (gauge)		MPa
25	Charge air pressure (gauge, before inlet valves or scavenge ports)		MPa
26	Nominal compression ratio		–
27	Articulated-type connecting rod (see Figure 1.3.1(2) of this Appendix)		
28	Distance to link point L_A		mm
29	Link angle a_N		deg
30	Length of connecting rod L_N		mm
31	Oscillating Mass of one cylinder (mass of piston, rings,pin, piston rod,crosshead, oscillating part of connecting rod)		kg
32	Digitized gas pressure curve presented at equidistant intervals [MPa/crank angle] (intervals not more than 5° CA)		
	For the Cylinder Bank with Inner Connecting Rod		
33	Oscillating Mass of one cylinder (mass of piston, rings,pin, piston rod,crosshead, oscillating part of connecting rod)		kg
	Data of Crankshaft (see Figures 2.3.1(1), (2) and 2.4.1(3) of this Appendix) Note: For asymmetric cranks the dimensions are to be entered both for the left and right part of crank throw		
34	Drawing No.		
35	Kind of crankshaft (e.g. solid-forged crankshaft, semi-built crankshaft, etc.)		
36	Method of manufacture (e.g. free form forged, cast steel, etc.)		
37	Heat treatment (e.g. tempered)		
38	Surface treatment of fillets, journals and pins (e.g. nitrided, rolled, etc.)		
39	For crank throw for in-line engine, see Figure 2.3.1(1) of this Appendix For crank throw for engine with 2 adjacent connecting rods, see Figure 2.3.1(2) of this Appendix For crank dimensions necessary for the calculation of stress concentration factors, see Figure 2.4.1(3) of this Appendix		
40	Crankpin diameter D_P		mm
41	Diameter of bore in crankpin D_{BH}		mm
42	Fillet radius of crankpin R_H		mm
43	Recess of crankpin T_H		mm
44	Journal diameter D_G		mm
45	Diameter of bore in journal D_{BG}		mm
46	Fillet radius of journal R_G		mm
47	Recess of journal T_G		mm
48	Web thickness W		mm
49	Web width B		mm
50	Bending length L_1		mm
51	Bending length L_2		mm
52	Bending length L		mm
53	Oil Bore Design ☐Safety margin against fatigue at the oil bores is not less than that acceptable in the fillets		
54	Diameter of oil bore		mm
55	Smallest edge radius of oil bore		mm
56	Surface roughness of oil bore fillet		μm
57	Inclination of oil bore axis related to shaft axis		deg
	Additional Data for Shrink-Fits of Semi-Built Crankshafts		
58	For crank throw of semi-built crankshaft, see Figure 4.1.1 of this Appendix		
59	Shrink diameter D_S		mm
60	Length of shrink-fit L_S		mm
61	Outside diameter of web D_4 or twice the minimum distance x mm (the smaller value is to be entered)		mm
62	Amount of shrink-fit (upper and lower tolerances)		mm %
63	Maximum torque (ascertained according to 2.3.3 of this Appendix with consideration of the mean torque)		N·m
	Data of Crankshaft Material Note: Minimum values of mechanical properties of material obtained from longitudinal test specimens		
64	Material designation (according to DIN, AISI, etc.)		
65	Method of material melting process (e.g. open-hearth furnace, electric furnace, etc.)		
66	Tensile strength		MPa
67	Yield strength		MPa

68	Reduction in area at break		%
69	Elongation A_5		%
70	Impact energy – KV		J
71	Young's modulus		MPa
Additional Data for Journals of Semi-Built Crankshafts			
72	Material designation (according to DIN, AISI, etc.)		
73	Tensile strength		MPa
74	Yield strength		MPa
Data According to Calculation of Torsional Stresses Note: In case CCS is entrusted with carrying out a forced vibration calculation to determine the alternating torsional stresses to be expected in the engine and possibly in its shafting, the data according to calculation of torsional vibration are to be submitted			
75	Max. nominal alternating torsional stress (ascertained by means of a harmonic synthesis according to 2.3.3(1) of this Appendix and related to cross-sectional area of bored crank pin)		MPa
76	Engine speed (at which the max. nominal alternating torsional stress occurs)		r/min
77	Minimum engine speed (for which the harmonic synthesis was carried out)		r/min
Data of Stress Concentration Factors (S.C.F.) and/or Fatigue Strength Furnished by Reliable Measurements Note: To be filled in only when data for stress concentration factors and/or fatigue are furnished by the engine manufacturer on the basis of measurements. Full supporting details are to be enclosed.			
78	S.C.F. for bending in crankpin fillet α_B		
79	S.C.F. for torsion in crankpin fillet α_T		
80	S.C.F. for bending in journal fillet β_B		
81	S.C.F. for compressing in journal fillet β_Q		
82	S.C.F. for torsion in journal fillet β_T		
83	Allowable fatigue strength of crankshaft σ_{DW}		MPa

(2) When crankshaft diameter check formula is adopted, only following drawings and particulars are to be submitted for approval:

① crankshaft drawing which must contain all data in respect of the geometrical configuration of the crankshaft;
② type designation and kind of engine (in-line engine or V-type engine with adjacent connecting rods, forked connecting rod or articulated-type connecting rod);
③ two-stroke or four-stroke;
④ direction of rotation (see Figure 1.3.1(1));
⑤ firing order with the respective ignition intervals and V angle (see Figure 1.3.1(1));
⑥ rated power (kW);
⑦ rated speed (r/min);
⑧ mean effective pressure (MPa);
⑨ mean indicated pressure (MPa);
⑩ maximum cylinder pressure (MPa);
⑪ number of cylinders;
⑫ cylinder diameter (mm);
⑬ piston stroke (mm);
⑭ trademark of crank material;
⑮ tensile strength (MPa);
⑯ heat treatment;
⑰ polishing method of fillets and oil holes.

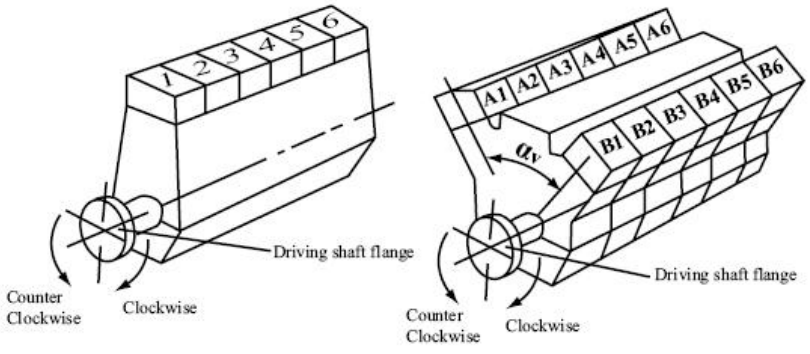


Figure 1.3.1(1) Designation of the Cylinders

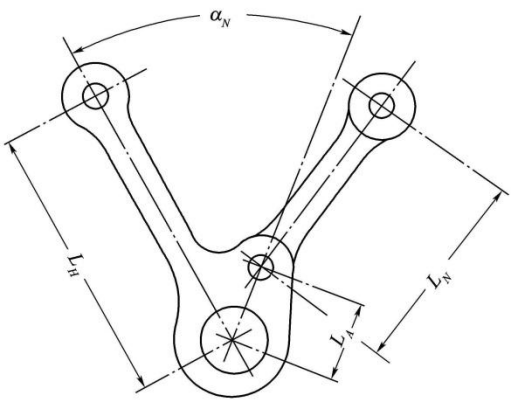


Figure 1.3.1(2) Articulated-Type Connecting Rod

1.3.2 Following particulars are to be submitted for information:
(1) Diesel engine manufacturers are to submit allowable torsional stresses, allowable longitudinal amplitudes (two-stroke), and values of crankshaft deflection regarding compulsory repairs for information.
(2) Diesel engine manufactures are to provide accurate equivalent parameters of torsional and longitudinal vibration and necessary instructions for shafting design and survey.

2 Check of Crankshaft Fatigue Strength (IACS)

2.1 Field of application

2.1.1 This calculation method applies only to solid-forged and semi-built crankshafts of forged or cast steel, with one crank throw between main bearings.

2.2 Principles of calculation

2.2.1 The calculation is based on the assumption that the areas exposed to highest stresses are:
(1) fillet transitions between the crankpin and web;
(2) fillet transitions between the journal and web;
(3) outlets of crankpin oil bores.
2.2.2 When journal diameter is equal or larger than the crankpin one, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate documentation of fatigue safety may be required.
2.2.3 Calculation of crankshaft strength consists initially in determining the nominal alternating bending and nominal alternating torsional stresses which, multiplied by the appropriate stress concentration factors using the theory of constant energy of distortion, result in an equivalent alternating stress. This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material. This comparison will then show whether or not the crankshaft concerned is dimensioned adequately.

2.3 Calculation of stresses

2.3.1 Calculation of nominal alternating stresses due to bending moments and radial forces
(1) Calculation of nominal alternating bending stress σ_{BN}
The calculation is based on a statically determined system, composed of one single crank throw supported in the centre of adjacent main journals. The bending length is taken as the length L between the two main bearing midpoints, see Figures 2.3.1(1) and 2.3.1(2) of this Appendix, and the imposed concentrated load is the radial force acting upon the crankpin due to connecting rod force. Radial forces are to be calculated in accordance with gas pressure from single cylinder, oscillating mass of piston mechanism, turning mass of cranks, mass and center of gravity of connecting rods, etc. The connecting rod force is to be obtained from calculation formula of diesel engine power, thus the radial force can be derived from the connecting rod force. At the same time, the maximum radial force F_{Rmax} (radial compression force acting on crank) and the minimum radial force F_{Rmin} (radial tension acting on crank) are to be found in one working cycle, so as to calculate the alternating radial force F_{BR} in one working cycle:

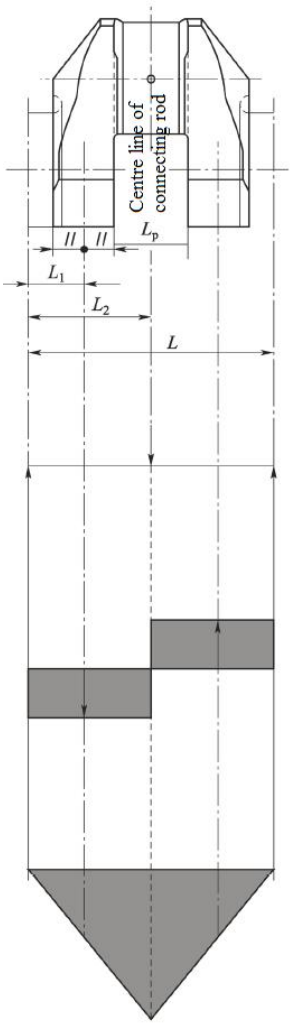


Figure 2.3.1(1)
Crank Throw for in Line Engine

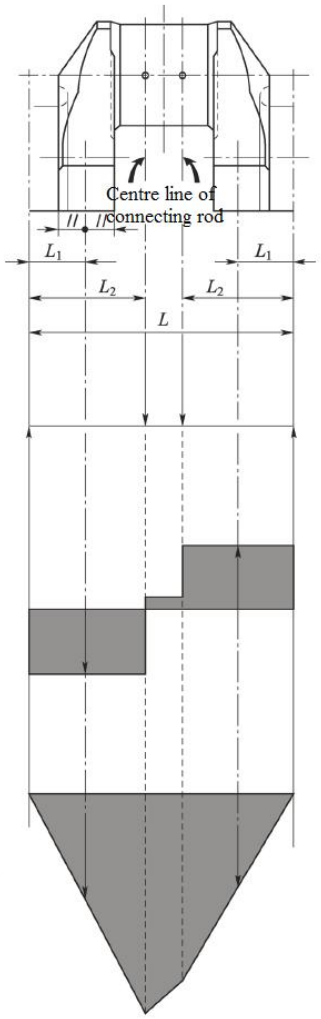


Figure 2.3.1(2)
Crank Throw for Vee Engine
with 2 Adjacent Connecting Rods

Connecting-rod
acting component forces
(F_R or F_T)

Radial shear force diagrams
(Q_R)

Bending moment diagrams
(M_{BR} or M_{BT})

$$F_{\mathrm{BR}} = \pm\frac{1}{2}(F_{\mathrm{Rmax}} - F_{\mathrm{Rmin}}) \quad \mathrm{N}$$

F_{BR} is the concentrated load of cranks, and its bending moment in way of the centerline of the crank web in the central cross section of crank is the nominal alternating bending moment M_{BN}, the value of which may be obtained by calculating the support reaction at the main bearing. In the case of the crank throw for in-line engines as shown in Figure 2.3.1(1), the support reaction at both main bearings is half the concentrated load F_{BR}, and then the nominal alternating bending moment M_{BN} in way of the centerline (L_1) of the crank web in the central cross section of crank is:

$$M_{\mathrm{BN}} = \pm\frac{F_{\mathrm{BR}}}{2}L_1 \times 10^{-3} \qquad \mathrm{N\cdot m}$$

The nominal alternating stresses due to bending moments and radial forces are to be related to the cross-sectional area of the crank web, and this cross-sectional area results from the web thickness W and the web width B. Figure 2.3.1(3) of this Appendix shows how W and B are to be measured in respect to overlapped crankshaft or crankshaft without overlap.

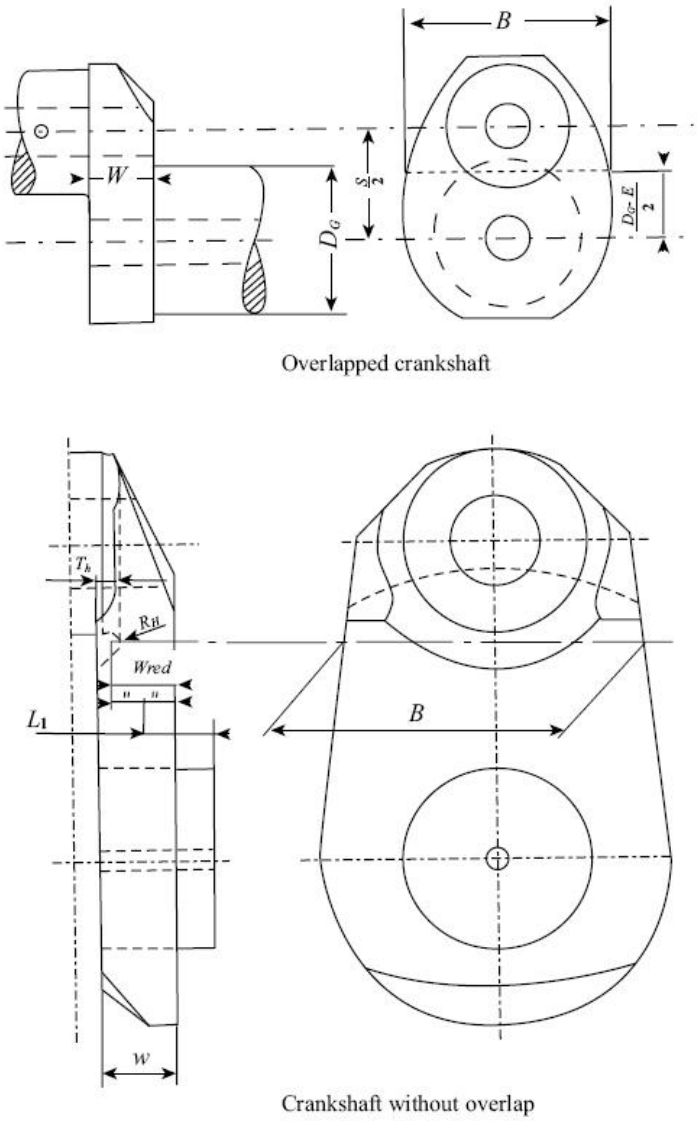


Figure 2.3.1(3) Reference Area of Crank Web Cross Section
(Symbols in the Figure are as defined in Figure 2.4.1(3) of this Appendix)

$$\sigma_{BN} = \pm \frac{M_{BN}}{W_{eq}} K_e \times 10^3 \qquad \text{MPa}$$

where: F_{BR} — alternating radial force, in N;
M_{BN} — nominal alternating bending moment, in N·m
L_1 — distance from main bearing centerline to crank web centerline, in mm, see Figures 2.3.1(1) and (2) of this Appendix;
K_e — empirical factor:
for two-stroke diesel engines $K_e = 0.80$;
for four-stroke diesel engines $K_e = 1.00$;
σ_{BN} — nominal alternating bending stress, in MPa;
$W_{eq} = \frac{BW^2}{6}$ mm^3.

For V-type diesel engines, two connecting rods act upon the same crankpin. The nominal alternating bending moments are to be taken as the bending moments of two triangular bending moments superposed according to phase, the differing designs (adjacent connecting rods, forked connecting rod or articulated-type connecting rod) being taken into account.
Where there are cranks of different geometrical configurations (e.g., asymmetric cranks) in one crankshaft, the calculation is to cover all crank variants.

(2) Calculation of nominal alternating compressive stress σ_{QN}

Radial forces resolved from the thrust of connecting rods are to be obtained in accordance with the simplified calculation method in 2.3.1(1). Radial force calculation table is to be listed in accordance with the formulae of diesel engine power, and a cylinder with maximum radial force value is to be found so as to gain nominal alternating radial force Q_N.

$$Q_N = \pm \frac{1}{2} (Q_{\max} - Q_{\min}) \quad \text{N}$$

$$\sigma_{QN} = \pm \frac{Q_N}{F} K_e \quad \text{MPa}$$

where: $Q_{\max}$ — maximum radial force of relevant cylinder, in N;

$Q_{\min}$ — minimum radial force of relevant cylinder, in N;

σ_{QN} — nominal alternating compressive stress due to radial force, in MPa;

$F = BW$, in mm^2.

(3) Calculation of nominal alternating bending stresses σ_{BO} in outlet of crankpin oil bore

The two relevant bending moments M_{BRO} and M_{BTO} are taken in the crankpin cross section through the oil bore (see Figure 2.3.1(4)), and the maximum moment M_{BOmax} and the minimum moment M_{BOmin} acting on the cross section are obtained by the superposition method to further determine the alternating bending moment M_{BON}:

$$M_{BO} = M_{BTO} \cos\psi + M_{BRO} \sin\psi \quad \text{N·m}$$

$$M_{BON} = \pm \frac{1}{2} \left[M_{BO_{\max}} - M_{BO_{\min}} \right] \quad \text{N·m}$$

where: ψ — angle between oil bore axis and tangential component of the connecting-rod force;

M_{BRO} — bending moment of the radial component of the connecting-rod force, in N·m;

M_{BTO} — bending moment of the tangential component of the connecting-rod force, in N·m.

The alternating bending stress σ_{BON} due to the alternating bending moment M_{BON} is to be related to the cross-sectional area of the axially bored crankpin, i.e.:

$$\sigma_{BON} = \pm \frac{M_{BON}}{W_e} \times 10^3 \quad \text{MPa}$$

The section modulus W_e of the crankpin cross section through the oil bore:

$$W_e = \frac{\pi}{32} \left[\frac{D_P^4 - D_{BH}^4}{D_P} \right] \quad \text{mm}^3$$

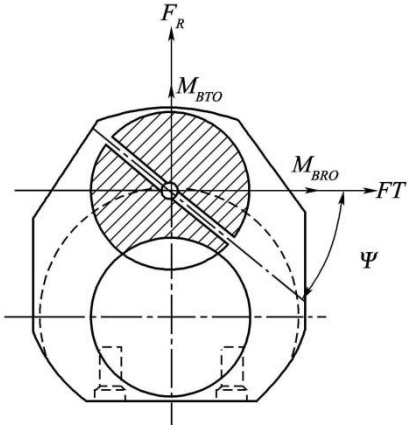


Figure 2.3.1(4) Crankpin section through the oil bore

2.3.2 Calculation of alternating bending stresses

The fillet transitions between the crankpin and web or between the journal and web as well as the outlets of crankpin oil bores are the areas exposed to the highest stresses. With the radial and tangential forces due to gas and inertia loads, the maximum alternating bending stresses will occur in the fillet or oil bore outlet.

(1) The alternating bending stress σ_{BH} in crankpin fillet

$$\sigma_{BH} = \pm(\alpha_B \sigma_{BN}) \quad \text{MPa}$$

where: α_B —stress concentration factor for bending in crankpin fillet (determination – see 2.4 of this Appendix).

(2) The alternating stress σ_{BG} in journal fillet

$$\sigma_{BG} = \pm(\beta_B \sigma_{BN} + \beta_Q \sigma_{QN}) \qquad \text{MPa}$$

where: β_B —stress concentration factor for bending in journal fillet (determination n tion factorr for bending);

β_Q —stress concentration factor for compressing in journal fillet (determination – see 2.4 of this Appendix).

(3) The alternating bending stress σ_{BO} in the outlet of crankpin oil bores

$$\sigma_{BO} = \pm(\gamma_B \sigma_{BON}) \qquad \text{MPa}$$

where: γ_B — stress concentration factor for bending in crankpin oil bore (determination – see 2.4 of this Appendix).

2.3.3 Calculation of alternating torsional stresses

(1) The calculation for nominal alternating torsional stress τ_N

The calculation for nominal alternating torsional stresses is to be undertaken by the engine manufacturer according to following provisions.

The calculation principle for nominal alternating torsional stresses is that the max. and min. alternating torques are to be ascertained for every mass point of the system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for two-stroke cycle engines and from the 0.5th order up to and including the 12th order for four-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavorable conditions, e.g. misfiring in one of the cylinders (misfiring is defined as cylinder condition when no combustion occurs but only compression cycle).

The nominal alternating torque M_T may be determined from above calculation:

$$M_T = \pm \frac{1}{2} (M_{T\max} - M_{T\min}) \qquad \text{N·m}$$

Corresponding nominal alternating torsional stress τ_N is to be calculated by the following formula:

$$\tau_N = \pm \frac{M_T}{W_P} \times 10^3 \qquad \text{MPa}$$

where: $W_P = \frac{\pi}{16} (\frac{D_P^4 - D_{BH}^4}{D_P})$, or $W_P = \frac{\pi}{16} (\frac{D_G^4 - D_{BG}^4}{D_G})$, mm^3;

$M_{T\max}$, $M_{T\min}$ — maximum and minimum valves of torque, in N·m.

(2) On determination of equivalent alternating stress σ_V, the maximum value gained from the calculation in 2.3.3(1) is to be adopted. Where barred speed ranges are arranged, the maximum value of the nominal alternating torsional stress occurring beyond is to be adopted. There are to be no barred speed ranges above a speed ratio of $\lambda \geq 0.8$ of the rated speed for normal firing conditions.

On calculation of crankshaft dimension, in the absence of such a maximum value, τ_N value is to be set as calculation basis. This assumption is based on the installation having the lowest acceptability factor, i.e., the calculation result is to satisfy $Q \geq 1.15$. Therefore, the pre-set τ_N value may be considered as ultimate value of torsional stress of the crankshaft. So far as the whole dynamic apparatus is concerned, provisions of the rules are also to be complied with, through appropriate calculation, so as to ensure that the approved nominal alternating torsional stress is not exceeded. The calculation is to be submitted for examination.

(3) Calculation of alternating torsional stresses τ_H in crankpin fillet:

$$\tau_H = \pm(\alpha_T \tau_N) \qquad \text{MPa}$$

where: α_T —stress concentration factor for torsion in crankpin fillet (determination – see 2.4 of this Appendix).

(4) The calculation of alternating torsional stress τ_G in journal fillet:

$$\tau_G = \pm (\beta_T \tau_N) \qquad \text{MPa}$$

where: β_T — stress concentration factor for torsion in journal fillet (determination – see 2.4 of this Appendix).

(5) The calculation of alternating torsional stress σ_{TO} in crankpin oil bore:

$$\sigma_{TO} = \pm(\gamma_T \tau_N) \qquad \text{MPa}$$

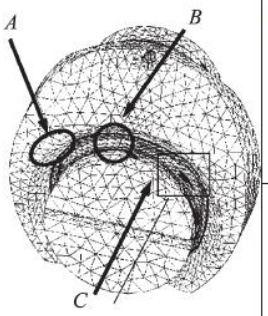
where: γ_T — stress concentration factor for torsion in outlet of crankpin oil bore (determination – see 2.4 of this Appendix).

2.4 Calculation of stress concentration factors

2.4.1 General requirements

(1) The stress concentration factors for bending (α_B, β_B) is defined as the ratio of the maximum bending stress occurring in the fillets under bending load acting in the central cross section of a crank to the nominal stress related to the web cross section (see Figure 2.4.1(1)).
The nominal stress is to be determined under the bending moment in the middle of the solid web.
(2) The stress concentration factor for torsion (α_T, β_T) is defined as the ratio of the maximum torsional stress – occurring under torsional load in the fillets – to the nominal stress related to the bored crankpin or journal cross-section (see Figure 2.4.1(1)).
(3) The stress concentration factor for compressing (β_Q) is defined as the ratio of the maximum compressive stress – occurring in the journal fillet under bending load – to the nominal compressive stress related to the web cross section.
(4) The stress concentration factors for bending (γ_B) and torsion (γ_T) are defined as the ratio of the maximum principal stress – occurring at the outlet of the crankpin oil bore under bending and torsional loads – to the corresponding nominal stress related to the axially bored crankpin cross section (see Figure 2.4.1(2)).
(5) The stress concentration factors may be evaluated by means of the formulae in accordance with 2.4.2, 2.4.3 and 2.4.4 of this Appendix applicable to the fillets and crankpin oil bores of solid-forged web-type crankshafts and to the crankpin fillets of semi-built crankshafts only. Stress concentration factor formulae concerning the oil bore are only applicable to a radially drilled oil bore.
(6) Where there are reliable measurement and/or calculation methods, direct assessment of Stress Concentration Factor (SCF) may be carried out, and relevant documents and analysis methods are to be submitted to CCS to prove that the adopted SCF calculation method is equivalent to the existing rule requirements. Where the geometry of crankshafts is outside the boundaries as specified in 2.4.1(8), (9) and (10), the stress concentration factors may be calculated by the method as specified in 2.4.5 and Annex III of this Appendix.
(7) All crank dimensions necessary for the calculation of stress concentration factors are shown in Figure 2.4.1(3).

Definition of Stress Concentration Factors in Crankshaft Fillets



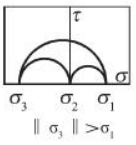
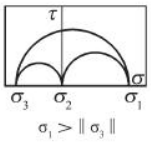
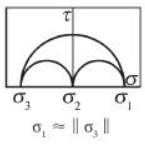
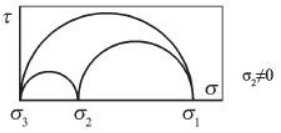
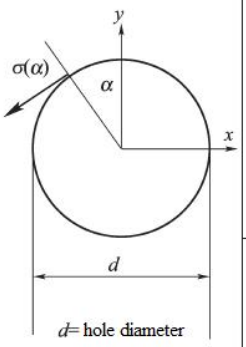
	Stress	Max$\|\|\sigma_3\|\|$	Maxσ_1	
Torsional loading	Location of maximal stresses	*A*	*C*	*B*
	Typical principal stress system Mohr's circle diagram with $\sigma_2 = 0$			
	Equivalent stress and S.C.F	$\tau_{equiv} = \frac{\sigma_1 - \sigma_3}{2}$ S.C.F.$= \frac{\tau_{equiv}}{\tau_n}$ for α_T, β_T		
Bending loading	Location of maximal stresses	*B*	*B*	*B*
	Typical principal stress system Mohr's circle diagram with $\sigma_3 = 0$			
	Equivalent stress and S.C.F	$\sigma_{equiv} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \cdot \sigma_2}$ S.C.F.$= \frac{\sigma_{equiv}}{\sigma_n}$ for $\alpha_B, \beta_B, \beta_Q$		

Figure 2.4.1(1) Stress Concentration Factors in Crankshaft Fillets

Stress Concentration Factors and Stress Distribution at the Edge of Oil Drillings



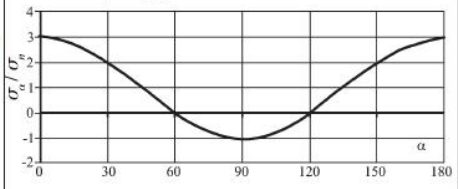
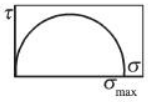
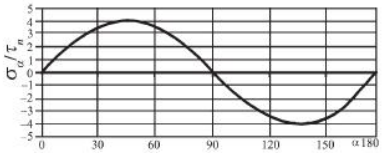
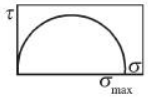
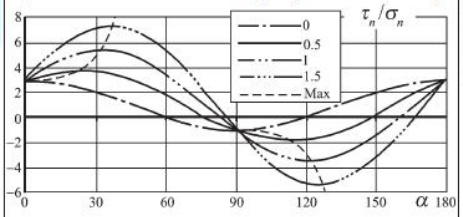
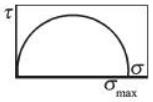
Stress type	Nominal stress tensor	Uniaxial stress distribution around the edge	Mohr's circle diagram
Tension	$\begin{bmatrix} \sigma_n & 0 \\ 0 & 0 \end{bmatrix}$	$\sigma_\alpha = \sigma_n \gamma_B / 3[1+2\cos(2\alpha)]$ 	 $\gamma_B = \sigma_{max}/\sigma_n$ for $\alpha = k\pi$
Shear	$\begin{bmatrix} 0 & \tau_n \\ \tau_n & 0 \end{bmatrix}$	$\sigma_\alpha = \gamma_T \tau_n \sin(2\alpha)$ 	 $\gamma_T = \sigma_{max}/\tau_n$ for $\alpha = \frac{\pi}{4} + k\frac{\pi}{2}$
Tension + shear	$\begin{bmatrix} \sigma_n & \tau_n \\ \tau_n & 0 \end{bmatrix}$	$\sigma_\alpha = \frac{\gamma_\beta}{3}\sigma_n \left\{1+2\left[\cos(2\alpha) + \frac{3\gamma_T\tau_n}{2\gamma_B\sigma_n}\sin(2\alpha)\right]\right\}$ 	 $\sigma_{max} = \sigma_n \frac{\gamma_B}{3}\sigma_n \left[1+2\sqrt{1+\frac{9}{4}\left(\frac{\gamma_T\tau_n}{\gamma_B\sigma_n}\right)^2}\right]$ $\alpha = \frac{1}{2}\tan^{-1}\left(\frac{3\gamma_T\tau_n}{2\gamma_B\sigma_n}\right)$

Figure 2.4.1(2) Stress Concentration Factors and Stress Distribution of Oil Drillings

Actual dimensions in the Figure:

D_P — crankpin diameter, in mm;

D_{BH} — diameter of bore in crankpin, in mm;

D_O — diameter of oil bore in crankpin, in mm;

R_H — fillet radius of crankpin, in mm;

T_H — recess of crankpin, in mm;

D_G — journal diameter, in mm;

D_{BG} — diameter of bore in journal, in mm;

R_G — fillet radius of journal, in mm;

T_G — recess of journal, in mm;

S — piston stroke, in mm;

E — journal overlap, $E = \frac{D_P + D_G}{2} - \frac{S}{2}$, in mm;

W — web thickness, in mm; in the case of 2 stroke semi-built crankshafts without journal overlap and when $T_H > R_H$, the web thickness must be considered as equal to $W_{red} = W - (T_H - R_H)$ (refer to Figure 2.3.1(3) of this Appendix);

B — web width, in mm; in the case of 2 stroke semi-built crankshafts without journal overlap, web width B is to be taken in way of crankpin fillet radius centre (refer to Figure 2.3.1(3) of this Appendix).

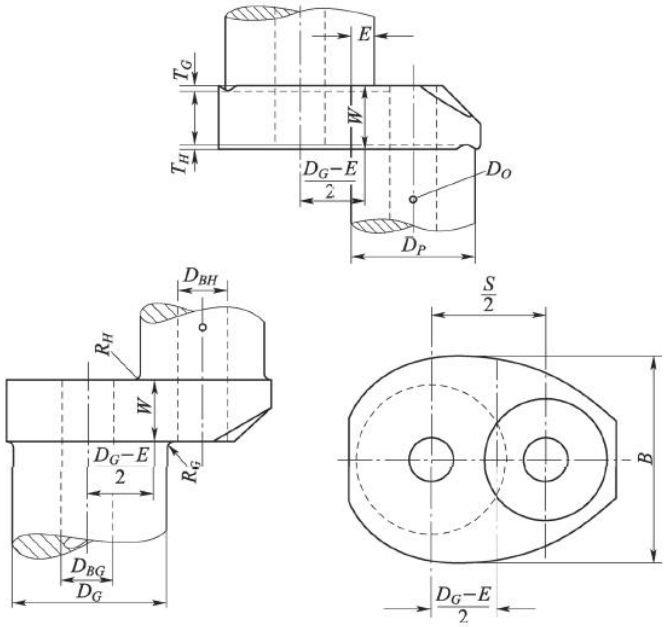


Figure 2.4.1(3)
Crank Dimensions Necessary for the Calculation of Stress Concentration Factors in Crank Throws

(8) The following related dimensions in Table 2.4.1 will be applied for the calculation of stress concentration factors.
(9) Stress concentration factors are valid for the ranges of related dimensions for which the investigations have been carried out. Ranges are as follows:

$$e \le 0.5$$
$$0.2 \le w \le 0.8$$
$$1.1 \le b \le 2.2$$
$$0.03 \le r \le 0.13$$
$$0 \le d_G \le 0.8$$
$$0 \le d_H \le 0.8$$
$$0 \le d_O \le 0.2$$

(10) Low range of e can be extended down to large negative values provided that:
a. If calculated f(rec) < 1 then the factor f(rec) is not to be considered (f(rec) = 1);
b. If e < -0.5 then $f(e, w)$ and $f(r, e)$ are to be evaluated replacing actual value of e by -0.5.

Table 2.4.1

Crankpin fillet	Journal fillet
$r = R_H/D_P$	$r = R_G/D_P$
$e = E/D_P$	
w① $= W/D_P$	
$b = B/D_P$	
$d_O = D_o/D_P$	
$d_G = D_{BG}/D_P$	
$d_H = D_{BH}/D_P$	
$t_H = T_H/D_P$	
$t_G = T_G/D_P$	

Note: ① This applies to crankshafts with overlap. For crankshafts without overlap, $w = W_{red}/D_P$.

2.4.2 Calculation of the stress concentration factor for crankpin
(1) The stress concentration factor α_B for bending:

$$\alpha_B = 2.6914 f(e,w) f(w) f(b) f(r) f(d_G) f(d_H) f(rec)$$

where:

$$f(e,w) = -4.1883 + 29.2004w - 77.5925w^2 + 91.9454w^3 - 40.0416w^4 + (1-e)\,(9.544 - 58.348w + 159.3415w^2 - 192.5846w^3 + 85.2916w^4) - (1-e)^2(3.8399 - 25.0444w + 70.5571w^2 - 87.0328w^3 + 39.1832w^4);$$

$$f(w) = 2.179w^{0.7171};$$

$$f(b) = 0.684 - 0.0077b + 0.1473b^2;$$

$$f(r) = 0.2081r^{-0.5231};$$

$$f(d_G) = 0.9993 + 0.27d_G - 1.0211{d_G}^2 + 0.5306{d_G}^3;$$

$$f(d_H) = 0.9978 + 0.3145d_H - 1.5241{d_H}^2 + 2.4147{d_H}^3;$$

$$f(rec) = 1 + (t_H + t_G)(1.8 + 3.2e).$$

(2) Stress concentration factor α_T for torsion:

$$\alpha_T = 0.8f(r,e)f(b)f(w)$$

where: $f(r,e) = r^{-(0.2205+0.1015e)}$;

$$f(b) = 7.8955 - 10.654b + 5.3482b^2 - 0.857b^3;$$

$$f(w) = w^{-0.145}.$$

2.4.3 Calculation of stress concentration factor for journal

(1) The stress concentration factor β_B for bending:

$$\beta_B = 2.7146f_B(e,w)f_B(w)f_B(b)f_B(r)f_B(d_G)f_B(d_H)f(rec)$$

where:

$$f_B(e,w) = -1.7625 + 2.9821w - 1.5276w^2 + (1-e)(5.1169 - 5.8089w + 3.1391w^2) + (1-e)^2(-2.1567 + 2.3297w - 1.2952w^2);$$

$$f_B(w) = 2.2422w^{0.7548};$$

$$f_B(b) = 0.5616 + 0.1197b + 0.1176b^2;$$

$$f_B(r) = 0.1908r^{-0.5568};$$

$$f_B(d_G) = 1.0012 - 0.6441d_G + 1.2265{d_G}^2;$$

$$f_B(d_H) = 1.0022 - 0.1903d_H + 0.0073{d_H}^2;$$

$$f(rec) = 1 + (t_H + t_G)(1.8 + 3.2e).$$

(2) The stress concentration factor β_Q for compressing:

$$\beta_Q = 3.0128f_Q(e)f_Q(w)f_Q(b)f_Q(r)f_Q(d_H)f_Q(rec)$$

where: $f_Q(e) = 0.4368 + 2.163(1-e) - 1.5212(1-e)^2$;

$$f_Q(w) = \frac{w}{0.0637 + 0.9369w};$$

$$f_Q(b) = b - 0.5;$$

$$f_Q(r) = 0.5331r^{-0.2038};$$

$$f_Q(d_H) = 0.9937 - 1.1949d_H + 1.7373{d_H}^2;$$

$$f(rec) = 1 + (t_H + t_G)(1.8 + 3.2e).$$

(3) The stress concentration factor β_T for torsion:

If the diameters and fillet radii of crankpin and journal are the same:

$$\beta_T = \alpha_T$$

If crankpin and journal diameters and/or radii are of different sizes:

$$\beta_T = 0.8f(r,e)f(b)f(w)$$

For $f(r, e), f(b), f(w)$, see the calculation of α_T, however, the radius of the journal fillet is to be related to the journal diameter:

$$r = \frac{R_G}{D_G}$$

2.4.4 Calculation of stress concentration factor for outlet of crankpin oil bore

(1) The stress concentration factor γ_B for bending:

$$\gamma_B = 3 - 5.88d_O + 34.6d_O^{\ 2}$$

(2) The stress concentration factor γ_T for torsion:

$$\gamma_T = 4 - 6d_O + 30d_O^{\ 2}$$

2.4.5 Calculation of stress concentration factors by means of finite element method

(1) General requirements

The formulae for the calculation of Stress Concentration Factors (SCF) in the crankshaft fillets as specified in 2.4.2, 2.4.3 and 2.4.4 of this Appendix are based on empirical formulae developed from strain gauge measurements of various crank geometries and accordingly the application of the formulae is limited to those geometries. Where the geometry of crankshafts is outside the boundaries as specified in 2.4.1(8) and (9), the SCF may be obtained as the ratio of stresses calculated by FEM to nominal stresses in both journal and pin fillets. When used in connection with the present method in this Appendix or the alternative methods, equivalent stresses are to be calculated for bending and principal stresses for torsion.

The procedure as well as evaluation guidelines of this Section are valid for both solid cranks and semi-built cranks (except journal fillets).

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

Prior to FE analysis, it is advised to check the element accuracy of the FE solver in use, e.g. by modeling a simple geometry and comparing the stresses obtained by FEM with the analytical solution for pure bending and torsion.

(2) Model requirements

The basic requirements for building the FE-model are presented in ① below. The material properties required for FE analysis are given in ② below. The FE-model is to comply with the element mesh quality criteria as specified in ③ below.

① Element mesh requirements

In order to fulfil the mesh quality criteria, the FE model is to be constructed in accordance with the following requirements:

—The FE model consists of one complete crank, from the main bearing centerline to the opposite side main bearing centerline.

—Element types used in the vicinity of the fillets include 10 node tetrahedral elements, 8 node hexahedral elements and 20 node hexahedral elements.

—Mesh properties in fillet radii and the element mesh of ±90° in circumferential direction from the crank plane are to comply with the following requirements:

- Maximum element size $a = r/4$ through the entire fillet as well as in the circumferential direction. When using 20 node hexahedral elements, the element size in the circumferential direction may be extended up to $5a$ (where r is fillet radius). In the case of multi-radii fillet r is the local fillet radius. (If 8 node hexahedral elements are used even smaller element size is required to meet the quality criteria.)
- Recommended manner for element size in fillet depth direction is as follows: first layer thickness equal to element size of a; second layer thickness equal to element to size of $2a$; third layer thickness equal to element to size of $3a$.
- Minimum 6 elements across web thickness.

—Generally the rest of the crank is to be suitable for numeric stability of the solver.

—Counterweights have to be modeled only when influencing the global stiffness of the crank significantly.

—Modeling of oil drillings is not necessary as long as the influence on global stiffness is negligible and the proximity to the fillet is more than $2r$, see Figure 2.4.5(1).

—Drillings and holes for weight reduction have to be modeled.

—Sub-modeling may be used as far as the software requirements are fulfilled.

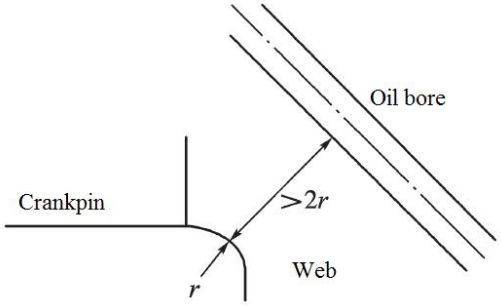


Figure 2.4.5(1) Oil Bore Proximity to Fillet

② Material

In FE analysis, the material properties such as Young's Modulus (E) and Poisson's ratio (ν) are required, as strain is primarily calculated and stress is derived from strain using the Young's Modulus and Poisson's ratio. Reliable values for material parameters have to be used, either as quoted in literature or as measured on representative material samples.

For steel the following Young's Modulus (E) and Poisson's ratio (ν) are advised:

$E = 2.05 \cdot 10^5$ MPa

$\nu = 0.3$.

③ Element mesh quality criteria

If the actual element mesh does not fulfil any of the following criteria at the examined area for SCF evaluation, then a second calculation with a refined mesh is to be performed.

—Principal stresses criterion

The quality of the mesh is to be assured by checking the stress component normal to the surface of the fillet radius. Ideally, this stress is to be zero. With principal stresses σ_1, σ_2 and σ_3 the following criterion is required:

$$\min\left(|\sigma_1|,|\sigma_2|,|\sigma_3|\right) < 0.03 \max\left(|\sigma_1|,|\sigma_2|,|\sigma_3|\right)$$

—Averaged/unaveraged stresses criterion

The criterion is based on observing the discontinuity of stress results over elements at the fillet for the calculation of SCF. unaveraged nodal stress results calculated from each element connected to a node$_i$ should differ less than by 5 % from the 100 % averaged nodal stress results at this node$_i$ at the examined location.

(3) Load cases

The following load cases are to be considered when stress concentration factors are calculated by FEM.

① Torsion

In analogy to the testing apparatus used for the investigations made by FVV the structure is loaded pure torsion. In the model surface warp at the end faces is suppressed. Torque is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face (see Figure 2.4.5(2)).

Boundary and load conditions as shown in Figure 2.4.5(2) are valid for both in-line and V-type engines.

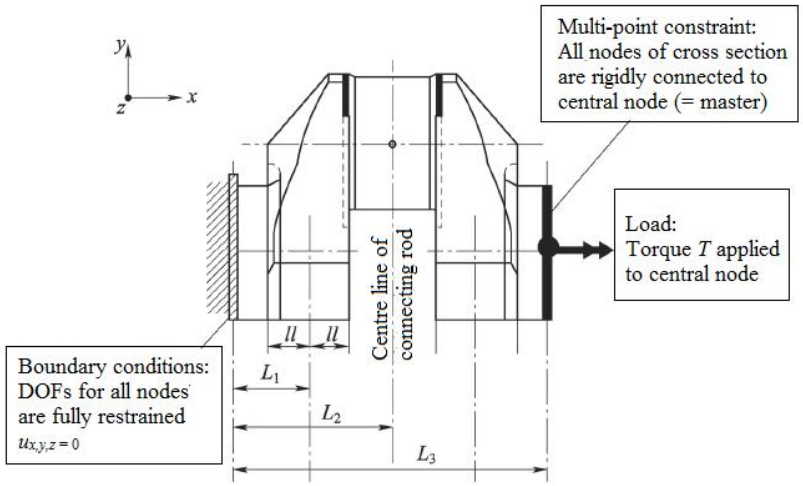


Figure 2.4.5(2) Boundary and Load Conditions for the Torsion Load Case

For all nodes in both the journal and crank pin fillet principal stresses are extracted and the equivalent torsional stress τ_{equiv} is calculated in accordance with the following formula:

$$\tau_{equiv} = \max\left(\frac{|\sigma_1 - \sigma_2|}{2}, \frac{|\sigma_2 - \sigma_3|}{2}, \frac{|\sigma_1 - \sigma_3|}{2}\right) \quad \text{MPa}$$

The maximum value taken for the subsequent calculation of the stress concentration factors α_T and β_T in the crank pin and journal fillet respectively as follows:

$$\alpha_T = \frac{\tau_{equiv,\alpha}}{\tau_N}$$

$$\beta_T = \frac{\tau_{equiv,\phi}}{\tau_N}$$

where: τ_N—nominal torsional stress calculated in accordance with 2.3.3, in MPa;

$\tau_{equiv,\alpha}$, $\tau_{equiv,\beta}$ —maximum equivalent torsional stress in the crank pin and journal fillet, in MPa.

② Pure bending

In analogy to the testing apparatus used for the investigations made by FVV the structure is loaded in pure bending. In the model surface warp at the end faces is suppressed. The bending moment is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face (see Figure 2.4.5(3)).

Boundary and load conditions as shown in Figure 2.4.5(3) are valid for both in-line and V-type engines.

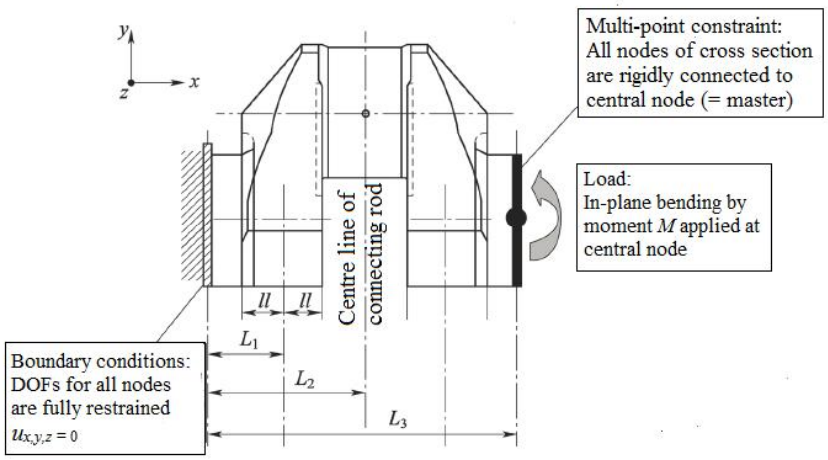


Figure 2.4.5(3) Boundary and Load Conditions for the Pure Bending Load Case

For all nodes in both the journal and pin fillet, the equivalent stresses are extracted. The maximum value is used to calculate the stress concentration factors α_B and β_B according to the following formulae:

$$\alpha_B = \frac{\sigma_{equiv,\alpha}}{\sigma_{BN}}$$

$$\beta_B = \frac{\sigma_{equiv,\beta}}{\sigma_{BN}}$$

where: σ_{BN} —nominal alternating bending stress calculated in accordance with 2.3.1(1), in MPa;

$\sigma_{equiv,\alpha}$, $\sigma_{equiv,\beta}$ —maximum equivalent stress in the crank pin and journal fillet, in MPa.

③ Bending with shear force

This load case is calculated to determine the stress concentration factor for compressive stress β_Q for the journal fillet.

In analogy to the testing apparatus used for the investigations made by FVV, the structure is loaded in 3-point bending. In the model, surface warp at the both end faces is suppressed. All nodes are connected rigidly to the centre node; boundary conditions are applied to the centre nodes. These nodes act as master nodes with 6 degrees of freedom. The force is applied to the central node located at the pin centre-line of the connecting rod (see Figure 2.4.5(5)). This node is connected to all nodes of the pin cross sectional area. Warping of the sectional area is not suppressed.

Boundary and load conditions as shown in Figure 2.4.5(4) are valid for in-line and V-type engines. V-type engines can be modeled with one connecting rod force only. Using two connecting rod forces will make no significant change in the SCF.

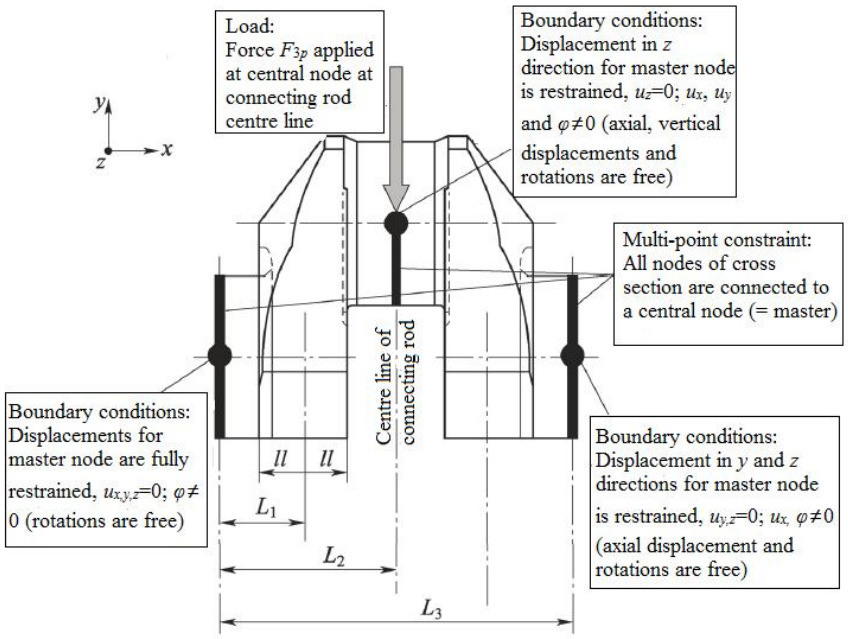


Figure 2.4.5(4) Boundary and Load Conditions for the 3-point Bending Load Case of an In-line Engine

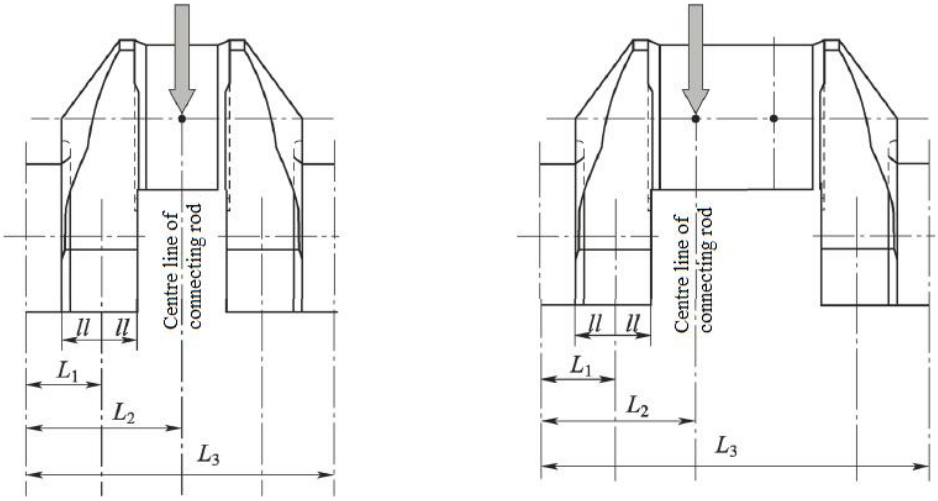


Figure 2.4.5(5) Load Applications for In-line and V-type Engines

The maximum equivalent stress σ_{3P} in the journal fillet is evaluated. The stress concentration factors in the journal fillet can be determined in two ways as shown below.

— Method 1. This method is analogue to the FVV investigation. The results from pure bending and bending with shear force in the journal fillet are combined as follows:

$$\sigma_{3P} = \beta_B \sigma_{N3P} + \beta_Q \sigma_{Q3P} \quad \text{MPa}$$

The stress concentration factor β_Q is calculated as follows:

$$\beta_Q = \frac{\sigma_{3P} - \beta_B \sigma_{N3P}}{\sigma_{Q3P}}$$

where: σ_{3P} — maximum equivalent stress as found by the FE calculation, in MPa;

σ_{N3P} — nominal bending stress in the web centre due to the force F_{3P} applied to the centre-line of the actual connecting rod, in MPa, see Figure 2.4.5(5);

β_B — stress concentration factor for bending in the journal fillet under pure bending load, as determined in 2.4.5(3)②;

σ_{Q3P} — nominal compressive stress due to radial (shear) force Q_{3P} in the web due to the force F_{3P} applied to the centre-line of the actual connecting rod, in MPa (see Figures 2.1.3(1) and (2)). $\sigma_{Q3P} = Q_{3P}/(BW)$, where B and W are web width and thickness respectively.

— Method 2. This method is not analogous to the FVV investigation. In a statically determined system with one crank throw supported by two bearings, the bending moment and radial (shear) force are proportional. Therefore the journal fillet stress concentration factor β_{BQ} can be found directly by the 3-point bending FE calculation.

$$\beta_{BQ} = \frac{\sigma_{3P}}{\sigma_{N3P}}$$

For symbols see Method 1.

When using Method 2 the radial force and stress becomes superfluous. The alternating bending stress σ_{BG} in the journal fillet as per 2.3.2(2) is calculated in accordance with the following formula:

$$\sigma_{BG} = \pm \left| \beta_{BQ} \sigma_{BN} \right|$$

Note that the use of Method 2 does not apply to the crankpin fillet and that this SCF must not be used in connection with calculation methods other than those assuming a statically determined system as in this Appendix.

2.5 Determination of additional bending stresses σ_{add}

2.5.1 In addition to the alternating bending stresses in fillets caused by gas and inertia loads, additional bending stresses σ_{add} (additional bending stress σ_{aa} due to misalignment and bedplate deformation as well as

additional bending stress σ_{ax} due to axial vibrations) will cause crankshaft fatigue damage unless restriction is imposed or accurate determination made.
Additional bending stresses are as given in Table 2.5.1 to different engine types:

Table 2.5.1

Type of engine	σ_{add} (MPa)
Crosshead engines	± 30①
Trunk piston engines	± 10

Note: ① The additional stress of ±30 MPa is composed of two components: an additional stress of ±20 MPa resulting from axial vibration, an additional stress of ±10 MPa resulting from misalignment/bedplate deformation. It is recommended that a value of ±20 MPa be used for the axial vibration component for assessment purposes where axial vibration calculation results of the complete dynamic system are not available. Where axial vibration calculation results of the complete dynamic system are available, the calculated figures may be used instead.

2.5.2 According to the calculation, the appraisal of the crankshaft is based on the minimum acceptability factor Q (see 2.8 of this Appendix). Therefore, where $Q > 1.15$ with a certain margin, the allowable amplitude of axial vibrations may be raised corresponding to the maximum value of the allowable crankshaft deflection provided by the diesel engine manufacturer.

2.6 Calculation of equivalent alternating stress σ_v

2.6.1 For calculation of equivalent alternating stress σ_v in fillets, the theory of constant energy of distortion is to be used. In this case, it is assumed that the maximum alternating bending stresses and maximum alternating torsional stresses within a crankshaft occur simultaneously and at the same point.
At the oil hole outlet, bending and torsion lead to two different stress fields which can be represented by an equivalent principal stress equal to the maximum of principal stress resulting from combination of these two stress fields with the assumption that bending and torsion are time phased (see Figure 2.4.1(2) of this Appendix).
2.6.2 Equivalent alternating stress
The equivalent alternating stress σ_v is calculated in accordance with the formulae given.
For the crankpin fillet:

$$\sigma_v = \pm\sqrt{(\sigma_{BH} + \sigma_{add})^2 + 3\tau_H^2} \quad \text{MPa}$$

For the journal fillet:

$$\sigma_v = \quad \text{t}\sqrt{(\sigma_{BG} + \sigma_{add})^2 + 3\tau_G^2} \quad \text{MPa}$$

For crankpin oil bore outlet:

$$\sigma_v = \pm\frac{1}{3}\sigma_{BO}\left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right] \quad \text{MPa}$$

For other parameters, see 2.3 of this Appendix.

2.7 Calculation of fatigue strength

2.7.1 The fatigue strength is to be understood as that value of alternating bending stress which a crankshaft can permanently withstand at the most highly stressed points of the fillets. Where the fatigue strength for a crankshaft cannot be furnished by reliable measurements, the allowable fatigue strength σ_{DW} may be evaluated by means of the following formulae:

Related to the crankpin diameter:

$$\sigma_{DW} = \pm K(0.42R_m + 39.3)\left[0.264 + 1.073D_P^{-0.2} + \frac{785 - R_m}{4900} + \frac{196}{R_m}\sqrt{\frac{1}{R_x}}\right] \quad \text{MPa}$$

with $R_x = R_H$ in the fillet area; $R_x = D_O/2$ in the oil bore area.
Related to the journal diameter:

$$\sigma_{DW} = \pm K(0.42R_m + 39.3)\left[0.264 + 1.073D_G^{-0.2} + \frac{785 - R_m}{4900} + \frac{196}{R_m}\sqrt{\frac{1}{R_G}}\right] \quad \text{MPa}$$

where: K — factor for different types of crankshafts without surface treatment. Values greater than 1 are only applicable to fatigue strength in fillet area:

= 1.05 for continuous grain flow forged or drop-forged crankshafts;
= 1.0 for free form forged crankshafts (without continuous grain flow);
= 0.93 for cast steel crankshafts (factor for cast steel crankshafts with cold rolling treatment in fillet area, using a CCS approved cold rolling process);

R_m — tensile strength of crankshaft material, in MPa.

For other parameters, see 2.4.1 of this Appendix.

These formulae are subject to the following conditions:

(1) surfaces of the fillet, the outlet of the oil bore and inside the oil bore (down to a minimum depth equal to 1.5 times the oil bore diameter) are to be smoothly finished;

(2) for calculation purposes RH, RG or Rx are to be taken as not less than 2 mm.

2.7.2 When a surface treatment process is applied, it is to be approved by CCS. The fatigue strength of fillets and outlets of oil bores that have been surface treated may be calculated according to the method specified in Annex II of this Appendix.

2.7.3 As an alternative, the fatigue strength of the crankshaft can be determined by experiment based either on full size crank throw (or crankshaft) or on specimens taken from a full size crank throw. The result of the fatigue test is to be evaluated according to the method specified in Annex I of this Appendix.

2.8 Acceptability criteria of a crankshaft

2.8.1 The sufficient dimensioning of a crankshaft is confirmed by a comparison of the equivalent alternating stress and the fatigue strength. This comparison through the acceptability factor Q is to be carried out for the crankpin fillet, the journal fillet, the outlet of crankpin oil bore and is based on the formula:

$$Q = \frac{\sigma_{DW}}{\sigma_V} \geq 1.15$$

2.8.2 The acceptability factor Q is not necessarily the safety factor of the crankshaft. It only stands for a value related to the calculation. The value of fatigue strength of the material is not the only cause for the damage of the crankshaft, which actually has something to do with the strained condition of the crankshaft. Where the crankshaft is excessively deformed, its reliability will be affected. However, the acceptability factor Q can also show the safety margin of the crankshaft itself, for the calculation is based on its torsional stress for appraisal of the crankshaft, combined with the bending stress concerned, so as to get the minimum acceptability factor. Therefore, where $Q > 1.15$ with a certain margin, the allowable values of torsional stress, axial vibration stress, crankshaft deflection regarding compulsory repairs are to be appropriately adjusted. This is useful to design, operation and survey.

2.9 Allowable values to be provided by manufacturers

2.9.1 Manufacturers are to provide the values of allowable torsional stresses, allowable axial amplitudes and crankshaft deflection regarding compulsory repairs.

2.9.2 The allowable values mentioned in 2.9.1 of this Appendix are to be taken as the relevant values on calculating Q in 2.8.1 of this Appendix, or to be taken as the limiting values concerned when $Q = 1.15$.

3 Calibration of Crankshaft Diameter

3.1 Scope

3.1.1 The calculation is applicable to crankshafts of in-line and V-diesel engines. These crankshafts have an equal span of bearings adjacent to cranks, and are made of forged steel, cast steel, alloy steel or nodular graphite cast iron.

3.2 Calculation principles

3.2.1 The calculation is also based on the assumption that the fillet transitions between the journal and web are the crankshaft areas to the highest stresses. It is the most concentrated stress area and the fatigue damage of the crankshafts is most probably to happen here.

3.2.2 Crankshaft strength calibration is based on the theory of maximum normal stress. This calculation is assuming that the damage of crankshaft is due to the combined action of the maximum bending moment (bending stress) and maximum torque (shearing stress) upon it. Therefore, the maximum bending moment and the maximum torque (multiplying relevant stress concentration factors) are to be combined to the maximum equivalent bending moment. By fatigue strength of material and adequate safety factors, the calculation formula of the minimum diameter necessary for the crankshafts can be inferred.

3.3 Calculation of the minimum diameter of the crankshafts

3.3.1 The specified tensile strength of forgings and castings for crankshafts is in general to be selected within the following scope and in compliance with the relevant requirements of CCS Rules for Materials and Welding.

(1) Carbon and carbon-manganese steel 400 to 600 MPa;
(2) Alloy steel 600 to 1,000 MPa;
(3) Nodular graphite cast iron 490 to 780 MPa.

3.3.2 The minimum diameter D_P (or D_G) of the crankpins or the journals of fully-built or semi-built crankshafts is to be calculated by the following.

For crankshafts made of forged steel, cast steel and alloy steel:

$$D_P = \sqrt[3]{\frac{D^2\left[Aa_B p_z (L - L_p) + Ca_T p_i S\right]}{65 \times (\frac{R_m + 160}{560})}} \quad \text{mm}$$

For crankshafts made of nodular graphite cast iron:

$$D_P = \sqrt[3]{\frac{D^2\left[Aa_B p_z (L - L_p) + Ca_T p_i S\right]}{59 \times (0.3 + \frac{0.7R_m}{490})}} \quad \text{mm}$$

where: D — cylinder diameter, in mm;

S — piston stroke, in mm;

L — span of adjacent bearings measured from center to center, in mm;

L_P — length of crankpin, in mm;

p_z — maximum combustion pressure, in MPa;

p_i — mean indicated pressure, in MPa;

R_m — tensile strength of the material used, in MPa;

A — coefficient:

for single acting in-line diesel engines, A = 0.50;
for two-stroke V-diesel engines, A is to be selected in accordance with Table 3.3.2(1);
for four-stroke V-diesel engines, A is to be selected in accordance with Table 3.3.2(2);

C — coefficient:

for single acting in-line diesel engines, C is to be selected in accordance with Table 3.3.2(3);
for two-stroke V-diesel engines, C is to be selected in accordance with Table 3.3.2(4);
for four-stroke V-diesel engines, C is to be selected in accordance with Table 3.3.2(5);

α_B — bending stress concentration factor;

α_T — torsional stress concentration factor.

3.3.3 Calculation and application of stress concentration factor

(1) Fracture of the diesel engine crankshafts is most probably caused by fatigue. When in bending fracture, fatigue appears mostly in the transition fillets between the crankpin and web or between journal and web. This is because the stress here is most concentrated. Therefore, the so called bending stress concentration factor means the ratio of the maximum bending stress occurring in the transition fillets of the crankpins under bending load acting in the central cross-section of a crank to the nominal bending stress related to the crankpin cross-section. The nominal bending stress is to be determined under the bending moment in the middle of the solid web.

(2) Torsional stress concentration factor means the ratio of the maximum torsional stress under the torsional load in the fillets to the nominal torsional stress related to the crankpin cross-section.

(3) Fatigue damage of the crankshafts is related to the actual stress in the transition fillets acted by the operation of the diesel engines. The actual stresses include the additional stress caused by misalignment of the crankshafts and highly concentrated stress caused by the geometry of the crankshafts. Therefore, bending stress concentration factor is actually the surface features of this ingredient, which is obtained through quantitative study of three-directional photoelasticity test.

(4) The geometrical dimensions of the crankshafts affecting the stress concentration in fillets mainly include the radius of transition fillets R_H, web thickness W, web breadth B (for taking B, see Figure 2.3.1(1) of this Appendix), journal overlap E, diameter of journal cavity D_{BH}, recess depth of fillet T_H, etc., which are more or less affecting. Anyhow, to improve the applicability of stress concentration factor, the geometrical dimensions mentioned above corresponding to crankpin diameter D_P (or fillet radius R_H) turn to dimensionless relative dimension, i.e.:

$$r = R_H / D_P$$

$$w = W / D_P$$
$$b = B / D_P$$
$$e_k = 1 - E / D_P$$
$$d_H = D_{BH} / D_P$$
$$\delta = T_H / R_H$$

Only when the relative dimensions mentioned above are used in a specified range can the stress concentration factor be effective, and they are only applicable to the crankpins of fully-built or semi-built crankshafts.

The applicable range of the relative dimensions is as follows:

$$0.03 \le r \le 0.10$$
$$0.25 \le w \le 0.60$$
$$1.30 \le b \le 2.00$$
$$0.50 \le e_k \le 1.50$$
$$0 \le d_H \le 0.70$$
$$0 \le \delta \le 0.65$$

The dimensions for the calculation of the stress concentration factor are shown in Figure 2.4.1(3).

(5) Bending stress concentration factor α_B is to be calculated as follows:

$$\alpha_B = 0.625 f_1(r) f_2(w) f_3(e_k, w) f_4(b) f_5(d_H)$$

where: $f_1(r), f_2(w), f_3(e_k, w), f_4(b), f_5(d_H)$ may be obtained from Figures 3.3.3(1), (2), (3)a, b, c and (4), (5). Where the transition fillets of the crankpins or journals are filleted arc and the recess depth is T_H (as shown in Figure 2.4.1(3)), α_B value is to multiply $f_6(\delta)$ value obtained from Table 3.3.2 (6).

(6) Torsional stress concentration factor α_T is to be obtained from Figure 3.3.3 (6).

Coefficient *A* for two-stroke V-diesel engines **Table 3.3.2(1)**

Coefficient	Firing interval between two cylinders on one crankpin			
	36º	45º	60º	90º
A	0.70	0.66	0.615	0.585

Coefficient *A* for four-stroke V-diesel engines **Table 3.3.2(2)**

Coefficient	Minimum firing interval between two cylinders on one crankpin							
	45º	60º	75º	90º	270º	285º	300º	315º
A	0.665	0.630	0.610	0.599	0.594	0.596	0.597	0.598

Coefficient *C* for single acting in-line diesel engines **Table 3.3.2(3)**

two-stroke		two-stroke		four-stroke		four-stroke	
Number of cylinders	*C*	Number of cylinders	*C*	Number of cylinders	*C*	Number of cylinders	*C*
1	2.043	7	3.446	1	1.872	7	2.915
2	2.069	8	3.960	2	1.872	8	2.915
3	2.616	9	4.148	3	2.082	9	2.933
4	2.933	10	4.661	4	2.082	10	2.933
5	3.273	11	4.782	5	2.553	11	3.300
6	3.300	12	4.840	6	2.553	12	3.300

Coefficient *C* for two-stroke V-diesel engines **Table 3.3.2(4)**

Number of cylinders	Firing interval between two cylinders on one crankpin			
	36º	45º	60º	90º
2×3	3.768	3.464	3.546	3.675
2×4	4.138	3.800	4.400	5.630
2×6	5.469	5.684	6.563	5.286
2×8	6.504	7.010	6.469	7.003

Coefficient *C* for four-stroke V-diesel engines **Table 3.3.2(5)**

Number of cylinders	Minimum firing interval between two cylinders on one crankpin							
	45º	60º	75º	90º	270º	285º	300º	315º
2×3	2.934	2.833	2.648	2.511	3.307	3.309	3.380	3.309
2×4	3.224	3.103	3.056	3.159	3.105	3.183	3.150	2.848
2×6	3.859	3.613	3.404	3.471	3.864	4.146	4.155	4.187
2×8	4.274	4.035	4.500	4.455	4.706	4.314	3.648	3.480

The recess influence coefficient $f_6(\delta)$ of the transition fillets Table 3.3.2(6)

δ	0	0.15	0.25	0.35	0.45	0.55	0.60	0.65
$f_6(\delta)$	1	0.993	0.989	0.996	1.020	1.072	1.110	1.158

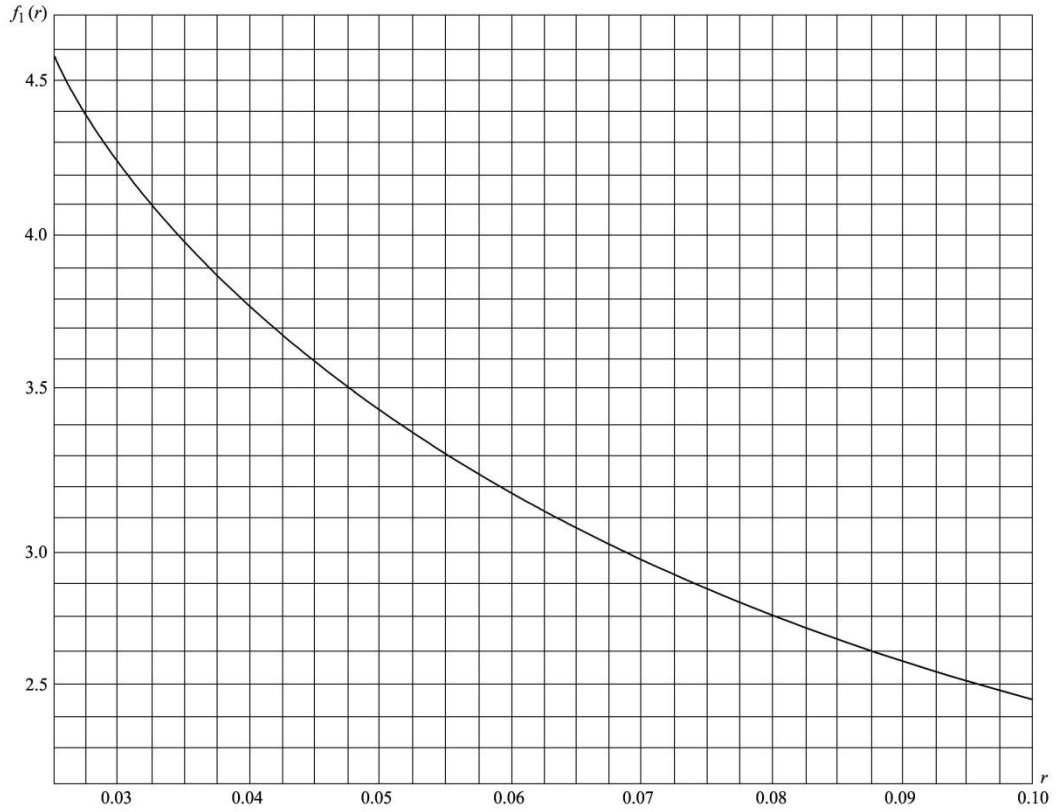


Figure 3.3.3(1)

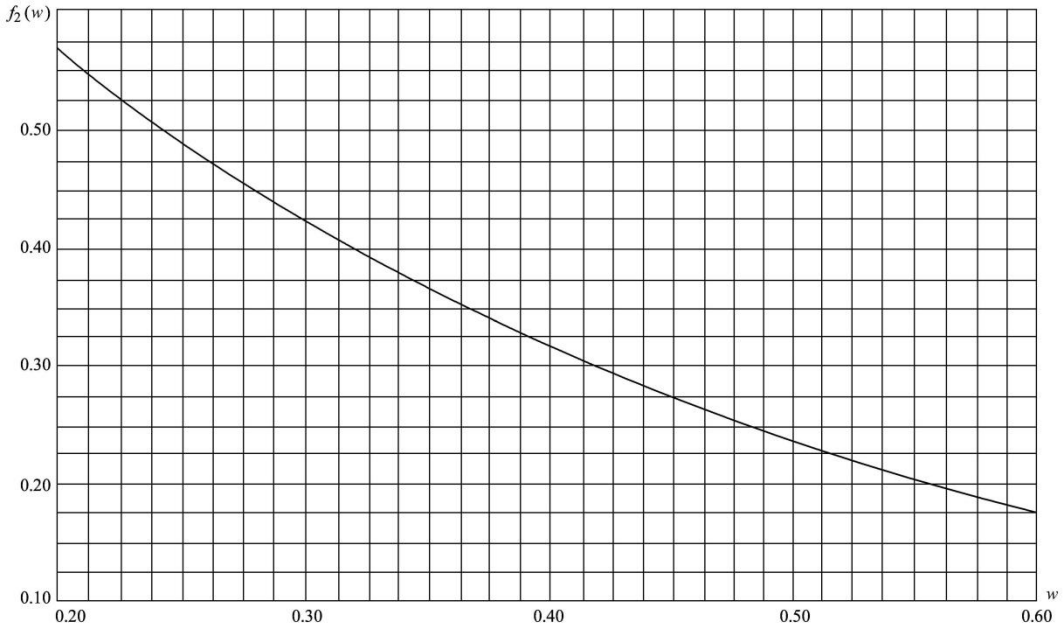


Figure 3.3.3(2)

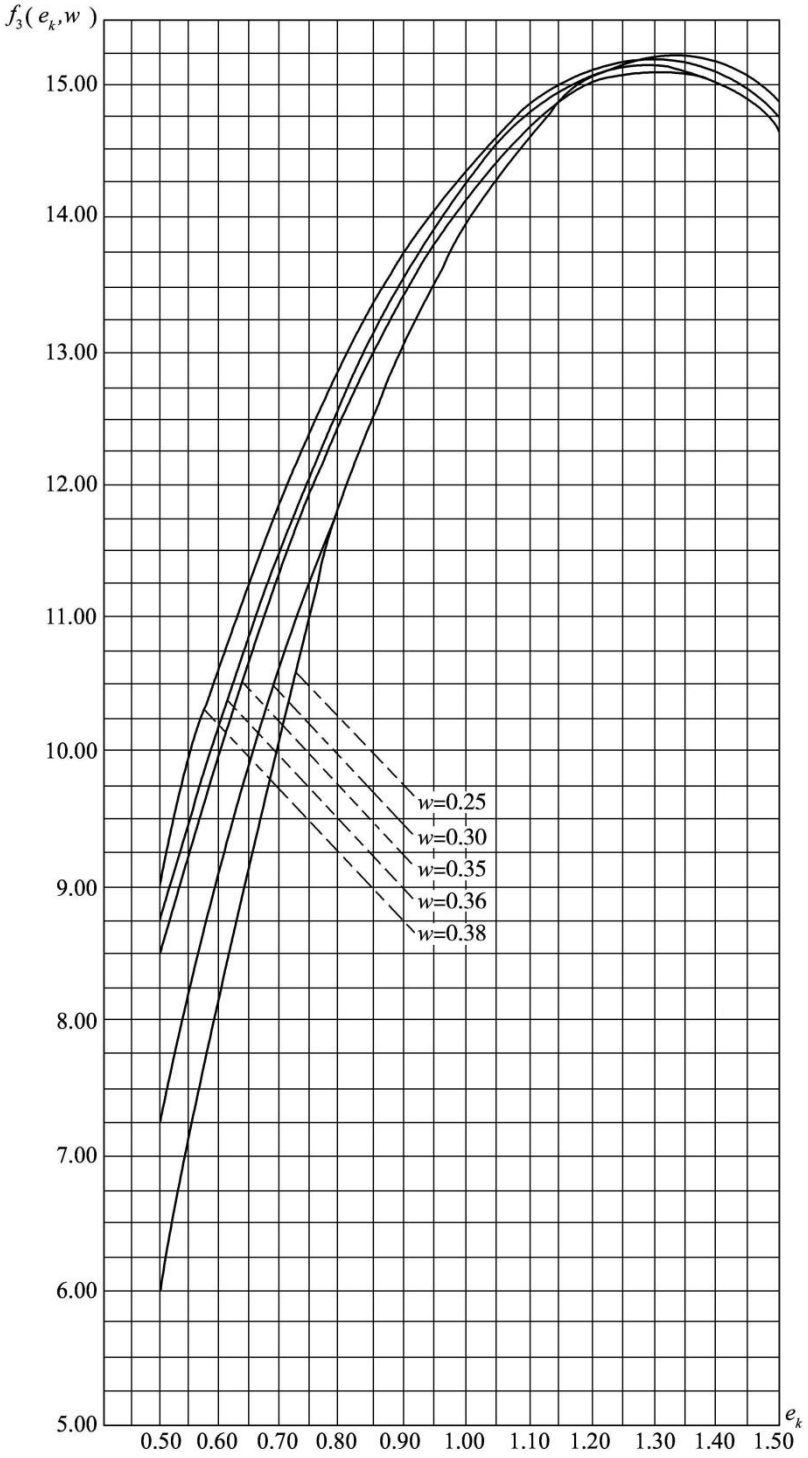


Figure 3.3.3(3)a

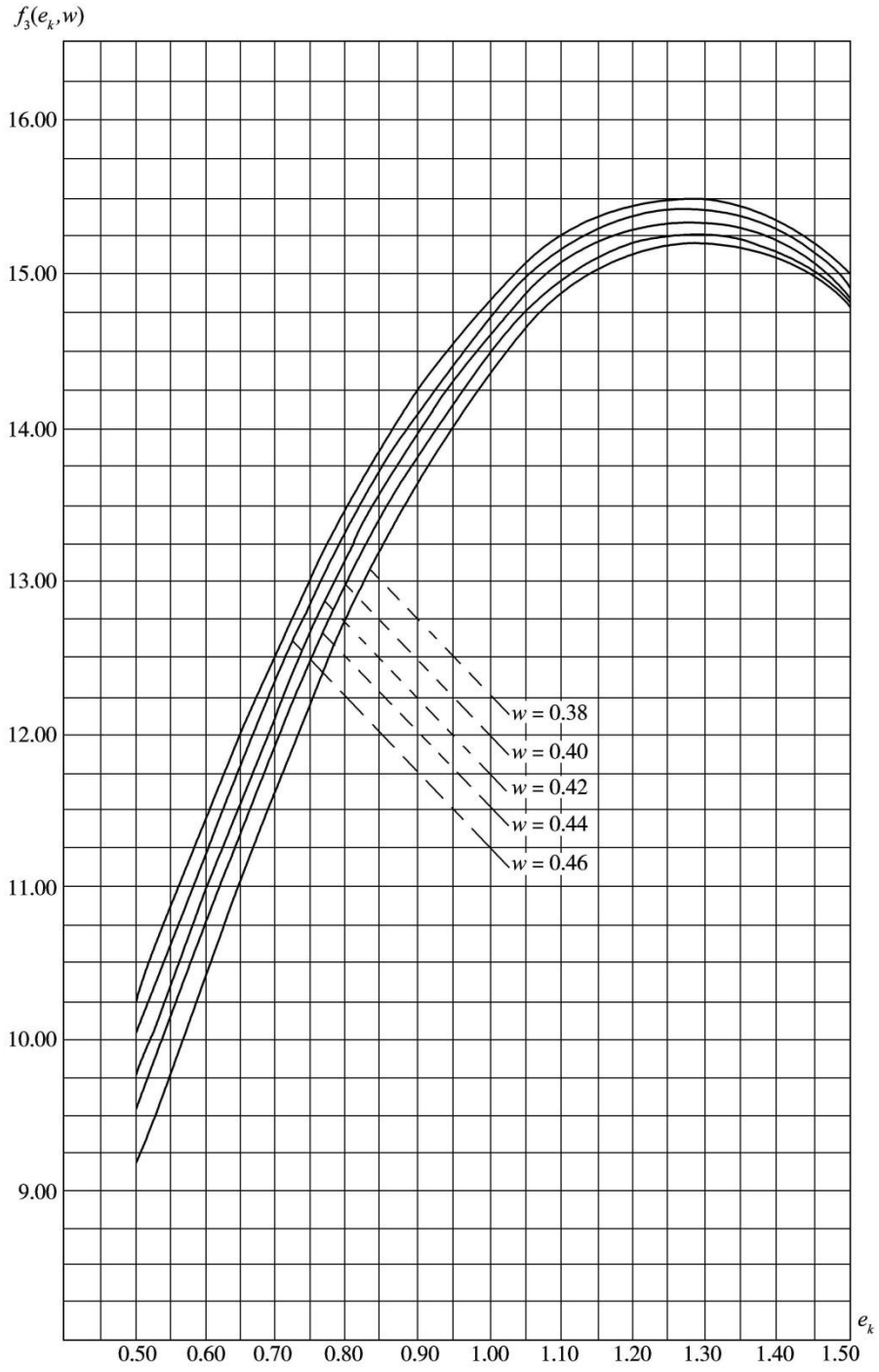


Figure 3.3.3(3)(b)

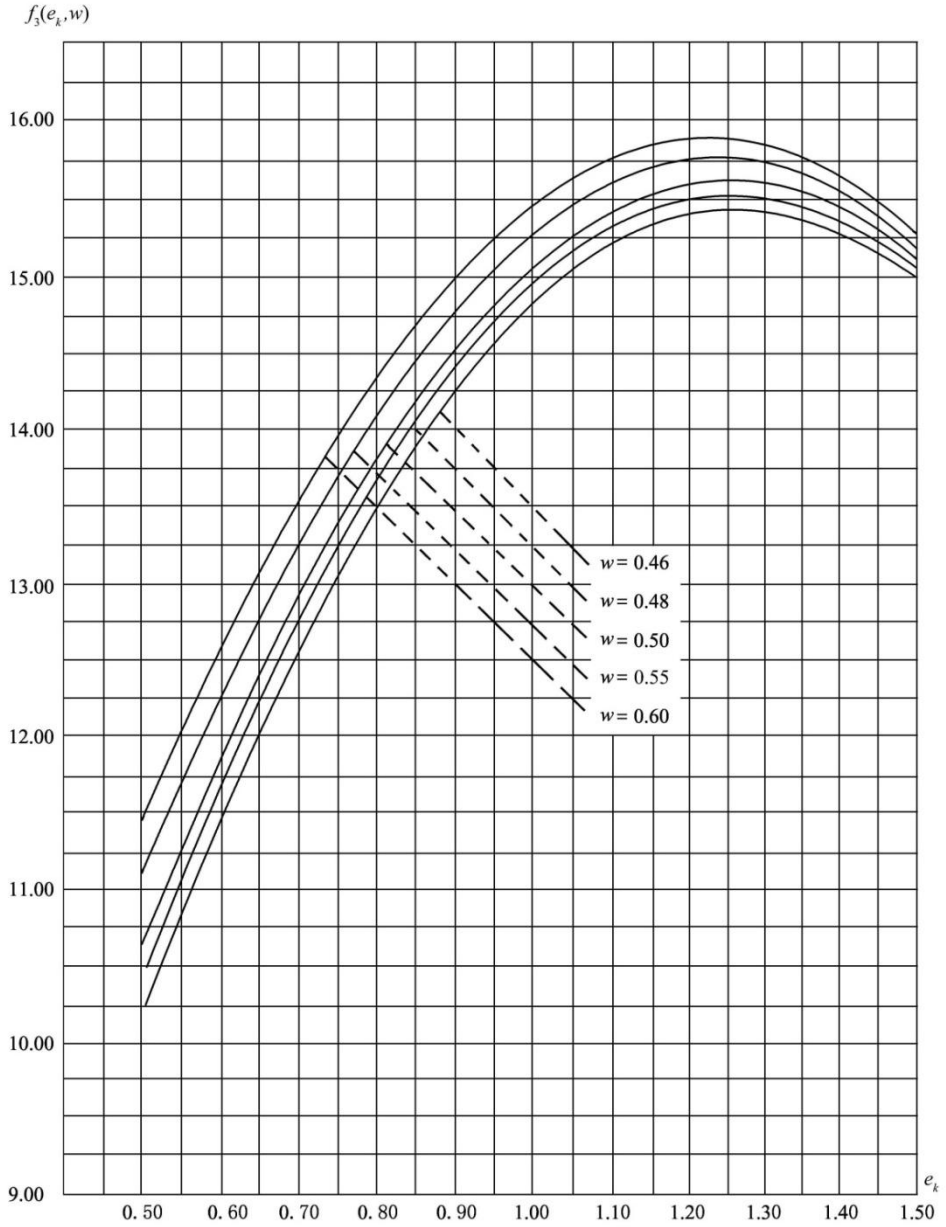


Figure 3.3.3(3)c

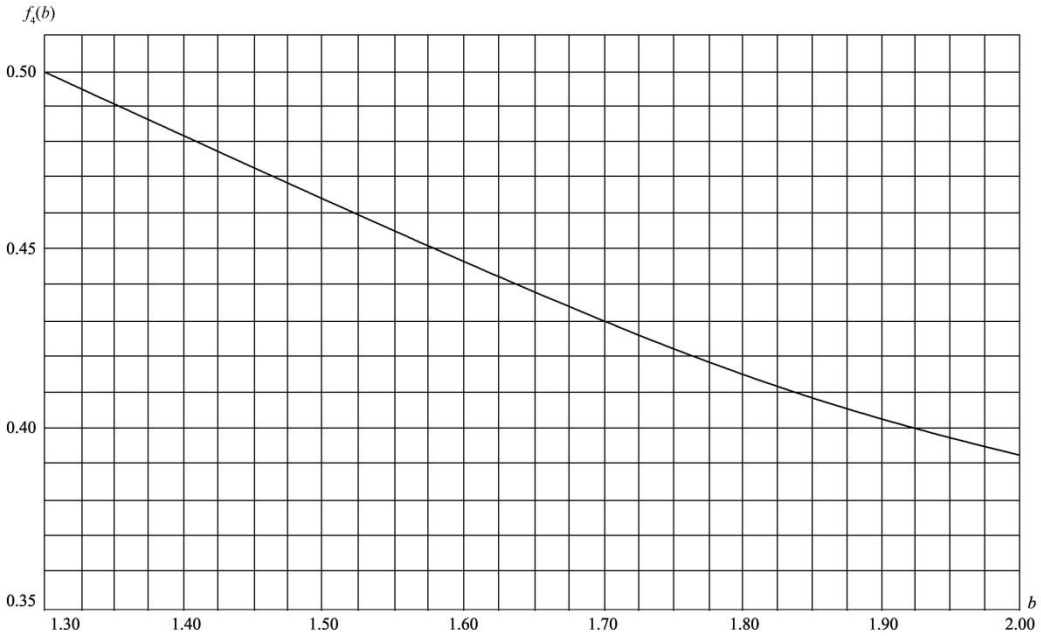


Figure 3.3.3(4)

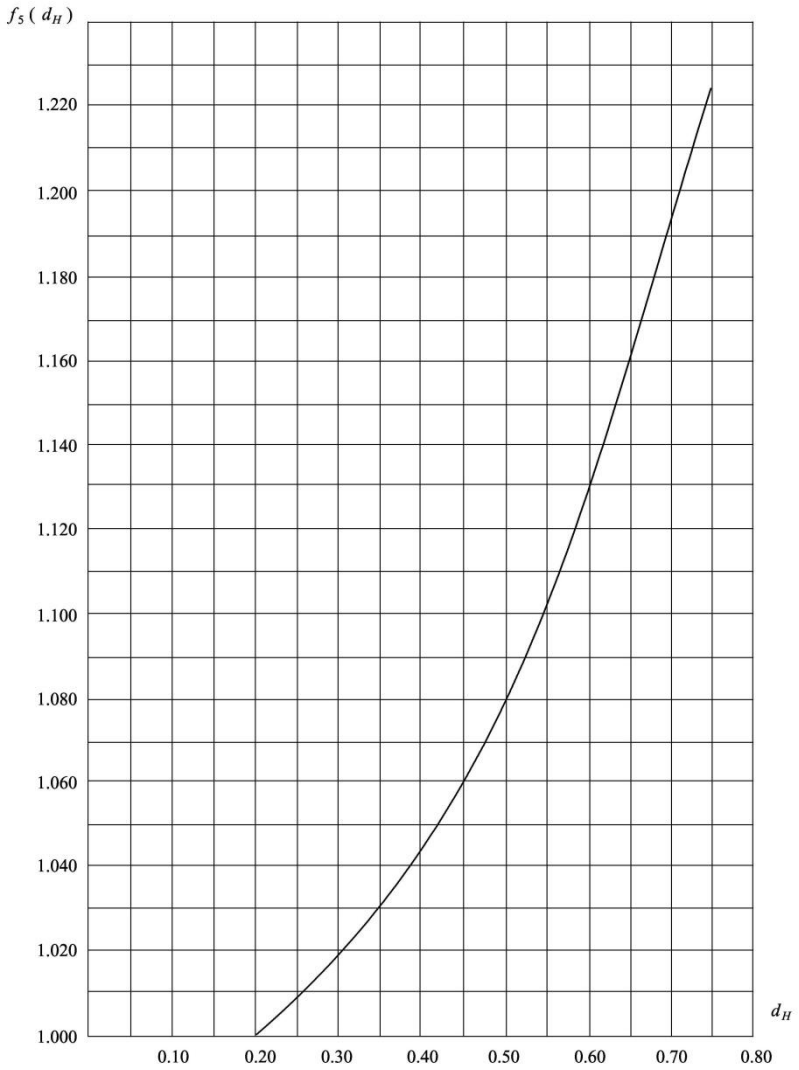


Figure 3.3.3(5)

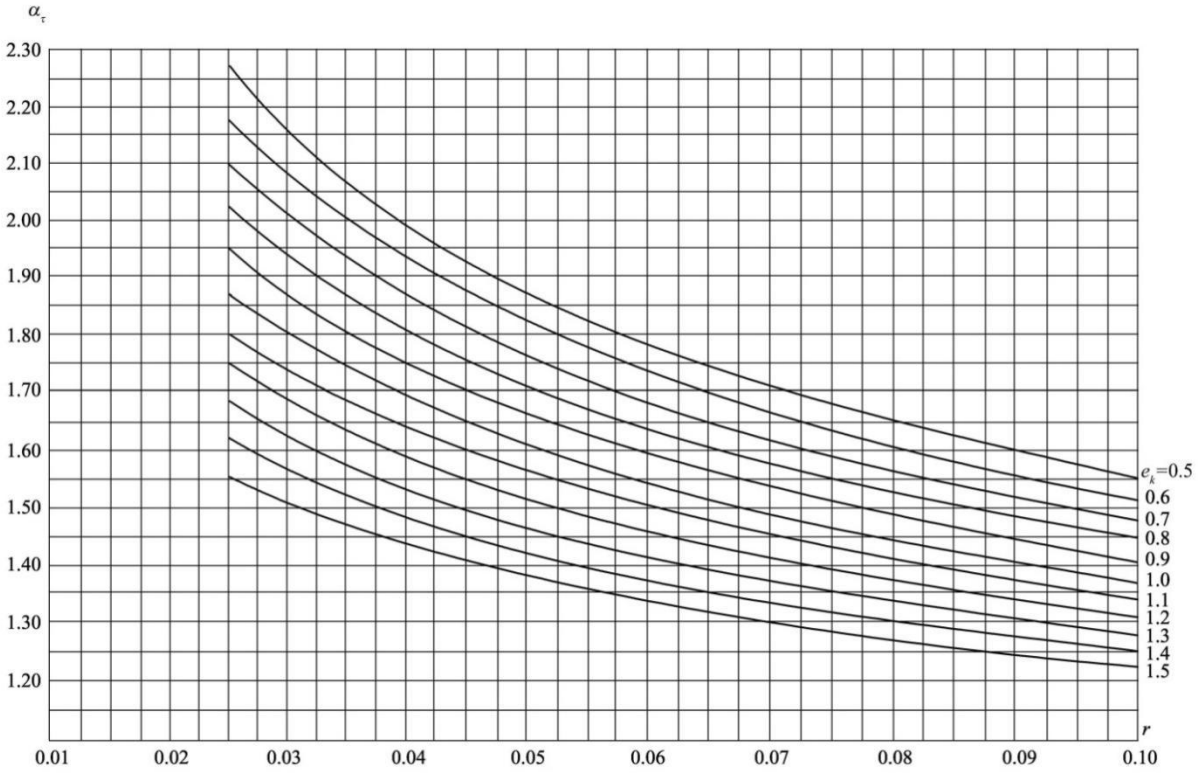


Figure 3.3.3(6)

4 Calculation of Shrink-fits of Semi-built Crankshafts

4.1 Geometry

4.1.1 All crank dimensions necessary for the calculation of shrink-fits are shown in Figure 4.1.1.

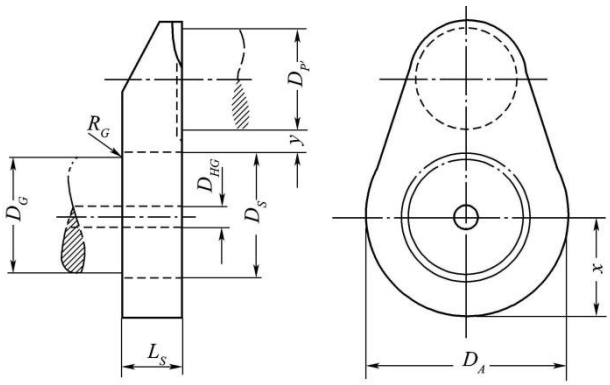


Figure 4.1.1 Crank Throw of Semi-built Crankshaft

where: D_S — shrink diameter, in mm;

L_S — length of shrink-fit, in mm;

D_A — outside diameter of web or twice the minimum distance x between centre-line of journals and outer edge of web, whichever is less, in mm;

y — distance between the adjacent generating lines of journal and pin.

$y \geq 0.05D_S$, in mm;

where y is less than $0.1D_S$, special consideration is to be given to the effect of the stress due to shrink on the fatigue strength at the crankpin fillet.

For other parameters, see 2.4.1 and Figure 2.4.1(3) of this Appendix.

4.1.2 For the arc radius of the journal transiting to the diameter of the shrink-fit, the following formulae are to be complied with:

$R_G \geq 0.015D_G$ and $R_G \geq 0.5(D_S - D_G)$, whichever is greater to be taken.

4.2 Maximum permissible hole diameter D_{BG} in the journal pin

4.2.1 In the case where the hole diameter in the journal pin is greater than the value obtained according to 4.2.2, then the calculation methods of minimum oversize Z_{min} and maximum oversize Z_{max} are not applicable to oversize of shrink-fit. In such case the maximum and minimum oversizes have to be established based on FEM calculations.

4.2.2 Calculation of maximum permissible hole diameter D_{BG}

The maximum permissible hole diameter D_{BG} in the journal pin is calculated in accordance with the following formula:

$$D_{BG} = D_S \cdot \sqrt{1 - \frac{4000 S_R M_{max}}{\mu \pi D_S^2 L_s R_{eH}}} \qquad \text{mm}$$

where: S_R — safety factor against slipping, however a value not less than 2 is to be taken unless documented by experiments;

μ — coefficient for static friction, $\mu = 0.20$ for $L_S / D_S \geq 040$;

$M_{max} = M_T + 9.55 \frac{N_e}{n_e}$ N·m , where the maximum torque M_{max} corresponds to the maximum torque M_{Tmax} of mass points of the crankshaft determined in 2.3.3(1), i.e., after mean torque is considered, M_{max} may be obtained from nominal torque M_T (see 2.3.3(1)) and mean transfer torque of crankshaft;

R_{eH} — minimum yield strength of material for journal, in MPa;

N_e — rated power of diesel engines, in kW;

n_e — corresponding rated speed, in r/min.

4.3 Interference fit

4.3.1 Calculation of minimum oversize of shrink-fit

The minimum oversize of shrink-fit is to be determined by the greater value calculated in accordance with the formulae in 4.3.1(1) and 4.3.1(2).

(1) The minimum oversize of shrink-fit Z_{min} is to comply with the following formula:

$$Z_{min} \geq \frac{4 \times 10^3}{\pi \mu} \times \frac{S_R M_{max}}{E_m D_S L_S} \times \frac{1 - Q_A^2 Q_S^2}{(1 - Q_A^2)(1 - Q_S^2)} \qquad \text{mm}$$

where: $Q_A = \frac{D_S}{D_A}$;

$Q_S = \frac{D_{BG}}{D_S}$;

E_m — Young's modulus, in MPa.

For other parameters, see 4.2.2 of this Appendix.

(2) Minimum oversize of shrink-fit Z_{min} is also to comply with the following formula:

$$Z_{min} \geq \frac{R_{eH} \cdot D_S}{E_m} \qquad \text{mm}$$

where: R_{eH} — minimum yield strength of material for crank web, in MPa.

4.3.2 Determination of maximum permissible interference

The maximum interference of shrink-fit crankshaft is to limit the influence of the interference fit on mean stress in fillets. The maximum permissible interference Z_{max} may be calculated in accordance with the following:

$$Z_{max} \leq \frac{\delta_S D_S}{E_m} + \frac{0.8 D_S}{1000} \qquad \text{mm}$$

5 Influence of Shafting on Crankshaft Strength

5.1 Summary

5.1.1 Crankshaft strength is not only related to crankshaft material, structure dimensions and technology, but also related to arrangement and installation of the whole shafting. During the stage of crankshaft design, fatigue strength of the crankshaft may be determined in accordance with the method in 2 of this Appendix, so that the allowable torsional stress, axial stress and compulsory repair span difference may be obtained.

5.1.2 During the stage of crankshaft design, the phenomena such as torsional vibration-axial vibration or torsion-longitudinal coupling vibration.
5.1.3 Where torsional antivibrator and/or axial antivibrator are installed, alternating torsional stress τ_H and additional axial bending stress σ_{ax} will be less than the values given in 2.3 and 2.5. Thus, the fatigue strength of the crankshaft may be increased.
5.1.4 Shafting arrangement and installation are to satisfy the requirements of torsional vibration, axial vibration and alignment as specified in rules and by the manufacturers. However, if one item is not in compliance with the specified value due to special condition, the actual value may be used in the fatigue acceptability factor Q. Where $Q \geq 1.15$ is still complied with, it is safe to the crankshaft. However attention is to be paid not to exceed the fatigue strength of the material.

5.2 Torsional vibration
5.2.1 To simplify calculation, the allowable torsional vibration stress specified by CCS Rules may be treated as τ_H.
5.2.2 Where the allowable torsional vibration stress provided by the manufacturer exceeds that specified in the Rules, calculation is to be submitted for review in accordance with the requirements of 2.3.3.
5.2.3 During shafting calculation or actual measurement, if the allowable value of the rated speed is found to exceed that specified in the Rules or by the manufacturer, the actual τ_H may be used in the fatigue acceptability factor Q, and the actual value of the additional bending stress caused in axial vibration may be used. Where $Q \geq 1.15$ is still complied with, it is safe to the crankshaft. However, the related calculation data are to be submitted for examination.

5.3 Longitudinal vibration
5.3.1 Propulsion shafting of two-stroke diesel engines is to be subject to longitudinal vibration calculation, while four-stroke diesel engines will not cause longitudinal vibration of shafting. It may be found from 2.5 of this Appendix that additional alternating bending stress σ_{ax} at fillet caused by axial vibration equals to 20 MPa, and additional alternating bending stress caused by shafting misalignment is 10 MPa. Therefore, the diesel engine manufacturers are to determine the allowable amplitude of longitudinal vibration of the crankshaft free end in accordance with 20 MPa additional axial stress.
5.3.2 Diesel engine manufacturers may also provide the allowable amplitude of longitudinal vibration in accordance with the determined crankshaft dimensions and technology parameters on the basis of $Q \geq 1.15$, and submit related calculations for examination.
5.3.3 Under special conditions, if the amplitude of the longitudinal vibration at rated speed during actual measurement is found to exceed the value specified in the Rules or by the manufacturers, the actual σ_{ax} and τ_H may be used in the acceptability factor Q. Where $Q \geq 1.15$ is still complied with, it is safe to the crankshaft.

5.4 Alignment
5.4.1 After the diesel engine is connected with shafting, the bending moment and shearing force at the crankshaft ends due to shafting alignment causes additional bending stress upon crankpins. It is generally to be measured by means of controlling the difference of crank span.
5.4.2 For propulsion shafting of diesel engines needing to be aligned as specified in the Rules, reasonable alignment calculation and installation technology are to be submitted. Diesel engine manufacturers also specify the bending moment and shearing force in hot state and cold state on crankshaft of diesel engine.
During reasonable shafting alignment, if the bending moment and shearing force provided by the diesel engine manufacturers are not complied with but the crankshaft span difference still complies with the requirements, it is also acceptable. This is because the bending moment applied to the crankshaft end is shown in the form of the changing of the span difference.

5.5 Span difference
5.5.1 Additional bending stress σ_{add} given in 2.5 of this Appendix is actually the combination of additional stress σ_{ax} caused by axial vibration of shafting and additional compulsory repair bending stress σ_{aa}. Therefore, diesel engine manufacturers are to provide the span difference of the compulsory repair crankshafts in accordance with the σ_{aa} value adopted in the calculation of acceptability factor Q for actual use.
5.5.2 For two-stroke diesel engines, if there is no axial vibration of shafting or bending stress σ_{ax} caused by axial vibration < 20 MPa, or the margin of acceptability factor Q is greater, the compulsory repair span difference may be deduced on the basis of $Q \geq 1.15$. However, the related calculations are to be submitted for examination.

5.5.3 Where the span difference of the crankshafts of the ship in service exceeds the normal value or design value, the actual values τ_H, σ_{ax} and σ_{aa} may be used in Q. Where $Q \geq 1.15$ is complied with, it is safe to the crankshaft.

Annex I Guidance for Evaluation of Fatigue Tests of Crankshafts

Contents

1 Introduction
1.1 Small specimen testing
1.2 Full-size crank throw testing

2 Evaluation of test results
2.1 Principles
2.2 Staircase method
2.3 Modified staircase method
2.4 Calculation of sample mean and standard deviation
2.5 Confidence interval for mean fatigue limit
2.6 Confidence interval for standard deviation

3 Small specimen testing
3.1 Determination of bending fatigue strength
3.2 Determination of torsional fatigue strength
3.3 Other test positions
3.4 Correlation of test results

4 Full size testing
4.1 Hydraulic pulsation
4.2 Resonance tester
4.3 Use of results and crankshaft acceptability

5 Use of existing results for similar crankshafts

1 Introduction

Fatigue testing can be divided into two main groups: testing of small specimens and full-size crank throws. Testing can be made using the staircase method or a modified version thereof which is presented in this document. Other statistical evaluation methods may also be applied.

1.1 Small specimen testing

For crankshafts without any fillet surface treatment, the fatigue strength can be determined by testing small specimens taken from a full-size crank throw. When other areas in the vicinity of the fillets are surface treated introducing residual stresses in the fillets, this approach cannot be applied.

One advantage of this approach is the rather high number of specimens which can be then manufactured. Another advantage is that the tests can be made with different stress ratios (R-ratios) and/or different modes e.g. axial, bending and torsion, with or without a notch. This is required for evaluation of the material data to be used with critical plane criteria.

1.2 Full-size crank throw testing

For crankshafts with surface treatment the fatigue strength can only be determined through testing of full size crank throws. For cost reasons, this usually means a low number of crank throws. The load can be applied by hydraulic actuators in a 3- or 4- point bending arrangement, or by an exciter in a resonance test rig. The latter is frequently used, although it usually limits the stress ratio to $R = -1$.

2 Evaluation of test results

2.1 Principles

Prior to fatigue testing the crankshaft must be tested as required by quality control procedures, e.g. for chemical composition, mechanical properties, surface hardness, hardness depth and extension, fillet surface finish, etc.

The test samples are to be prepared so as to represent the “lower end” of the acceptance range e.g. for induction hardened crankshafts this means the lower range of acceptable hardness depth, the shortest extension through a fillet, etc. Otherwise the mean value test results are to be corrected with a confidence interval: a 90% confidence interval may be used both for the sample mean and the standard deviation.

The test results, when applied in check of crankshaft fatigue strength, are to be evaluated to represent the mean fatigue strength, with or without taking into consideration the 90% confidence interval as mentioned above. The standard deviation is to be considered by taking the 90% confidence into account. Subsequently the result to be used as the fatigue strength is then the mean fatigue strength minus one standard deviation.

If the evaluation aims to find a relationship between (static) mechanical properties and the fatigue strength, the relation must be based on the real (measured) mechanical properties, not on the specified minimum properties.

The calculation technique presented in 2.4 of this Annex was developed for the original staircase method. However, since there is no similar method dedicated to the modified staircase method the same is applied for both.

2.2 Staircase method

In the original staircase method, the first specimen is subjected to a stress corresponding to the expected average fatigue strength. If the specimen survives 10^7 cycles, it is discarded and the next specimen is subjected to a stress that is one increment above the previous, i.e. a survivor is always followed by the next using a stress one increment above the previous. The increment is to be selected to correspond to the expected level of the standard deviation.

When a specimen fails prior to reaching 10^7 cycles, the obtained number of cycles is noted and the next specimen is subjected to a stress that is one increment below the previous. With this approach, the sum of failures and run-outs is equal to the number of specimens.

This original staircase method is only suitable when a high number of specimens are available. Through simulations it has been found that the use of about 25 specimens in a staircase test leads to a sufficient accuracy in the result.

2.3 Modified staircase method

When a limited number of specimens are available, it is advisable to apply the modified staircase method. Here the first specimen is subjected to a stress level that is most likely well below the average fatigue strength. When this specimen has survived 10^7 cycles, this same specimen is subjected to a stress level one increment above the previous. The increment is to be selected to correspond to the expected level of the standard deviation.

This is continued with the same specimen until failure. Then the number of cycles is recorded and the next specimen is subjected to a stress that is at least 2 increments below the level where the previous specimen failed.

With this approach, the number of failures usually equals the number of specimens. The number of

run-outs, counted as the highest level where 10^7 cycles were reached, also equals the number of specimens.
The acquired result of a modified staircase method is to be used with care, since some results available indicate that testing a run-out on a higher test level, especially at high mean stresses, tends to increase the fatigue limit. However, this "training effect" is less pronounced for high strength steels (e.g. UTS > 800 MPa).
If the confidence calculation is desired or necessary, the minimum number of test specimens is 3.

2.4 Calculation of sample mean and standard deviation

A hypothetical example of tests for 5 crank throws is presented further in the subsequent text. When using the modified staircase method and the evaluation method of Dixon and Mood, the number of samples will be 10, meaning 5 run-outs and 5 failures, i.e.:
Number of samples, n=10
Furthermore, the method distinguishes between:
(1) *Less frequent event is failures C=1*
(2) *Less frequent event is run-outs C=2*
The method uses only the less frequent occurrence in the test results, i.e. if there are more failures than run-outs, then the number of run-outs is used, and vice versa.
In the modified staircase method, the number of run-outs and failures are usually equal. However, the testing can be unsuccessful, e.g. the number of run-outs can be less than the number of failures if a specimen with 2 increments below the previous failure level goes directly to failure. On the other hand, if this unexpected premature failure occurs after a rather high number of cycles, it is possible to define the level below this as a run-out.
Dixon and Mood's approach, derived from the maximum likelihood theory, which also may be applied here, especially on tests with few samples, presented some simple approximate equations for calculating the sample mean and the standard deviation from the outcome of the staircase test.
The sample mean can be calculated as follows:

$$\bar{S}_a = S_{a0} + d \cdot \left(\frac{A}{F} - \frac{1}{2} \right) \quad \text{when } C=1$$

$$\bar{S}_a = S_{a0} + d \cdot \left(\frac{A}{F} + \frac{1}{2} \right) \quad \text{when } C=2$$

The standard deviation can be found by:

$$s = 1.62 \cdot d \cdot \left(\frac{F \cdot B - A^2}{F^2} + 0.029 \right)$$

where:
S_{a0} is the lowest stress level for the less frequent occurrence;
d is the stress increment;

$$F = \sum f_i ;$$
$$A = \sum i \cdot f_i ;$$
$$B = \sum i^2 \cdot f_i ;$$

i is the stress level numbering;
f_i is the number of samples at stress level i;
The formula for the standard deviation is an approximation and can be used when:
(1) $\frac{B \cdot F - A^2}{F^2} > 0.3$;
(2) $0.5 \cdot s < d < 1.5 \cdot s$.
If any of these two conditions are not fulfilled, a new staircase test is to be considered or the standard deviation is to be taken quite large in order to be on the safe side.
If increment d is greatly higher than the standard deviation s, the procedure leads to a lower standard deviation and a slightly higher sample mean, both compared to values calculated when the difference between the increment and the standard deviation is relatively small.
Respectively, if increment d is much less than the standard deviation s, the procedure leads to a higher standard deviation and a slightly lower sample mean.

2.5 Confidence interval for mean fatigue limit

If the staircase fatigue test is repeated, the sample mean and the standard deviation will most likely be

different from the previous test. Therefore, it is necessary to assure with a given confidence that the repeated test values will be above the chosen fatigue limit by using a confidence interval for the sample mean.
The confidence interval for the sample mean value with unknown variance is known to be distributed according to the *t*-distribution (also called *student's t-distribution*) which is a distribution symmetric around the average.
The confidence level normally used for the sample mean is 90%, meaning that 90% of sample means from repeated tests will be above the value calculated with the chosen confidence level. Figure I-2.1 shows the *t*-value for (1 - α)·100% confidence interval for the sample mean.

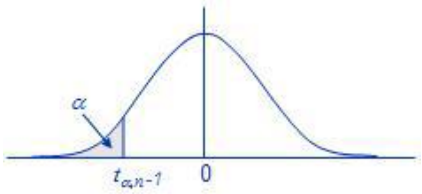


Figure I-2.1 Student's t-distribution

If S_a is the empirical mean and s is the empirical standard deviation over a series of n samples, in which the variable values are normally distributed with an unknown sample mean and unknown variance, the (1 - α)·100% confidence interval for the mean is:

$$P\left(S_a - t_{\alpha,n-1} \cdot \frac{s}{\sqrt{n}} < S_{aX\%}\right) = 1 - \alpha$$

The resulting confidence interval is symmetric around the empirical mean of the sample values, and the lower endpoint can be found as:

$$S_{aX\%} = S_a - t_{\alpha,n-1} \cdot \frac{s}{\sqrt{n}}$$

which is the mean fatigue limit (population value) to be used to obtain the reduced fatigue limit where the limits for the probability of failure are taken into consideration.

2.6 Confidence interval for standard deviation

The confidence interval for the variance of a normal random variable is known to possess a chi-square distribution with n - 1 degrees of freedom.
The confidence level on the standard deviation is used to ensure that the standard deviations for repeated tests are below an upper limit obtained from the fatigue test standard deviation with a confidence level. Figure I-2.2 shows the chi-square for (1 - α)·100% confidence interval for the variance.

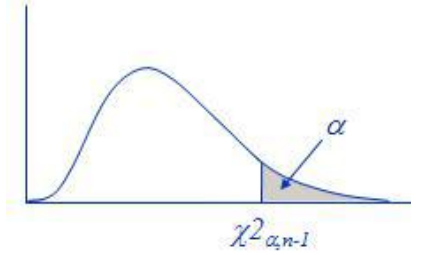


Figure I-2.2 Chi-square distribution

An assumed fatigue test value from n samples is a normal random variable with a variance of σ^2 and has an empirical variance s^2. Then a (1 - α)·100% confidence interval for the variance is:

$$P\left(\frac{(n-1)s^2}{\sigma^2} < X^2_{\alpha,n-1}\right) = 1 - \alpha$$

A (1 - α)·100% confidence interval for the standard deviation is obtained as follows:

$$s_{X\%} = \sqrt{\frac{n-1}{X^2_{\alpha,n-1}}} \cdot s$$

This standard deviation (population value) is to be used to obtain the fatigue limit, where the limits for the probability of failure are taken into consideration.

3 Small specimen testing

In this connection, a small specimen is considered to be one of the specimens taken from a crank throw. Since the specimens are to be representative for the fillet fatigue strength, they are to be taken out close to the fillets, as shown in Figure I-3.1.

It is to be made certain that the principal stress direction in the specimen testing is equivalent to the full-size crank throw. The verification is recommended to be done by utilizing the finite element method.

The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

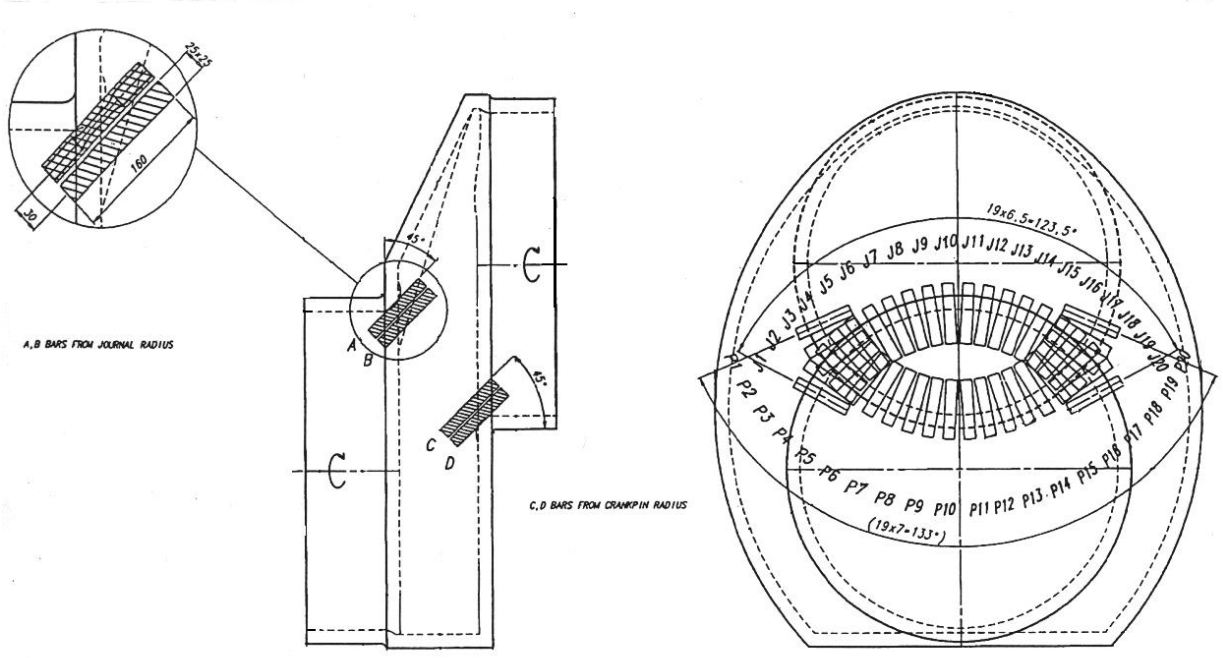


Figure I-3.1 Specimen locations in a crank throw

3.1 Determination of bending fatigue strength

It is advisable to use un-notched specimens in order to avoid uncertainties related to the stress gradient influence. Push-pull testing method (stress ratio R = -1) is preferred, but especially for the purpose of critical plane criteria other stress ratios and methods may be added.

In order to ensure principal stress direction in push-pull testing to represent the full-size crank throw principal stress direction and when no further information is available, the specimen is to be taken in 45 degrees angle as shown in Figure I-3.1.

(1) If the objective of the testing is to document the influence of high cleanliness, test samples taken from positions approximately 120 degrees in a circumferential direction may be used. See Figure I-3.1.

(2) If the objective of the testing is to document the influence of continuous grain flow (cgf) forging, the specimens are to be restricted to the vicinity of the crank plane.

3.2 Determination of torsional fatigue strength

(1) If the specimens are subjected to torsional testing, the selection of samples is to follow the same guidelines as for bending above. The stress gradient influence has to be considered in the evaluation.

(2) If the specimens are tested in push-pull and no further information is available, the samples are to be taken out at an angle of 45 degrees to the crank plane in order to ensure collinearity of the principal stress direction between the specimen and the full-size crank throw. When taking the specimen at a distance from the (crank) middle plane of the crankshaft along the fillet, this plane rotates around the pin centre point making it possible to re-sample the fracture direction due to torsion (the results are to be converted into the pertinent torsional values).

3.3 Other test positions

If the test purpose is to find fatigue properties and the crankshaft is forged in a manner likely to lead to cgf, the specimens may also be taken longitudinally from a prolonged shaft piece where specimens for mechanical testing are usually taken. The condition is that this prolonged shaft piece is heat treated as a part of the crankshaft and that the size is so as to result in a similar quenching rate as the crank throw.

When using test results from a prolonged shaft piece, it must be considered how well the grain flow in that shaft piece is representative for the crank fillets.

3.4 Correlation of test results

The fatigue strength achieved by specimen testing is to be converted to correspond to the full-size crankshaft fatigue strength with an appropriate method (size effect).
When using the bending fatigue properties from tests mentioned in this section, it is to be kept in mind that successful continuous grain flow (cgf) forging leading to elevated values compared to other (non cgf) forging, will normally not lead to a torsional fatigue strength improvement of the same magnitude.
In such cases it is advised to either carry out also torsional testing or to make a conservative assessment of the torsional fatigue strength, e.g. by using no credit for cgf. This approach is applicable when using the Gough Pollard criterion. However, this approach is not recognized when using the von Mises or a multi-axial criterion such as Findley.
If the found ratio between bending and torsion fatigue differs significantly from $\sqrt{3}$, one is to consider replacing the use of the von Mises criterion with the Gough Pollard criterion. Also, if critical plane criteria are used, it must be kept in mind that cgf makes the material inhomogeneous in terms of fatigue strength, meaning that the material parameters differ with the directions of the planes.
Any addition of influence factors must be made with caution. If for example a certain addition for clean steel is documented, it may not necessarily be fully combined with a *K*-factor for cgf. Direct testing of samples from a clean and cgf forged crank is preferred.

4 Full size testing

4.1 Hydraulic pulsation

A hydraulic test rig can be arranged for testing a crankshaft in 3-point or 4-point bending as well as in torsion. This allows for testing with any *R*-ratio.
Although the applied load is to be verified by strain gauge measurements on plain shaft sections for the initiation of the test, it is not necessarily used during the test for controlling load. It is also pertinent to check fillet stresses with strain gauge chains.
Furthermore, it is important that the test rig provides boundary conditions as defined in 2.4.5(3)①~③ of this Appendix.
The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

4.2 Resonance tester

A rig for bending fatigue normally works with an *R*-ratio of -1. Due to operation close to resonance, the energy consumption is moderate. Moreover, the frequency is usually relatively high, meaning that 10^7 cycles can be reached within some days. Figure I-4.1 shows a layout of the testing arrangement.
The applied load is to be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains.

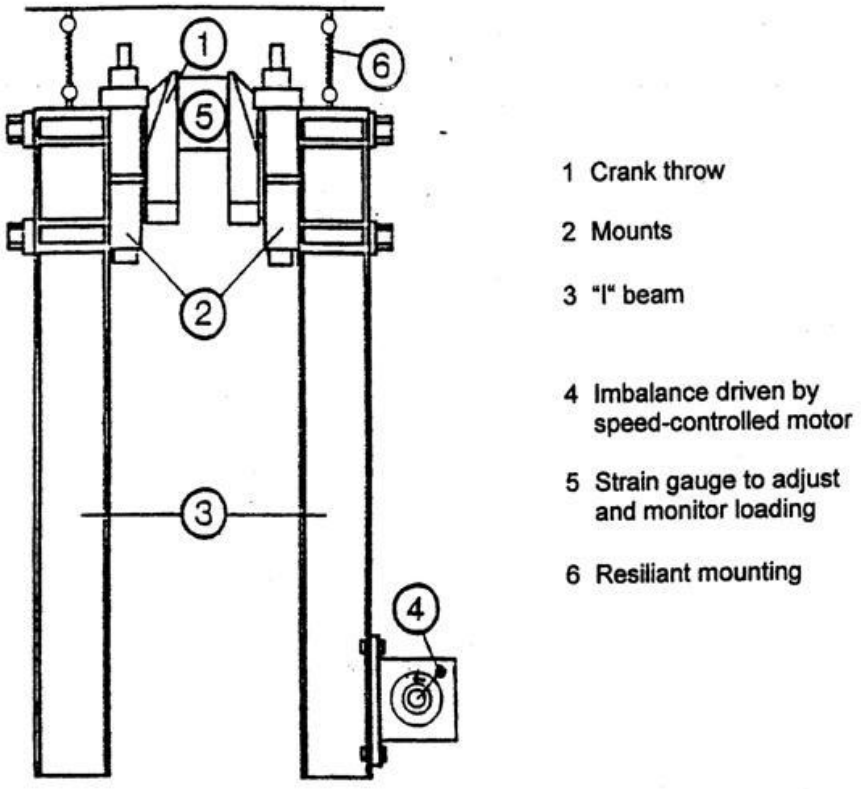


Figure I-4.1 An example of testing arrangement of the resonance tester for bending loading

Clamping around the journals must be arranged in a way that prevents severe fretting which could lead to a failure under the edges of the clamps. If some distance between the clamps and the journal fillets is provided, the loading is consistent with 4-point bending and thus representative for the journal fillets also.
In an engine, the crankpin fillets normally operate with an *R*-ratio slightly above -1 and the journal fillets slightly below -1. If found necessary, it is possible to introduce a mean load (deviate from $R = -1$) by means of a spring preload.
A rig for torsion fatigue can also be arranged as shown in Figure I-4.2. When a crank throw is subjected to torsion, the twist of the crankpin makes the journals move sideways. If one single crank throw is tested in a torsion resonance test rig, the journals with their clamped-on weights will vibrate heavily sideways.
This sideway movement of the clamped-on weights can be reduced by having two crank throws, especially if the cranks are almost in the same direction. However, the journal in the middle will move more.

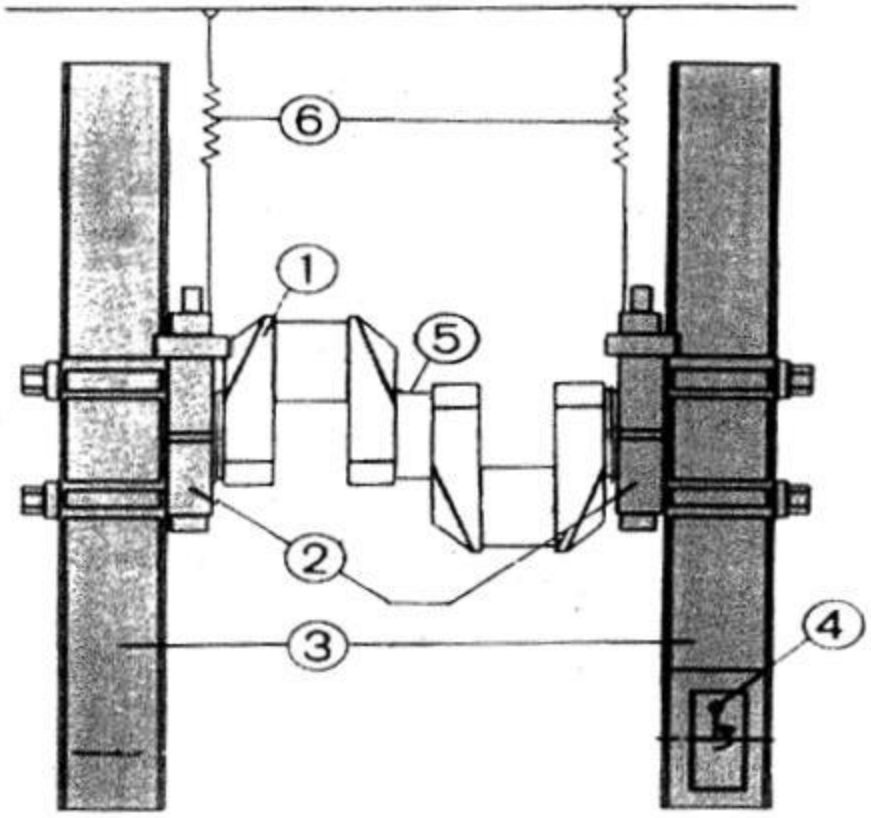


Figure I-4.2 An example of testing arrangement of the resonance tester for torsion loading with double crank throw section

Since sideway movements can cause some bending stresses, the plain portions of the crankpins are also to be provided with strain gauges arranged to measure any possible bending that could have an influence on the test results.
Similarly, to the bending case the applied load is to be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains as well.

4.3 Use of results and crankshaft acceptability

In order to combine tested bending and torsion fatigue strength results in calculation of crankshaft acceptability, see 2.8 of this Appendix, the Gough-Pollard approach and the maximum principal equivalent stress formulation can be applied for the following cases:

At the crankpin fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BH} + \sigma_{add}}{\sigma_{DWCT}} \right)^2 + \left(\frac{\tau_H}{\tau_{DWCT}} \right)^2} \right)^{-1}$$

where:

σ_{DWCT}— fatigue strength by bending testing;

τ_{DWCT}— fatigue strength by torsion testing.

For other parameters see this Appendix.

Related to crankpin oil bore:

$$Q = \frac{\sigma_{DWOT}}{\sigma_v}$$

where:

σ_{DWOT}—fatigue strength by means of largest principal stress from torsion testing;

$$\sigma_v = \pm \frac{1}{3} \sigma_{BO} \left[1 + 2 \sqrt{1 + \frac{9}{4} \left(\frac{\sigma_{TO}}{\sigma_{BO}} \right)^2} \right], \quad \text{MPa}$$

At the journal fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BG} + \sigma_{add}}{\sigma_{DWJT}} \right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}} \right)^2} \right)^{-1}$$

where:

σ_{DWJT}— fatigue strength by bending testing;

τ_{DWJT}— fatigue strength by torsion testing.

For other parameters see this Appendix.

In case increase in fatigue strength due to the surface treatment is considered to be similar between the above cases, it is sufficient to test only the most critical location according to the calculation where the surface treatment had not been taken into account.

5 Use of existing results for similar crankshafts

For fillets or oil bores without surface treatment, the fatigue properties found by testing may be used for similar crankshaft designs providing:

(1) **Material:**

- Similar material type;
- Cleanliness on the same or better level;
- The same mechanical properties can be granted (size versus hardenability).

(2) **Geometry:**

- Difference in the size effect of stress gradient is insignificant or it is considered;
- Principal stress direction is equivalent. See Part 3 of this Annex.

(3) **Manufacturing:**

- Similar manufacturing process.

Induction hardened or gas nitrited crankshafts will suffer fatigue either at the surface or at the transition to the core. The surface fatigue strength as determined by fatigue tests of full size cranks, may be used on an equal or similar design as the tested crankshaft when the fatigue initiation occurred at the surface. With the similar design, it is meant that a similar material type and surface hardness are used and the fillet radius and hardening depth are within approximately ± 30 % of the tested crankshaft.

Fatigue initiation in the transition zone can be either subsurface, i.e. below the hard layer, or at the surface where the hardening ends. The fatigue strength at the transition to the core can be determined by fatigue tests as described above, provided that the fatigue initiation occurred at the transition to the core. Tests made with the core material only will not be representative since the tension residual stresses at the transition are lacking.

It has to be noted also what some recent research has shown: The fatigue limit can decrease in the very high cycle domain with subsurface crack initiation due to trapped hydrogen that accumulates through diffusion around some internal defect functioning as an initiation point.
In these cases, it would be appropriate to reduce the fatigue limit by some percent per decade of cycles beyond 10^7. Based on a publication by Yukitaka Murakami “Metal Fatigue: Effects of Small Defects and Non-metallic Inclusions” the reduction is suggested to be 5 % per decade especially when the hydrogen content is considered to be high.

Annex II Guidance for Calculation of Fatigue Strength of Surface Treated Fillets and Oil Bore Outlets

Contents

1 Introduction

2 Definition of surface treatment
2.1 Surface treatment methods

3 Calculation principles
3.1 Evaluation of local fillet stresses
3.2 Evaluation of oil bore stresses
3.3 Acceptability criteria

4 Induction hardening
4.1 Local fatigue strength

5 Nitriding
5.1 Local fatigue strength

6 Cold forming
6.1 Stroke peening by means of a ball
6.1.1 Use of existing results for similar crankshafts
6.2 Cold rolling
6.2.1 Use of existing results for similar crankshafts

1 Introduction

This Annex deals with surface treated fillets and oil bore outlets. The various treatments are explained and some empirical formulae are given for calculation purposes. Conservative empiricism has been applied intentionally, in order to be on the safe side from a calculation standpoint.

Please note that measurements or more specific knowledge are to be used if available. However, in the case of a wide scatter (e.g. for residual stresses) the values are to be chosen from the end of the range that would be on the safe side for calculation purposes.

2 Definition of surface treatment

Surface treatment is a term covering treatments such as thermal, chemical or mechanical operations, leading to inhomogeneous material properties - such as hardness, chemistry or residual stresses – from the surface to the core.

2.1 Surface treatment methods

Table 2.1 covers possible treatment methods and how they influence the properties that are decisive for the fatigue strength.

Surface treatment methods and the characteristics they affect **Table 2.1**

Treatment method	Affecting
Induction hardening	Hardness and residual stresses
Nitriding	Chemistry, hardness and residual stresses
Case hardening	Chemistry, hardness and residual stresses
Die quenching (no temper)	hardness and residual stresses
Cold rolling	residual stresses
Stroke peening	residual stresses
Shot peening	residual stresses
Laser peening	residual stresses
Ball coining	residual stresses

It is important to note that since only induction hardening, nitriding, cold rolling and stroke peening are considered relevant for marine engines, other methods as well as combination of two or more of the above are not dealt with in this Annex. In addition, die quenching can be considered in the same way as induction hardening.

3 Calculation principles

The basic principle is that the alternating working stresses are to be below the local fatigue strength (including the effect of surface treatment) wherein non-propagating cracks may occur, see also section 6.1 of this Annex for details. This is then divided by a certain safety factor. This applies through the entire fillet or oil bore contour as well as below the surface to a depth below the treatment- i.e. to cover the depth all the way to the core.

Consideration of the local fatigue strength is to include the influence of the local hardness, residual stress and mean working stress. The influence of the “giga-cycle effect”, especially for initiation of subsurface cracks, is to be covered by the choice of safety margin.

It is of vital importance that the extension of hardening/peening in an area with concentrated stresses be duly considered. Any transition where the hardening/peening is ended is likely to have considerable tensile residual stresses. This forms a “weak spot” and is important if it coincides with an area of high stresses.

Alternating and mean working stresses must be known for the entire area of the stress concentration as well as to a depth of about 1.2 times the depth of the treatment. Figure II-3.1 indicates this principle in the case of induction hardening. The base axis is either the depth (perpendicular to the surface) or along the fillet contour.

The acceptability criterion is to be applied stepwise from the surface to the core as well as from the point of maximum stress concentration along the fillet surface contour to the web.

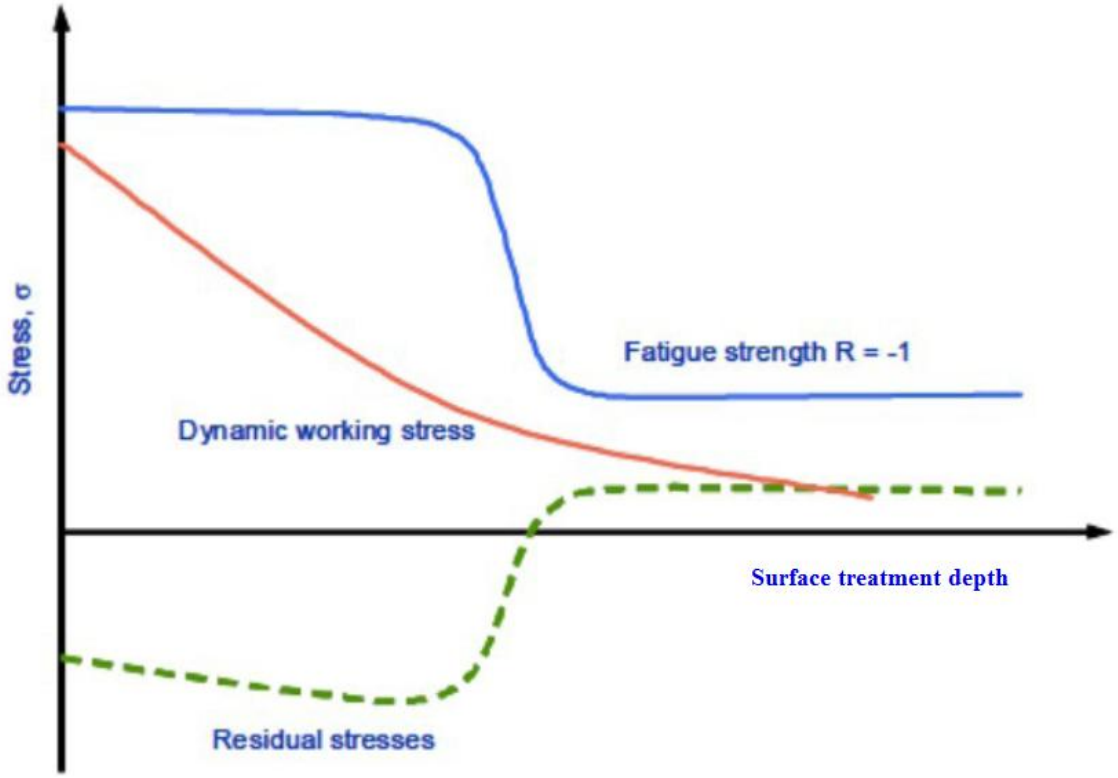


Figure II-3.1 Stresses as functions of depth, general principles

3.1 Evaluation of local fillet stresses

It is necessary to have knowledge of the stresses along the fillet contour as well as in the subsurface to a depth somewhat beyond the hardened layer. Normally this will be found via FEA as described in 2.4.5 of this Appendix. However, the element size in the subsurface range will have to be the same size as at the surface. For crankpin hardening only the small element size will have to be continued along the surface to the hard layer.

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined stress concentration factors (SCFs), as in 2.4 of this Appendix if within its validity range, and a relative stress gradient inversely proportional to the fillet radius.

Bending and torsional stresses must be addressed separately. The combination of these is addressed by the acceptability criterion.

The subsurface transition-zone stresses, with the minimum hardening depth, can be determined by means of local stress concentration factors along an axis perpendicular to the fillet surface. These functions $\alpha_{B\text{-local}}$ and $\alpha_{T\text{-local}}$ have different shapes due to the different stress gradients.

The SCFs α_B and α_T are valid at the surface. The local $\alpha_{B\text{-local}}$ and $\alpha_{T\text{-local}}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin fillets they can be simplified to $2/R_H$ in bending and $1/R_H$ in torsion. The journal fillets are handled analogously by using R_G and D_G. The nominal stresses are assumed to be linear from the surface to a midpoint in the web between the crankpin fillet and the journal fillet for bending and to the crankpin or journal centre for torsion.

The local SCFs for crankpin fillet are then functions of depth t according to Equation 3.1 as shown in Figure II-3.2 for bending and respectively for torsion in Equation 3.2 and Figure II-3.3. The corresponding bending SCF and torsion SCF for the journal fillet can be found by replacing R_H with R_G and D_P with D_G.

$$\alpha_{B-local} = (\alpha_B - 1) \cdot e_1^{\frac{-2t}{R_H}} + 1 - \left(\frac{2 \cdot t}{\sqrt{W^2 + e^2}} \right)^{\frac{0.6}{\sqrt{\alpha_B}}} \qquad (3.1)$$

$$\alpha_{T-local} = (\alpha_T - 1) \cdot e_1^{\frac{-t}{R_H}} + 1 - \left(\frac{2 \cdot t}{D_p} \right)^{\frac{1}{\sqrt{\alpha_T}}} \qquad (3.2)$$

where: e_1 is natural constant, and other symbols are defined in 2.4.1 in this Appendix.

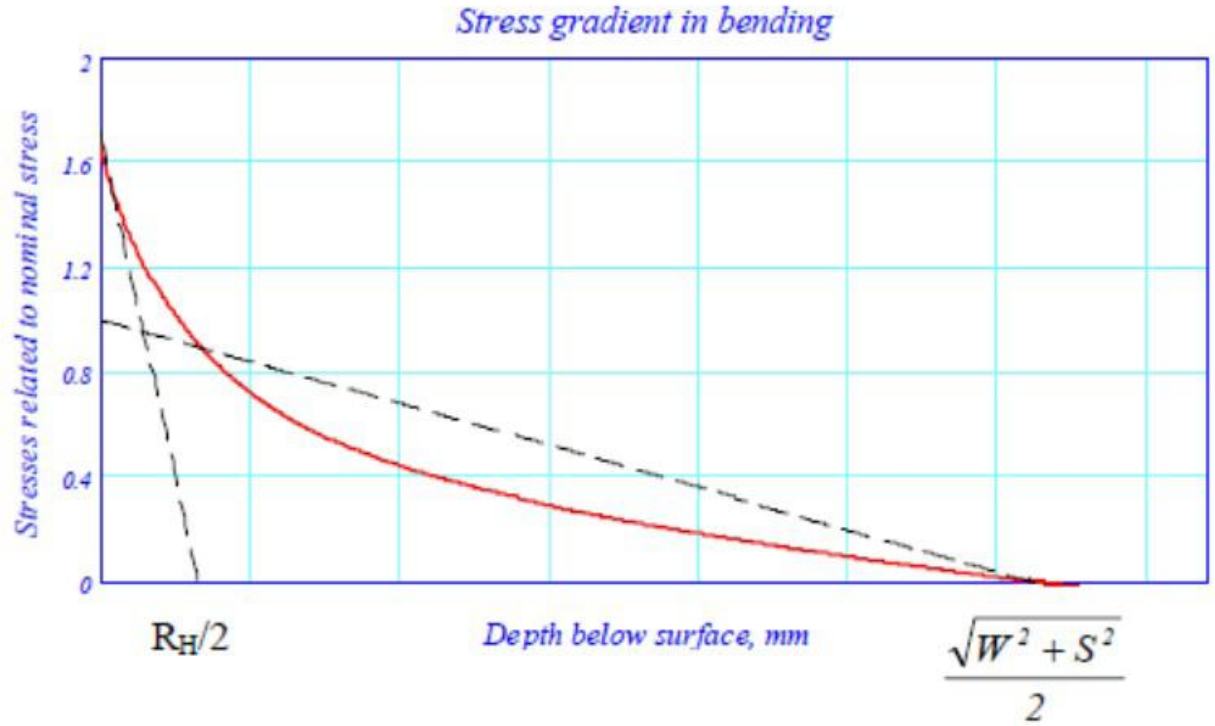


Figure II-3.2 Bending SCF in the crankpin fillet as a function of depth

Figure II-3.3 Torsional SCF in the crankpin fillet as a function of depth

If the pin is hardened only and the end of the hardened zone is closer to the fillet than three times the maximum hardness depth, FEA is to be used to determine the actual stresses in the transition zone.

3.2 Evaluation of oil bore stresses

Stresses in the oil bores can be determined also by FEA. The element size is to be less than 1/8 of the oil bore diameter D_o and the element mesh quality criteria is to be followed as prescribed in Annex III. The fine element mesh is to continue well beyond a radial depth corresponding to the hardening depth.

The loads to be applied in the FEA are the torque – see Annex III item 3.1 – and the bending moment, with four-point bending as in Annex III item 3.2 of this Appendix.

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined SCF from 2.4 of this Appendix if within its applicability range. Bending and torsional stresses at the point of peak stresses are combined as in 2.6 of this Appendix.

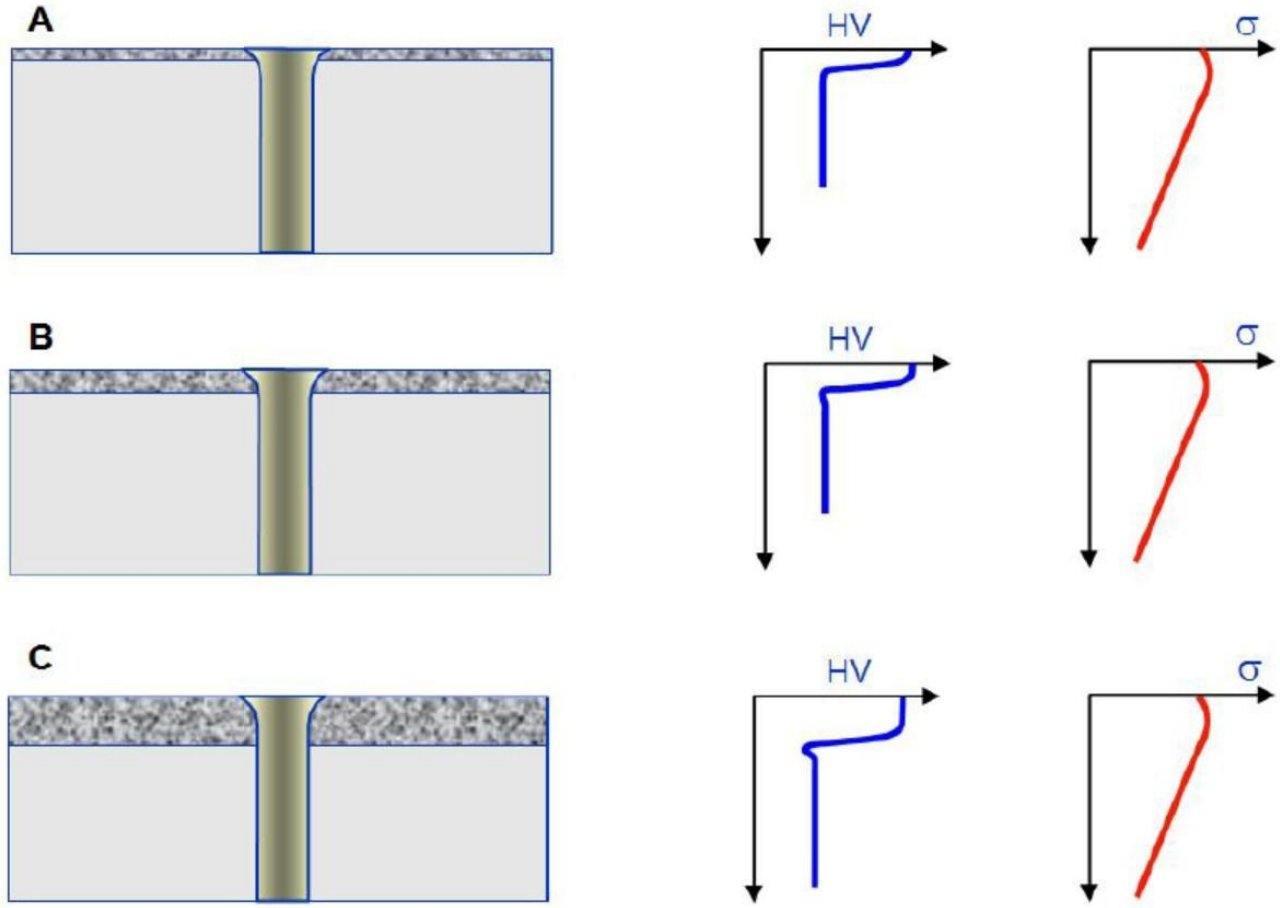


Figure II-3.4 Stresses and hardness in induction hardened oil holes

Figure II-3.4 indicates a local drop of the hardness in the transition zone between a hard and soft material. Whether this drop occurs depends also on the tempering temperature after quenching in the QT process.
The peak stress in the bore occurs at the end of the edge rounding. Within this zone the stress drops almost linearly to the centre of the pin. As can be seen from Figure II-3.4, for shallow (A) and intermediate (B) hardening, the transition point practically coincides with the point of maximal stresses. For deep hardening the transition point comes outside of the point of peak stress and the local stress can be assessed as a portion (1-2*tH/D*) of the peak stresses where *tH* is the hardening depth.
The subsurface transition-zone stresses (using the minimum hardening depth) can be determined by means of local stress concentration factors along an axis perpendicular to the oil bore surface. These functions $\gamma_{B-local}$ and $\gamma_{T-local}$ have different shapes, because of the different stress gradients.
The stress concentration factors γ_B and γ_T are valid at the surface. The local SCFs $\gamma_{B-local}$ and $\gamma_{T-local}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin oil bores they can be simplified to $4/D_o$ in bending and $2/D_o$ in torsion. The local SCFs are then functions of the depth *t*:

$$\gamma_{B-local} = (\gamma_B - 1) \cdot e^{\frac{-4 \cdot t}{D_0}} + 1 \qquad (3.3)$$

$$\gamma_{T-local} = (\gamma_T - 1) \cdot e^{\frac{-2 \cdot t}{D_0}} + 1 \qquad (3.4)$$

where: e_1 is natural constant, and other symbols are defined in 2.4.1 in this Appendix.

3.3 Acceptability criteria

Acceptance of crankshafts is based on fatigue considerations; the equivalent alternating stress and the fatigue strength ratio are compared to an acceptability factor of $Q \geq 1.15$ for oil bore outlets, crankpin fillets and journal fillets. This is to be extended to cover also surface treated areas independent of whether surface or transition zone is examined.

4 Induction hardening

Generally, the hardness specification is to specify the surface hardness range i.e. minimum and maximum values, the minimum and maximum extension in or through the fillet and also the minimum and maximum depth along the fillet contour. The referenced Vickers hardness is considered to be HV0.5-HV5.

The induction hardening depth is defined as the depth where the hardness is 80% of the minimum specified surface hardness.

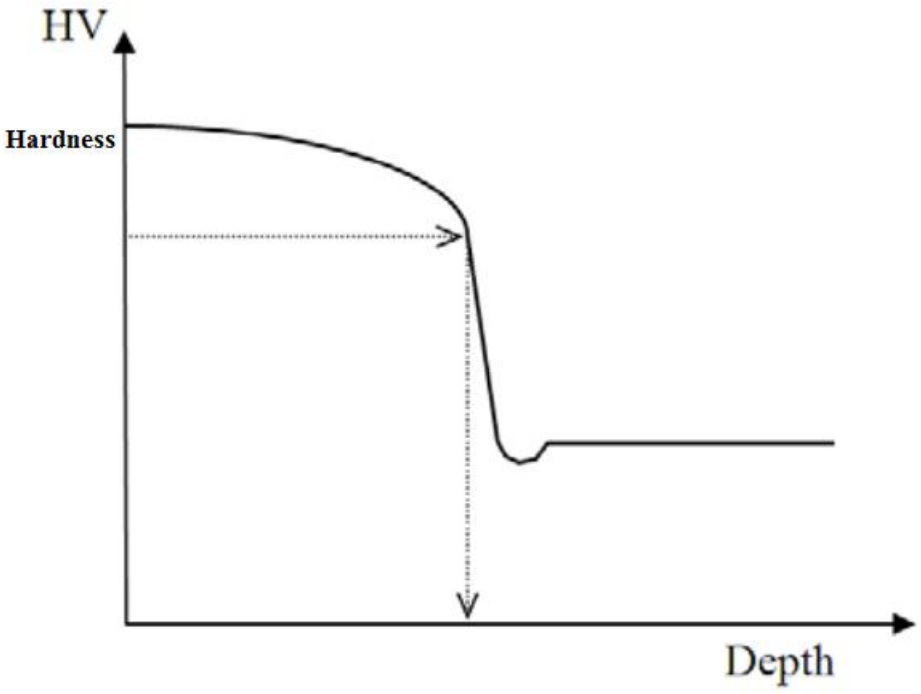


Figure II-4.1 Typical hardness as a function of depth

The arrows indicate the defined hardening depth. Note the indicated potential hardness drop at the transition to the core. This can be a weak point as local strength may be reduced and tensile residual stresses may occur.

In the case of crankpin or journal hardening only, the minimum distance to the fillet is to be specified due to the tensile stress at the heat-affected zone as shown in Figure II-4.2.

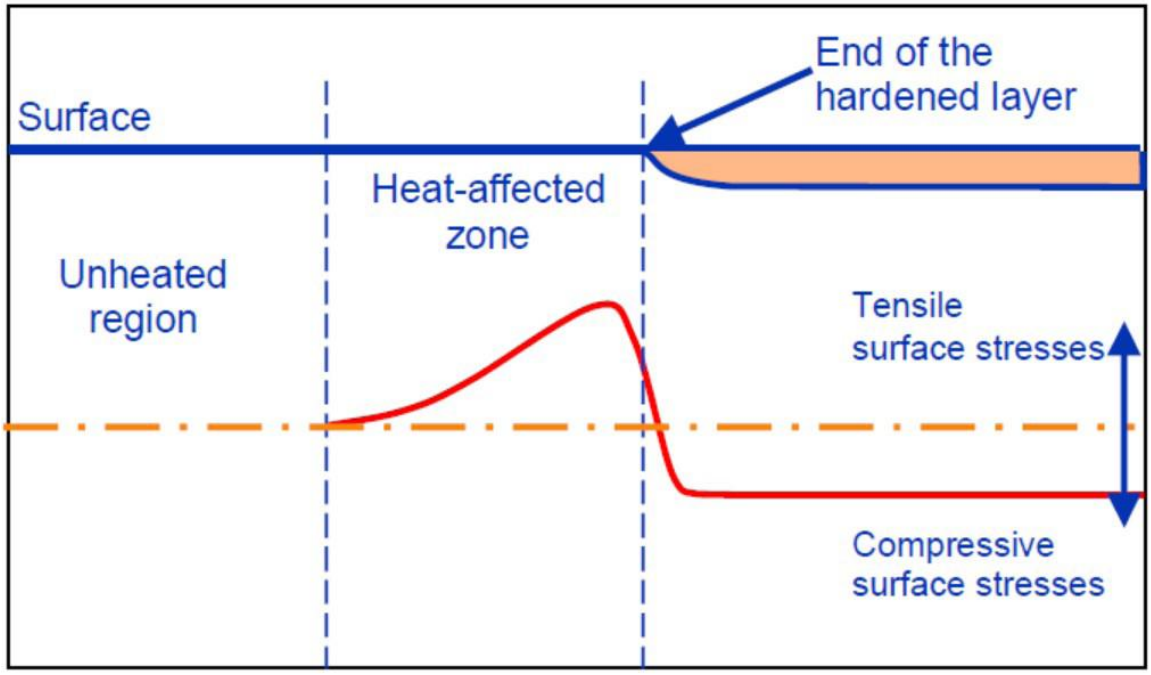


Figure II-4.2 Residual stresses along the surface of a pin and fillet

If the hardness-versus-depth profile and residual stresses are not known or specified, one may assume the following:
(1) The hardness profile consists of two layers (see Figure II-4.1):
- Constant hardness from the surface to the transition zone;
- Constant hardness from the transition zone to the core material;

(2) Residual stresses in the hard zone of 200 MPa (compression);
(3) Transition-zone hardness as 90% of the core hardness unless the local hardness drop is avoided;
(4) Transition-zone maximum residual stresses (von Mises) of 300 MPa tension.
If the crankpin or journal hardening ends close to the fillet, the influence of tensile residual stresses has to be considered. If the minimum distance between the end of the hardening and the beginning of the fillet is more than 3 times the maximum hardening depth, the influence may be disregarded.

4.1 Local fatigue strength

Induction-hardened crankshafts will suffer fatigue either at the surface or at the transition to the core. The fatigue strengths, for both the surface and the transition zone, can be determined by fatigue testing of full size cranks as described in Annex I of this Appendix. In the case of a transition zone, the initiation of the fatigue can be either subsurface (i.e. below the hard layer) or at the surface where the hardening ends.
Tests made with the core material only will not be representative since the tensile residual stresses at the transition are lacking.
Alternatively, the surface fatigue strength can be determined empirically as follows where *HV* is the surface Vickers hardness. The Equation 4.1 provides a conservative value, with which the fatigue strength is assumed to include the influence of the residual stress. The resulting value is valid for a working stress ratio of R = -1:

$$\sigma_{Fsurface} = 400 + 0.5 \cdot (HV - 400) \quad \text{MPa} \quad (4.1)$$

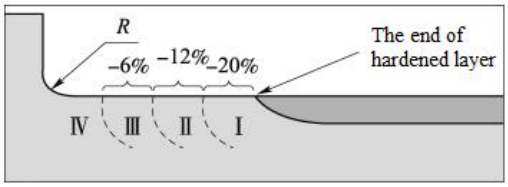
It has to be noted also that the mean stress influence of induction-hardened steels may be significantly higher than that for QT steels.
The fatigue strength in the transition zone, without taking into account any possible local hardness drop, is to be determined by the equation introduced in 2.7 of this Appendix.
For journal and respectively to crankpin fillet applies:

$$\sigma_{\text{Ftransition,cpin}} = \pm K \cdot \left(0.42R_m + 39.3\right) \cdot \left[0.264 + 1.073\text{Y}^{-0.2} + \frac{785 - R_m}{4900} + \frac{196}{R_m} \cdot \sqrt{\frac{1}{\text{X}}}\right] \quad (4.2)$$

where:
$Y = D_G$ and $X = R_G$ for journal fillet
$Y = D_p$ and $X = R_H$ for crankpin fillet
$Y = D_p$ and $X = D_o/2$ for oil bore outlet
The influence of the residual stress is not included in 4.2.
For the purpose of considering subsurface fatigue, below the hard layer, the disadvantage of tensile residual stresses has to be considered by subtracting 20% from the value determined above. This 20% is based on the mean stress influence of alloyed quenched and tempered steel having a residual tensile stress of 300 MPa.
When the residual stresses are known to be lower, also smaller value of subtraction is to be used. For low-strength steels the percentage chosen is to be higher.
For the purpose of considering surface fatigue near the end of the hardened zone – i.e. in the heat-affected zone shown in the Figure II-4.2 - the influence of the tensile residual stresses can be considered by subtracting a certain percentage, in accordance with Table 4.1, from the value determined by the above formula.

The influence of tensile residual stresses at a given distance from the end of the hardening towards the fillet

Table 4.1

Zone	Scope	Strength coefficient	Illustration of heat affected zones and strength coefficients
I II III IV	0-tH tH-2tH 2tH-3tH 3tH or more	0.8 0.88 0.94 1	

5 Nitriding

The hardness specification is to include the surface hardness range (min and max) and the minimum and maximum depth. Only gas nitriding is considered. The referenced Vickers hardness is considered to be HV0.5.

The depth of the hardening is defined in different ways in the various standards and the literature. The most practical method to use in this context is to define the nitriding depth tN as the depth to a hardness of 50 HV above the core hardness.

The hardening profile is to be specified all the way to the core. If this is not known, it may be determined empirically via the following formula:

$$HV(t) = HV_{core} + (HV_{surface} - HV_{core}) \cdot \left(\frac{50}{HV_{surface} - HV_{core}} \right)^{\left(\frac{t}{tN}\right)^2} \qquad (5.1)$$

where:

t = The local depth;

$HV(t)$ = Hardness at depth t;

HV_{core} = Core hardness (minimum);

$HV_{surface}$ = Surface hardness (minimum);

tN = Nitriding depth as defined above (minimum).

5.1 Local fatigue strength

It is important to note that in nitrided crankshaft cases, fatigue is found either at the surface or at the transition to the core. This means that the fatigue strength can be determined by tests as described in Annex I of this Appendix.

Alternatively, the surface fatigue strength (principal stress) can be determined empirically and conservatively as follows. This is valid for a surface hardness of 600 HV or greater:

$$\sigma_{Fsurface} = 450 \quad \text{MPa} \qquad (5.2)$$

Note that this fatigue strength is assumed to include the influence of the surface residual stress and applies for a working stress ratio of R = -1.

The fatigue strength in the transition zone can be determined by the equation introduced in 2.7 of this Appendix. For crankpin and respectively to journal applies:

$$\sigma_{\text{Ftransition,cpin}} = \pm K \cdot \left(0.42 R_m + 39.3\right) \cdot \left[0.264 + 1.073 \cdot \mathrm{Y}^{-0.2} + \frac{785 - R_m}{4900} + \frac{196}{R_m} \cdot \sqrt{\frac{1}{\mathrm{X}}} \right] \qquad (5.3)$$

where:

$Y = D_G$ and $X = R_G$ for journal fillet;

$Y = D_p$ and $X = R_H$ for crankpin fillet;

$Y = D_p$ and $X = D_0/2$ for oil bore outlet.

Note that this fatigue strength is not assumed to include the influence of the residual stresses.

In contrast to induction-hardening the nitrited components have no such distinct transition to the core, as indicated by Figure II-5.1. Although the compressive residual stresses at the surface are high, the balancing tensile stresses in the core are moderate because of the shallow depth. For the purpose of analysis of subsurface fatigue the disadvantage of tensile residual stresses in and below the transition zone may be even disregarded in view of this smooth contour of a nitriding hardness profile.

Although in principle the calculation is to be carried out along the entire hardness profile, it can be limited to a simplified approach of examining the surface and an artificial transition point. This artificial transition

point can be taken at the depth where the local hardness is approximately 20 HV above the core hardness. In such a case, the properties of the core material are to be used. This means that the stresses at the transition to the core can be found by using the local SCF formulae mentioned earlier when inserting t=1.2tN.

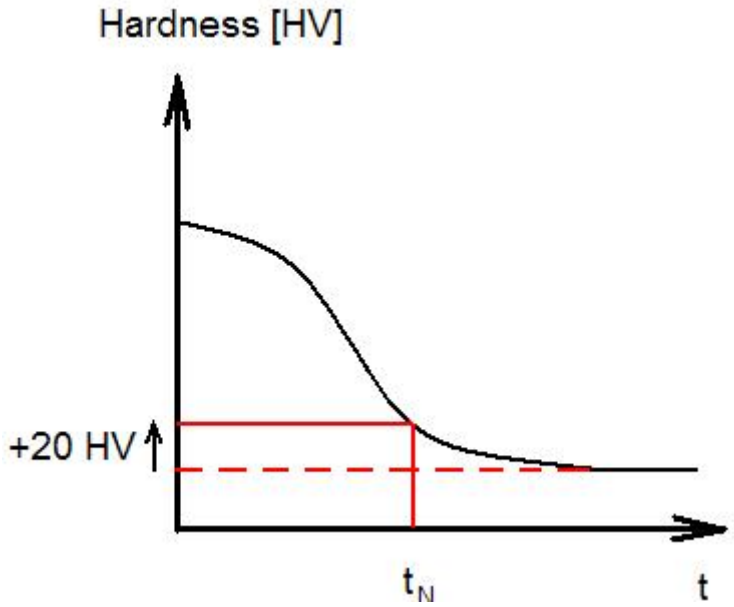


Figure II-5.1 Sketch of the location for the artificial transition point in the depth direction

6 Cold forming

The advantage of stroke peening or cold rolling of fillets is the compressive residual stresses introduced in the high-loaded area. Even though surface residual stresses can be determined by X-ray diffraction technique and subsurface residual stresses can be determined through neutron diffraction, the local fatigue strength is virtually non-assessable on that basis since suitable and reliable correlation formulae are hardly known.

Therefore, the fatigue strength has to be determined by fatigue testing; see also Annex I of this Appendix. Such testing is normally carried out as four-point bending, with a working stress ratio of R = -1. From these results, the bending fatigue strength - surface- or subsurface-initiated depending on the manner of failure- can be determined and expressed as the representative fatigue strength for applied bending in the fillet.

In comparison to bending, the torsion fatigue strength in the fillet may differ considerably from the ratio $\sqrt{3}$ (utilized by the von Mises criterion). The forming-affected depth that is sufficient to prevent subsurface fatigue in bending, may still allow subsurface fatigue in torsion. Another possible reason for the difference in bending and torsion could be the extension of the highly stressed area.

The results obtained in a full-size crank test can be applied for another crank size provided that the base material (alloyed Q+T) is of the similar type and that the forming is done so as to obtain the similar level of compressive residual stresses at the surface as well as through the depth. This means that both the extension and the depth of the cold forming must be proportional to the fillet radius.

6.1 Stroke peening by means of a ball

The fatigue strength obtained can be documented by means of full size crank tests or by empirical methods if applied on the safe side. If both bending and torsion fatigue strengths have been investigated and differ from the ratio $\sqrt{3}$, the von Mises criterion is to be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength is to be assessed conservatively. If the bending fatigue strength is concluded to be x% above the fatigue strength of the non-peened material, the torsional fatigue strength is not to be assumed to be more than 2/3 of x% above that of the non-peened material.

As a result of the stroke peening process the maximum of the compressive residual stress is found in the subsurface area. Therefore, depending on the fatigue testing load and the stress gradient, it is possible to have higher working stresses at the surface in comparison to the local fatigue strength of the surface. This is illustrated in Figure II-6.1. Because of this phenomenon small cracks may appear during the fatigue testing, which will not be able to propagate in further load cycles and/or with further slight increases of the testing load because of the profile of the compressive residual stress. Put simply, the high compressive residual

stresses below the surface “arrest” small surface cracks.

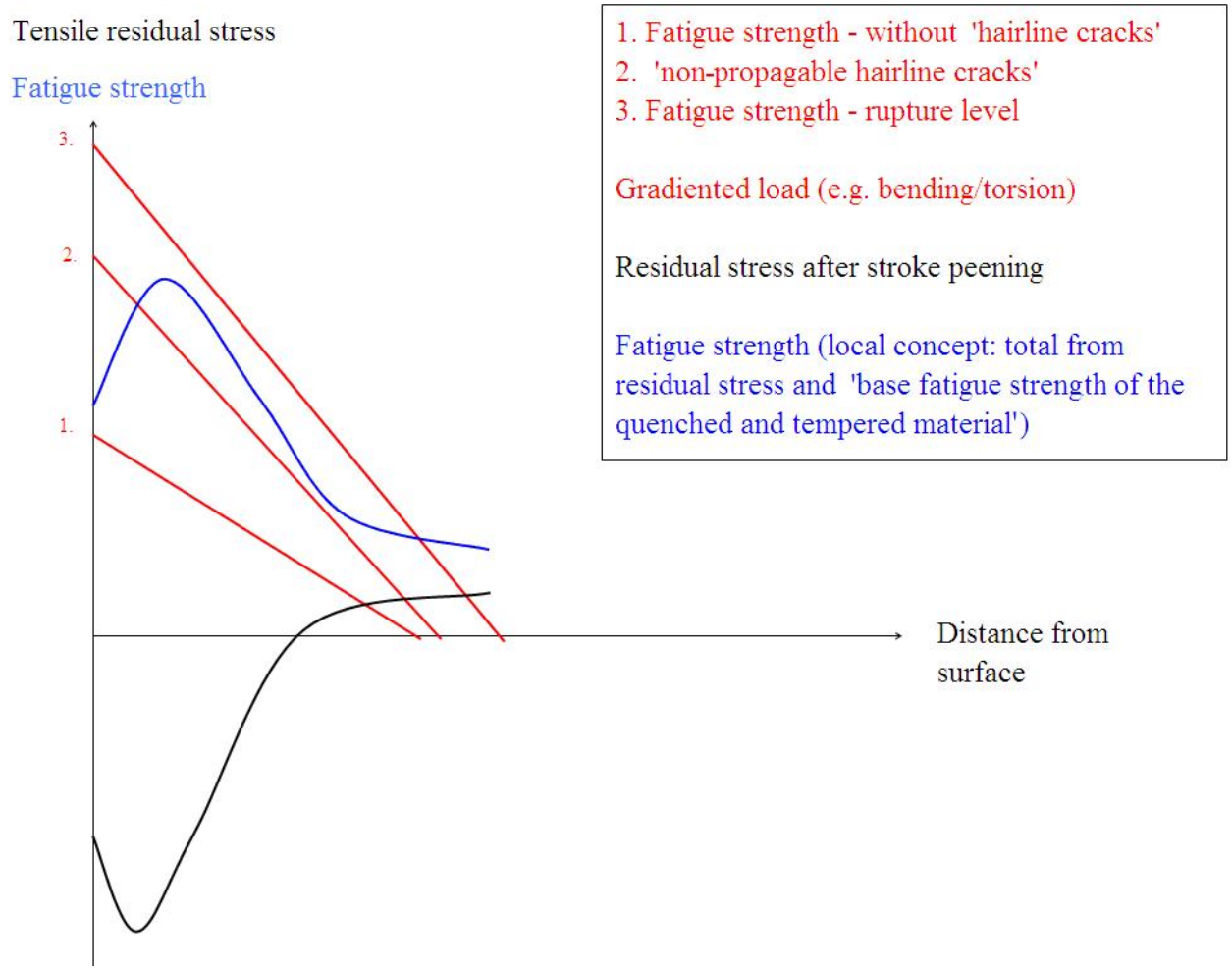


Figure II-6.1 Working and residual stresses below the stroke-peened surface

In fatigue testing with full-size crankshafts these small “hairline cracks” are not to be considered to be the failure crack. The crack that is technically the fatigue crack leading to failure, and that therefore shuts off the test-bench, is to be considered for determination of the failure load level. This also applies if induction-hardened fillets are stroke-peened.

In order to improve the fatigue strength of induction-hardened fillets it is possible to apply the stroke peening process in the crankshafts’ fillets after they have been induction-hardened and tempered to the required surface hardness. If this is done, it might be necessary to adapt the stroke peening force to the hardness of the surface layer and not to the tensile strength of the base material. The effect on the fatigue strength of induction hardening and stroke peening the fillets are to be determined by a full-size crankshaft test.

6.1.1 Use of existing results for similar crankshafts

The increase in fatigue strength, which is achieved by applying stroke peening, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

(1) Ball size relative to fillet radius within ±10% in comparison to the tested crankshaft;

(2) At least the same circumferential extension of the stroke peening;

(3) Angular extension of the fillet contour relative to fillet radius within ±15% in comparison to the tested crankshaft and located to cover the stress concentration during engine operation;

(4) Similar base material, e.g. alloyed quenched and tempered;

(5) Forward feed of ball of the same proportion of the radius;

(6) Force applied to ball proportional to base material hardness (if different);

(7) Force applied to ball proportional to square of ball radius.

6.2 Cold rolling

The fatigue strength can be obtained by means of full size crank tests or by empirical methods, if these are

applied so as to be on the safe side. If both, bending and torsion fatigue strengths have been investigated, and differ from the ratio $\sqrt{3}$, the von Mises criterion is to be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength is to be assessed conservatively. If the bending fatigue strength is concluded to be x% above the fatigue strength of the non-rolled material, the torsional fatigue strength is not to be assumed to be more than 2/3 of x% above that of the non-rolled material.

6.2.1 Use of existing results for similar crankshafts

The increase in fatigue strength, which is achieved applying cold rolling, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

(1) At least the same circumferential extension of cold rolling;

(2) Angular extension of the fillet contour relative to fillet radius within ±15% in comparison to the tested crankshaft and located to cover the stress concentration during engine operation;

(3) Similar base material, e.g. alloyed quenched and tempered;

(4) Roller force to be calculated so as to achieve at least the same relative (to fillet radius) depth of treatment.

Annex III Guidance for Calculation of Stress Concentration Factors in the Oil Bore Outlets of crankshafts through utilisation of the Finite Element Method

Contents

1 General

2 Model requirements
2.1 Element mesh recommendations
2.2 Material
2.3 Element mesh quality criteria

3 Load cases and assessment of stress
3.1 Torsion
3.2 Bending

1 General

The objective of the analysis described in this Annex is to substitute the analytical calculation of the stress concentration factor (SCF) at the oil bore outlet with suitable finite element method (FEM) calculated figures. The former method specified in 2.4.4 of this Appendix is based on empirical formulae developed from strain gauge readings or photo-elasticity measurements of various round bars. Because use of these formulae beyond any of the validity ranges can lead to erroneous results in either direction, the FEM-based method is highly recommended.

The SCF calculated according to the rules set forth in this document is defined as the ratio of FEM-calculated stresses to nominal stresses calculated analytically. In use in connection with the present method in this Appendix, principal stresses are to be calculated.

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

It is advisable to check the element accuracy of the FE solver in use, e.g. by modelling a simple geometry and comparing the FEM-obtained stresses with the analytical solution.

A boundary element method (BEM) approach may be used instead of FEM.

2 Model requirements

The basic recommendations and assumptions for building of the FE-model are presented in 2.1 of this Annex. The final FE-model must meet one of the criteria in 2.3 of this Annex.

2.1 Element mesh recommendations

For the mesh quality criteria to be met, construction of the FE model for the evaluation of stress concentration factors according to the following recommendations is advised:

(1) The model consists of one complete crank, from the main bearing centre line to the opposite side's main bearing centre line.

(2) The following element types are used in the vicinity of the outlets: 10-node tetrahedral elements; 8-node hexahedral elements; 20-node hexahedral elements.

(3) The following mesh properties for the oil bore outlet are used:

- Maximum element size a = r / 4 through the entire outlet fillet as well as in the bore direction (if 8-node hexahedral elements are used, even smaller elements are required for meeting of the quality criterion).
- Recommended manner for element size in the fillet depth direction: first layer's thickness equal to element size of *a*; second layer's thickness equal to element size of *2a*; third-layer's thickness equal to element size of *3a*.

(4) In general, the rest of the crank is to be suitable for numeric stability of the solver.

(5) Drillings and holes for weight reduction have to be modelled.

(6) Submodeling may be used as long as the software requirements are fulfilled.

2.2 Material

In the FE analysis, material parameters such as Young's modulus (*E*) and Poisson's ratio (ν) are required, as primarily strain is calculated and stress is derived from strain through the use of Young's modulus and Poisson's ratio. Reliable values for material parameters have to be used, either as quoted in the literature or measured from representative material samples.

For steel the following is advised: $E = 2.05 \times 10^5$ MPa and ν = 0.3.

2.3 Element mesh quality criteria

If the actual element mesh does not fulfil any of the following criteria in the area examined for SCF evaluation, a second calculation, with a finer mesh is to be performed.

(1) Principal -stresses criterion:

The quality of the mesh is to be assured through checking of the stress component normal to the surface of the oil bore outlet radius. With principal stresses σ_1, σ_2 and σ_3 the following criterion must be met:

$$\min\left(|\sigma_1|,|\sigma_2|,|\sigma_3|\right) < 0.03\max\left(|\sigma_1|,|\sigma_2|,|\sigma_3|\right).$$

(2) Averaged/unaveraged -stresses criterion:

The averaged/unaveraged -stresses criterion is based on observation of the discontinuity of stress results over elements at the fillet for the calculation of the SCF: unaveraged nodal stress results calculated from each element connected to a node i are to differ less than 5% from the 100% averaged nodal stress results at this node i at the location examined.

3 Load cases and assessment of stress

FE calculation is to be performed for the following load cases.

3.1 Torsion

The structure is loaded in pure torsion. The surface warp at the end faces of the model is suppressed. Torque is applied to the central node, on the crankshaft axis. This node acts as the master node with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions are valid for both in-line- and V- type engines, as shown in Figure III-3.1.

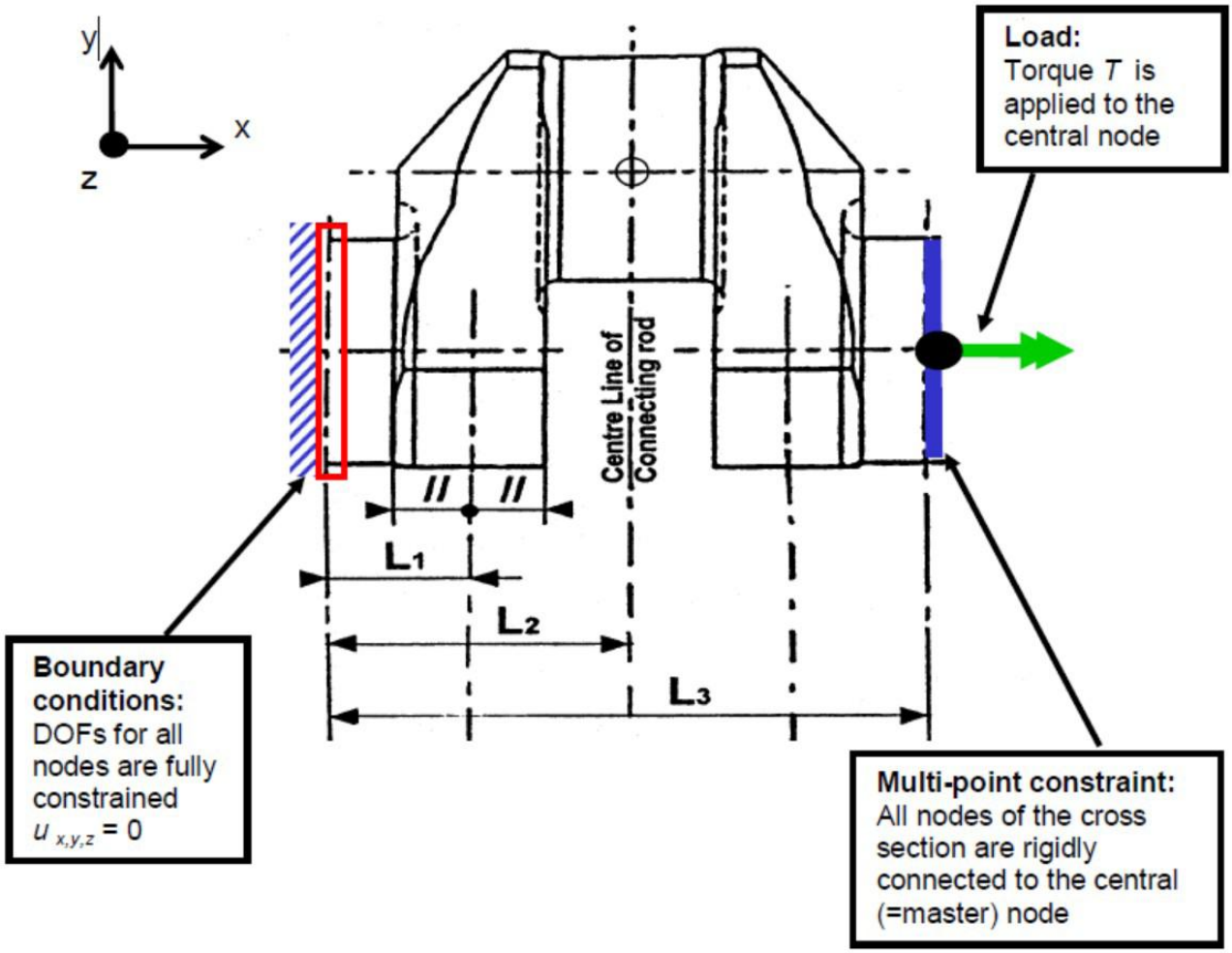


Figure III-3.1 Boundary and load conditions for the torsion load case

For all nodes in an oil bore outlet, the principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_T = \frac{\max\left(\left|\sigma_1\right|, \left|\sigma_2\right|, \left|\sigma_3\right|\right)}{\tau_N}$$

where the nominal torsion stress τ_N referred to the crankpin is evaluated per 2.3.3 of this Appendix with torque T: $\tau_N = \frac{T}{W_P}$.

3.2 Bending

The structure is loaded in pure bending. The surface warp at the end faces of the model is suppressed.

The bending moment is applied to the central node on the crankshaft axis. This node acts as the master node, with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions are valid for both in-line- and V- type engines, as shown in Figure III-3.2.

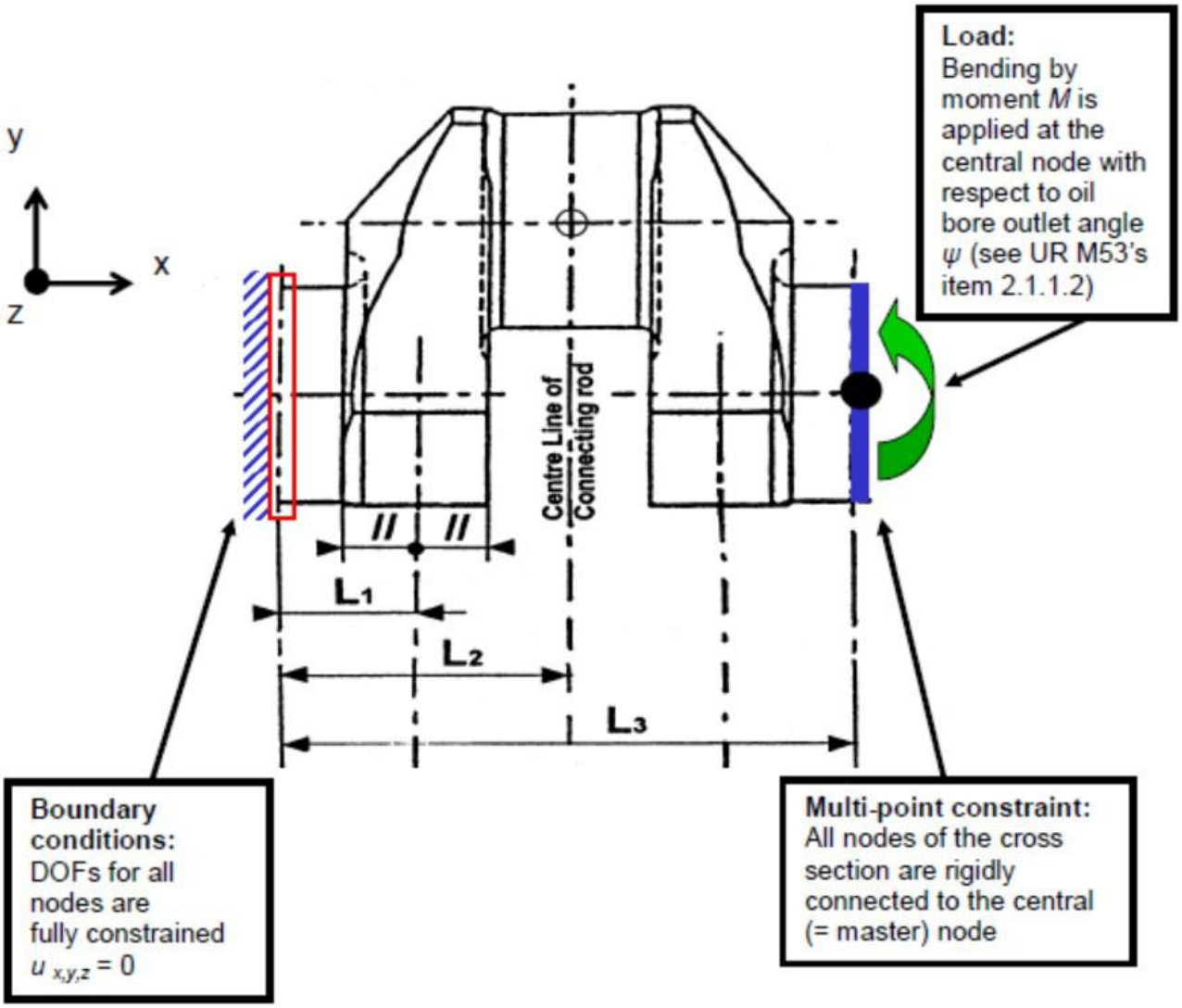


Figure III-3.2 Boundary and load conditions for the pure bending load case

For all nodes in the oil bore outlet, principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_B = \frac{\max\left(\left|\sigma_1\right|, \left|\sigma_2\right|, \left|\sigma_3\right|\right)}{\sigma_{BON}}$$

where the nominal bending stress σ_{BON} referred to the crankpin is calculated per 2.3.1(3) of this Appendix with bending moment M: $\sigma_{BON} = \frac{M}{W_e}$.

Appendix 4 TYPE TEST OF DIESEL ENGINES

1 General Requirements

1.1 Application

1.1.1 The type testing, documented in this Appendix, is to be arranged to represent typical foreseen service load profiles, as specified by the engine builder, as well as to cover for required margins due to fatigue scatter and reasonably foreseen in-service deterioration.

1.1.2 This applies to:

(1) Parts subjected to high cycle fatigue (HCF) such as connecting rods, cams, rollers and spring tuned dampers where higher stresses may be provided by means of elevated injection pressure, cylinder maximum pressure, etc.;

(2) Parts subjected to low cycle fatigue (LCF) such as "hot" parts when load profiles such as idle − full load − idle (with steep ramps) are frequently used;

(3) Operation of the engine at limits as defined by its specified alarm system, such as running at maximum permissible power with the lowest permissible oil pressure and/or highest permissible oil inlet temperature.

1.2 Safety precautions

1.2.1 Before any test run is carried out, all relevant equipment for the safety of attending personnel, including crankcase explosive conditions protection, overspeed protection and any other shut down function, is to be made available by the manufacturer/shipyard and is to be operational, and its correct functioning is to be verified.

1.2.2 The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections (as required in 2.2.8 of this Appendix) is also to be carried out before the test runs.

1.2.3 Interlock test of turning gear is to be performed when installed.

1.3 Test program

1.3.1 The type testing is divided into 3 stages:

(1) Stage A − internal tests, including some of the testing made during the engine development, function testing, and collection of measured parameters and records of testing hours. The results of testing required by the Rules or specified by the designer are to be presented to CCS before starting stage B;

(2) Stage B − witnessed tests, which are the testing made in the presence of the surveyor;

(3) Stage C − component inspection, which is the inspection of engine parts to the extent as rules required.

1.3.2 The complete type testing program is subject to approval by CCS. The extent of the surveyor's presence during each stage may be agreed by both sides, but at least during stage B and C.

1.3.3 Testing prior to the witnessed type testing (stage B and C), is also considered as a part of the complete type testing program.

1.3.4 Upon completion of complete type testing (stage A through C), a type test report is to be submitted to CCS for review. The type test report is to contain:

(1) overall description of tests performed during stage A. Records are to be kept by the builder's QA management for presentation to CCS;

(2) detailed description of the load and functional tests conducted during stage B;

(3) inspection results from stage C.

1.3.5 As required in 1.1.2 of this Appendix, the type testing is to substantiate the capability of the design and its suitability for the intended operation. Special testing such as LCF and endurance testing will normally be conducted during stage A.

1.3.6 High speed engines for marine use are normally to be subjected to an endurance test of 100 hours at full load. Omission or simplification of the type test may be considered for the type approval of engines with long service experience from non-marine fields or for the extension of type approval of engines of a well-known type, in excess of the limits given in 9.10.2 of this Chapter.

Propulsion engines for high speed vessels that may be used for frequent load changes from idle to full are normally to be tested with at least 500 cycles (idle − full load − idle) using the steepest load ramp that the control system (or operation manual if not automatically controlled) permits. The duration at each end is to be sufficient for reaching stable temperatures of the hot parts.

1.4 Measurements and recordings

1.4.1 During all testing the ambient conditions (air temperature, air pressure and humidity) are to be recorded.

1.4.2 As a minimum, the following engine data are to be measured and recorded:
(1) engine r.p.m.;
(2) torque;
(3) maximum combustion pressure for each cylinder①;
(4) mean indicated pressure for each cylinder①;
(5) charging air pressure and temperature;
(6) exhaust gas temperature;
(7) fuel rack position or similar parameter related to engine load;
(8) turbocharger speed;
(9) all engine parameters that are required for control and monitoring for the intended use (propulsion, auxiliary, emergency).

Note:

① For engines where the standard production cylinder heads are not designed for such measurements, a special cylinder head made for this purpose may be used. In such a case, the measurements may be carried out as part of Stage A and are to be properly documented. Where deemed necessary e.g. for dual fuel engines, the measurement of maximum combustion pressure and mean indicated pressure may be carried out by indirect means, provided the reliability of the method is documented.

1.4.3 Calibration records for the instrumentation used to collect data as listed above are to be presented to- and reviewed by the attending Surveyor.
1.4.4 Additional measurements may be required in connection with the design assessment.

2 Type Testing

2.1 Stage A − internal tests

2.1.1 During the internal tests, the engine is to be operated at the load points important for the engine designer and the pertaining operating values are to be recorded. The load conditions to be tested are also to include the testing specified in the applicable type approval program.
2.1.2 At least the following conditions are to be tested:
(1) Normal case: The load points 25%, 50%, 75%, 100% and 110% of the maximum rated power for continuous operation, to be made along the normal (theoretical) propeller curve and at constant speed for propulsion engines (if applicable mode of operation i.e. driving controllable pitch propellers), and at constant speed for engines intended for generator sets including a test at no load and rated speed.
(2) The limit points of the permissible operating range. These limit points are to be defined by the engine manufacturer.
(3) For high speed engines, the 100 h full load test and the low cycle fatigue test apply as required in connection with the design assessment.
(4) Specific tests of parts of the engine, required by CCS or specified by the designer.

2.2 Stage B − witnessed tests

2.2.1 The tests listed below are to be carried out in the presence of a Surveyor. The achieved results are to be recorded and signed by the attending Surveyor after the type test is completed.
2.2.2 The overspeed test is to be carried out and is to demonstrate that the engine is not damaged by an actual engine overspeed within the overspeed shutdown system set-point. This test may be carried out at the manufacturer's choice either with or without load during the speed overshoot.
2.2.3 Load test. The engine is to be operated according to the power and speed diagram (see Figure 2.2.3). The data to be measured and recorded when testing the engine at the various load points have to include all engine parameters listed in 1.4 of this Appendix. The operating time per load point depends on the engine size (achievement of steady state condition) and on the time for collection of the operating values. Normally, an operating time of 0.5 h can be assumed per load point, however sufficient time should be allowed for visual inspection by the Surveyor.
The load points are:
(1) rated power (MCR), i.e. 100% output at 100% torque and 100% speed corresponding to load point 1, normally for 2 h with data collection with an interval of 1 h. If operation of the engine at limits as defined by its specified alarm system (e.g. at alarm levels of lub oil pressure and inlet temperature) is required, the test is to be made here;
(2) 100% power at maximum permissible speed corresponding to load point 2;
(3) maximum permissible torque (at least and normally 110%) at 100% speed corresponding to load at point 3, or maximum permissible power (at least and normally 110%) and 103.2% speed according to the

nominal propeller curve corresponding to load point 3a. Load point 3a applies to engines only driving fixed pitch propellers or water jets. Load point 3 applies to all other purposes.
Load point 3 (or 3a as applicable) is to be replaced with a load that corresponds to the specified overload and duration approved for intermittent use. This applies where such overload rating exceeds 110% of MCR. Where the approved intermittent overload rating is less than 110% of MCR, subject overload rating has to replace the load point at 100% of MCR. In such case the load point at 110% of MCR remains;
(4) minimum permissible speed at 100% torque, corresponding to load point 4;
(5) minimum permissible speed at 90% torque corresponding to load point 5. (Applicable to propulsion engines only);
(6) part loads e.g. 75%, 50% and 25% of rated power and speed according to nominal propeller curve (i.e. 90.8%, 79.3% and 62.9% speed) corresponding to points 6, 7 and 8 or at constant rated speed setting corresponding to points 9, 10 and 11, depending on the intended application of the engine;
(7) crosshead engines not restricted for use with C.P. propellers are to be tested with no load at the associated maximum permissible engine speed.
2.2.4 During all these load points, engine parameters are to be within the specified and approved values.

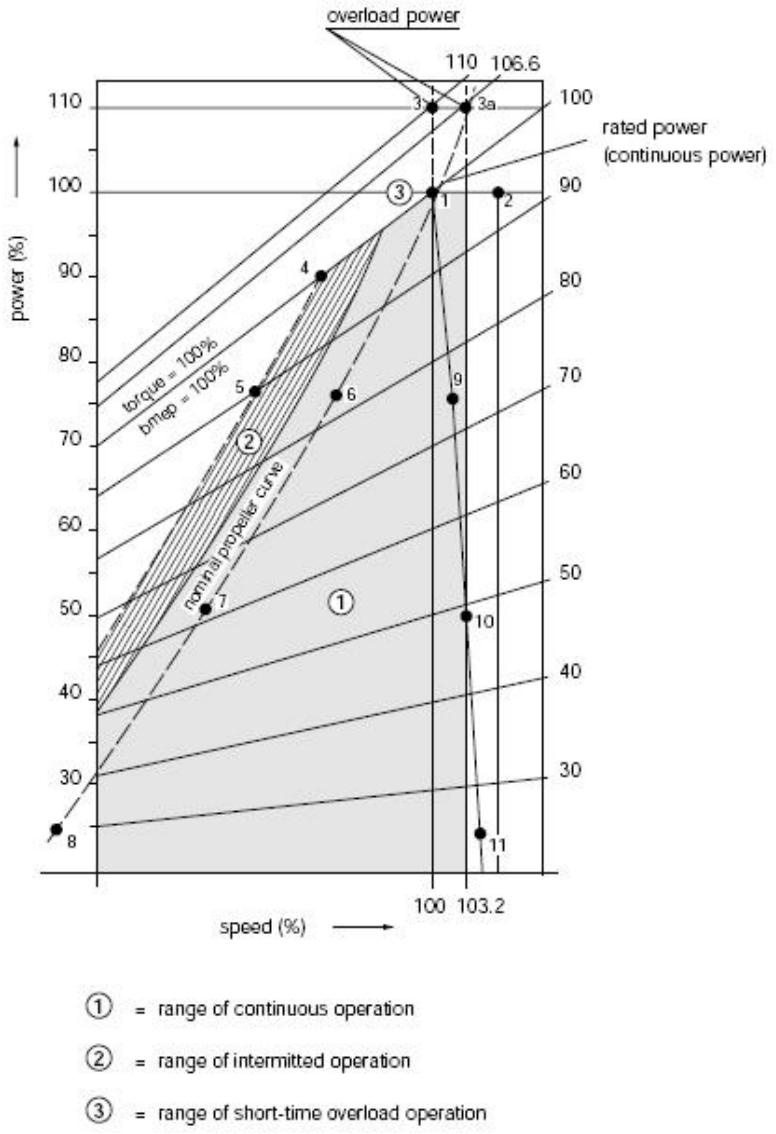


Figure 2.2.3 Diagram of power-speed

2.2.5 Operation with damaged turbocharger. For 2-stroke propulsion engines, the achievable continuous output is to be determined in the case of turbocharger damage.
Engines intended for single propulsion with a fixed pitch propeller are to be able to run continuously at a speed (r.p.m.) of 40% of full speed along the theoretical propeller curve when one turbocharger is out of operation. The test can be performed by either by-passing the turbocharger, fixing the turbocharger rotor

shaft or removing the rotor.
2.2.6 Functional tests are as follows:
(1) Verification of the lowest specified propulsion engine speed according to the nominal propeller curve as specified by the engine designer (even though it works on a water-brake). During this operation, no alarm is to occur.
(2) Starting tests, for non-reversible engines and/or starting and reversing tests, for reversible engines, for the purpose of determining the minimum air pressure and the consumption for a start.
(3) Governor tests: tests for compliance with 9.7.8 and 9.7.10 of this Chapter are to be carried out.
2.2.7 Integration test. For electronically controlled diesel engines, integration tests are to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests is to be agreed with CCS for selected cases based on the FMEA.
2.2.8 Fire protection measures. Verification of compliance with requirements for jacketing of high-pressure fuel oil lines, screening of pipe connections in piping containing flammable liquids and insulation of hot surfaces:
(1) The engine is to be inspected for jacketing of high-pressure fuel oil lines, including the system for the detection of leakage, and proper screening of pipe connections in piping containing flammable liquids.
(2) Proper insulation of hot surfaces is to be verified while running the engine at 100% load, alternatively at the overload approved for intermittent use. Readings of surface temperatures are to be done by use of Infrared Thermoscanning Equipment. Equivalent measurement equipment may be used when so approved by CCS. Readings obtained are to be randomly verified by use of contact thermometers.

2.3 Stage C − Opening up for Inspections

2.3.1 The crankshaft deflections are to be measured in the specified (by designer) condition.
2.3.2 High speed engines for marine use are normally to be stripped down for a complete inspection after the type test.
2.3.3 For all the other engines, after the test run, the components are to be presented for inspection as follows:
(1) piston removed and dismantled;
(2) crosshead bearing dismantled;
(3) guide planes;
(4) connecting rod bearings (big and small end) dismantled (special attention to serrations and fretting on contact surfaces with the bearing backsides);
(5) main bearing dismantled;
(6) cylinder liner in the installed condition;
(7) cylinder head, valves disassembled;
(8) cam drive gear or chain, camshaft and crankcase with opened covers. (The engine must be turnable by turning gear for this inspection.)
Note: Engines with long service experience from non-marine fields can have a reduced extent of opening.

2.3.4 One cylinder for in-line engines and two cylinders for V-engines are to be selected. For V-engines, the cylinder units are to be selected from both cylinder banks and different crank throws.
2.3.5 Where deemed necessary by the surveyor, further dismantling of the engine may be required.

Appendix 5 APPROVAL AND CERTIFICATION OF DIESEL ENGINES

1 General Provisions

1.1 Scope

1.1.1 The approval and certification process of a diesel engine and the documents for use during manufacture and installation, and the document flow between engine designer, classification society approval center, engine builder/licensee and surveyors are provided in this Appendix.

1.1.2 The engine plans and documents are to be submitted for approval in accordance with the requirements of 9.1.12.1 and 9.1.12.2 of this Chapter.

1.2 Definitions

1.2.1 Definitions relating to approval and certification of diesel engines are given in Annex 1 of this Appendix.

1.3 Type approval certificate

1.3.1 For each type of engine that is required to be approved, a type approval certificate is to be obtained by the engine designer. The process details for obtaining a type approval certificate are in 3.1 of this Appendix.

1.3.2 This process consists of the engine designer obtaining:

(1) drawing and specification approval;

(2) conformity of production;

(3) approval of type testing program;

(4) type testing of engines;

(5) review of the obtained type testing results;

(6) evaluation of the manufacturing arrangements;

(7) issue of a type approval certificate upon satisfactorily meeting the Rule requirements.

1.4 Marine product certificate

1.4.1 Each diesel engine manufactured for a shipboard application is to have a marine product certificate. The certification process details for obtaining the marine product certificate are in 3.2 of this Appendix.

1.4.2 This process consists of following steps:

(1) the engine builder/licensee obtaining design appraisal of the engine application specific documents;

(2) submitting a comparison list of the production drawings to the previously approved engine design drawings;

(3) forwarding the relevant production drawings and comparison list for the use of the Surveyors at the manufacturing plant and shipyard if necessary;

(4) engine testing; and

(5) upon satisfactorily meeting CCS Rule requirements, the issuance of an engine certificate.

1.5 Approval of diesel engine components

1.5.1 Components of engine designer’s design which are covered by the type approval certificate of the relevant engine type are regarded as approved whether manufactured by the engine manufacturer or sub-supplied. For components of subcontractor’s design, necessary approvals are to be obtained by the relevant suppliers (e.g. exhaust gas turbochargers, charge air coolers, etc.).

1.6 Submission format of documentation

1.6.1 The documentation is to be submitted to CCS in electronic or paper format. If the documentation is in paper format, it is to be submitted in triplicate.

2 Document Flow for Diesel Engines

2.1 Document flow for obtaining a type approval certificate

2.1.1 For the initial engine type, the engine designer prepares the documentation in accordance with requirements in 9.1.12.1 and 9.1.12.2 of this Chapter and forwards to CCS according to the agreed procedure for review.

2.1.2 Upon review and approval of the submitted documentation (evidence of approval), it is returned to

the engine designer.
2.1.3 The engine designer arranges for a surveyor to attend an engine type test and upon satisfactory testing CCS issues a type approval certificate.
2.1.4 A representative document flow process for obtaining a type approval certificate is shown in Annex 2 of this Appendix.

2.2 Document flow for engine certificate

2.2.1 The engine type must have a type approval certificate. For the first engine of a type, the type approval process and the engine certification process (ECP) may be performed simultaneously.
2.2.2 Engines to be installed in specific applications may require the engine designer/licensor to modify the design or performance requirements. The modified drawings are forwarded by the engine designer to the engine builder/licensee to develop production documentation for use in the engine manufacture in accordance with Table 1.
2.2.3 The engine builder/licensee develops a comparison list of the production documentation to the approval documentation. An example comparison list is provided in Annex 4. If there are differences in the technical content on the licensee's production drawings/documents compared to the corresponding licensor's drawings, the licensee must obtain agreement to such differences from the licensor using the template in Annex 5.
If the designer acceptance is not confirmed, the engine is to be regarded as a different engine type and is to be subjected to the complete type approval process by the licensee.
2.2.4 The engine builder/licensee is to submit the comparison list and the production documentation to CCS according to the agreed procedure for review/approval.
2.2.5 CCS returns documentation to the engine builder/licensee with confirmation that the design has been approved. This documentation is intended to be used by the engine builder/licensee and their subcontractors and attending surveyors. As the attending Surveyors may request the engine builder/licensee or their subcontractors to provide the actual documents indicated in the list, the documents are necessary to be prepared and available for the Surveyors.
2.2.6 The attending Surveyors, at the engine builder/licensee/subcontractors, will issue product certificates as necessary for components manufactured upon satisfactory inspections and tests.
2.2.7 The engine builder/licensee assembles the engine, tests the engine with a Surveyor present. An engine certificate is issued by the Surveyor upon satisfactory completion of assembly and tests.
2.2.8 A representative document flow process for obtaining an engine certificate is shown in Figure 2, Annex 2 of this Appendix.

3 Type Approval and Certification Process

3.1 Type approval process

3.1.1 The type approval process consists of the steps in 3.1.2 to 3.1.5. The document flow for this process is shown in Figure 1, Annex 2 of this Appendix. The documentation, as far as applicable to the type of engine, to be submitted by the engine designer/licensor to CCS is listed in 9.1.12.1 and 9.1.12.2 of this Chapter.
3.1.2 9.1.12.2 lists basic descriptive information to provide the CCS an overview of the engine's design, engine characteristics and performance. Additionally, there are requirements related to auxiliary systems for the engine's design including installation arrangements, list of capacities, technical specifications and requirements, along with information needed for maintenance and operation of the engine.
3.1.3 9.1.12.1 lists the documents and drawings, which are to be approved by CCS.
3.1.4 Design appraisal (DA) is valid as long as no substantial modifications have been implemented. Where substantial modifications have been made, the validity of the DA's may be renewed based on evidence that the design is in conformance with all current Rules and statutory regulations.
3.1.5 A type approval test is to be carried out in accordance with Appendix 4 of this Chapter and is to be witnessed by the attending surveyor. The manufacturing facility of the engine presented for the type approval test is to be assessed in accordance with Section 2 of this Chapter.
3.1.6 After the requirements in 3.1.2 through 3.1.5 have been satisfactorily completed, CCS issues a type approval certificate (TAC).
3.1.7 After the engine type has been approved for the first time, only those documents as listed in 9.1.12.1 and 9.1.12.2 of this Chapter, which have undergone substantive changes, will have to be resubmitted for consideration.
3.1.8 A renewal of type approval certificates will be granted upon submission of information in:
(1) the submission of modified documents or new documents with substantial modifications replacing

former documents compared to the previous submission(s) for DA; or
(2) a declaration that no substantial modifications have been applied since the last DA issued.
3.1.9 CCS reserves the right to limit the duration of validity of the type approval certificate. The type approval certificate will be invalid if there are substantial modifications in the design, in the manufacturing or control processes or in the characteristics of the materials unless approved in advance by CCS.
3.1.10 The assignment of documents to 9.1.12.2 for information does not preclude possible comments by CCS.
3.1.11 Where considered necessary, CCS may request further documents to be submitted. This may include details or evidence of existing type approval or proposals for a type testing program.

3.2 Certification process
3.2.1 The certification process consists of the steps in 3.2.2 to 3.2.7. This process is illustrated in Figure 2, Annex 2 of this Appendix showing the document flows between the engine designer/licensor, engine builder/licensee, component manufacturers, classification society approval center and local offices.
For those cases when a licensor – licensee agreement does NOT apply, an "engine designer" is to be understood as the entity that has the design rights for the engine type or is delegated by the entity having the design rights to modify the design.
The documents listed in Table 1 of this Appendix may be submitted by the engine designer (licensor) or the manufacturer/licensee.
3.2.2 Prior to the start of the engine certification process, a design appraisal is to be obtained per 3.1.2 through 3.1.4 of this Appendix for each type of engine. Each type of engine is to be provided with a type approval certificate obtained by the engine designer/licensor prior to the engine builder/licensee beginning production manufacturing. For the first engine of a type, the type approval process and the certification process may be performed simultaneously.
The engine designer/licensor reviews the documents for the application and develops, if necessary, application specific documentation for the use of the engine builder/licensee in developing engine specific production documents.
If substantive changes have been made, the affected documents are to be resubmitted to CCS.
3.2.3 Table 1 lists the production documents, which are to be submitted by the engine builder/licensee to CCS following acceptance by the engine designer/licensor. The Surveyor uses the information for inspection purposes during manufacture and testing of the engine and its components. See 2.2.3 through 2.2.6 of this Appendix.
3.2.4 If there are differences in the technical content on the licensee's production drawings/documents compared to the corresponding licensor's drawings, the licensee must provide to CCS approval center a "Confirmation of the licensor's acceptance of licensee's modifications" approved by the licensor and signed by licensee and licensor. Modifications applied by the licensee are to be provided with appropriate quality requirements. See Annex 5 of this Appendix for a sample format.
3.2.5 CCS carries out uniformity assessment on the manufacturer's production capability and quality control capability comprising manufacturing facilities and processes, machining tools, quality assurance, testing facilities, etc. Satisfactory conformance results in the issue of a class approval document.
3.2.6 In addition to the documents listed in Table 1, the engine builder/licensee is to be able to provide to the Surveyor performing the inspection upon request the relevant detail drawings, production quality control specifications and acceptance criteria. These documents are for supplemental purposes to the survey only.
3.2.7 Each engine assembly and testing procedure required according to the Rules are to be witnessed by the attending surveyor unless an Alternative Certification Scheme is agreed between manufacturer and CCS.

Documentation for the inspection of components and systems Table 1

No.	Item
1	Engine particulars as per data sheet in Annex 3
2	Material specifications of main parts with information on non-destructive material tests and pressure tests[1]
3	Bedplate, crankcase, frame, framebox, gearbox and thrust bearing bedplate of welded design, with welding details and welding instructions[2]
4	Crankshaft (including shaft coupling bolts, counterweights, including fastening), assembly and details, thrust shaft or intermediate shaft (if integral with engine)
5	Bolts and studs for main bearings, cylinder heads and exhaust valve (two stroke design) and connecting rods
6	Tie rods

No.	Item
7	Schematic layout or other equivalent documents on the engine of fuel oil system, lubricating oil system, cooling water system, starting air system and hydraulic system (for valve lift) [3]
8	Engine control and safety system
9	Shielding of high pressure fuel pipes, assembly[4]
10	Construction of accumulators for hydraulic oil and fuel oil
11	High pressure parts for fuel oil injection system[5]
12	Arrangement and details of the crankcase explosion relief valve[6]
13	Oil mist detection and/or alternative alarm arrangements
14	Cylinder head
15	Cylinder block, engine block
16	Cylinder liner
17	Counterweights (if not integral with crankshaft), including fastening
18	Connecting rod with cap, piston rod and crosshead
19	Piston, assembly[7]
20	Piston head
21	Camshaft drive, assembly[7]
22	Flywheel
23	Arrangement of foundation (for main engines only)
24	Fuel oil injection pump
25	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
26	Construction and arrangement of dampers
27	For electronically controlled engines, assembly drawings or arrangements of control valves, high-pressure pumps, drive for high pressure pumps and valve bodies, if applicable
28	Operation and service manuals[8]
29	Test program resulting from FMEA (for engine control system)[9]
30	Production specifications for castings and welding (sequence)
31	Type approval certification for environmental tests, control components[10]
32	Quality requirements for engine production

Notes:

1. For comparison with Rule requirements for material, NDT and pressure testing as applicable.
2. For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
3. Details of the system so far as supplied by the engine manufacturer such as: main dimensions, operating media and maximum working pressures.
4. All engines.
5. The documentation to contain specifications for pressures, pipe dimensions and materials.
6. Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m^3 or more.
7. Including identification (e.g. drawing number) of components.
8. Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.
9. Required for engines that rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves.
10. Documents modified for a specific application are to be submitted to the classification society for approval or information.

Annex 1 Glossary

Term	Definition
Acceptance criteria	A set of values or criteria which a design, product, service or process is required to conform with, in order to be considered in compliance
Accepted	Status of a design, product, service or process, which has been found to conform to specific acceptance criteria
Alternative Certification Scheme (ACS)	A system, by which a society evaluates a manufacturer's quality assurance and quality control arrangements for compliance with Rule requirements, then authorizes a manufacturer to undertake and witness testing normally required to be done in the presence of a Surveyor. It corresponds to CCS Type approval A.
Appraisal	Evaluation by a competent body
Approval	The granting of permission for a design, product, service or process to be used for a stated purpose under specific conditions based upon a satisfactory appraisal
Assembly	Equipment or a system made up of components or parts
Assess	Determine the degree of conformity of a design, product, service, process, system or organization with identified specifications, Rules, standards or other normative documents
Audit	Planned systematic and independent examination to determine whether the activities are documented, the documented activities are implemented, and the results meet the stated objectives
Auditor	Individual who has the qualifications and experience to perform audits
Certificate	A formal document attesting to the compliance of a design, product, service or process with acceptance criteria
Certification	A procedure whereby a design, product, service or process is approved in accordance with acceptance criteria
Class approval	Approved by a Classification Society
Classification	Specific type of certification, which relates to the Rules of the relevant Classification Society
Competent body	Organization recognized as having appropriate knowledge and expertise in a specific area
Component	Part, member of equipment or system
Conformity	Where a design, product, process or service demonstrates compliance with its specific requirements
Contract	Agreement between two or more parties relating to the scope of service
Contractor	see Supplier
Customer	Party who purchases or receives goods or services from another
Design	All relevant plans, documents, calculations described in the performance, installation and manufacturing of a product
Design analysis	Investigative methodology selectively used to assess the design
Design appraisal	Evaluation of all relevant plans, calculations and documents related to the design
Design review	Part of the appraisal process to evaluate specific aspects of the design
Drawings approval / plan approval	Part of the design appraisal process which relates to the evaluation of drawings and plans
Equipment	Part of a system assembled from components
Equivalent	An acceptable, no less effective alternative to specified criteria
Evaluation	Systematic examination of the extent to which a design, product, service or process satisfies specific criteria
Examination	Assessment by a competent person to determine compliance with requirements
Inspection	Examination of a design, product service or process by an Inspector
Inspection plan	List of tasks of inspection to be performed by the Inspector
Installation	The assembling and final placement of components, equipment and subsystems to permit operation of the system
Manufacturer	Party responsible for the manufacturing and quality of the product
Manufacturing process	Systematic series of actions directed towards manufacturing a product
Manufacturing process approval	Approval of the manufacturing process adopted by the manufacturer during production of a specific product
Material	Goods supplied by one manufacturer to another manufacturer that will require further forming or manufacturing before becoming a new product
Modification	A limited change that does not affect the current approval
Modification notice	Information about a design modification with new modification index or new drawing number replacing the earlier drawing
Performance test	Technical operation where a specific performance characteristic is determined

Term	Definition
Producer	See manufacturer
Product	Result of the manufacturing process
Prototype test	Investigations on the first or one of the first new engines with regard to optimization, fine tuning of engine parameters and verification of the expected running behavior
Quality assurance	All the planned and systematic activities implemented within the quality system, and demonstrated as needed to provide adequate confidence that an entity will fulfil requirements for quality. Refer to ISO 9001
Regulation	Rule or order issued by an executive authority or regulatory agency of a government and having the force of law
Repair	Restore to original or near original condition from the results of wear and tear or damages for a product or system in service
Requirement	Specified characteristics used for evaluation purposes
Information	Additional technical data or details supplementing the drawings requiring approval
Revision	Means to record changes in one or more particulars of design drawings or specifications
Specification	Technical data or particulars which are used to establish the suitability of materials, products, components or systems for their intended use
Substantive modifications or major modifications or major changes	Design modifications, which lead to alterations in the stress levels, operational behavior, fatigue life or an effect on other components or characteristics of importance such as emissions
Subsupplier/subcontractor	One who contracts to supply material to another supplier
Supplier	One who contracts to furnish materials or design, products, service or components to a customer or user
Test	A technical operation that consists of the determination of one or more characteristics or performance of a given product, material, equipment, organism, physical phenomenon, process or service according to a specified procedure
Traceability	Ability to follow back through the design and manufacturing process to the origin
Type approval	The establishment of the acceptability of a product through the systematic: 1 evaluation of a design to determine conformance with specifications; 2 witnessing manufacture and testing of a type of product to determine compliance with the specification; 3 evaluation of the manufacturing arrangements to confirm that the product can be consistently produced in accordance with the specification
Type approval test	Last step of the type approval procedure. Test program in accordance with Appendix 4 of this Chapter
Witness	Individual physically present at a test and being able to record and give evidence about its outcome

Annex 2 Representative Document Flow Diagrams

The document flow diagrams are provided as an aid to all parties involved in the engine certification process as to their roles and responsibilities. Variations in the document flow may vary in response to unique issues with regard to various factors related to location, availability of components and surveys. In any case, the text in the Appendix takes precedence over these flow diagrams.

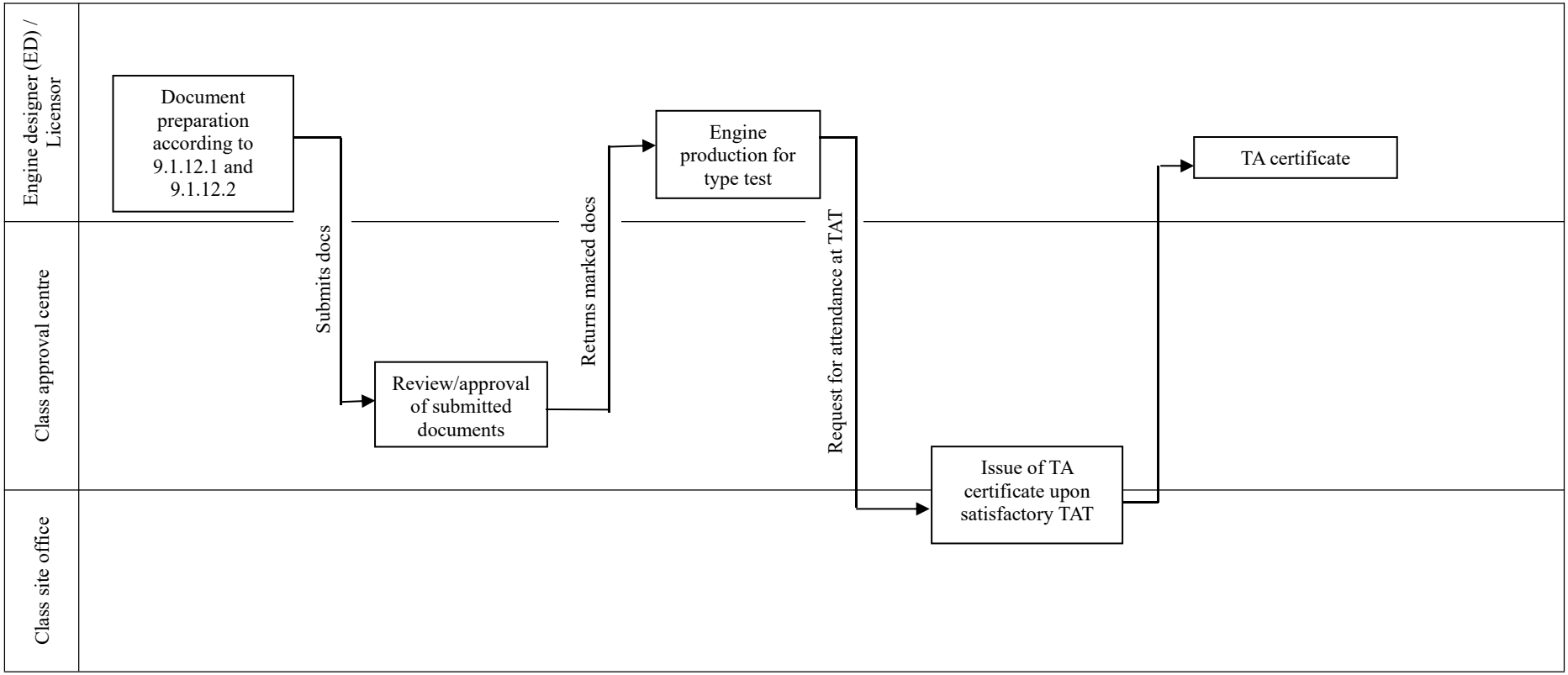


Figure 1 Type approval document flow

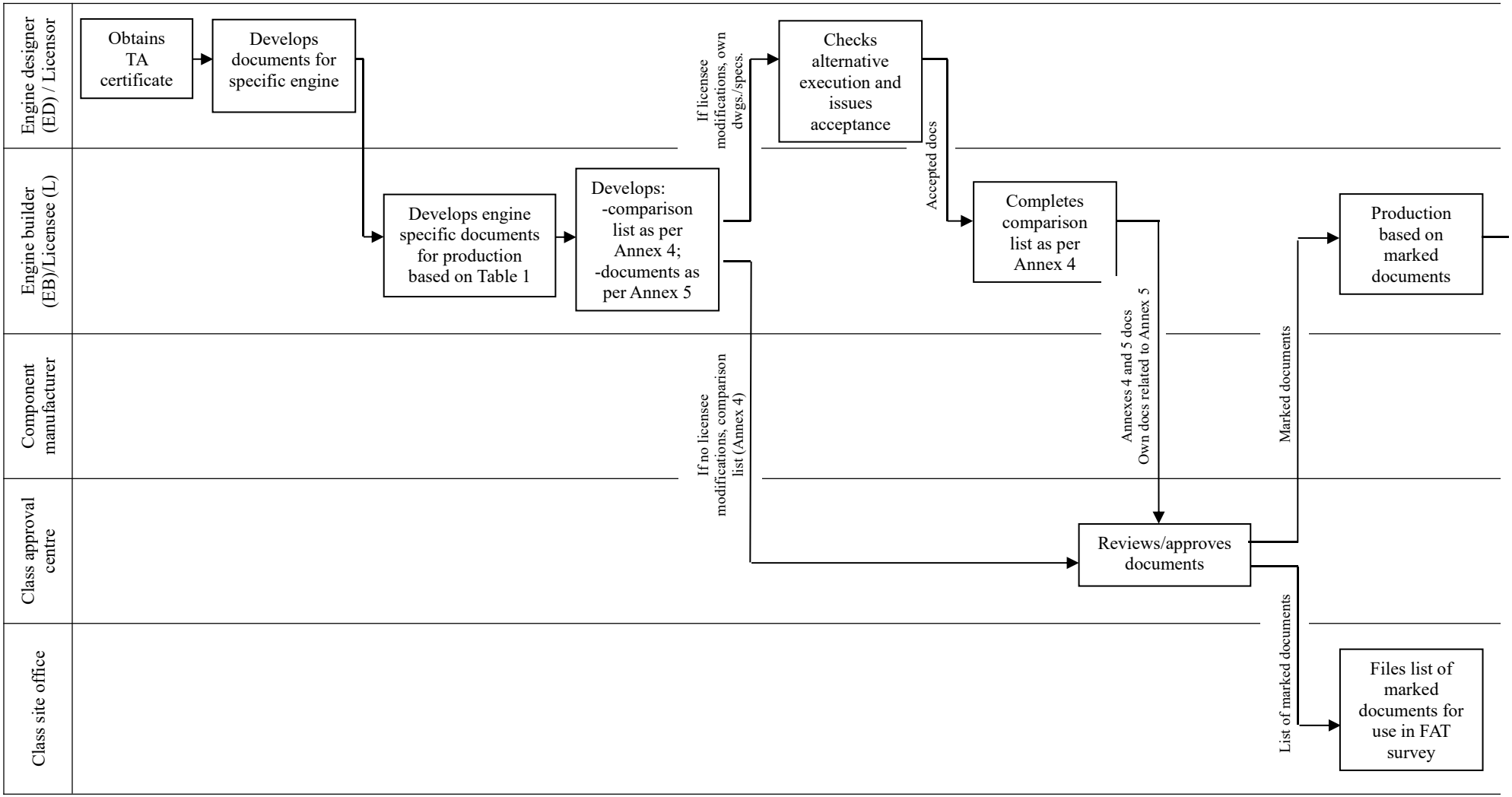


Figure 2 Engine certificate document flow

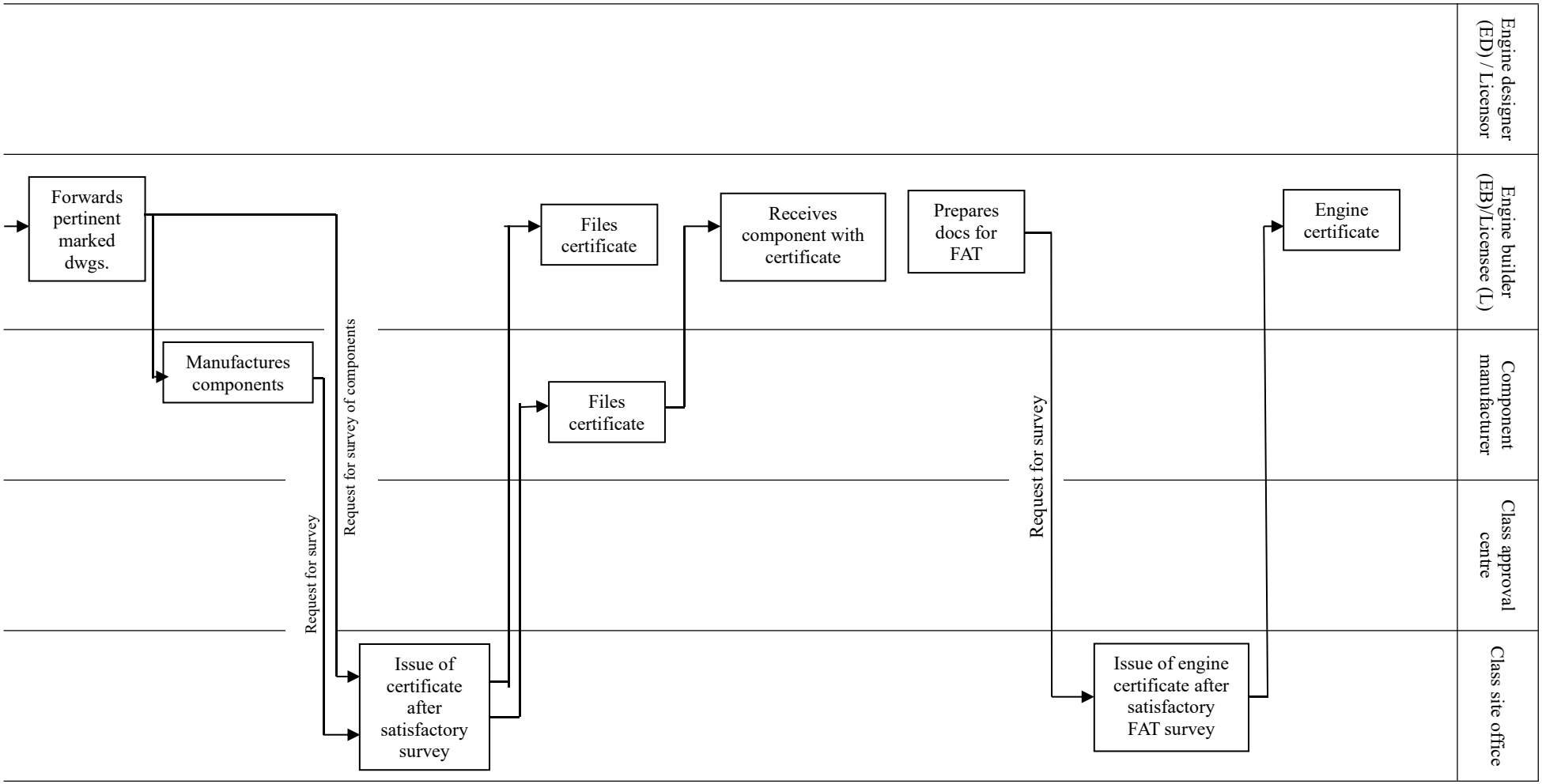


Figure 2 Engine certificate document flow (continued)

Annex 3 Internal Combustion Engine Approval Application Form and Data Sheet

CCS Application number (if applicable): Engine Manufacturer's Application Identification Number:

General Data	
Engine Designer: Contact Person: Address:	Engine Manufacturer(s), Licensee(s) and/or Manufacturing Sites① Name Country

1. Document purpose (select options from either 1a or 1b)	
1a. Type Approval Application	
Service Requested	Required activities②
☐ New Type Approval	• DA, TT, CoP
☐ Renew Type Approval	• CoP, if design change then amended or new certificate process to be followed
☐ Amend Type Approval	• DA & CoP, Further TT if previously approved engine has been substantively modified (as required by URM71)
☐ Design Evaluation	• DA, TT, applicable where designer does not have production facilities, Type Approval to be granted to specific production facility once associated CoP has been completed.
☐ Update TA Supplement	• Update to Supplement, only for minor changes not affecting the Type Approval Certificate
☐ Other	• e.g. National/Statutory Administration requirements, i.e. MSC.81(70), as amended, for emergency engines
For TA Cert amendments or Supplement updates, details of what is to be changed:	
For 'Other', Details of the requirements to be considered:	
1b. Addendum for Individual Engine FAT and Certification	
☐ Individual engine requiring FAT and Certification, only where the performance data for the engine being certified differs from the details provided on the original Type Approval Application. Only section 3b requires completion. Where changes to other sections are necessary, a new Type Approval application may be required.	
Reference number of Internal Combustion Engine Approval Application Form previously submitted and reference number of the Type Approval certificate	(Copy of original application form to be attached to this document)

2. Existing documentation			
Previous Class Type Approval Certificate No. or related Design Appraisal No. (if applicable)			
Formerly issued documentation for engine (E.g. previous type test reports, in-service experience justification reports, etc.)	Issuing Body:	Document Type:	Document No.:
Existing Certification (E.g. Manufacturer's quality certification ISO 9001 etc.)	Issuing Body	Document Type	Document No.

3. Design (mark all that apply)					
3a. Engine Particulars:					
Engine Type Manufactured Since③:			Number of delivered marine engines:		
Application	☐ Direct drive Propulsion (☐ Single engine / ☐ Multi-engine installation)		☐ Auxiliary (☐ Aux. Services / ☐ Electric Propulsion)		☐ Emergency
Mechanical Design	☐ 2-stroke ☐ Cross-head Cylinder bore(mm)	☐ 4-stroke ☐ Trunk-piston	☐ In-line ☐ Reversible Length of piston stroke (mm)	☐ Vee (V-angle °) ☐ Non-reversible	☐ Other ( )
Supercharging	☐ Without supercharging	☐ With supercharging ☐ Without charge air cooling ☐ Constant-pressure charging system		☐ With charge air cooling ☐ Pulsating pressure charging system	

① All parties that affect the final complete engine (e.g. manufacture, modify, adjust) are to be listed. All sites where such work is carried out may be required to complete CoP assessment.
② DA = Design Appraisal, TT = Type Test, CoP = Assessment of Conformity of Production. See 'Definitions' at the end of this application form for more information.
③ Only in case of TA Extension.

Valve operation	☐ Cam control	☐ Electronic control		
Fuel Injection	☐ Direct injection	☐ Indirect injection	☐ Cam controlled injection	☐ Electronically controlled injection

Fuel Types (Classification according to ISO 8216)	☐ Marine residual fuel	cSt (Max. kinematic viscosity at 50°C)
	☐ Marine distillate fuel	DMA, DMB, DMC
	☐ Marine distillate fuel	DMX
	☐ Low flashpoint liquid fuel (specify fuel type)	
	☐ Gas (specify gas type)	
	☐ Other (specify)	
	☐ Dual Fuel (specify combinations of fuels to be used simultaneously)	

3b. Performance Data
(Related to: Barometric pressure 1,000 mbar; Air temperature 45°C; Relative humidity 60%; Seawater temperature 32°C)

Model reference No. (if applicable)	
Max. continuous rating	kW/cyl
Rated speed	1/min
Mean indicated pressure	MPa
Mean effective pressure	MPa
Max. firing pressure	MPa
Charge air pressure	MPa
Compression ratio	-
Mean piston speed	m/s

3c. Crankshaft

Design	☐ Solid	☐ Semi-built	☐ Built	
Method of Manufacture	☐ Cast	☐ Forged		
		☐ Slab forged	☐ Approved die forged	☐ Continuous grain flow process

State approved forge/works name:

Is the crankshaft hardened by an approved process which includes the fillet radii of crankpins and journals? ☐ Yes ☐ No

If yes, state process:

Crankshaft material specification:

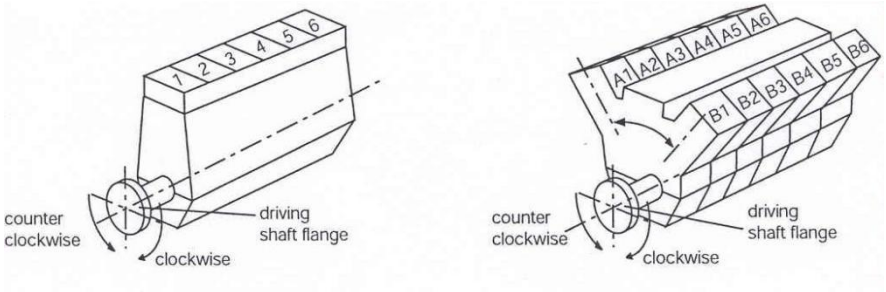
U.T.S. (N/mm^2) Yield strength (N/mm^2)

Hardness value (Brinell/Vickers) Elongation (%)

Dimensional Data

If shrunk on webs, state shrinkage allowance (mm)	Yield strength of crankweb material (N/mm^2)
Centre of gravity of connecting rod from large end centre (mm)	Radius of gyration of connecting rod (mm)
Mass of each crankweb (kg)	Centre of gravity of web from journal axis (mm)
Mass of each counterweight (kg)	Centre of gravity of each counterweight from journal axis (mm)
Axial length of main bearing (mm)	Main bearing working clearance (mm)
Mass of flywheel at driving end (kg)	Mass of flywheel at opposite end (kg)
Nominal alternating torsional stress in crankpin (N/mm^2)	Nominal alternating torsional stress in crank journal (N/mm^2)
Length between centres (Total length)(mm)	

3d. Firing order



State numbering system of cylinders from left to right as per above diagrams (as applicable)

Number of cylinders	Clockwise firing order	Counter-clockwise firing order

4. Engine Ancillary Systems

4a. Turbochargers ☐ Fitted ☐ Not Fitted

Turbocharger oil supply by: ☐ Engine lub. oil system ☐ TC internal lub. oil system

No. of cylinders	No. of aux blowers	No. of charge air coolers	No. of TC	TC manufacturer & type	TC type approval certificate No.
				/ / / / / /	

4b. Speed governor

Engine application (Main/Aux/Emergency)	Manufacturer / type	Mode of operation	Type approval cert. No. (if electric / electronic gov.)
	/ / /		

4c. Overspeed protection

Independent overspeed protection available ☐ Yes ☐ No Mode of operation:

Manufacturer / type, if electronic: / Type approval certificate No.

4d. Electronic systems

Engine control and management system

Note: use Remarks section to identify when a different engine control system will be used for Type Test

Hardware: Manufacturer & Model: / Type approval certificate No.

Software: Name & Version: / Software conformity certificate No.

Additional electronic system 1: System function:

Manufacturer & type: / Type approval certificate No.

Additional electronic system 2: System function:

Manufacturer & type: / Type approval certificate No.

Additional electronic system 3: System function:

Manufacturer & type: / Type approval certificate No.

4e. Starting System

Type:

4f. Safety devices/functions

A flame arrestor or a bursting disk is installed in the starting air system: before each starting valve ☐ Yes ☐ No; in the starting air manifold ☐ Yes ☐ No

Crank case relief valves available ☐ Yes ☐ No Manufacturer / type: /

Type approval certificate No.

No. of cyl.	Total crankcase gross volume incl. attachments (m^3)	Type & size (mm) of relief valve	Relief area per relief valve (mm^2)	No. of relief valves
		/ / / /		

Method used for detection of potentially explosive crankcase condition:

☐ Oil mist detector: Manufacturer / type: / Type approval certificate No.

☐ Alternative method: (mark all that apply) ☐ crankcase pressure monitoring ☐ oil splash temperature monitoring ☐ bearing temperature monitoring ☐ recirculation arrangements ☐ other:

Cylinder overpressure warning device available ☐ Yes ☐ No

Type: Opening pressure (bar):

4g. Attached ancillary equipment(Mark all that apply)

Engine driven pumps:

☐ Main lubricating oil pump ☐ Sea cooling water pump ☐ LT-fresh cooling water pump

☐ HT-fresh cooling water pump ☐ Fuel oil booster pump ☐ Hydraulic oil pump ☐ Other ( )

Engine attached motor driven pumps:

☐ Lubricating oil pump ☐ Cooling fresh water pump ☐ Fuel oil booster pump

☐ Hydraulic oil pump ☐ Other ( )

Engine attached cooler or heater:

☐ Lubricating oil cooler ☐ Lubricating oil heater ☐ Fuel oil valve cooler

☐ Hydraulic oil cooler ☐ Cooling fresh water cooler

Engine attached filter:			
Lubricating oil filter	☐ Single	☐ Duplex	☐ Automatic
Fuel oil filter	☐ Single	☐ Duplex	☐ Automatic

5. Inclination limits (engine operation is safeguarded under the following limits)	Athwartships		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main & Auxiliary machinery	☐ 15.0°	☐ 22.5°	☐ 5.0°	☐ 7.5°
Emergency machinery	☐ 22.5°	☐ 22.5°	☐ 10.0°	☐ 10.0°
Emergency machinery on ships for the carriage of liquefied gas and liquid chemicals	☐ 30.0°	☐ 30.0°		

6. Main engine emergency operation		
At failure of one auxiliary blower, engine can be started and operated at partial load	☐ Yes	☐ No
At failure of one turbo charger, engine operation can be continued	☐ Yes	☐ No

7. References: Additional Information Attached to Application	
Document Name/Number	Summary of information contained in document

8. Further Remarks:

Completed By: Signature: _____

Company:

Job Title: Stamp:

Date:

Definitions:

(1) Design Appraisal: Evaluation of all relevant plans, calculations and documents related to the design to determine compliance with the individual Societies' technical requirements. This includes requirements for all associated ancillary equipment and systems essential for the safe operation of the engine, i.e. the Complete Engine. The Design Appraisal is recorded on a Supplement to the Type Approval Certificate.

(2) **Type Testing** requires satisfactory completion of testing of the Complete Engine against the requirements applicable engine Type Testing program. Type testing is only applicable to the first in series; all engines are to complete factory acceptance and shipboard trials as defined in Appendix 6 of this Chapter.

(3) **Design Approval Certification** may be granted upon satisfactory completion of Design Appraisal and Type Testing.

(4) **Assessment of Conformity of Production** means the assessment of quality assurance, manufacturing facilities and processes and testing facilities, to confirm the manufacturer's capability to repeatedly produce the complete engine in accordance with the approved and type tested design.

(5) **Type Approval Certification** will be granted upon satisfactory completion of Design Appraisal, Type Testing and assessment of Conformity of Production of the complete engine. The Type Approval Certificate will incorporate outputs from the Design Appraisal, the Type Test and the Assessment of Conformity of Production.

(6) **Complete Engine** includes the control system and all ancillary systems and equipment referred to in the Rules that are used for safe operation of the engine and for which there are rule requirements, this includes systems allowing the use of different fuel types. The exact list of components/items that will need to be tested in together with the bare engine will depend on the specific design of the engine, its control system and the fuel(s) used may include, but are not limited to, the following:

① Turbocharger(s)
② Crank case explosion relief devices
③ Oil mist detection and alarm devices
④ Piping
⑤ Electronic monitoring and control system(s) – software and hardware

⑥ Fuel management system (where dual fuel arrangements are fitted)

⑦ Engine driven pumps

⑧ Engine mounted filters.

(7) Fuel Types: All fuels that the engine is designed to operate with are to be identified on the application form as this may impact on the requirements that are applicable for Design Appraisal and the scope of the tests required for Type Testing. Where the engine is to operate in a Dual Fuel mode, the combinations of fuel types are to be detailed. E.g. Natural Gas + DMA, Natural Gas + Marine Residual Fuel, the specific details of each fuel are to be provided as indicated in the relevant rows of the Fuel Types part of section 3a of this form.

Annex 4 Tabular Listing of Licensor's and Licensee's Drawing and Data

Licensee:_____ Licensor:_____
Licensee Engine No. :_____ Engine type:_____

No.	Components or System	Licensor			Licensee		Has Design been modified by Licensee?		If Yes, indicate following information	
		Dwg. No. & Title	Rev. No.	Date of Class Approval or Review	Dwg. No.	Rev. No.	Yes	No	Identification of Alternative approved by Licensor	Date of Class Approval or Review of Licensee Dwg.
1										
2										
3										
4										
5										
6										
7										
8										
9 ...										

I attest the above information to be correct and accurate.

Person in Charge (Licensee): _____ _____
Printed Name Signature

Date:_____

Annex 5 Sample Template for confirmation of the Licensor's Acceptance of Licensee's Modifications

<table>
<tr><td colspan="6">Engine Licensee Proposed Alternative to Licensor's Design</td></tr>
<tr><td colspan="6">Licensee information</td></tr>
<tr><td>Licensee:</td><td colspan="2"></td><td>Ref No.:</td><td colspan="2"></td></tr>
<tr><td>Description:</td><td colspan="2"></td><td>Info No.:</td><td colspan="2"></td></tr>
<tr><td>Engine type:</td><td colspan="2"></td><td>Main Section:</td><td colspan="2"></td></tr>
<tr><td>Engine No.:</td><td colspan="2"></td><td>Plant Id.:</td><td colspan="2"></td></tr>
<tr><td colspan="6">Design Spec: ☐ General ☐ Specific Nos:</td></tr>
<tr><td>Licensor design:</td><td colspan="3">State relevant part or drawing. numbers. Insert drawing clips or pictures.
Add any relevant information</td><td colspan="2">Licensee Proposed Alternative</td></tr>
<tr><td colspan="3"></td><td colspan="3">For example:
• Differences in geometry
• Differences in the functionality
• Material
• Hardness
• Surface condition
• Alternative standard
• Licensee production information introduced on the drawing
• Weldings or castings
• etc.</td></tr>
<tr><td>Reason:
☐ Licensee's production
☐ Sub-supplier's production
☐ Cost down
☐ Tools</td><td colspan="2">Interchangeability w. licensor design
☐ Yes ☐ No</td><td colspan="2">Non-conformity Report
Research, Assessment, Evaluation
☐ NCR ☐ RAE</td><td>Certified by licensee:
Initials:
Date:</td></tr>
<tr><td colspan="6">Licensor comments</td></tr>
<tr><td colspan="3">LoAE:
☐ Accepted as alternative execution (Licensor undertakes responsibility)
☐ No objection (Licensee undertakes responsibility)
☐ Not acceptable</td><td colspan="2">NCR:
☐ Approved
☐ Conditionally approved
☐ Rejected</td><td>Certified by licensor:
Initials:
Date:</td></tr>
<tr><td>Licensor ref.:</td><td colspan="4"></td><td>Date:</td></tr>
<tr><td>Licensee ref.:</td><td colspan="4"></td><td>Date:</td></tr>
</table>

Appendix 6 WORKS ACCEPTANCE TEST AND SHIPBOARD TRIALS OF DIESEL ENGINES①

1 General Provisions

1.1 Safety precautions

1.1.1 Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer / shipyard and is to be operational.

1.1.2 This applies especially to crankcase explosive conditions protection, but also to overspeed protection and any other shut down function.

1.1.3 The overspeed protective device is to be set to a value, which is not higher than the overspeed value that was demonstrated during the type test for that engine. This set point is to be verified by the surveyor.

1.2 General requirements

1.2.1 Before any official testing, the engines are to be run-in as prescribed by the engine manufacturer.

1.2.2 Adequate test bed facilities for loads as required are to be provided. All fluids used for testing purposes such as fuel, lubrication oil and cooling water are to be suitable for the purpose intended, e.g. they are to be clean, preheated if necessary and cause no harm to engine parts.

1.2.3 The testing consists of workshop and shipboard (quay and sea trial) testing.

1.2.4 Engines are to be inspected for:

(1) jacketing of high-pressure fuel oil lines including the system used for the detection of leakage;

(2) screening of pipe connections in piping containing flammable liquids;

(3) insulation of hot surfaces by taking random temperature readings that are to be compared with corresponding readings obtained during the type test. This is to be done while running at the rated power of engine. Use of contact thermometers may be accepted at the discretion of the attending Surveyor. If the insulation is modified subsequently to the Type Approval Test, CCS may request temperature measurements as required by Appendix 4 of this Chapter.

1.2.5 These inspections are normally to be made during the works trials, but at the discretion of CCS, parts of these inspections may be postponed to the shipboard testing.

2 Factory Acceptance Test

2.1 Objectives

2.1.1 The purpose of the works trials is to verify design premises such as power, safety against fire, adherence to approved limits (e.g. maximum pressure), and functionality and to establish reference values or base lines for later reference in the operational phase.

2.2 Records

2.2.1 The following environmental test conditions are to be recorded:

(1) Ambient air temperature;

(2) Ambient air pressure;

(3) Atmospheric humidity.

2.2.2 For each required load point, the following parameters are normally to be recorded:

(1) Power and speed;

(2) Fuel index (or equivalent reading);

(3) Maximum combustion pressures (only when the cylinder heads installed are designed for such measurement);

(4) Exhaust gas temperature before turbine and from each cylinder (to the extent that monitoring is required in 9.6.2 of this Chapter);

(5) Charge air temperature;

(6) Charge air pressure;

(7) Turbocharger speed (to the extent that monitoring is required in 9.6.2 of this Chapter).

2.2.3 Calibration records for the instrumentation are, upon request, to be presented to the attending

---

① In this Appendix, the requirements for works acceptance test are applicable to diesel engines with an application for certification dated on or after 1 July 2016, and those for shipboard trials are applicable to diesel engines:
(1) with an application for certification dated on or after 1 July 2016; or
(2) installed on ships contracted for construction on or after 1 July 2016.

Surveyor.

2.2.4 For all stages at which the engine is to be tested, the pertaining operational values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer. This also includes crankshaft deflections if considered necessary by the engine designer.

2.2.5 In each case, all measurements conducted at the various load points are to be carried out at steady state operating conditions. However, for all load points provision are to be made for time needed by the Surveyor to carry out visual inspections. The readings for MCR, i.e. 100% power (rated maximum continuous power at corresponding rpm) are to be taken at least twice at an interval of normally 30 min.

2.3 Test loads

2.3.1 Test loads for various engine applications are given in 2.3.2 to 2.3.6.

2.3.2 Propulsion engines driving propeller or impeller only.

(1) 100% power (MCR) at corresponding speed n_0: at least 60 min.

(2) 110% power at engine speed $1.032n_0$: Records to be taken after 15 min or after steady conditions have been reached, whichever is shorter.

Note: Only required once for each different engine/turbocharger configuration.

(3) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

(4) 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve, the sequence to be selected by the engine manufacturer.

(5) Reversing manoeuvers (if applicable).

Note: After running on the test bed, the fuel delivery system is to be so adjusted that overload power cannot be given in service, unless intermittent overload power is approved by CCS. In that case, the fuel delivery system is to be blocked to that power.

2.3.3 Engines driving generators for electric propulsion:

(1) 100% power (MCR) at corresponding speed n_0: at least 60 min.

(2) 110% power at engine speed n_0: 15 min after having reached steady conditions.

(3) Governor tests for compliance with 9.7.8 and 9.7.10 of this Chapter are to be carried out.

(4) 75%, 50% and 25% power and idle, the sequence to be selected by the engine manufacturer.

Note: After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a 10% margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the required transient governing characteristics are achieved also at 100% loading of the engine, and so that the protection system utilized in the electric distribution system can be activated before the engine stalls.

2.3.4 Engines driving generators for auxiliary purposes:

Tests are to be performed as in 2.3.3.

2.3.5 Propulsion engines also driving power take off (PTO) generator.

(1) 100% power (MCR) at corresponding speed n_0: at least 60 min.

(2) 110% power at engine speed n_0: 15 min after having reached steady conditions.

(3) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

(4) 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve or at constant speed n_0, the sequence to be selected by the engine manufacturer.

Note: After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the electrical protection of downstream system components is activated before the engine stalls. This margin may be 10% of the engine power but at least 10% of the PTO power.

2.3.6 Engines driving auxiliaries

(1) 100% power (MCR) at corresponding speed n_0: at least 30 min.

(2) 110% power at engine speed n_0: 15 min after having reached steady conditions.

(3) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

(4) For variable speed engines, 75%, 50% and 25% power in accordance with the nominal power consumption curve, the sequence to be selected by the engine manufacturer.

Note: After running on the test bed, the fuel delivery system is normally to be so adjusted that overload power cannot be delivered in service, unless intermittent overload power is approved. In that case, the fuel delivery system is to be blocked to that power.

2.4 Turbocharger matching with engine

2.4.1 Turbochargers are to have a compressor characteristic that allows the engine, for which it is intended, to operate without surging during all operating conditions and also after extended periods in operation. For abnormal, but permissible, operation conditions, such as misfiring and sudden load reduction, no continuous surging is to occur.

Notes: Surging and continuous surging are defined as follows:

① Surging means the phenomenon, which results in a high pitch vibration of an audible level or explosion-like noise from the scavenger area of the engine.
② Continuous surging means that surging happens repeatedly and not only once.

2.4.2 Category C turbochargers used on propulsion engines are to be checked for surge margins during the engine workshop testing as specified below. These tests may be waived if successfully tested earlier on an identical configuration of engine and turbocharger (including same nozzle rings).

For 4-stroke engines, the following are to be performed without indication of surging:

− with maximum continuous power and speed (=100%), the speed is to be reduced with constant torque (fuel index) down to 90% power;
− with 50% power at 80% speed (= propeller characteristic for fixed pitch), the speed is to be reduced to 72% while keeping constant torque (fuel index).

For 2-stroke engines, the surge margin is to be demonstrated by at least one of the following methods:

(1) The engine working characteristic established at workshop testing of the engine is to be plotted into the compressor chart of the turbocharger (established in a test rig). There is to be at least 10% surge margin in the full load range, i.e. working flow is to be 10% above the theoretical (mass) flow at surge limit (at no pressure fluctuations).

(2) Sudden fuel cut-off to at least one cylinder is not to result in continuous surging and the turbocharger is to be stabilized at the new load within 20 seconds. For applications with more than one turbocharger, the fuel is to be cut-off to the cylinders closest upstream to each turbocharger. This test is to be performed at two different engine loads:

− the maximum power permitted for one cylinder misfiring;
− the engine load corresponding to a charge air pressure of about 0.6 bar (but without auxiliary blowers running).

(3) No continuous surging and the turbocharger is to be stabilized at the new load within 20 seconds when the power is abruptly reduced from 100% to 50% of the maximum continuous power.

2.5 Integration tests

2.5.1 For electronically controlled engines, integration tests are to be made to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes and the tests considered as a system are to be carried out at the works. If such tests are technically unfeasible at the works, however, these tests may be conducted during sea trial. The scope of these tests is to be agreed with CCS for selected cases based on the FMEA.

2.6 Component inspections

2.6.1 Random checks of components to be presented for inspection after works trials are left to the discretion of the surveyor.

3 Shipboard Trials

3.1 Objectives

3.1.1 The purpose of the shipboard testing is to verify compatibility with power transmission and driven machinery in the system, control systems and auxiliary systems necessary for the engine and integration of engine/shipboard control systems, as well as other items that had not been dealt with in the FAT (Factory Acceptance Testing).

3.2 Starting capacity

3.2.1 Starting manoeuvers are to be carried out in order to verify that the capacity of the starting media satisfies the required number of start attempts.

3.3 Monitoring and alarm system

3.3.1 The monitoring and alarm systems are to be checked to the full extent for all engines, except items already verified during the works trials.

3.4 Test loads

3.4.1 Test loads for various engine applications are given in 3.4.3 to 3.4.7. In addition, the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

3.4.2 The suitability of the engine to operate on fuels intended for use is to be demonstrated.

Note: Tests other than those listed in 3.4.3 to 3.4.7 may be required by statutory instruments (e.g. EEDI verification).

3.4.3 Propulsion engines driving fixed pitch propeller or impeller:
(1) At rated engine speed n_0: at least 4 h.
(2) At engine speed $1.032n_0$ (if engine adjustment permits, see 2.3.2 of this Appendix): 30 min.
(3) At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer
(4) Minimum engine speed to be determined.
(5) The ability of reversible engines to be operated in reverse direction is to be demonstrated.
Note: During stopping tests according to resolution MSC.137(76), see 3.5.1 for additional requirements in the case of a barred speed range.
3.4.4 Propulsion engines driving controllable pitch propellers:
(1) At rated engine speed n_0 with a propeller pitch leading to rated engine power (or to the maximum achievable power if 100% cannot be reached): at least 4 h.
(2) At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
(3) With reverse pitch suitable for manoeuvring, see 3.5.1 for additional requirements in the case of a barred speed range.
3.4.5 Engine(s) driving generator(s) for electrical propulsion and/or main power supply:
(1) At 100% power (rated electrical power of generator): at least 60 min.
(2) At 110% power (rated electrical power of generator): at least 10 min.
Note: Each engine is to be tested 100% electrical power for at least 60 min and 110% of rated electrical power of the generator for at least 10 min. This may, if possible, be done during the electrical propulsion plant test, which is required to be tested with 100% propulsion power (i.e. total electric motor capacity for propulsion) by distributing the power on as few generators as possible. The duration of this test is to be sufficient to reach stable operating temperatures of all rotating machines or for at least 4 h. When some of the gen. set(s) cannot be tested due to insufficient time during the propulsion system test mentioned above, those required tests are to be carried out separately.
(3) Demonstration of the generator prime movers' and governors' ability to handle load steps as described in 9.7.10 of this Chapter.
3.4.6 Propulsion engines also driving power take off (PTO) generator:
(1) 100% engine power (MCR) at corresponding speed n_0: at least 4 h.
(2) 100% propeller branch power at engine speed n_0 (unless already covered in (1)): 2 h.
(3) 100% PTO branch power at engine speed n_0: at least 1 h.
3.4.7 Engines driving auxiliaries:
(1) 100% power (MCR) at corresponding speed n_0: at least 30 min.
(2) Approved intermittent overload: testing for duration as approved.

3.5 Torsional vibrations

3.5.1 Where a barred speed range (bsr) is required, passages through this bsr, both accelerating and decelerating, are to be demonstrated. The times taken are to be recorded and are to be equal to or below those times specified in the approved documentation, if any. This also includes when passing through the bsr in reverse rotational direction, especially during the stopping test.
Note: Applies both for manual and automatic passing-through systems.
The ship's draft and speed during all these demonstrations is to be recorded. In the case of a controllable pitch propeller, the pitch is also to be recorded.
The engine is to be checked for stable running (steady fuel index) at both upper and lower borders of the bsr. Steady fuel index means an oscillation range less than 5% of the effective stroke (idle to full index).

Appendix 7 TYPE TESTING PROCEDURE FOR CRANKCASE EXPLOSION RELIEF VALVES

1 Scope

1.1 To specify type tests and identify standard test conditions using methane gas and air mixture to demonstrate that relevant requirements of CCS are satisfied for crankcase explosion relief valves intended to be fitted to engines and gear cases.

1.2 This test procedure is only applicable to explosion relief valves fitted with flame arresters.

Note: Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative testing arrangements that demonstrate compliance with this Appendix may be proposed by the manufacturer. The alternative testing arrangements are to be agreed by CCS.

2 Applicable standards or rules

2.1 ISO 16852.

2.2 ISO/IEC 17025.

2.3 ISO 12100.

2.4 VDI 3673-1.

2.5 IMO MSC/Circular 677 as amended by MSC/Circ.1009 and MSC.1/Circ.1324.

3 Purpose

3.1 The purpose of type testing crankcase explosion relief valves is fourfold:

(1) to verify the effectiveness of the flame arrester;

(2) to verify that the valve closes after an explosion;

(3) to verify that the valve is gas/air tight after an explosion;

(4) to establish the level of overpressure protection provided by the valve.

4 Test facilities

4.1 Test houses carrying out type testing of crankcase explosion relief valves are to meet the following requirements specified in 4.1.1 to 4.1.11.

4.1.1 The test houses where testing is carried out are to be accredited to a recognized national or international standard, e.g. ISO/IEC 17025, and are to be acceptable to CCS.

4.1.2 The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

4.1.3 The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ± 0.1%.

4.1.4 The test facilities are to be capable of effective point-located ignition of a methane gas in air mixture.

4.1.5 The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions, one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognizing the speed of events during an explosion. The result of each test is to be documented by video recording and by recording with a heat sensitive camera.

4.1.6 The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not “pipe like” with the distance between dished ends being not more than 2.5 times its diameter. The internal volume of the test vessel is to include any standpipe arrangements.

4.1.7 The test vessel is to be provided with a flange, located centrally at one end perpendicular to the vessel longitudinal axis, for mounting the explosion relief valve. The test vessel is to be arranged in an orientation consistent with how the valve will be installed in service, i.e., in the vertical plane or the horizontal plane.

4.1.8 A circular plate is to be provided for fitting between the pressure vessel flange and valve to be tested with the following dimensions:

(1) outside diameter of 2 times the outer diameter of the valve top cover;

(2) internal bore having the same internal diameter as the valve to be tested.

4.1.9 The test vessel is to have connections for measuring the methane in air mixture at the top and bottom.

4.1.10 The test vessel is to be provided with a means of fitting an ignition source at a position specified in 5.3 of this Appendix.

4.1.11 The test vessel volume is to be as far as practicable, related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the relevant requirements in 9.7.4.6 of this Chapter for the free area of explosion relief valve to be not less than 115 cm^2/m^3 of crankcase gross volume.

Notes:

① This means that the testing of a valve having 1,150 cm^2 of free area, would require a test vessel with a volume of 10 m^3.

② Where the free area of relief valves is greater than 115 cm^2/m^3 of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.

③ In no case is the volume of the test vessel to vary by more than -10% to +15% from the design cm^2/m^3 volume ratio.

5 Explosion test process

5.1 All explosion tests to verify the functionality of crankcase explosion relief valves are to be carried out using an air and methane mixture with a volumetric methane concentration of 9.5%±0.5%. The pressure in the test vessel is to be not less than atmospheric and is not to exceed the opening pressure of the relief valve.

5.2 The concentration of methane in the test vessel is to be measured at the top and bottom of the vessel and these concentrations are not to differ by more than 0.5%.

5.3 The ignition of the methane and air mixture is to be made at the centerline of the test vessel at a position approximately one third of the height or length of the test vessel opposite to where the valve is mounted.

5.4 The ignition is to be made using a maximum 100 J explosive charge.

6 Valves to be tested

6.1 The valves used for type testing (including testing specified in 6.3) are to be selected from the manufacturer's normal production line for such valves by the Surveyor witnessing the tests.

6.2 For approval of a specific valve size, three valves are to be tested in accordance with 6.3 and 7.1 to 7.2 of this Appendix. For approval of a series of valves, 9.1 to 9.4 of this Appendix are to be complied with.

6.3 The valves selected for type testing are to have been previously tested at the manufacturer's works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of ±20% and that the valve is air tight at a pressure below the opening pressure for at least 30 seconds.

Note: This test is to verify that the valve is air tight following assembly at the manufacturer's works and that the valve begins to open at the required pressure demonstrating that the correct spring has been fitted.

6.4 The type testing of valves is to recognize the orientation in which they are intended to be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e. in the vertical and/or horizontal positions.

7 Method

7.1 The following requirements of 7.1.1 to 7.1.5 are to be satisfied at explosion testing.

7.1.1 The explosion testing is to be witnessed by a Surveyor.

7.1.2 Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.

7.1.3 Successive explosion testing to establish a valve's functionality is to be carried out as quickly as possible during stable weather conditions.

7.1.4 The pressure rise and decay during all explosion testing is to be recorded.

7.1.5 The external condition of the valves is to be monitored during each test for indication of any flame release by video and heat sensitive camera.

7.2 The explosion testing is to be in three stages as specified in 7.2.1 to 7.2.3 for each valve that is required to be approved as being type tested.

7.2.1 Stage 1: Two explosion tests are to be carried out in the test vessel with the circular plate described in 4.1.8 fitted and the opening in the plate covered by a 0.05 mm thick polythene film.

Note: These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel, see 8.1.6 of this Appendix.

7.2.2 Stage 2:

(1) Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought, i.e. in the vertical or horizontal position with the circular plate described in 4.1.8 located between the valve and pressure vessel mounting flange.

(2) The first of the two tests on each valve is to be carried out with a 0.05mm thick polythene bag, having a minimum diameter of three times the diameter of the circular plate and volume not less than 30% of the test

vessel, enclosing the valve and circular plate. Before carrying out the explosion test, the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion consistent with the requirements of the standards identified in 2.1 to 2.5 of this Appendix.

Note: During the test, the explosion pressure will open the valve and some unburned methane/air mixture will be collected in the polythene bag. When the flame reaches the flame arrester and if there is flame transmission through the flame arrester, the methane/air mixture in the bag will be ignited and this will be visible.

(3) Provided that the first explosion test successfully demonstrated that there was no indication of combustion outside the flame arrester and there are no visible signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be carried out as quickly as possible after the first test. During the second explosion test, the valve is to be visually monitored for any indication of combustion outside the flame arrester and video records are to be kept for subsequent analysis. The second test is required to demonstrate that the valve can still function in the event of a secondary crankcase explosion.

(4) After each explosion, the test vessel is to be maintained in the closed condition for at least 10 seconds to enable the tightness of the valve to be ascertained. The tightness of the valve can be verified during the test from the pressure/time records or by a separate test after completing the second explosion test.

7.2.3 Stage 3: Carry out two further explosion tests as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise, recognizing that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

8 Assessment and records

8.1 For the purposes of verifying compliance with the requirements of this Appendix, the assessment and records of the valves used for explosion testing are to address the requirements as specified in 8.1.1 to 8.1.9.

8.1.1 The valves to be tested are to have evidence of design appraisal/approval by CCS witnessing tests.

8.1.2 The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the free area of the valve and of the flame arrester and the amount of valve lift at 0.02 MPa.

8.1.3 The test vessel volume is to be determined and recorded.

8.1.4 For acceptance of the functioning of the flame arrester, there is not to be any indication of flame or combustion outside the valve during an explosion test. This should be confirmed by the test laboratory taking into account measurements from the heat sensitive camera.

8.1.5 The pressure rise and decay during an explosion is to be recorded, with indication of the pressure variation showing the maximum overpressure and steady underpressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.

8.1.6 The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2. The pressure rise is not to exceed the limit specified by the manufacturer.

8.1.7 The valve tightness is to be ascertained by verifying from the records at the time of testing that an underpressure of at least 0.3 bar is held by the test vessel for at least 10 seconds following an explosion. This test is to verify that the valve has effectively closed and is reasonably gas-tight following dynamic operation during an explosion.

8.1.8 After each explosion test specified in 7.2.2, the external condition of the flame arrester is to be examined for signs of serious damage and/or deformation that may affect the operation of the valve.

8.1.9 After completing the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

9 Design series qualification

9.1 The qualification of quenching devices to prevent the passage of flame can be evaluated for other similar devices of identical type where one device has been tested and found satisfactory.

9.2 The quenching ability of a flame arrester depends on the total mass of quenching lamellas/mesh. Provided the materials, thickness of materials, depth of lamellas/thickness of mesh layer and the quenching gaps are the same, then the same quenching ability can be qualified for different sizes of flame arresters subject to the following requirements being satisfied.

$$\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

$$\frac{A_1}{A_2} = \frac{S_1}{S_2}$$

where: n_1 = total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1;

n_2 = total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to S_2;

A_1 = free area of quenching device for a valve with a relief area equal to S_1;

A_2 = free area of quenching device for a valve with a relief area equal to S_2.

9.3 The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with 7 and 8 of this Appendix can be evaluated, where valves are of identical type and have identical features of construction, in accordance with 9.3.1 to 9.3.3:

9.3.1 The free area of a larger valve does not exceed three times +5% that of the valve that has been satisfactorily tested.

9.3.2 One valve of the largest size, subject to 9.3.1, requiring qualification is subject to satisfactory testing required by 6.3 and 7.2.2 except that a single valve will be accepted in 7.2.2(1) and the volume of the test vessel is not to be less than one third of the volume required by 4.1.11.

9.3.3 The assessment and records are to be in accordance with Section 8 of this Appendix noting that 8.1.6 will only be applicable to Stage 2 for a single valve.

9.4 The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with Sections 7 and 8 of this Appendix can be evaluated, where valves are of identical type and have identical features of construction , in accordance with 9.4.1 to 9.4.3:

9.4.1 The free area of a smaller valve is not less than one third of the valve that has been satisfactorily tested.

9.4.2 One valve of the smallest size, subject to 9.4.1, requiring qualification is subject to satisfactory testing required by 6.3 and 7.2.2 except that a single valve will be accepted in 7.2.2(1) and the volume of the test vessel is not to be more than the volume required by 4.1.11.

9.4.3 The assessment and records are to be in accordance with Section 8 of this Appendix noting that 8.1.6 will only be applicable to Stage 2 for a single valve.

10 The report

10.1 The test facility is to deliver a full report that includes the following information and documents specified in 10.1.1 to 10.1.8.

10.1.1 Test specification.

10.1.2 Details of test pressure vessel and valves tested.

10.1.3 The orientation in which the valve was tested (vertical or horizontal position).

10.1.4 Methane in air concentration for each test.

10.1.5 Ignition source.

10.1.6 Pressure curves for each test.

10.1.7 Video recordings of each valve test.

10.1.8 The assessment and records stated in Section 8 of this Appendix.

11 Approval

11.1 The approval of an explosion relief valve is at the discretion of CCS based on the appraisal plans and particulars and the test facility’s report of the results of type testing.

Appendix 8 TYPE TESTING PROCEDURE FOR CRANKCASE OIL MIST DETECTION AND ALARM EQUIPMENT

1 Scope

1.1 To specify the tests required to demonstrate that crankcase oil mist detection and alarm equipment intended to be fitted to diesel engines satisfy the requirements of CCS rules.

Note: This test procedure is also applicable to oil mist detection and alarm equipment intended for gear cases.

2 Applicable standards or rules

2.1 CCS Guidelines for Type Approval Test of Electric and Electronic Products, 2006.

3 Purpose

3.1 The purpose of type testing crankcase oil mist detection and alarm equipment is seven fold:

(1) to verify the functionality of the system;
(2) to verify the effectiveness of the oil mist detectors;
(3) to verify the accuracy of oil mist detectors;
(4) to verify the alarm set points;
(5) to verify time delays between oil mist leaving the source and alarm activation;
(6) to verify functional failure detection;
(7) to verify the influence of optical obscuration on detection.

4 Test facilities

4.1 Test houses carrying out type testing of crankcase oil mist detection and alarm equipment are to satisfy the following criteria:

(1) A full range of facilities for carrying out the environmental and functionality tests required by this procedure is to be available and be acceptable to CCS.

(2) The test house that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/*l* to an accuracy of ±10% in accordance with this procedure.

(3) When verifying the functionality, test houses are to consider the possible hazards associated with the generation of the oil mist required and take adequate precautions. Use of low toxicity, low hazard oils as used in other applications is accepted, provided it is demonstrated to have similar properties to SAE 40 monograde mineral oil specified in this Appendix.

5 Equipment testing

5.1 The range of tests is to include the items specified in 5.1.1 to 5.1.2:

5.1.1 For the alarm/monitoring panel:

(1) functional tests described in 6.1 to 6.8 of this Appendix;
(2) electrical power supply failure test;
(3) power supply variation test;
(4) dry heat test;
(5) damp heat test;
(6) vibration test;
(7) EMC test;
(8) insulation resistance test;
(9) high voltage test;
(10) static and dynamic inclinations, if moving parts are contained.

5.1.2 For the detectors:

(1) functional tests described in 6.1 to 6.8 of this Appendix;
(2) electrical power supply failure test;
(3) power supply variation test;
(4) dry heat test;
(5) damp heat test;
(6) vibration test;
(7) EMC test where susceptible;
(8) insulation resistance test;
(9) high voltage test;

(10) static and dynamic inclinations.

6 Functional tests

6.1 All tests to verify the functionality of crankcase oil mist detection and alarm equipment are to be carried out in accordance with 6.2 to 6.6 with an oil mist concentration in air, known in terms of mg/*l* to an accuracy of ±10%.

6.2 The concentration of oil mist in the test chamber is to be measured in the top and bottom of the chamber and these concentrations are not to differ by more than 10%. See also 8.1.1.1 of this Appendix.

6.3 The oil mist monitoring arrangements are to be capable of detecting oil mist in air concentrations of:

- between 0 and 10% of the lower explosive limit (LEL); or
- between 0 and *x*%, *x*% is a percentage of weight of oil in air determined by the manufacturer based on the sensor measurement method (e.g. obscuration or light scattering) that is acceptable to CCS taking into account the alarm level specified in 6.4.

Note: The LEL corresponds to an oil mist concentration of approximately 50 mg/*l* (4.1% weight of oil in air mixture).

6.4 The alarm set point for oil mist concentration in air is to provide an alarm at a maximum level corresponding to not more than 5% of the LEL or approximately 2.5 mg/*l*.

6.5 Where alarm set points can be altered, the means of adjustment and indication of set points are to be verified against the equipment manufacturer's instructions.

6.6 The performance of the detector which can measure and output the oil mist concentration, in mg/*l*, is to be demonstrated. This is to include the following:

(1) range;

(2) resolution;

(3) sensitivity.

Notes:

Sensitivity means quotient of the change in an indication of a measuring system and the corresponding change in a value of a quantity being measured.

Resolution means smallest change in a quantity being measured that causes a perceptible change in the corresponding indication.

6.7 Where oil mist is drawn into a detector via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be in accordance with the manufacturer's instructions/recommendations. Piping is to be arranged to prevent pooling of oil condensate which may cause a blockage of the sampling pipe over time.

6.8 It is to be demonstrated that the openings of detector equipment does not become occluded or blocked under continuous splash and spray of engine lubricating oil, as may occur in the crankcase atmosphere. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by CCS. The temperature, quantity and angle of impact of the oil to be used is to be declared and their selection justified by the manufacturer.

6.9 Detector equipment may be exposed to water vapour from the crankcase atmosphere which may affect the sensitivity of the equipment and it is to be demonstrated that exposure to such conditions will not affect the functional operation of the detector equipment. Where exposure to water vapour and/or water condensation has been identified as a possible source of equipment malfunctioning, testing is to demonstrate that any mitigating arrangements such as heating are effective. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by CCS.

Note: This testing is in addition to that required by 5.1.2(5) and is concerned with the effects of condensation caused by the detection equipment being at a lower temperature than the crankcase atmosphere.

6.10 It is to be demonstrated that an indication is given where lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

7 Detectors and alarm equipment to be tested

7.1 The detectors and alarm equipment selected for the type testing are to be selected from the manufacturer's normal production line by the Surveyor witnessing the tests.

7.2 Two detectors are to be tested. One is to be tested in clean condition and the other in a condition representing the maximum level of lens obscuration specified by the manufacturer.

8 Method

8.1 The following requirements are to be satisfied at type testing:

8.1.1 Oil mist generation is to satisfy 8.1.1.1 to 8.1.1.5.

8.1.1.1 The ambient temperature in and around the test chamber is to be at the standard atmospheric

conditions defined in CCS Guidelines for Type Approval Test of Electric and Electronic Products before any test run is started.

8.1.1.2 Oil mist is to be generated with suitable equipment using an SAE 40 monograde mineral oil or equivalent and supplied to a test chamber. The selection of the oil to be used is to take into consideration risks to health and safety, and the appropriate controls implemented. A low toxicity, low flammability oil of similar viscosity may be used as an alternative. The oil mist produced is to have an average (or arithmetic mean) droplet size not exceeding 5 μm. The oil droplet size is to be checked using the sedimentation method or an equivalent method to a relevant international or national standard. If the sedimentation method is chosen, the test chamber is to have a minimum height of 1m and volume of not less than 1 m^3.

Note: The calculated oil droplet size using the sedimentation method represents the average droplet size.

8.1.1.3 The oil mist concentrations used are to be ascertained by the gravimetric deterministic method or equivalent. Where an alternative technique is used its equivalence is to be demonstrated.

Note: For this test, the gravimetric deterministic method is a process where the difference in weight of a 0.8 μm pore size membrane filter is ascertained from weighing the filter before and after drawing 1 litre of oil mist through the filter from the oil mist test chamber. The oil mist chamber is to be fitted with a recirculating fan.

8.1.1.4 Samples of oil mist are to be taken at regular intervals and the results plotted against the oil mist detector output. The oil mist detector is to be located adjacent to where the oil mist samples are drawn off.

8.1.1.5 The results of a gravimetric analysis are considered invalid and are to be rejected if the resultant calibration curve has an increasing gradient with respect to the oil mist detection reading. This situation occurs when insufficient time has been allowed for the oil mist to become homogeneous. Single results that are more than 10% below the calibration curve are to be rejected. This situation occurs when the integrity of the filter unit has been compromised and not all of the oil is collected on the filter paper.

8.1.1.6 The filters require to be weighed to a precision of 0.1 mg and the volume of air/oil mist sampled to 10 m*l*.

8.1.2 For type approval by CCS, the testing is to be witnessed by the Surveyor or authorised personnel from CCS.

8.1.3 Oil mist detection equipment is to be tested in the orientation (vertical, horizontal or inclined) in which it is intended to be installed on an engine or gear case as specified by the equipment manufacturer.

8.1.4 Type testing is to be carried out for each type of oil mist detection and alarm equipment for which a manufacturer seeks classification approval. Where sensitivity levels can be adjusted, testing is to be carried out at the extreme and mid-point level settings.

9 Assessment

9.1 Assessment of oil mist detection equipment after testing is to address the requirements specified in 9.1.1 to 9.1.3.

9.1.1 The equipment to be tested is to have evidence of design appraisal/approval by CCS witnessing tests.

9.1.2 Details of the detection equipment to be tested are to be recorded such as name of manufacturer, type designation, oil mist concentration assessment capability and alarm settings, and the maximum percentage level of lens obscuration.

9.1.3 After completing the tests, the detection equipment is to be examined and the condition of all components ascertained and documented. Photographic records of the monitoring equipment condition are to be taken and included in the report.

10 Design series qualification

10.1 The approval of one type of detection equipment may be used to qualify other devices having identical construction details. An application and related information are to be submitted for confirmation.

11 The report

11.1 The test house is to provide a full report which includes the information specified in 11.1.1 to 11.1.3.

11.1.1 Test specification.

11.1.2 Details of equipment tested.

11.1.3 Results of tests, including a declaration by the manufacturer of the oil mist detector of its performance, accuracy and precision of oil mist concentration in air, range, resolution, response time, sensitivity, obscuration of sensor detection, declared as percentage of obscuration (0% totally clean, 100% totally obscure) and detector failure alarm..

12 Acceptance

12.1 Acceptance of crankcase oil mist detection equipment is at the discretion of CCS based on the

appraisal plans and particulars and the test house report of the results of type testing.

12.2 The plans and information specified in 12.2.1 to 12.2.4 are to be submitted for acceptance of oil mist detection equipment and alarm arrangements:

12.2.1 Description of oil mist detection equipment and system including alarms.

12.2.2 Copy of the test house report identified in 11.1 of this Appendix.

12.2.3 Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.

12.2.4 Maintenance and test manual which is to include the following information:

(1) intended use of equipment and its operation;

(2) functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified;

(3) maintenance routines and spare parts recommendations;

(4) limit setting and instructions for safe limit levels;

(5) where necessary, details of configurations in which the equipment is and is not to be used.

Appendix 9 TYPE TESTING PROCEDURE OF EXPLOSION RELIEF DEVICES FOR COMBUSTION AIR INLET AND EXHAUST GAS MANIFOLDS OF I.C. ENGINES USING GAS AS FUEL

1 Scope

1.1 This Appendix specifies testing procedure for explosion relief devices for combustion air inlet manifold and exhaust gas manifold of internal combustion engines using gas as fuel.

2 Definitions

2.1 Definitions addressing gas as fuel as given in Appendix 1 Safety of Low Pressure Gas Fuel Engines of this Chapter, apply.
2.2 Explosion relief device (ERD) means a device to protect a component against a determined overpressure in the event of a gas explosion. The device is fitted with a flame arrester and may be a valve, a rupture disc or other, as applicable.

3 Documents

3.1 Prior to testing, the following documentation for the ERD shall be submitted for approval:
(1) drawings (sectional drawings, details, assembly etc.);
(2) specification data sheet including operating conditions and design limits such as:
① maximum permissible operating pressure, resulting from maximum charging air or exhaust gas back pressure;
② maximum permissible operating temperature, resulting from maximum charging air or exhaust gas temperature;
③ static opening pressure, resulting from maximum charging air or exhaust gas back pressure;
④ maximum explosion pressure, i.e. maximum pressure that the device can withstand;
⑤ geometric relief area;
(3) product marking;
(4) installation and operation manual;
(5) test program;
(6) specification of test vessel.

4 Tests

4.1 Test specimens

4.1.1 The ERD used for the explosion test is to be selected from the manufacturer's production line by CCS:
(1) as a finished certified component itself, or
(2) on samples taken from earlier stages in the production of the component, when applicable.
4.1.2 If necessary, an additional ERD may need to be selected for the demonstration of the opening pressure. The selected ERD has to be clearly marked.
4.1.3 If applicable, the selected ERD shall be representative for the type range and operating conditions, for example:
(1) kind of ERD (valve, rupture disc, etc.);
(2) mounting orientation (vertical, horizontal);
(3) design of ERD (e.g., spring design, sealing);
(4) design of flame arrester;
(5) ERD intended to be fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with characteristics as per the testing conditions in 4.3.2 of this Appendix.
4.1.4 The selection of the representative ERD is subject to approval by the CCS.

4.2 Demonstration of opening pressure

The ERD which has been selected is to be subjected to a pressure test at the manufacturer's works to demonstrate that the static opening pressure is kept within the manufacturer's specification and that the

ERD is air tight at the maximum permissible operating pressure for at least 30 seconds.

4.3 Explosion test

4.3.1 Test facility

4.3.1.1 The test facilities are to be accredited to a national or international standard, e.g. ISO/IEC 17025, and are to be acceptable to the CCS.

4.3.1.2 The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

4.3.1.3 The test facilities are to have equipment for controlling and measuring a methane gas concentration within a test vessel to an accuracy of ±0.1%.

4.3.1.4 The test facilities are to be capable of effective point-located ignition of a methane/air mixture.

4.3.1.5 The test facility arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognizing the speed of the events during an explosion (10 kHz or above).

4.3.1.6 The explosion test (Para 4.3.5 of this Appendix) is to be documented by high speed (250 frames/s or above) video recording. The video recording shall be provided with a time stamp.

4.3.2 Test vessel

4.3.2.1 The test vessel is a simplified model of the air inlet or exhaust gas manifold. The free area of the connected turbo charger (compressor or turbine wheel) is to be considered.

4.3.2.2 The test vessel shall comply with the following requirements:

(1) The shape of the test vessel is to correspond to a pipe with L/D ≥ 10.

(2) The test vessel is to be equipped with a rupture disc at one front end to simulate the turbo charger. The relief area of the rupture disc shall be in relationship to the test vessel diameter based on turbocharger manufacturer data for an equivalent free area of compressor or turbine wheel. The opening pressure shall be ± 10% of the static opening pressure of the ERD.

(3) The volume of the test vessel is to comply with the specific relief area of the ERD of 700 cm^2/m^3 ± 15%.

(4) The test vessel is to be provided with all necessary flanges and connection to mount the ERD in the intended position, to mount a rupture disc as turbo charger simulation, to connect the Methane-air mixture supply and the measurement equipment.

(5) The ignition is to be made at the middle of the test vessel.

(6) The test vessel is to be designed to verify a homogeneous air / methane mixture inside the vessel.

(7) The test vessel is to have connections for measuring the pressure in the test vessel in at least two positions, one at the ERD and the other at the test vessel center.

(8) The test vessel is to have a design pressure of not less than the maximum explosion pressure of a stoichiometric air / methane mixture at test conditions in Para 4.3.6 of this Appendix.

(9) The test vessel configuration is subject to approval by CCS.

4.3.2.3 Typical test vessel configurations:

As shown in Figures 4.3.2.3(1) to 4.3.2.3(3), all test vessel configurations to be equipped with a rupture disc (1) (turbo charger simulation) at one front end. The ignition is in the centre of the test vessel (↯). The pressure sensors are mounted at the valve flanges (p1) and at the test vessel centre (p2). The measuring of the methane concentration to verify a homogeneous air / methane mixture can be performed at both ends of the test vessel, e.g. (c1) and (c2).

Figure 4.3.2.3(1) Configuration without ERD (flanges for ERDs closed (2))

Figure 4.3.2.3(2) Configuration with ERD (3) mounted at the front end of the test vessel

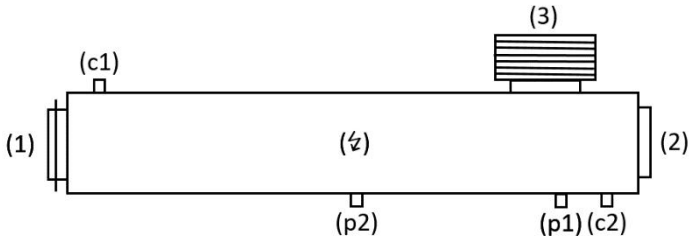


Figure 4.3.2.3(3) Configuration with ERD (3) mounted on top of the test vessel

4.3.3 Explosion test process

4.3.3.1 The explosion testing is to be performed in two stages according to 4.3.4 and 4.3.5 of this Appendix for each ERD that is required to be approved as type tested.

4.3.3.2 The explosion testing is to be witnessed by a Society surveyor.

4.3.3.3 Calibration records for the instrumentation used to collect data are to be presented to, and reviewed by, the attending surveyor.

4.3.4 Reference test – Explosion test without ERD

4.3.4.1 Two explosion tests are to be carried out in the test vessel without ERD. The test vessel configuration is shown in Figure 4.3.2.3(1) of this Appendix.

4.3.4.2 The aim of this test is to establish a reference pressure level in the test vessel which can be used for determination of the capability of a relief valve in terms of pressure relief.

4.3.5 ERD test – Explosion test with ERD

4.3.5.1 Two explosion tests are to be carried out in the test vessel with the same ERD at the required position. If the ERD is a rupture disc with flame arrester, the rupture disc shall be replaced.

4.3.5.2 If shielding arrangements to deflect the emission of explosion combustion products at the ERD are intended, the ERD are to be tested with the shielding arrangements fitted. The test vessel configuration is shown in Figure 4.3.2.3(2) or 4.3.2.3(3).

4.3.6 Explosion test method

4.3.6.1 The test conditions shall comply with the intended use of the ERD, such as:

(1) pipe diameter;

(2) operating pressure;

(3) operating temperature;

(4) installation orientation.

4.3.6.2 All explosion tests are to be carried out using an air and methane mixture with a volumetric methane concentration of 9.5% ± 0.5%. A homogeneous air / methane mixture inside the test vessel is to be verified. The concentration of methane shall not differ by more than 0.5%.

4.3.6.3 The initial pressure in the test vessel is to be the specified maximum operating pressure of the ERD.

4.3.6.4 The initial temperature in the test vessel is to be the specified maximum operating temperature of the ERD.

4.3.6.5 If the initial pressure and/or initial temperature deviate from the design limits, the ERD manufacturer shall prove the acceptability of this deviation either using standards or generally applicable calculation methods.

4.3.6.6 The ignition is to be made using an explosive charge of 50 - 100 Joule.

4.3.6.7 Successive explosion testing to establish an ERD functionality is to be carried out as quickly as possible during stable weather conditions.

4.3.6.8 The pressure rise and decay during all explosion testing is to be recorded.

4.3.6.9 The effect of an ERD in terms of pressure relief following an explosion is ascertained from maximum pressure recorded at the centre of the test vessel during the two stages. The pressure relief within the test vessel due to the installation of an ERD is the difference between average pressure of the two explosions of the reference test (4.3.4 of this Appendix) and the average of the two explosions of the ERD test (4.3.5 of this Appendix).

4.3.6.10 For acceptance of correct functioning of the flame arrester, there is to be no indication of flame or combustion outside of the ERD during its testing (4.3.5 of this Appendix). This is to be monitored by a high-speed video camera (4.3.1 of this Appendix), for which ambient light conditions are to be considered to maximise the potential for flame/combustion detection. The use of a dark, ideally matt finish, background and an avoidance of direct light onto the video camera monitored area are recommended.

4.3.6.11 After each ERD test (4.3.5 of this Appendix), the external condition of the flame arrester to be

examined for signs of damage and/or deformation that may affect the operation of the ERD.

4.4 Check of ERD components

4.4.1 After completing the explosion tests, the ERDs are to be dismantled and the condition of all components are to be ascertained and documented.

5 Test report

5.1 A complete test report has to be submitted to CCS for:
(1) the demonstration of opening pressure (4.2 of this Appendix);
(2) the explosion test (4.3 of this Appendix).
5.2 The reports shall include respective information according to the requirements in 4 of this Appendix, as applicable:
(1) test specimens;
(2) test facility, including measuring equipment and test vessel;
(3) measuring results (pressures, temperatures, flame velocities, volumetric methane concentration, ambient conditions etc.);
(4) video documentation of explosion tests;
(5) photo documentation of ERD components.

6 Assessment

6.1 To verify compliance with this requirement the assessment has to address the following:
6.1.1 Function and mechanical integrity of the ERD.
(1) After dismantling of the ERD, the flame arrester shall not show signs of damage or any deformation that may affect the operation of the ERD.
(2) If a valve is used any indication of valve sticking or uneven opening during the explosion that may affect subsequent operation of the valve has to be considered.
(3) The mechanical integrity of the ERD is proven up to a maximum explosion pressure (as average of the two explosions) of the ERD tests in 4.3.5 of this Appendix.
6.1.2 The functioning of the flame arresters is considered satisfactory if there is no indication of flame or combustion outside the ERD during the explosion tests.

7 Approval

7.1 The approval of an ERD is at the discretion of individual classification societies based on the appraisal of plans and particulars and the test report of type testing.
7.2 The type approval is valid only for an ERD fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with compressor or turbine wheel characteristics corresponding to those required in 4.3.2 of this Appendix for the test vessel rupture disc in terms of free area.

Appendix 10 SAFETY OF METHANOL/ETHANOL FUEL ENGINES

1 General Requirements

1.1 Application and scope

1.1.1 This Appendix applies to engines supplied with methanol/ethanol as fuel. This Appendix only specifies relevant requirements for the use of methanol/ethanol fuel, and in addition, methanol/ethanol fuel engines are to comply with relevant provisions of this Chapter.

1.1.2 Methanol/ethanol fuel engines can be either dual fuel engines or methanol/ethanol fuel only engines. Methanol/ethanol fuel can be introduced as follows:

(1) cylinder air inlet channel port; or

(2) cylinder direct injection.

The methanol/ethanol and air mixture in the cylinder can be ignited by the combustion of a certain amount of fuel (pilot injection) or by extraneous ignition (sparking plug).

1.1.3 This Appendix covers the following applications, but is not limited to:

(1) mechanical propulsion;

(2) generating sets intended for main propulsion and auxiliary applications;

(3) single engine or multi-engine installations.

1.1.4 For fuel only engines, applicable requirements of this Appendix can be determined in consultation with CCS.

1.2 Definitions

(1) Dual fuel engine means an engine that can burn methanol/ethanol as fuel simultaneously with liquid diesel fuel, either as pilot oil or bigger amount of liquid diesel fuel (methanol/ethanol mode), and also has the capability of running on liquid diesel fuel oil only (Diesel mode).

(2) Fuel only engine means an engine capable of operating on methanol/ethanol fuel only and not able to switch over to oil fuel operation.

(3) Methanol/ethanol fuel engine means either a methanol/ethanol fuel only engine or a dual fuel engine.

(4) Pilot fuel means the fuel oil that is injected into the cylinder to ignite the methanol/ethanol and air mixture on dual fuel engines.

(5) Methanol/ethanol fuel valve unit is a set of valves and fittings used to control the methanol/ethanol fuel supply to each engine, which is used to control or adjust the methanol/ethanol fuel supply before the engine.

(6) Recognized standards mean applicable international or national standards acceptable to CCS or standards laid down and maintained by an organisation which complies with the standards adopted by IMO and which are recognized by the Classification Society.

(7) Safety Concept is a document describing the safety philosophy with regard to methanol/ethanol as fuel. It describes how risks associated with this type of fuel are controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures.

Note: A detailed evaluation regarding the hazard potential of injury from a possible explosion is to be carried out and reflected in the safety concept of the engine.

1.3 Plans and documents

1.3.1 The following plans and documents are to be submitted for approval with regard to the approval of methanol/ethanol fuel engines, in addition to those required in 9.1.12.1 of this Chapter :

No.	Plans and documents
(1)	Schematic layout or other equivalent documents of methanol/ethanol fuel system on the engine
(2)	Methanol/ethanol piping system (including double-walled arrangement where applicable)
(3)	Parts for methanol/ethanol admission system②
(4)	Arrangement of explosion relief valves (crankcase①, charge air manifold, exhaust gas manifold) as applicable
(5)	List of certified safe equipment and evidence of relevant certification
(6)	Schematic layout or other equivalent documents of fuel oil system (main and pilot fuel systems) on the engine (only for dual fuel engine)
(7)	Shielding of high pressure fuel pipes for pilot fuel system, assembly (only for dual fuel engine)
(8)	High pressure parts for pilot fuel oil injection system②(only for dual fuel engine)
(9)	Ignition system (only for fuel only engine)

Note:
① If required by 9.1.12 of this Chapter.
② The documentation to contain specification of pressures, pipe dimensions and materials.

1.3.2 The following plans and documents are to be submitted for information with regard to the approval of methanol/ethanol fuel engines, in addition to those required in 9.1.12.2 of this Chapter:

No.	Plans and documents
(1)	Safety concept
(2)	Report of the risk analysis①
(3)	Methanol/ethanol specification
(4)	Other plans and documents as deemed necessary by CCS

Note:
① see 1.4 of this Appendix.

1.4 Risk analysis

1.4.1 The risk analysis is to address:
(1) a failure or malfunction of any system or component involved in the methanol/ethanol operation of the engine;
(2) a fuel leakage downstream of the methanol/ethanol valve unit;
(3) the safety of the engine in case of emergency shutdown or blackout, when running on methanol/ethanol;
(4) the inter-actions between the methanol/ethanol fuel system and the engine.
Note: With regard to the scope of the risk analysis it shall be noted that failures in systems external to the engine, such as fuel storage or fuel gas supply systems, may require action from the engine control and monitoring system in the event of an alarm or fault condition. Conversely failures in these external systems may, from the vessel perspective, require additional safety actions from those required by the engine limited risk analysis.
1.4.2 The risk analysis is to be carried out in accordance with international standard ISO 31010: Risk management - Risk assessment techniques, or other recognized standards.
The required analysis is to be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.
1.4.3 The risk analysis is to:
(1) Identify all the possible failures in the concerned equipment and systems which could lead:
① to the presence of methanol/ethanol in components or locations not designed for such purpose, and/or
② to ignition, fire or explosion.
(2) Evaluate the consequences.
(3) Where necessary, identify the failure detection method.
(4) Where the risk cannot be eliminated, identify the corrective measures, e.g. in the system design such as redundancies or safety devices, monitoring or alarm provisions which permit restricted operation of the system; in the system operation, such as initiation of the redundancy or activation of an alternative mode of operation.
The results of the risk analysis are to be documented.
1.4.4 The risk analysis required for engines is to cover at least the following equipment and systems:
(1) failure of the methanol/ethanol-related systems or components, in particular methanol/ethanol piping and cylinder methanol/ethanol supply valves etc. Failures of the methanol/ethanol supply components not located directly on the engine, are not to be considered in the analysis;
(2) failure of the ignition system (oil fuel pilot injection or sparking plugs);
(3) failure of the methanol/ethanol combustion or abnormal combustion (misfiring, knocking);
(4) failure of the engine monitoring, control and safety systems;
Note: Where engines incorporate electronic control systems, a failure mode and effects analysis (FMEA) is to be carried out in accordance with 9.1.12.2(23) and Note 5 of this Chapter.
(5) changes of operating modes for dual fuel engines, including fuel oil mode, methanol/ethanol fuel mode and other working mode;
(6) hazard potential for crankcase methanol/ethanol fuel accumulation, for engines where the space below the piston is in direct communication with the crankcase.

2 Design Requirements

2.1 General principles

2.1.1 The manufacturer is to declare the methanol/ethanol fuel for the engine.

2.1.2 Components containing or likely to contain methanol/ethanol are to be designed to:
(1) minimise the risk of fire and explosion so as to demonstrate an appropriate level of safety commensurate with that of an oil-fuelled engine;
(2) mitigate the consequences of a possible explosion to a level providing a tolerable degree of residual risk, due to the strength of the component(s) to withstand the overpressure due to the ignition of leaked methanol/ethanol in the most severe condition or the fitting of suitable pressure relief devices of an approved type.
Note:
① Discharge from pressure relief devices is to prevent the passage of flame to the machinery space and be arranged such that the discharge does not endanger personnel or damage other engine components or systems.
② Relief devices are to be fitted with a flame arrester.

2.2 Design requirements

2.2.1 A means is to be provided to monitor and detect poor combustion or misfiring in the engine. In the event that it is detected, continued operation may be allowed, provided that the fuel supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respect to torsional vibrations.
Engine components through which methanol/ethanol fuel may flow are to be effectively sealed to prevent leakage of fuel into the machinery space.
2.2.2 Engine-mounted methanol/ethanol pipes are to be designed in accordance with the methanol/ethanol pipe requirements (e.g. wall thickness, allowable stress, material, pipe manufacture and connection etc.) in Chapter 3 of CCS Guidelines for Ships Using Methanol/Ethanol Fuel and the arrangement is to satisfy the following requirements:
(1) Pipes and equipment containing methanol/ethanol fuel are defined as hazardous area Zone 0. The space between the methanol/ethanol fuel piping and the wall of the outer pipe or duct is defined as hazardous area Zone 1.
(2) Methanol/ethanol fuel fuel piping is to be arranged for gas freeing and purging.
(3) The arrangement and installation of methanol/ethanol fuel piping are to provide the necessary flexibility to accommodate the sway or vibration of the engine and prevent fatigue damage at the connection between the piping and the engine.
2.2.3 Charge air system on the engine
(1) The charge air system on the engine is to be designed in accordance with 2.1.2 above.
(2) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.
Note: Load reduction is to be considered on a case by case basis, depending on engine configuration (single or multiple) and relief mechanism (self-closing valve or bursting disk).
2.2.4 Exhaust system on the engine
(1) The exhaust gas system on the engine is to be designed in accordance with 2.1.2 above.
(2) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.
(3) Each methanol/ethanol engine is to be provided with independent exhaust system.
2.2.5 For engines where the space below the piston is in direct communication with the crankcase, protection of crankcase is also to comply with the following requirements:
(1) Detailed assessment is to be carried out to hazard potential for crankcase gas accumulation.
(2) For maintenance purposes, a connection, or other means, are to be provided for crankcase inerting and ventilating and gas concentration measuring.
2.2.6 Control, monitoring, alarm and safety systems
(1) The engine control system is to be independent and separate from the safety system.
(2) The methanol/ethanol supply valves are to be controlled by the engine control system or by the engine methanol/ethanol demand.
(3) Combustion is to be monitored on an individual cylinder basis.
(4) If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.
(5) Unless the risk analysis required by 1.4 of this Appendix proves otherwise, the monitoring and safety system functions for dual fuel or fuel only engines are to be provided in accordance with Table 1 of this Appendix in addition to the general monitoring and safety system functions given by the Rules.
Note: For dual fuel engines, Table 1 applies only to the methanol/ethanol mode.

Monitoring and Safety System Functions for Methanol/Ethanol Fuel Engines

Table 1

Parameter	Alarm	Automatic activation of the engine block valve	Automatic switching over to oil fuel mode①	Engine shutdown
Abnormal pressures in the methanol/ethanol fuel supply line	×	×	×	× ⑤
Methanol/ethanol fuel supply systems - malfunction	×	×	×	× ⑤
Pilot fuel injection or spark ignition systems - malfunction	×	× ②	×	× ②⑤
Exhaust gas temperature after each cylinder - high	×	× ②	×	× ②⑤
Exhaust gas temperature after each cylinder, deviation from average – low③	×	× ②	×	× ②⑤
Cylinder pressure or ignition - failure, including misfiring, knocking and unstable combustion	×	× ②④	× ④	× ②④⑤
Oil mist concentration in crankcase or bearing temperature⑥ - high	×	×		×
Pressure in the crankcase – high④ (for engines where the space below the piston is in direct communication with the crankcase)	×	×	×	
Engine stops - any cause	×	×		
Failure of the control-actuating medium of the methanol/ethanol fuel block valve	×	×	×	

Symbol: × Applicable

Note:

① Dual fuel engine only, when running in methanol/ethanol mode.

② For fuel only engines, the block valve and the engine shutdown may not be activated in case of specific failures affecting only one cylinder, provided that the concerned cylinder can be individually shutoff and the safe operation of the engine in such conditions is demonstrated by the risk analysis.

③ Required only if necessary for the detection of misfiring.

④ In the case where the failure can be corrected by an automatic mitigation action, only the alarm may be activated. If the failure persists after a given time, the safety actions are to be activated.

⑤ Fuel only engine only.

⑥ Where required by 9.7.6 of this Chapter.

3 Specific Design Requirements

3.1 Dual fuel engines

3.1.1 The maximum continuous power that a dual fuel engine can develop in methanol/ethanol mode may be lower than the approved MCR of the engine (i.e. in oil fuel mode), depending in particular on the methanol/ethanol quality. This maximum power available in methanol/ethanol mode and the corresponding conditions are to be stated by the engine manufacturer and demonstrated during the type test. The 110% load tests are not required in the methanol/ethanol mode of dual fuel engines when 4.1.4, 4.2.1 and 4.3 of this Appendix are implemented in accordance with the provisions in 1.3 of Appendix 4, 2.3 and 3.4 of Appendix 6 of this Chapter.

3.1.2 Dual fuel engines are to be arranged to use either oil fuel or methanol/ethanol fuel for the main fuel charge and with pilot oil fuel for ignition. The engines are to be arranged for rapid changeover from methanol/ethanol use to fuel oil use. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply without interruption to the power supply.

Changeover to methanol/ethanol fuel operation is to be only possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing.

Changeover from methanol/ethanol fuel operation mode to oil fuel operation mode is to be possible at all situations and power levels.

The changeover process itself from and to methanol/ethanol operation is to be automatic but manual interruption is to be possible in all cases.

In case of shut-off of the methanol/ethanol supply, the engines are to be capable of continuous operation by oil fuel only.

3.1.3 Methanol/ethanol supply to the combustion chamber is not to be possible without operation of the pilot oil injection.
Note: Pilot injection is to be monitored for example by fuel oil pressure and combustion parameters.
3.1.4 In case of an emergency stop or a normal stop, the methanol/ethanol fuel is to be automatically shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the methanol/ethanol fuel supply to each cylinder or to the complete engine.

3.2 Fuel only engines
3.2.1 In case of ignition failure of the ignition system, the engine is to be shut down except if this failure is limited to one cylinder, subject to immediate shut off of the cylinder methanol/ethanol supply and provided that the safe operation of the engine is substantiated by the risk analysis and by tests.
3.2.2 In case of an emergency stop or a normal stop, the methanol/ethanol fuel is to be automatically shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the methanol/ethanol fuel supply to each cylinder or to the complete engine.

4 Type Testing, Factory Acceptance Tests and Shipboard Trials

4.1 Type Testing
4.1.1 Type approval of dual fuel and fuel only engines is to be carried out in accordance with 9.10.1 and 9.10.2 of this Chapter, taking into account the additional requirements below.
4.1.2 In addition to the criteria given in 9.1.2.1(1) of this Chapter, the type of engine is defined by the following:
(1) methanol/ethanol admission method (direct cylinder injection, cylinder intake channel injection etc.);
(2) methanol/ethanol supply valve operation (mechanical or electronically controlled);
(3) ignition system (pilot injection, spark ignition etc.);
(4) ignition system (mechanical or electronically controlled).
4.1.3 In addition to the safety precautions mentioned in 1.2, Appendix 4 of this Chapter, measures to verify that methanol/ethanol fuel piping on engine is gas tight and liquid tight are to be carried out prior to start-up of the engine.
4.1.4 The type testing of the engine is to be carried out in accordance with 1.3, Appendix 4 of this Chapter.
For dual fuel engines, the load tests are to be carried out in methanol/ethanol mode at the different percentages of the maximum power available in methanol/ethanol mode (see 3.1.1 of this Appendix).
4.1.5 In addition to the measurements and records required in 1.4, Appendix 4 of this Chapter, the following engine data are to be measured and recorded:
(1) Each fuel index for methanol/ethanol and diesel as applicable (or equivalent reading).
(2) Methanol/ethanol pressure and temperature at the inlet of the methanol/ethanol manifold.
Additional measurements may be required in connection with the design assessment.
4.1.6 In addition to internal tests required in 2.1, Appendix 4 of this Chapter, the following conditions are to be tested:
(1) dual fuel engines are to run the load points in both methanol/ethanol and diesel modes (with and without pilot injection in service) as found applicable for the engine type.
(2) for dual fuel engines, switch over between methanol/ethanol and diesel modes are to be tested at different loads.
4.1.7 Witnessed tests are to be carried out in accordance with 2.2, Appendix 4 of this Chapter. The following requirements are to be considered:
(1) The following test conditions are to be considered for dual fuel engine during the load test:
① All load points must be run in both methanol/ethanol and diesel modes that apply for the engine type as defined by the engine designer. This also applies to the overspeed test.
(2) The following items are to be carried out for functional test:
① For dual fuel engines, the lowest specified speed is to be verified in diesel mode and methanol/ethanol mode.
② For dual fuel engines, switch over between methanol/ethanol and diesel modes are to be tested at different loads.
③ The efficiency of the ventilation arrangement of the double walled piping system is to be verified.
④ Simulation of a methanol/ethanol leakage in way of a cylinder methanol/ethanol supply valve.
Engines intended to produce electrical power are to be tested as follows:
① Capability to take sudden load and loss of load in accordance with the provisions of 9.7.10.1 of this Chapter.

Notes:
1. For dual fuel engines, switchover to oil fuel during the test is acceptable.
2. Application of electrical load in more than 2 load steps can be permitted in the conditions stated in 9.7.10.1 of this Chapter.

(3) Fuel only and dual fuel engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes. The scope of these tests is to be agreed with CCS for selected cases based on the risk analysis, and is at least to include the following incidents:

① Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;
② Failure of a cylinder methanol/ethanol supply valve;
③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);
④ Abnormal methanol/ethanol pressure;
⑤ Abnormal methanol/ethanol temperature*.

Note*: This test may be carried out using a simulation signal of the temperature.

4.1.8 Component inspection is to be carried out in accordance with the provisions of 2.3, Appendix 4 of this Chapter. The components to be inspected after the test run are to include also:
(1) methanol/ethanol supply valve;
(2) pilot fuel injection valve/spark igniter.

4.2 Factory acceptance test

4.2.1 Factory acceptance tests are to be carried out in accordance with Appendix 6 of this Chapter, taking into account the additional requirements below.
For dual fuel engines, the load tests referred to in 2.3, Appendix 6 of this Chapter are to be carried out in methanol/ethanol mode at the different percentages of the maximum power available in methanol/ethanol mode (see 3.1.1 of this Appendix).

4.2.2 In addition to the safety precautions mentioned in 1.1, Appendix 6 of this Chapter , measures to verify that methanol/ethanol fuel piping on engine is gas tight and liquid tight are to be carried out prior to start-up of the engine.

4.2.3 In addition to the records required in 2.2, Appendix 6 of this Chapter, the following engine data are to be recorded:
(1) Fuel index, both methanol/ethanol and diesel as applicable (or equivalent reading);
(2) Methanol/ethanol pressure and temperature at the inlet of the methanol/ethanol manifold.

4.2.4 Test loads for various engine applications are given in 2.3, Appendix 6 of this Chapter. Dual fuel engines are to be tested in both diesel and methanol/ethanol pressure and temperature at the inlet of the methanol/ethanol manifold mode as found applicable. In addition the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

4.2.5 Methanol/ethanol fuel engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes.
The scope of these tests is to be agreed with CCS for selected cases based on the risk analysis, and is at least to include the following incidents:

① Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;
② Failure of a cylinder methanol/ethanol supply valve;
③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);
④ Abnormal methanol/ethanol pressure;
⑤ Abnormal methanol/ethanol temperature.

Note: The above tests may be carried out using simulation or other alternative methods, subject to special consideration by CCS.

4.3 Shipboard trials

4.3.1 Shipboard trials are to be carried out in accordance with the provisions of Appendix 6 of this Chapter. For dual fuel engines, the test loads are to be carried out in all operating modes (methanol/ethanol mode, diesel mode, etc.). For dual fuel engines, when load tests specified in 3.4, Appendix 6 of this Chapter are carried out in methanol/ethanol mode, test loads are taken as each percentage of the maximum output power in methanol/ethanol mode (see 3.1.1 of this Appendix).

Appendix 11 SAFETY OF AMMONIA FUEL ENGINES

1 General Requirements

1.1 Application and scope

1.1.1 This Appendix applies to engines supplied with ammonia as fuel.

1.1.2 This Appendix only specifies relevant requirements for engines supplied with ammonia as fuel, and in addition, ammonia fuel engines are to comply with relevant provisions of this Chapter.

1.1.3 Ammonia fuel engines intended for ammonia carriers are, in addition to satisfying the requirements of this Appendix, to comply with the provisions of Chapter 16, PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

Note: When this Appendix refers to CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, the terms "natural gas", "liquefied natural gas" or "methane" in relation to the fuel are to be understood to mean anhydrous ammonia to which the requirements of this Appendix apply.

1.1.4 This Appendix covers the following applications, but is not limited to:

(1) mechanical propulsion;

(2) generating sets intended for main propulsion and auxiliary applications;

(3) single engine or multi-engine installations.

1.2 Definitions

(1) Ammonia dual fuel engine means an engine that can burn ammonia as fuel simultaneously with liquid fuel oil, either as pilot oil or bigger amount of liquid fuel oil (ammonia fuel mode), and also has the capability of running on liquid fuel oil only (fuel oil mode).

(2) Ammonia fuel only engine means an engine capable of operating in ammonia mode only and not able to switch over to oil fuel operation.

(3) Ammonia fuel engine means either an ammonia fuel only engine or an ammonia dual fuel engine.

(4) Pilot fuel means the fuel oil that is injected into the cylinder to ignite the ammonia and air mixture on ammonia dual fuel engines.

(5) Ammonia fuel means anhydrous ammonia suitable for safe operation on board and meeting the requirements of engines (corresponding to UN code 1005).

(6) Ammonia fuel valve unit is a set of valves and fittings used to control the ammonia fuel supply to each engine, which is used to control or adjust the ammonia fuel supply before the engine.

(7) Double block and bleed valve means a set of two valves in series in a pipe and a third valve enabling the pressure release from the pipe between those two valves. The arrangement may also consist of a two-way three-port valve and a closing valve instead of three separate valves.

(8) Recognized standards mean applicable international or national standards acceptable to CCS or standards laid down and maintained by IMO and an organisation acceptable to CCS.

(9) Safety Concept is a document describing the safety philosophy with regard to ammonia as fuel. It describes how risks associated with this type of fuel are controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures.

Note: A detailed evaluation regarding the hazard potential and toxic injury from a possible explosion is to be carried out and reflected in the safety concept of the engine.

1.3 Plans and documents

1.3.1 The following plans and documents are to be submitted for approval with regard to the approval of ammonia fuel engines, in addition to those required in 9.1.12.1 of this Chapter:

No.	Plans and documents
(1)	Schematic layout or other equivalent documents of ammonia fuel system on the engine
(2)	Ammonia piping system (including double-walled arrangement where applicable)
(3)	Parts for ammonia admission system①
(4)	Arrangement of explosion relief valves (crankcase②, charge air manifold, exhaust gas manifold) as applicable
(5)	List of certified safe equipment and evidence of relevant certification
(6)	Schematic layout or other equivalent documents of fuel oil system (main and pilot fuel systems) on the engine (where applicable)
(7)	Shielding of high pressure fuel pipes for pilot fuel system, assembly (only for ammonia dual fuel engine)
(8)	High pressure parts for pilot fuel oil injection system①(only for ammonia dual fuel engine)
(9)	Ignition system (where applicable)

(10)	Schematic diagram of engine control system related to ammonia fuel (including monitoring, alarm and safety protection devices)
(11)	Engine test procedures and test reports related to ammonia fuel
Note: ① The documentation to contain specification of pressures, pipe dimensions and materials. ② If required by 9.1.12 of this Chapter.	

1.3.2 The following plans and documents are to be submitted for information with regard to the approval of ammonia fuel engines, in addition to those required in 9.1.12.2 of this Chapter:

No.	Plans and documents
(1)	Safety concept①
(2)	Report of the risk analysis②
(3)	Ammonia fuel specification
(4)	Other plans and documents as deemed necessary by CCS
Note: ① see 1.5 of this Appendix. ② see 1.4 of this Appendix.	

1.4 Risk analysis

1.4.1 The risk analysis is to address:

(1) a failure or malfunction of any system or component involved in the ammonia fuel mode operation of the engine;

(2) a fuel leakage downstream of the ammonia valve unit;

(3) the safety of the engine in case of emergency shutdown or blackout, when running on ammonia fuel mode;

(4) the inter-actions between the ammonia fuel system and the engine.

Note: With regard to the scope of the risk analysis it is to be noted that failures in systems external to the engine, such as fuel storage or fuel gas supply systems, may require action from the engine control and monitoring system in the event of an alarm or fault condition. Conversely failures in these external systems may, from the vessel perspective, require additional safety actions from those required by the engine limited risk analysis.

1.4.2 The risk analysis is to be carried out in accordance with international standard ISO 31010: Risk management - Risk assessment techniques, or other recognized standards. The required analysis is to be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.

1.4.3 The risk analysis is to:

(1) Identify all the possible failures in the concerned equipment and systems which could lead:

① to the presence of ammonia in components or locations not designed for such purpose,

② to ignition, fire, explosion or personnel poisoning.

(2) Evaluate the consequences.

(3) Where necessary, identify the failure detection method.

(4) Where the risk cannot be eliminated, identify the corrective measures, e.g. in the system design such as redundancies or safety devices, monitoring or alarm provisions which permit restricted operation of the system; in the system operation, such as initiation of the redundancy or activation of an alternative mode of operation.

The results of the risk analysis are to be documented.

1.4.4 The risk analysis required for engines is to cover at least the following equipment and systems:

(1) failure of the ammonia-related systems or components, in particular ammonia piping and cylinder ammonia supply valves etc. Failures of the ammonia supply components not located directly on the engine, are not to be considered in the analysis;

(2) failure of the ignition system, where applicable (oil fuel pilot injection or sparking plugs);

(3) failure of the ammonia combustion or abnormal combustion (misfiring, knocking);

(4) failure of the engine monitoring, control and safety systems;

Note: With regard to electronic control systems, a failure mode and effects analysis (FMEA) is to be carried out in accordance with no. (23) of Table 9.1.12.2 of this Chapter.

(5) ammonia leakage into engine components (such as the intake and exhaust main) and the external systems connected to them (such as the exhaust pipe).

(6) changes of operating modes for ammonia dual fuel engines, including fuel oil mode, ammonia fuel mode and other working mode;

(7) hazard potential for crankcase ammonia fuel accumulation, for engines where the space below the piston is in direct communication with the crankcase.

1.5 Safety concept

A detailed analysis and assessment of events that may occur during the use of ammonia fuel engines are to be conducted. If necessary, safety measures for handling each event are to be incorporated into the safety concept of the ammonia fuel engine, covering at least the following:
(1) ammonia accumulation in the ammonia fuel engine;
(2) ammonia slip at the side of the ammonia fuel engine, e.g. exhaust emission, pressure relief valve etc.;
(3) ammonia leakage into the cooling water system, lubricating oil system and other auxiliary systems;
(4) crankcase ammonia fuel accumulation, for engines where the space below the piston is in direct communication with the crankcase;
(5) unburned ammonia accumulation throughout the exhaust pipe system, from the cylinder to the outlet of the exhaust pipe.

2 Design Requirements

2.1 General principles

2.1.1 The manufacturer is to declare the ammonia fuel mode operating scope for the engine (applicable to ammonia dual fuel engine).
2.1.2 Components containing or likely to contain ammonia are to be designed to:
(1) minimise the risk of fire and explosion, with an appropriate level of safety commensurate with that of an oil-fuelled engine;
(2) mitigate the consequences of a possible explosion to a level providing a tolerable degree of residual risk, due to the strength of the component(s) to withstand the overpressure due to the ignition of leaked ammonia in the most severe condition or the fitting of suitable pressure relief devices of an approved type.
Note:
① Discharge from pressure relief devices is to prevent the passage of flame to the machinery space and be arranged such that the discharge does not endanger personnel or damage other engine components or systems.
② Relief devices are to be fitted with a flame arrester.

2.2 Design requirements

2.2.1 Ammonia fuel engine-mounted fuel pipes are to be designed and manufactured in accordance with Chapter 5 and Chapter 16 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.
2.2.2 Engine-mounted ammonia pipes are to be arranged in accordance with the following requirements:
(1) Pipes and equipment containing ammonia fuel are defined as hazardous area Zone 0. The space between the ammonia fuel piping and the wall of the outer pipe or duct is defined as hazardous area Zone 1.
(2) Double-wall pipe or duct is to be arranged in accordance with 16.4.3 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.
The pipe or duct is to be pressure tested in accordance with 2.7.1, Chapter 2 of this PART to ensure gas tight integrity and to demonstrate that it can withstand the maximum pressure at gas pipe rupture.
A double block and bleed valve is to be fitted on the main fuel supply pipe; an ammonia temperature detection device is to be fitted in front of the main fuel valve to measure the temperature at the inlet of the ammonia main pipe.
(3) Materials susceptible to ammonia corrosion such as copper, copper alloys, zinc, zinc alloys, cadmium and mercury are not to be used in pipes, valves, fittings and other equipment in contact with ammonia. Stress corrosion caused by ammonia is to be considered in ammonia fuel piping systems made of carbon manganese steel or nickel steel.
(4) For engines using liquid ammonia fuel, the pressure in the fuel pipe is to ensure that the ammonia fuel is in a liquid state. The design pressure of the liquid ammonia fuel piping system is to be at least 1.8 MPa (corresponding to the vapor pressure of ammonia at 45 ℃).
(5) For an engine using gaseous ammonia fuel, if the ambient temperature at the maximum expected pressure of the air intake is lower than the dew point temperature of ammonia, the ammonia fuel is to be fully heated and the following measures are to be taken to prevent liquid ammonia from entering the engine:
① Ammonia fuel inlet temperature monitoring;
② Ammonia fuel inlet pressure monitoring.
(6) The ammonia fuel piping is to be provided with means for inerting or purging, and the purged fuel is to

be stored in a suitable collection tank or treated by an ammonia treatment system, if available.
(7) The arrangement and installation of ammonia fuel piping are to provide the necessary flexibility to accommodate the sway or vibration of the engine and prevent fatigue damage at the connection between the piping and the engine.
2.2.3 Charge air system on the engine is to comply with the following requirements:
(1) The charge air system on the engine is to be designed in accordance with 2.1.2 above.
(2) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.
Note: Load reduction is to be considered on a case by case basis, depending on engine configuration (single or multiple) and relief mechanism (self-closing valve or bursting disk).
2.2.4 Exhaust system on the engine is to comply with the following requirements:
(1) The exhaust gas system on the engine is to be designed in accordance with 2.1.2 above.
(2) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained. It is to be ensured that after pressure release, ammonia fuel is directed to an open area which satisfies requirements for hazardous area and toxic area. The selected explosion-proof devices are to meet the requirements in Appendix 9 of this Chapter.
(3) Each ammonia engine is to be provided with independent exhaust system.
(4) In accordance with the requirements of 1.5(5) of this Appendix, safety assessment is to be carried out to unburned ammonia fuel possibly existing in the engine exhaust and safety disposal plan is to be detailed in the safety concept, so as to ensure that the engine exhaust does not affect the safety of the ship and personnel.
2.2.5 The protection of crankcase is to comply with the following requirements:
(1)The crankcase is to be fitted with a crankcase safety valve in accordance with the requirements of 9.7.4 of this Chapter.
(2)For maintenance purposes, a connection, or other means, are to be provided for crankcase inerting and ventilating and gas concentration measuring.
(3) For engines where the space below the piston is in direct communication with the crankcase, protection of crankcase is also to comply with the following requirements:
Detailed assessment is to be carried out to hazard potential for crankcase gas accumulation. If it cannot be proved that the gas concentration in the crankcase will not exceed the lower explosive limit for ammonia under any circumstances, an appropriate device is to be fitted in the crankcase to monitor ammonia accumulation in the crankcase.
Except for two-stroke crosshead engines, each engine crankcase is to be provided with a vent system independent of other engines. A flame arrester or other equivalent device is to be fitted on the vent pipe, and the vent outlet is to be directed to an open area or another location where the gas can be safely disposed.
(4)For engines using glands to isolate the space below the piston from the crankcase, appropriate means for drainage are to be provided. The drained mixture is to be stored in a suitable collection tank. The vent outlet of the collection tank is to be fitted with appropriate monitoring and alarm devices, and appropriate measures are to be taken after the outlet to collect ammonia to avoid diffusion.
2.2.6 The explosion-proof category and temperature group of explosion-proof equipment for explosive gas environments that may be mixed with ammonia vapor are to not be lower than IIA, T1 respectively.
2.2.7 If the fuel can leak directly into the engine auxiliary system media (lubricating oil, cooling water), appropriate monitoring and alarm devices are to be fitted in the auxiliary system, and appropriate measures are to be taken after the outlet of these media to collect fuel vapor to avoid diffusion. The cooling water containing leaked ammonia is to be replaced in time to avoid corrosion of material. The fuel and the mixture of ammonia and water collected from the auxiliary system medium are to be stored in a suitable collection tank.
2.2.8 Control, monitoring, alarm and safety system are to comply with the following requirements:
(1) The control system, safety system and alarm system of the engine are to be designed or made to function independently of each other, and when one or more systems fail, the normal operation of the other systems is not to be affected.
(2) The ammonia supply valves are to be controlled by the engine control system or by the engine ammonia demand.
(3) Combustion is to be monitored on an individual cylinder basis.
(4) If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.

(5) A means is to be provided to monitor and detect poor combustion or misfiring in the engine. In the event that it is detected, continued operation in the ammonia fuel mode may be allowed, provided that the fuel supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respect to torsional vibrations.
(6) Unless the risk analysis required by 1.4 of this Appendix proves otherwise, the monitoring and safety system functions for ammonia dual fuel or ammonia fuel only engines are to be provided in accordance with Table 1 of this Appendix in addition to the general monitoring and safety system functions given by the Rules.
Note: For ammonia dual fuel engines, Table 1 applies only to the ammonia fuel mode.

Monitoring and Safety System Functions for ammonia Fuel Engines

Table 1

Parameter	Alarm	Automatic activation of the double block and bleed valve	Automatic switching over to oil fuel mode①	Engine shutdown
Abnormal pressures in the ammonia fuel supply line	×	×	×	×⑤
Ammonia fuel supply systems - malfunction	×	×	×	×⑤
Pilot fuel injection malfunction	×	×②	×	×②⑤
Exhaust gas temperature after each cylinder - high	×	×②	×	×②⑤
Exhaust gas temperature after each cylinder, deviation from average – low③	×	×②	×	×②⑤
Cylinder pressure or ignition - failure, including misfiring, knocking and unstable combustion	×	×②④	×④	×②④⑤
Oil mist concentration in crankcase or bearing temperature⑥ - high	×	×		×
Ammonia concentration in crankcase - high or pressure in the crankcase – high④ (for engines where the space below the piston is in direct communication with the crankcase)	×	×	×	
Engine stops - any cause	×	×		
Failure of the control-actuating medium of the ammonia fuel block valve	×	×	×	

Symbol: × Applicable
Note:
① Ammonia dual fuel engine only, when running in ammonia fuel mode.
② For ammonia fuel only engines, the block valve and the engine shutdown may not be activated in case of specific failures affecting only one cylinder, provided that the concerned cylinder can be individually shutoff and the safe operation of the engine in such conditions is demonstrated by the risk analysis.
③ Required only if necessary for the detection of misfiring.
④ In the case where the failure can be corrected by an automatic mitigation action, only the alarm may be activated. If the failure persists after a given time, the safety actions are to be activated.
⑤ Ammonia fuel only engine only.
⑥ Where required by 9.7.6 of this Chapter.

2.2.9 The ammonia fuel injection valve is to be certified according to the following hazardous area classification:
(1) The interior of the valve contains ammonia fuel; therefore, it is to be certified for hazardous area zone 0.
(2) In accordance with 2.2.2(2), when the ammonia fuel injection valve is fitted within the double wall pipe or ventilation pipe, the external part of the valve is to be certified for hazardous area zone 1.
However, if the ammonia fuel injection valve has not been certified for the hazardous area classification for which it is intended to operate, an analysis is to be conducted in accordance with the IEC 60079-10-1 or IEC 60092-502 standard, which is to be documented as evidence to demonstrate that the valve is suitable for the area in which it will operate.
2.2.10 The ammonia fuel injection valve is to satisfy the following requirements:
(1) The ammonia fuel injection valve is to have good performance characteristics and durability throughout

its service life.
(2) The ammonia fuel injection valve is to be provided with a sealing system to effectively prevent fuel leakage around the valve shaft.
(3) An appropriate method is to be provided to clean the driving oil of the ammonia fuel injection valve.

3 Specific Design Requirements

3.1 Ammonia dual fuel engines

3.1.1 The maximum continuous power that an ammonia dual fuel engine can develop in ammonia fuel mode may be lower than the approved MCR of the engine (i.e. in oil fuel mode), depending in particular on the ammonia quality. This maximum power available in ammonia fuel mode and the corresponding conditions are to be stated by the engine manufacturer and demonstrated during the type test. The 110% load tests are not required in the ammonia fuel mode of ammonia dual fuel engines when 4.1.4, 4.2.1 and 4.3 of this Appendix are implemented in accordance with the provisions in 1.3 of Appendix 4, 2.3 and 3.4 of Appendix 6 of this Chapter.

3.1.2 Ammonia dual fuel engines are to be arranged to use either oil fuel or ammonia fuel for the main fuel charge and with pilot oil fuel for ignition. The engines are to be arranged for rapid changeover from ammonia use to fuel oil use. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply without interruption to the power supply.

Changeover to ammonia fuel operation is to be only possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing.

Changeover from ammonia fuel operation mode to oil fuel operation mode is to be possible at all situations and power levels.

The changeover process itself from and to ammonia fuel operation is to be automatic but manual interruption is to be possible in all cases.

In case of shut-off of the ammonia supply, the engines are to be capable of continuous operation by oil fuel only.

After changeover from ammonia fuel mode to oil fuel mode due to a failure, the use of ammonia fuel mode is not allowed until the failure is rectified.

If the engine has an emergency stop in ammonia fuel mode, or has a sudden flameout during the operation of ammonia fuel mode, measures are to be taken to purge the exhaust pipe before restarting the engine, and the purge gas is to be handled properly (such as using an ammonia gas treatment system).

3.1.3 Ammonia supply to the combustion chamber is not to be possible without operation of the pilot oil injection or sparking plug, where applicable.

Note: Pilot injection is to be monitored for example by fuel oil pressure and combustion parameters.

3.1.4 In case of an emergency stop or a normal stop, the ammonia fuel is to be automatically shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the ammonia fuel supply to each cylinder or to the complete engine.

3.2 Ammonia fuel only engines

3.2.1 In case of ignition failure of the ignition system, the engine is to be shut down except if this failure is limited to one cylinder, subject to immediate shut off of the cylinder ammonia supply and provided that the safe operation of the engine is substantiated by the risk analysis and by tests.

3.2.2 In case of an emergency stop or a normal stop, the ammonia fuel is to be automatically shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the ammonia fuel supply to each cylinder or to the complete engine.

3.3 Two stroke engines

3.3.1 Risk analysis is to be carried out in accordance with the requirements of 1.4 to consider the risk due to potential ammonia accumulation in the gas-purging space.

3.3.2 Risk analysis is to be carried out in accordance with the requirements of 1.4 to consider the possible failure of piston rod glands.

4 Type Testing, Factory Acceptance Tests and Shipboard Trials

4.1 Type Testing

4.1.1 Type approval of ammonia dual fuel and ammonia fuel only engines is to be carried out in accordance with 9.10.1 and 9.10.2 of this Chapter, taking into account the additional requirements below.

4.1.2 In addition to the criteria given in 9.1.2.1(1) of this Chapter, the type of engine is defined by the

following:
(1) ammonia admission method (direct cylinder injection, cylinder intake channel injection etc.);
(2) ammonia supply valve operation (mechanical or electronically controlled);
(3) ignition system (pilot injection, spark ignition etc.);
(4) ignition system (mechanical or electronically controlled).

4.1.3 In addition to the safety precautions mentioned in 1.2, Appendix 4 of this Chapter, measures to verify that ammonia fuel piping on engine is gas tight and liquid tight are to be carried out prior to start-up of the engine.

4.1.4 The type testing of the engine is to be carried out in accordance with 1.3, Appendix 4 of this Chapter.

For ammonia dual fuel engines, the load tests are to be carried out in ammonia fuel mode at the different percentages of the maximum power available in ammonia fuel mode (see 3.1.1 of this Appendix).

4.1.5 In addition to the measurements and records required in 1.4, Appendix 4 of this Chapter, the following engine data are to be measured and recorded:
(1) Each fuel index for ammonia and fuel oil as applicable (or equivalent reading).
(2) Ammonia pressure and temperature at the inlet of the ammonia manifold.
(3) Crankcase ammonia gas concentration.
Additional measurements may be required in connection with the design assessment.

4.1.6 In addition to internal tests required in 2.1, Appendix 4 of this Chapter, the following conditions are to be tested:
(1) Ammonia dual fuel engines are to run the load points in both ammonia fuel and fuel oil modes (with and without pilot injection in service) as found applicable for the engine type.
(2) For ammonia dual fuel engines with variable ammonia/fuel oil ratio, different ammonia/fuel oil ratios are to be selected between the minimum and maximum allowable values for load tests (the most common and severe ratios are to be selected for testing).
(3)For ammonia dual fuel engines, switch over between ammonia fuel and fuel oil modes are to be tested at different loads.

4.1.7 Witnessed tests are to be carried out in accordance with 2.2, Appendix 4 of this Chapter. The following requirements are to be considered:
(1) The following test conditions are to be considered for ammonia dual fuel engine during the load test:
① All load points must be run in both ammonia fuel and fuel oil modes that apply for the engine type as defined by the engine designer. This also applies to the overspeed test.
② For ammonia dual fuel engines with variable ammonia/fuel oil ratio, different ammonia/fuel oil ratios as necessary are to be selected between the minimum and maximum allowable values for load tests.
(2) The following items are to be carried out for functional test:
① For ammonia dual fuel engines, the lowest specified speed is to be verified in fuel oil mode and ammonia fuel mode.
② For ammonia dual fuel engines, switch over between ammonia fuel and fuel oil modes are to be tested at different loads.
③ The efficiency of the ventilation arrangement of the double walled piping system is to be verified.

For engines intended to produce electrical power, capability to take sudden load and loss of load is to be verified in accordance with the provisions of 9.7.10.1 of this Chapter.

Notes:
1. For ammonia dual fuel engines, switchover to oil fuel during the test is acceptable.
2. Application of electrical load in more than 2 load steps can be permitted in the conditions stated in 9.7.10.1 of this Chapter.

(3) Ammonia fuel only and ammonia dual fuel engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes. The scope of these tests is to be agreed with CCS for selected cases based on the risk analysis, and is at least to include the following incidents:
① Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;
② Failure of a cylinder ammonia supply valve;
③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);
④ Abnormal ammonia pressure;
⑤ Abnormal ammonia temperature.

Note: The above tests may be carried out using simulation or other alternative methods, subject to special consideration by CCS.

4.1.8 Component inspection is to be carried out in accordance with the provisions of 2.3, Appendix 4 of this Chapter. The components to be inspected after the test run are to include also:
(1) ammonia supply valve;
(2) spark igniter (ammonia fuel only engine);
(3) pilot fuel injection valve/spark igniter (ammonia dual fuel engine).
4.1.9 Engine type approval certificate
For ammonia dual fuel engines, if the maximum continuous power in different operating modes is inconsistent, the respective maximum continuous power in diesel mode and in ammonia fuel mode is to be indicated on the type approval certificate.

4.2 Factory acceptance test
4.2.1 Factory acceptance tests are to be carried out in accordance with Appendix 6 of this Chapter. For ammonia dual fuel engines, the load tests referred to in 2.3, Appendix 6 of this Chapter are to be carried out in ammonia fuel mode at the different percentages of the maximum power available in ammonia fuel mode (see 3.1.1 of this Appendix).
4.2.2 In addition to the safety precautions mentioned in 1.1, Appendix 6 of this Chapter , measures to verify that ammonia fuel piping on engine is gas tight and liquid tight are to be carried out prior to start-up of the engine.
4.2.3 In addition to the records required in 2.2, Appendix 6 of this Chapter, the following engine data are to be recorded:
(1) Fuel index, both ammonia and diesel as applicable (or equivalent reading);
(2) Ammonia pressure and temperature at the inlet of the ammonia manifold.
4.2.4 Test loads for various engine applications are given in 2.3, Appendix 6 of this Chapter. For ammonia dual fuel engines, all load tests are to be carried out in applicable ammonia fuel and fuel oil modes. In addition the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.
4.2.5 Ammonia fuel engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes.
The scope of these tests is to be agreed with CCS for selected cases based on the risk analysis, and is at least to include the following incidents:
① Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;
② Failure of a cylinder ammonia supply valve;
③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);
④ Abnormal ammonia pressure;
⑤ Abnormal ammonia temperature.
Note: The above tests may be carried out using simulation or other alternative methods, subject to special consideration by CCS.

4.3 Shipboard trials
4.3.1 After gas pipes are installed on board, gas tightness test is to be carried out.
4.3.2 Shipboard trials are to be carried out in accordance with the provisions of Appendix 6 of this Chapter. For ammonia dual fuel engines, the test loads are to be carried out in all operating modes (ammonia fuel mode, fuel oil mode, etc.). For ammonia dual fuel engines, when load tests specified in 3.4, Appendix 6 of this Chapter are carried out in ammonia fuel mode, test loads are taken as each percentage of the maximum output power in ammonia fuel mode (see 3.1.1 of this Appendix).

CHAPTER 10 TRANSMISSION GEARING

Section 1 GENERAL PROVISIONS

10.1.1 General requirements

10.1.1.1 The requirements of this Chapter are applicable to transmission gearing for main propulsion machinery and driving auxiliary machinery where the transmitted power is equal to or more than 100 kW.

10.1.1.2 The certification requirements and inspection of products for transmission gearing are to comply with the relevant requirements in Chapter 3, PART ONE of the Rules.

10.1.2 Strengthening for navigation in ice

10.1.2.1 In the case of ships strengthened in ice, the transmission gearing of main propulsion systems is to comply with the relevant requirements in Chapter 14 of this PART.

10.1.3 Vibration and alignment

10.1.3.1 For the requirements for vibration and alignment of the transmission gearing, see Chapter 12 of this PART.

10.1.4 Plans and documents

10.1.4.1 Following plans and documents are to be submitted for approval:

(1) General arrangement (longitudinal and transverse sections);

(2) Details of pinions and wheels, including ring gear, where applicable, and parameters necessary for calculation of load capacity;

(3) Gear shafts;

(4) Bosses, if any;

(5) Clutches and/or couplings;

(6) Other power transmitting parts;

(7) Gear casing, incl. propeller thrust bearing housing, if any;

(8) Basic sizes of the tooth profile of the tools;

(9) Calculations of the load capacity of gears;

(10) Strength calculations of shafts;

(11) Strength calculations of clutches and/or couplings;

(12) Calculation of combined dynamic reaction forces and its acting direction of sliding bearings for gearboxes;

(13) Details of heat treatment of gears;

(14) Details of gear materials;

(15) Details of weld procedures for gears or gearbox, if any;

(16) Plans and documents for gear box lubricating and cooling systems;

(17) Diagram of the hydraulic system, if applicable;

(18) Other plans and documents deemed necessary by CCS.

Section 2 MATERIALS

10.2.1 Material properties

10.2.1.1 Shafts, gear, wheel's rim, if any, couplings, etc. of the transmission gearing are to be made of steel forgings, and the materials for forgings are to be in accordance with the relevant requirements of CCS Rules for Materials and Welding.

10.2.1.2 For gears of through-hardened steels, provision is to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified tensile strength of the wheel material is not to be more than 85% of that of the pinion.

10.2.1.3 The full specified minimum tensile strength of the core is to be 800 N/mm^2 for induction-hardened or nitrided gearing and 750 N/mm^2 for carburized gearing.

10.2.1.4 Where it is proposed to use alloy steel forgings, the chemical composition and mechanical properties are to comply with relevant requirements of CCS Rules for Materials and Welding.

10.2.2 Non-destructive tests

10.2.2.1 An ultrasonic examination is to be carried out on all gear blanks where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm.
10.2.2.2 Magnetic particle or liquid penetrant examination is to be carried out on all surface-hardened teeth. This examination may also be requested on the finished machined teeth of through-hardened gears.

Section 3 DESIGN AND CONSTRUCTION

10.3.1 Design
10.3.1.1 Appraisal of gear strength is to comply with the requirements of "Appraisal of gear strength" in Appendix 1 of this Chapter. For the enclosed reduction transmission gearing used for main propulsion machinery where the maximum continuous transmitted power is less than 220 kW and for essential auxiliary machinery where the maximum continuous transmitted power is less than 110 kW, the calculation of load capacity of gears need not satisfy the requirements of this Chapter.

10.3.2 Tooth form
10.3.2.1 The roots of teeth are to be formed with smooth fillets of radius not less than 0.25 m_n.
10.3.2.2 Where the ratio of working length over the gear faces to reference diameter of pinion exceeds 1.5, the ends of the teeth are to be chamfered.
10.3.2.3 The teeth of pinions and wheels are to be suitably relieved on flanks in cases where any of the following conditions applies:
(1) normal module of teeth exceeds 6 mm;
(2) addendum of pinion teeth exceeds 65% of total working depth of engagement;
(3) ratio of total working depth of engagement to normal pitch of teeth exceeds 0.75.

10.3.3 Tooth surface
10.3.3.1 The hardened layer of the surface-hardened gear is to be distributed over and extended to the whole tooth surfaces and fillets.
10.3.3.2 For nitrided gear, generally, the depth of nitrided layer is not to be less than 0.40 mm.
10.3.3.3 For surface-hardened gears (except the nitrided) the depth of hardened layer is not to be less than 0.15 m_n.
10.3.3.4 For carburized gears, the surface hardness is generally not to be less than HRC 58.

10.3.4 Gear
10.3.4.1 The grade of accuracy of gear cutting is not to be less than 7 for diesel engines and 6 for turbines.
10.3.4.2 Where bolts or shrink-fit are used to secure the side plates to rim and boss of the wheels, the bolts are to be tight fit in holes and the nuts are to be suitably locked.

10.3.5 Gear shafts
10.3.5.1 The diameter d of the quill shafts is not to be less than the value obtained from the following formula:

$$d = 100 \sqrt[3]{\frac{400 N_e}{n_e \mathrm{R}_m}} \quad \text{mm}$$

where: N_e — the maximum continuous output transmitted by the shaft, in kW;
n_e — speed of the shaft at N_e, in r/min;
R_m — minimum tensile strength of shaft material, in N/mm^2, but not exceeding 1,100 N/mm^2.
10.3.5.2 The diameter of gear shafts is to be calculated in accordance with 11.2.2 of this PART.
10.3.5.3 Where the gear is fitted on the gear shaft by key or shrink-fit, the diameter of gear shafts at the fitting area is to be increased by 5% over the value determined in 10.3.5.2.
10.3.5.4 Where the wheel shaft is driven by only one pinion or by two pinions arranged to subtend an angle at the centre of the shaft of less than 120°, the diameter of the wheel shaft between bearings is at least to be increased by 15% over the value determined by 10.3.5.2. Where it is driven by two pinions arranged to subtend an angle at the centre of the shaft of more than 120°, the diameter of the wheel shaft between bearings is at least to be increased by 10% over the value determined in 10.3.5.2.

10.3.6 Gear casings
10.3.6.1 Gear casings of welded construction are to be stress-relief heat treated on completion of welding

in accordance with the relevant requirements of CCS Rules for Materials and Welding.
10.3.6.2 Gear casings are to be of sufficient strength and rigidity, and are to be provided with inspection openings and adequate venting devices.
10.3.6.3 Where thrust bearing is provided inside the gear casing, the latter is to be adequately strengthened.

10.3.7 Connections
10.3.7.1 Where the coupling of the output shaft is fitted by means of the oil pressure injection method, the actual shrinkage allowance δ is to comply with the requirements of 11.3.2.3 of this PART; where shrink-fit is employed, 0.03 in the formula may be ignored.
10.3.7.2 For the shrink-fit of rim to boss, boss to shaft and the shrink-fit of other items, a safety factor against slippage in design is not to be less than $2.8C$, where C is a coefficient having the following values:
C = 1 for gears driven by turbines or electric motors and gears driven through a hydraulic, electromagnetic or high elasticity coupling;
C = 1.2 in other cases.
10.3.7.3 Clutches and couplings in the transmission gearing are to comply with the requirements of Section 3, Chapter 11 of this PART.

10.3.8 Grade of Meshing
10.3.8.1 Tooth faces are to be evenly meshed. For diesel or turbine transmission gearing, the contact marking is not to be less than Grade 7 or Grade 6 respectively.

10.3.9 Reversal
10.3.9.1 For reversible gearing:
(1) the speed at free clutching and declutching is not to be less than 50% of the rated speed;
(2) the time required for reversal is not to be more than 15 s;
(3) sufficient astern power is to be available.

10.3.10 Lubricating and cooling
10.3.10.1 The construction and arrangement of lubricating oil and cooling systems of transmission gearing are to be in accordance with the requirements of 1.2.1.1 of this PART.
10.3.10.2 Lubricating oil is to be efficiently conveyed to all bearings, meshed gears and other portions requiring lubrication. The arrangement of oil pockets of sliding bearings is to be such that the effect of combined dynamic force of bearings is taken into account.
10.3.10.3 The lubricating oil system of transmission gearing for diesel engines is to be independent.
10.3.10.4 The lubricating oil pump for the transmission gearing is to comply with the requirements in 4.6.1, Chapter 4 of this PART.
10.3.10.5 Thermometers and pressure gauges are to be provided in the pressure lubricating oil systems, and working oil pressure gauge is to be fitted in addition when hydraulic system is employed. An oil level indicator is to be provided for the oil sump of splash lubrication.
10.3.10.6 Where the lubricating oil for the transmission gearing is circulated under pressure, provision is to be made for efficient filtration of the oil. The filters are to comply with the relevant provisions of 4.6.2.2 of this PART.
10.3.10.7 The lubricating oil temperature in the transmission gearing is not to exceed 70℃, and not to exceed 80℃ if roller bearing is fitted.
10.3.10.8 Cooling pipes passing through gear casings are not to have any detachable joint.

10.3.11 Alarm
10.3.11.1 Transmission gearing is to be fitted with alarm devices for low pressure of lubricating oil and in addition, an alarm device for high temperature of lubricating oil is to be fitted in case of transmission gearing whose input power is more than 1,470 kW.

10.3.12 Emergency devices
10.3.12.1 For hydraulically controlled transmission gearing in single screw ships, emergency mechanical means are to be provided to ensure that the ship can run at a reasonable speed in the event of failure of hydraulic control systems.

10.3.13 Markings
10.3.13.1 For reversible gearing, the directions of lever or handwheel for ahead and astern running are to

be marked at control station. As a common practice, to push the lever forward or to turn the handwheel clockwise is the way to move the ship ahead.

Section 4 TESTS

10.4.1 Material tests

10.4.1.1 Chemical composition and material test are to comply with the relevant requirements in CCS Rules for Materials and Welding.

10.4.2 Balance tests

10.4.2.1 All pinion and gear wheels are to be statically balanced. Where the linear velocity at the reference circle exceeds 25 m/s, dynamic balance test is to be made. Driven parts of the coupling are to be attached to the gear before balancing.

The residual dynamic unbalance is not to exceed:

$\frac{6.0m}{n} \times 10^2$ N·mm, for transmission gearing of diesel engines;

$\frac{2.4m}{n} \times 10^2$ N·mm, for transmission gearing of turbines.

where: m — mass of components, in kg;

n — maximum working speed of components, in r/min.

10.4.2.2 Balance test may, however, be omitted for diesel engine gearing, provided that the rotating components are of solid forged construction or have a solid forged centre with shrunk-on rim, and in both cases are machined to give a concentric and uniform cross-section.

10.4.3 Gear mesh tests

10.4.3.1 Gear mesh tests are to be carried out and gear contact spots are not to be less than the value in Table 10.4.3.1.

Contact spots **Table 10.4.3.1**

Contact spots	Grade of accuracy			
	6	7	8	9
Not less than (%) according to height	50	45	40	30
Not less than (%) according to length	70	60	50	40

10.4.4 Bench trials

10.4.4.1 The transmission gearing is to be tested according to the test programs approved by CCS during bench trials.

Appendix 1 APPRAISAL OF GEAR STRENGTH

1 General

1.1 Application

1.1.1 This Appendix is applicable to the enclosed gears intended for main propulsion and for essential auxiliary services of ships and mobile offshore units, which accumulate a large number of load cycles (several millions), whose gear set is intended to transmit a maximum continuous power equal to, or greater than 220 kW for gears intended for main propulsion and 110 kW for gears intended for essential auxiliary services. These requirements, however, may be applied to the enclosed gears, whose gear set is intended to transmit a maximum continuous power less than those specified above.

1.1.2 This Appendix is applicable to strength appraisal of involute spur and helical gears having parallel axis, and of bevel gears having transverse contact ratio $\varepsilon_{va} < 2$ for equivalent cylindrical gear.

1.1.3 This Appendix includes general, tooth surface contact stress, tooth root bending stress and alignment of gearbox shafting. All influence factors are defined regarding their physical interpretation. Some of the influence factors are determined by the gear geometry or have been established by conventions. These factors are to be calculated in accordance with the equations provided. Other factors, which are approximations, can be calculated according to methods acceptable to CCS.

1.2 Symbol, name and unit

1.2.1 The main symbols used in this Appendix are listed below. Other symbols introduced in connection with the definition of influence factors are described in the appropriate sections.

a — centre distance, in mm;
b — common face width, in mm;
$b_{1,2}$ — face width of pinion, wheel, in mm;
b_e — effective face width, in mm;
$d_{1,2}$ — reference diameter of pinion, wheel, in mm;
$d_{a1,2}$ — tip diameter of pinion, wheel, in mm;
$d_{b1,2}$ — base diameter of pinion, wheel, in mm;
$d_{f1,2}$ — root diameter of pinion, wheel, in mm;
$d_{w1,2}$ — working pitch diameter of pinion, wheel, in mm;
$d_{e1,2}$ — out pitch diameter of pinion, wheel, in mm;
F_t — nominal tangential load, in N;
$h_{1,2}$ — tooth depth, in mm;
$h_{a1,2}$ — addendum, in mm;
$h_{f1,2}$ — dedendum, in mm;
h_{ao} — addendum of cutter, in mm;
$h_{F1,2}$ — bending moment arm for load acting at the outer point of single tooth pair contact for pinion, wheel, in mm;
HV — Vickers hardness;
HRC — Rockwell hardness;
HB — Brinell hardness;
m_n — normal module, in mm;
$n_{1,2}$ — rotational speed of pinion, wheel, in r/min;
N_L — number of load cycles;
P — maximum continuous power or nominal power transmitted by the gear set (determined according to purpose), in kW;
P_{ro} — protuberance of tool, in mm;
P_{bt} — plane base terminal, in mm;
q_s — base circle parameter;
R_a — arithmetic mean of roughness, in μm;
R_z — mean peak-to-valley roughness, in μm;
S_{Fn} — tooth root chord in the critical section, in mm;
$T_{1,2}$ — torque in way of pinion, wheel, in N·m;
u — gear ratio;
V — linear velocity at pitch diameter, in m/s;
x — addendum modification coefficient of pinion, wheel;
$x_{hm1,2}$ — profile shift coefficient (midface);

$x_{sm1,2}$ — tooth thickness modification coefficient (midface);
$z_{1,2}$ — number of teeth;
$z_{n1,2}$ — virtual number of teeth;
$\alpha_{Fen1,2}$ — normal pressure angle relevant to direction of application of load at the outer point of single pair tooth contact of pinion, wheel, in °;
α_{pro} — cutter boss angle, in °;
α_n — normal pressure angle at reference cylinder, in °;
α_t — transverse pressure angle at reference cylinder, in °;
β — helix angle at reference cylinder, in °;
β_b — helix angle at base cylinder, in °;
ε_a — transverse contact ratio;
ε_β — overlap ratio;
ε_γ — total contact ratio;
$\rho_{ao1,2}$ — tip radius of tool of pinion, wheel, in mm;
$\rho_{F1,2}$ — root fillet radius at the 30° tangent point, in mm;
R_m — tensile strength, in N/mm²;
R_{eH} — yield point, in N/mm²;
$\delta_{1,2}$ — reference cone angle of pinion, wheel, in °;
$\delta_{a1,2}$ — tip angle of pinion, wheel, in °;
Σ — shaft angle, in °;
β_m — mean spiral angle, in °;
S — cone distance, in mm;
S_m — middle cone distance, in mm;
S_e — outer cone distance, in mm.
In calculation, pinion and wheel are indicated respectively by subscript 1 and subscript 2.

1.3 Definitions①

1.3.1 For the purpose of this Appendix:
(1) For internal gears, z_2, a, d_{a2}, d_2, d_{b2}, d_{w2} are negative.
(2) The pinion is defined as the gear with the less teeth, therefore:

$$|u| = \frac{|z_2|}{z_1} \geq 1$$

where: for external gears, u is positive; for internal gears, u is negative.
(3) In the equation of surface durability, b is the common face width on the pitch diameter.
(4) In the equation of tooth root bending stress, b_1 and b_2 are the face widths at the respective tooth roots. In any case, b_1 and b_2 are not to be taken as greater than b by more than one module m_n on either side.
(5) The common face width b may be used also in the equation of teeth root bending stress if significant crowning or end relief has been adopted.
(6) Geometry equations concerned are as follows:

$$\tan a_t = \tan a_n / \cos\beta$$
$$\tan\beta_b = \tan\beta\cos\alpha_t$$
$$d_{1,2} = z_{1,2} m_n / \cos\beta$$
$$d_{b1,2} = d_{1,2}\cos\alpha_t$$
$$d_{W1} = \frac{2a}{u+1}$$
$$d_{W2} = \frac{2au}{u+1}$$
$$a = 0.5(d_{w1} + d_{w2})$$
$$z_{n1,2} = z_{1,2} / (\cos^2\beta_b \cdot \cos\beta)$$
$$m_t = m_n / \cos\beta$$
$$inv\alpha = \tan\alpha - \pi\alpha / 180\,, \quad \alpha(°)$$

① The following definitions are mainly based on the ISO 6336 standard for the calculation of load capacity of spur and helical gears.

$$inv\alpha_{tw}=inv\alpha_t+2\tan\alpha_n(x_1+x_2)/(z_1+z_2) \quad \text{or} \quad \cos\alpha_{tw}=\frac{m_t(z_1+z_2)}{2a}\cos\alpha_t$$

$$a_{tw}=\arccos\left(\frac{d_{b1}+d_{b2}}{2a}\right), \quad \alpha_{tw}(°)$$

$$x_{hm1}+x_{hm2}=\frac{\left(z_1+z_2\right)\cdot\left(inv\alpha_{tw}-inv\alpha_t\right)}{2\tan\alpha_n}$$

$$x_{hm1,2}=\frac{h_{ao}}{m_n}-\frac{d_{1,2}-d_{f1,2}}{2m_n}$$

$$\varepsilon_\alpha=\frac{0.5\sqrt{d_{a1}^2-d_{b1}^2}\pm0.5\sqrt{d_{a2}^2-d_{b2}^2}-a\sin a_{tw}}{\pi\cdot m_t\cdot\cos\alpha_t}$$

where the positive sign is used for external gears, the negative sign for internal gears.

$$\varepsilon_\beta=\frac{b\cdot\sin\beta}{\pi m_n}$$

where for double helix, *b* is to be taken as the width of one helix.

$$\varepsilon_r=\varepsilon_a+\varepsilon_\beta$$

$$v=\frac{\pi\cdot d_{1,2}n_{1,2}}{60\cdot10^3}$$

$$P_{bt}=\pi m_n\cos\alpha_t/\cos\beta$$

1.3.2 Equations for bevel gears

1.3.2.1 The calculation of bevel gear strength is technically based on the equivalent cylindrical gear at the bevel gear midsection. The calculation of geometric parameters of the equivalent cylindrical gear is shown in 1.3.2.3 of this Appendix.

1.3.2.2 Index *m* refers to the midsection of bevel gear; index *v* refers to the virtual (equivalent) cylindrical gear.

1.3.2.3 The geometric parameters of the equivalent cylindrical gear are to be calculated as follows:

(1) Number of teeth z_v:

$$z_{v1,2}=\frac{z_{1,2}}{\cos\delta_{1,2}}$$

For Σ = 90º:

$$z_{v1}=z_1\frac{\sqrt{u^2+1}}{u}$$

$$z_{v2}=z_2\sqrt{u^2+1}$$

(2) Gear ratio u_v:

$$u_v=u\frac{\cos\delta_1}{\cos\delta_2}=\frac{z_{v2}}{z_{v1}}$$

For Σ = 90º:

$$u_v=(\frac{z_2}{z_1})^2=u^2$$

(3) Reference diameter d_v:

$$d_{v1,2}=\frac{d_{m1,2}}{\cos\delta_{1,2}}=\frac{d_{e1,2}}{\cos\delta_{1,2}}\frac{S_m}{S_e}$$

For Σ = 90º:

$$d_{v1}=d_{m1}\frac{\sqrt{u^2+1}}{u}$$

$$d_{v2}=u^2d_{v1}$$

(4) Centre distance a_v:

$$a_v=\frac{d_{v1}+d_{v2}}{2}$$

(5) Tip diameter d_{va}:

$$d_{va1,2} = d_{v1,2} + 2h_{am1,2}$$

(6) Base diameter d_{vb}:

$$d_{vb1,2} = d_{v1,2} \times \cos\alpha_{vt}$$

$$\alpha_{vt} = \arctan(\frac{\tan\alpha_n}{\cos\beta_m})$$

(7) Helix angle at base cylinder β_{vb}:

$$\beta_{vb} = \arcsin(\sin\beta_m \cos a_n)$$

(8) Transverse contact ratio ε_{va}:

$$\varepsilon_{va} = \frac{g_{va}\cos\beta_m}{m_{mn}\pi\cos a_{vt}}$$

$$g_{va} = \frac{1}{2}\left[\sqrt{d_{va1}^2 - d_{vb1}^2} + \sqrt{d_{va2}^2 - d_{vb2}^2}\right] - a_v \sin a_{vt}$$

(9) Overlap ratio $\varepsilon_{v\beta}$:

$$\varepsilon_{v\beta} = \frac{b\sin\beta_m}{m_{mn}\pi}$$

(10) Modified contact ratio $\varepsilon_{v\gamma}$:

$$\varepsilon_{v\gamma} = \sqrt{\varepsilon_{v\alpha}^2 + \varepsilon_{v\beta}^2}$$

(11) Mean addendum h_{am}:

$$h_{am1,2} = m_{mn} \times (1 + x_{hm1,2})$$

1.3.2.4 The geometric parameters of the normal section of the equivalent cylindrical gear are to be calculated as follows:

(1) Number of teeth z_{vn}:

$$z_{vn1} = \frac{z_{v1}}{\cos^2\beta_{vb}\cos\beta_m}$$

$$z_{vn2} = u_v z_{vn1}$$

(2) Reference diameter d_{vn}:

$$d_{vn1} = \frac{d_{v1}}{\cos^2\beta_{vb}} = z_{vn1}m_{mn}$$

$$d_{vn2} = u_v d_{vn1} = z_{vn2}m_{mn}$$

(3) Centre distance a_{vn}:

$$a_{vn} = \frac{d_{vn1} + d_{vn2}}{2}$$

(4) Tip diameter d_{van}:

$$d_{van1,2} = d_{vn1,2} + d_{va1,2} - d_{v1,2} = d_{vn1,2} + 2h_{am1,2}$$

(5) Base diameter d_{vbn}:

$$d_{vbn1,2} = d_{vn1,2}\cos a_n = z_{vn1,2}m_{mn}\cos a_n$$

(6) Contact ratio ε_{van}:

$$\varepsilon_{v\alpha n} = \frac{\varepsilon_{v\alpha}}{\cos^2\beta_{vb}}$$

1.4 Nominal tangential loads F_t, F_{mt}

1.4.1 The nominal tangential loads, F_t, F_{mt}, tangential to the reference cylinder and perpendicular to the relevant axial plane, are calculated directly from the maximum continuous power or nominal power transmitted by the gear set by means of the following equations:

$$T_{1,2} = \frac{30\cdot 10^3 P}{\pi\cdot n_{1,2}}$$

Cylindrical gears:

$$F_t = \frac{2000T_{1,2}}{d_{1,2}} = \frac{19.1P\times 10^6}{n_{1,2}d_{1,2}}$$

Bevel gears:

$$F_{mt} = \frac{2000T_{1,2}}{d_{m1,2}} = \frac{19.1P\times 10^6}{n_{1,2}d_{m1,2}}$$

$$V_{mt} = \frac{d_{m1,2} n_{1,2}}{19098}$$

1.5 Relevant factors

1.5.1 Application factor K_A

1.5.1.1 The application factor K_A accounts for dynamic overloads from sources external to gearing. K_A, for gears designed for infinite life, is defined as the ratio between the maximum repetitive cyclic torque applied to the gear and the nominal rated torque. The nominal rated torque is defined by the rated power and speed and is the torque used in the rating calculations.

1.5.1.2 Factor K_A mainly depends on:

(1) characteristics of driving and driven machines;

(2) ratio of masses;

(3) type of couplings;

(4) operating conditions (overspeeds, changes in propeller load conditions, ...).

1.5.1.3 When operating near a critical speed of the drive system, a careful analysis of conditions must be made. The application factor K_A is to be determined by measurements or by system analysis. Where a value determined in such a way cannot be supplied, the following values in Table 1.5.1.3 may be considered.

Application factor K_A **Table 1.5.1.3**

Equipment type		K_A
Main propulsion diesel engines	With hydraulic coupling or equivalent parts	1.00
	With high elasticity coupling (general angle of torsion more than 6°)	1.30
	With elasticity coupling (general angle of torsion 2° to 6°)	1.40
	With other couplings	1.50
Main propulsion motors	Electric drive	1.00
Auxiliary gears	Electric motor and diesel engine, with hydraulic coupling or equivalent parts	1.00
	Diesel engine with high elasticity coupling (general angle of torsion more than 6°)	1.20
	Diesel engine with elasticity coupling (general angle of torsion 2° to 6°)	1.30
	Diesel engine, with other couplings	1.40

1.5.1.4 Where the ship using reduction gearing for main propulsion has an ice or PC N class notation, the nominal tangential force or the application factor is to be calculated according to the torque transmitted by reduction gearing in association with the ice or PC N class notation. See the relevant requirements in Chapter 14 of this PART or Chapter 13 of PART EIGHT of the Rules.

1.5.2 Load sharing factor K_γ

1.5.2.1 The load sharing factor K_γ accounts for the maldistribution of load in multiple path transmissions (dual tandem, epicyclic, double helix, etc.).

1.5.2.2 K_γ is defined as the ratio between the maximum load through an actual path and the evenly shared load. The factor mainly depends on accuracy and flexibility of the branches.

1.5.2.3 The load sharing factor K_γ is to be determined by measurements or by system analysis. Where a value determined in such a way cannot be supplied, the following values may be considered for epicyclic gears:

up to 3 planetary gears: K_γ =1.00;

4 planetary gears: K_γ =1.20;

5 planetary gears: K_γ =1.30;

6 planetary gears and over: K_γ =1.40;

other gear arrangements: K_γ = 1.00;

Bevels: K_γ = 1.00.

1.5.3 Internal dynamic factor K_V

1.5.3.1 The internal dynamic factor K_V accounts for internally generated dynamic loads due to vibrations of pinion and wheel against each other. K_V is defined as the ratio between the maximum load which dynamically acts on the tooth flanks and the maximum externally applied load ($F_t \cdot K_A \cdot K_\gamma$).

1.5.3.2 The factor K_V mainly depends on:

(1) transmission errors (depending on pitch and profile errors);

(2) masses of pinion and wheel;

(3) gear mesh stiffness variation as the gear teeth pass through the meshing cycle;

(4) transmitted load including application factor;

(5) pitch line velocity;

(6) dynamic unbalance of gears and shaft;
(7) shaft and bearing stiffness;
(8) damping characteristics of the gear system.

1.5.3.3 Where all the following conditions are satisfied, the internal dynamic factor K_V is to be calculated as follows:

(1) running velocity in the subcritical range, i.e.:

$$\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 10 \quad \text{m/s}$$

(2) spur gears ($\beta = 0°$) and helical gears with $\beta \leq 30°$;
(3) pinion with relatively low number of teeth, $z_1 < 50$;
(4) solid disc wheels or heavy steel gear rim.

This method may be applied to all types of gears if $\frac{v \times z_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 3$ m/s, as well as to helical gears where $\beta > 30°$.

For gears other than the above, reference is to be made to Method B outlined in the reference standard ISO 6336-1.

(1) For spur gears and for helical gears with overlap ratio $\varepsilon_\beta \geq 1$:

$$K_V = 1 + \left(\frac{K_1}{K_A \frac{F_t}{b}} + K_2 \right) \times \frac{V \times Z_1}{100} K_3 \sqrt{\frac{u^2}{1+u^2}}$$

If $K_A F_t/b$ is less than 100 N/mm, this value is assumed to be equal to 100 N/mm.

Numerical values for the factor K_1 are to be as specified in Table 1.5.3.3.

Values of K_1 **Table 1.5.3.3**

Accuracy grades①						
Gear type	3	4	5	6	7	8
spur gears	2.1	3.9	7.5	14.9	26.8	39.1
helical gears	1.9	3.5	6.7	13.3	23.9	34.8

① The accuracy grades are to be according to ISO 1328-1:2013. In case of mating gears with different accuracy grades, the grade corresponding to the lower accuracy is to be used.

For all accuracy grades, the factor K_2 is to be in accordance with the following:
for spur gears, K_2=0.0193;
for helical gears, K_2=0.0087.
Factor K_3 is to be in accordance with the following:

If $\frac{v \times z_1}{100}\sqrt{\frac{u^2}{1+u^2}} \leqslant 0.2$, then $K_3 = 2.0$;

If $\frac{v \times z_1}{100}\sqrt{\frac{u^2}{1+u^2}} > 0.2$, then $K_3 = 2.071 - 0.357\frac{v \times z_1}{100}\sqrt{\frac{u^2}{1+u^2}}$

(2) For helical gears with overlap ratio $\varepsilon_\beta < 1$, the value K_V is determined by linear interpolation between values determined for spur gears ($K_{V\alpha}$) and helical gears ($K_{V\beta}$) in accordance with:

$$K_V = K_{V\alpha} - \varepsilon_\beta (K_{V\alpha} - K_{V\beta})$$

where: $K_{v\alpha}$ is the K_v value for spur gears, in accordance with 1.5.3.3(1);
$K_{v\beta}$ is the K_v value for helical gears, in accordance with 1.5.3.3(1).

1.5.3.4 K_V of bevel gears is to be calculated according to 1.5.3.3, with z_1, V, F_t therein being substituted by Z_{v1}, V_{mt}, F_{mt} respectively.

1.5.4 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$

1.5.4.1 The face load distribution factors, K_{Hh} for contact stress and K_{Fo} for tooth root bending stress, account for the effects of non-uniform distribution of load across the face width.

$K_{H\beta}$ is defined as follows:

$$K_{H\beta} = \frac{\text{maximum load per unit facewidth}}{\text{mean load per unit facewidth}}$$

$K_{F\beta}$ is defined as follows:

$$K_{F\beta} = \frac{\text{maximum bending stress at tooth root per unit facewidth}}{\text{mean bending stress at tooth root per unit facewidth}}$$

1.5.4.2 The factors $K_{H\beta}$ and $K_{F\beta}$ mainly depend on:
(1) gear tooth manufacturing accuracy;
(2) errors in mounting due to bore errors;
(3) bearing clearances;
(4) wheel and pinion shaft alignment errors;
(5) elastic deflection of gear elements, shafts, bearings, housing and foundations which support the gear elements;
(6) thermal expansion and distortion due to operating temperature;
(7) compensating design elements(tooth crowning, end relief, etc.).
1.5.4.3 The face load distribution factors K_{Hh} and K_{Fa} are to be determined according to the Method C outlined in the reference standard ISO 6336-1. Alternative methods acceptable to CCS may be applied.
In case the hardest contact is at the end of the face width, $K_{F\beta}$ is defined as follows:

$$K_{F\beta} = (K_{H\beta})^N$$

where: $N = \frac{(b/h)^2}{1+(b/h)+(b/h)^2}$, where ($b/h$) is the ratio of tooth width and tooth depth, to be taken as the minimum value of b_1/h_1 and b_2/h_2. Only one helical face width is to be taken for herringbone gear b. When $b/h < 3$ the value $b/h = 3$ is to be used.
In case of gears where the ends of the face width are lightly loaded or unloaded (end relief or crowning): $K_{F\beta} = K_{H\beta}$.
1.5.4.4 Calculation of K_{Ha}, K_F for bevel gears
(1) $K_{H\beta}$ is to be calculated as follows:
For $b_e \geq 0.85b$:

$$K_{H\beta} = 1.5K_{H\beta-be}$$

For $b_e < 0.85b$:

$$K_{H\beta} = 1.5K_{H\beta\text{-}be}\frac{0.85b}{b_e}$$

where: $K_{H\beta-be}$ — assembling factor, see Table 1.5.4.4.

Assembling Factor $K_{H\beta\text{-}be}$ **Table 1.5.4.4**

Mounting conditions of pinion and wheel		
Both members straddle mounted	One member straddle mounted	Neither member straddle mounted
1.10	1.25	1.50

(2) $K_{F\beta}$ is to be calculated as follows:

$$K_{F\beta} = \frac{K_{H\beta}}{K_{F0}}$$

where: K_{F0} — curvature factor of tine length for bending strength, depending on helix angle and curvature in the direction of tine length, to be calculated as follows:

$$K_{F0} = 0.211\left(\frac{r_{c0}}{S_m}\right)^q + 0.789$$

$$q = \frac{0.279}{\lg(\sin\beta_m)}$$

where: r_{c0} — radius of tool, in mm;
S_m — middle cone distance, in mm;
β_m — helical angle at midpoint;
$K_{F0} = 1.15$, for $K_{F0} > 1.15$;
$K_{F0} = 1$, for $K_{F0} < 1$;
$K_{F0} = 1$, for straight or zero bevel gears.
1.5.5 Transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$
1.5.5.1 The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.
1.5.5.2 The factors $K_{H\alpha}$ and $K_{F\alpha}$ mainly depend on:
(1) total mesh stiffness;
(2) total tangential load, i.e. equivalent tangential load, including load produced by K_A, K_V, $K_{H\beta}$;
(3) base pitch error;

(4) tip relief;
(5) running-in allowance.

1.5.5.3 The transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$ of cylindrical gears are to be determined according to Method B outlined in the reference standard ISO 6336-1.

1.5.5.4 K_{Ha} of bevel gears is to be determined as follows:

(1) Contact ratio $\varepsilon_{vr} \leq 2$ for equivalent cylindrical gear

$$K_{H\alpha} = \frac{\varepsilon_{vr}}{2}\left[0.9 + \frac{0.4c_r(f_{pt} - y_\alpha)}{F_{mtH}/b}\right]$$

$$F_{mtH} = F_{mt}K_A K_\gamma K_V K_{H\beta}$$

where: c_r — mesh stiffness, see 1.5.7 of this Appendix;
f_{pt} — pitch deviation of pinion or wheel, whichever is the greater;
y_a — running-in allowance, see 1.5.6 of this Appendix;
F_{mt} — nominal tangential load, see 1.4 of this Appendix;
For K_A, K_γ, K_V and $K_{H\beta}$, see 1.5 of this Appendix.

(2) Contact ratio $\varepsilon_{vr} > 2$ for equivalent cylindrical gear

$$K_{H\alpha} = 0.9 + \frac{0.4c_r(f_{pt} - y_\alpha)}{F_{mtH}/b}\sqrt{\frac{2(\varepsilon_{vr} - 1)}{\varepsilon_{vr}}}$$

(3) $K_{Ha} = 1$, for $K_{Ha} < 1$;

$K_{H\alpha} = \dfrac{\varepsilon_{vr}}{\varepsilon_{va}Z_{LS}^2}$, for $K_{H\alpha} > \dfrac{\varepsilon_{vr}}{\varepsilon_{va}Z_{LS}^2}$, where Z_{LS} is as given in 2.7 of this Appendix.

1.5.5.5 K_{Fa} of bevel gears is to be determined as follows:

$$K_{Fa} = K_{Ha}$$

$K_{Fa} = 1$, for $K_{Fa} < 1$;

$K_{F\alpha} = \dfrac{\varepsilon_{vr}}{\varepsilon_{va}Y_\varepsilon}$, for $K_{F\alpha} > \dfrac{\varepsilon_{vr}}{\varepsilon_{va}Y_\varepsilon}$ where Y_ε is as given in 3.6 of this Appendix.

1.5.6 Running-in allowance y_a

1.5.6.1 The running-in allowance y_a is the amount due to running-in by which the mesh alignment error is reduced from the start of the operation. In lack of direct experience, the value may be calculated according to Table 1.5.6.1.

Running-in Allowance **Table 1.5.6.1**

Gear material	Running-in allowance y_a	Limitation	
		Tangential speed at reference diameter (m/s)	Maximum running-in allowance (μm)
Quenched and tempered steels	$y_\alpha = \dfrac{160f_{pt}}{\sigma_{H\lim}}$	$v_{mt} \leq 5$	not limited
		$5 < v_{mt} \leq 10$	$y_a \leq 12800/\sigma_{H\lim}$
		$v_{mt} > 10$	$y_a \leq 6400/\sigma_{H\lim}$
Hardened steel and nitrided steels	$y_\alpha = 0.075f_{pt}$	Unlimited	$y_a \leq 3$
Two gears of different materials	$y_\alpha = \dfrac{y_{\alpha 1} + y_{\alpha 2}}{2}$	y_{a1} to be taken for pinion material; y_{a2} to be taken for wheel material	

1.5.7 Mesh stiffness c_γ

1.5.7.1 The mesh stiffness is the load to be applied on the line of contact to induce a deflection of 1 μm at 1 mm face width for one or more pairs of simultaneously meshed precision gears.

1.5.7.2 The mesh stiffness of bevel gears may be determined as follows:

$$c_\gamma = c_{\gamma 0}c_F c_b$$

where: $c_{\gamma 0}$ — mesh stiffness in the mean condition, taken as 20 N/mm·μm if no direct experience being available;
c_F and c_b — modification coefficients:
$c_F = 1$, for $F_{mt}K_A/b_e \geq 100$ N/mm;
$c_F = F_{mt}K_A/100b_e$, for $F_{mt}K_A/b_e < 100$ N/mm;
$c_b = 1$, for $b_e/b \geq 0.85$;
$c_b = b_e/0.85b$, for $b_e/b < 0.85$.

2 Surface Durability

2.1 Calculation requirements

2.1.1 The criterion for surface durability is based on the Hertz pressure on the operating pitch point or at the inner point of single pair contact. The surface contact stress σ_H must be equal to or less than the permissible contact stress σ_{HP}.

2.1.2 Surface contact stress and permissible contact stress of pinion and wheel are to be calculated respectively.

2.2 Surface contact stress σ_H

2.2.1 Surface contact stress σ_H is to be determined as follows:

$$\sigma_H = \sigma_{HO}\sqrt{K_A K_\gamma K_V K_{H\alpha} K_{H\beta}} \le \sigma_{HP}$$

where: σ_{HO} = basic value of contact stress for pinion and wheel:

(1) Cylindrical gears:

for pinion:

$$\sigma_{HO} = Z_B Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t}{d_1 b} \times \frac{u+1}{u}} \quad \text{N/mm}^2$$

for wheel:

$$\sigma_{HO} = Z_D Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t}{d_1 b} \times \frac{u+1}{u}} \quad \text{N/mm}^2$$

(2) Bevel gears:

$$\sigma_{HO} = Z_{M\text{-}B} Z_H Z_E Z_{LS} Z_\beta Z_K \sqrt{\frac{F_{mt}}{d_{v1} l_{bm}} \times \frac{u_v+1}{u_v}} \quad \text{N/mm}^2$$

For the shaft angle $\Sigma = \delta_1 + \delta_2 = 90°$, the following applies:

$$\sigma_{HO} = Z_{M-B} Z_H Z_E Z_{LS} Z_\beta Z_K \sqrt{\frac{F_{mt}}{d_{m1} l_{bm}} \times \frac{\sqrt{u_v^2+1}}{u_v}} \quad \text{N/mm}^2$$

where: Z_B — single pair tooth contact factor for pinion , see 2.3 of this Appendix;

Z_D — single pair tooth contact factor for wheel, see 2.3 of this Appendix;

$Z_{M\text{-}B}$ — mid-zone factor, see 2.3 of this Appendix;

Z_H — zone factor, see 2.4 of this Appendix;

Z_E — elasticity factor, see 2.5 of this Appendix;

Z_ε — contact ratio factor, see 2.6 of this Appendix;

Z_{LS} — load sharing factor, see 2.7 of this Appendix;

Z_K — bevel gear factor (flank), see 2.8 of this Appendix;

Z_β — helix angle factor, see 2.9 of this Appendix;

l_{bm} — length of middle line of contact, see 3.7 of this Appendix;

for K_A, K_V, $K_{H\alpha}$ and $K_{H\beta}$, see 1.5 of this Appendix.

2.2.2 Permissible contact stress σ_{HP} is to be determined as follows:

$$\sigma_{HP} = (\sigma_{H\lim} / S_H) Z_N Z_L Z_V Z_R Z_W Z_X \quad \text{N/mm}^2$$

where: $\sigma_{H\lim}$ — endurance limit for contact stress, see 2.10 of this Appendix;

Z_N — life factor for contact stress, see 2.11 of this Appendix;

Z_L, Z_V, Z_R —lubrication factor, velocity factor and roughness factor respectively, see 2.12 of this Appendix;

Z_W — hardness ratio factor, see 2.13 of this Appendix;

Z_X — size factor for contact stress, see 2.14 of this Appendix;

S_H — safety factor for contact stress, see 2.15 of this Appendix.

2.3 Single pair tooth contact factors Z_B, Z_D and mid-zone factor $Z_{M\text{-}B}$

2.3.1 The single pair tooth contact factors, Z_B for pinion and Z_D for wheel, account for the influence of the tooth flank curvature on contact stresses at the inner point of single pair contact in relation to Z_H.

The mid-zone factor $Z_{M\text{-}B}$ is used to convert the contact stress at the pitch point to the contact stress at the midpoint M of loading, see Figure 2.3.1.

2.3.2 The single pair tooth contact factors, Z_B for pinion and Z_D for wheel, are to be determined as follows:

2.3.2.1 For spur gears, $\varepsilon_\beta = 0$

(1) $Z_B = M_1$ or 1, whichever is greater:

$$M_1 = \frac{\tan \alpha_{tw}}{\sqrt{\left[\sqrt{(\frac{d_{a1}}{d_{b1}})^2 - 1} - (\frac{2\pi}{z_1})\right]\left[\sqrt{(\frac{d_{a2}}{d_{b2}})^2 - 1} - (\varepsilon_\alpha - 1)(\frac{2\pi}{z_2})\right]}}$$

(2) $Z_D = M_2$ or 1, whichever is greater:

$$M_2 = \frac{\tan \alpha_{tw}}{\sqrt{\left[\sqrt{(\frac{d_{a2}}{d_{b2}})^2 - 1} - (\frac{2\pi}{z_2})\right]\left[\sqrt{(\frac{d_{a1}}{d_{b1}})^2 - 1} - (\varepsilon_\alpha - 1)(\frac{2\pi}{z_1})\right]}}$$

2.3.2.2 For helical gears,

(1) if $\varepsilon_\beta \geq 1$, $Z_B = Z_D = 1$;

(2) if $\varepsilon_\beta < 1$, to be calculated by interpolation:

$Z_B = M_1 - \varepsilon_\beta (M_1 - 1)$, and $Z_B \geq 1$;

$Z_D = M_2 - \varepsilon_\beta (M_2 - 1)$, and $Z_D \geq 1$.

2.3.2.3 For internal gears, $Z_D = 1$.

2.3.3 Mid-zone factor $Z_{M\text{-}B}$

The factor $Z_{M\text{-}B}$ may be calculated as follows:

$$Z_{M\text{-}B} = \frac{\tan \alpha_{vt}}{\sqrt{\left[\sqrt{(\frac{d_{va1}}{d_{vb1}})^2 - 1} - F_1 \frac{\pi}{z_{v1}}\right]\left[\sqrt{(\frac{d_{va2}}{d_{vb2}})^2 - 1} - F_2 \frac{\pi}{z_{v2}}\right]}}$$

where: F_1, F_2 — auxiliary factors, see Table 2.3.3.

Auxiliary Factors for Determination of Mid-Zone Factor **Table 2.3.3**

Overlap ratio of equivalent cylindrical gear	F_1	F_2
$\varepsilon_{v\beta} = 0$	2	$2(\varepsilon_{v\alpha} - 1)$
$0 < \varepsilon_{v\beta} \leq 1$	$2 + (\varepsilon_{v\alpha} - 2)\varepsilon_{v\beta}$	$2\varepsilon_{v\alpha} - 2 + (2 - \varepsilon_{v\alpha})\varepsilon_{v\beta}$
$\varepsilon_{v\beta} > 1$	$\varepsilon_{v\alpha}$	$\varepsilon_{v\alpha}$

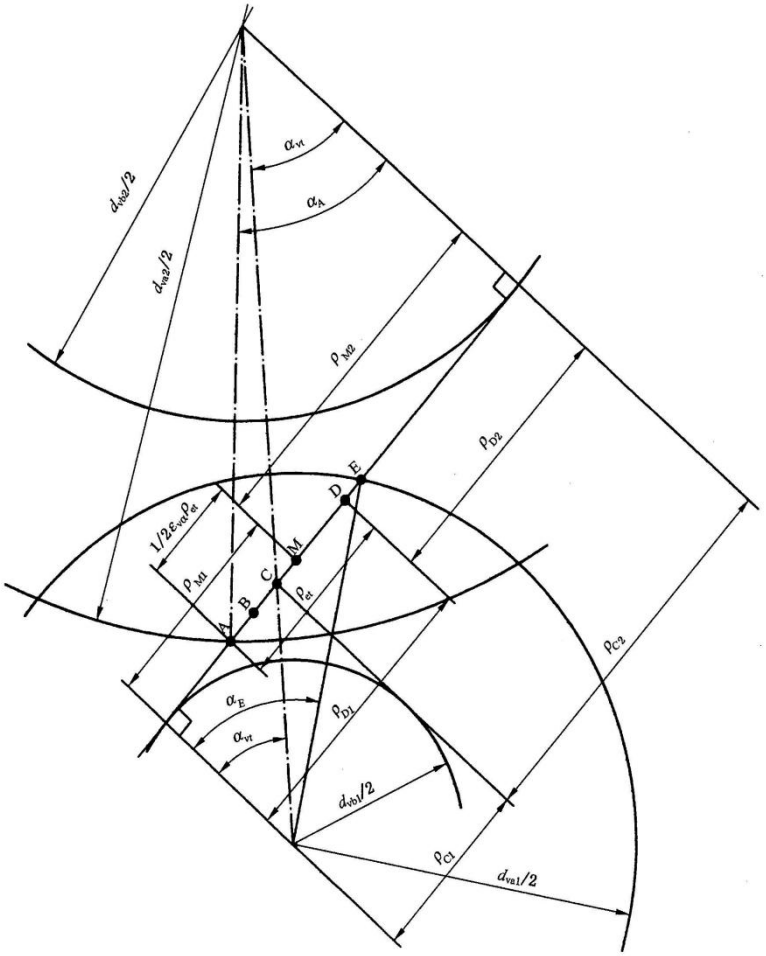


Figure 2.3.1 Radius of Curvature at Midpoint M and Single-Pair Mesh Point B of the Pinion, for Determination of Mid-Zone Factor

2.4 Zone factor Z_H

2.4.1 The zone factor, Z_H, accounts for the influence on the Hertzian pressure of tooth flank curvature at pitch point and transforms the tangential load at the reference cylinder to the normal load at the pitch cylinder.

2.4.2 The zone factor Z_H is to be calculated as follows:

(1) For cylindrical gears:

$$Z_H = \sqrt{\frac{2\cos\beta_b}{\cos^2\alpha_t \tan\alpha_{tw}}}$$

(2) For bevel gears:

$$Z_H = 2\sqrt{\frac{\cos\beta_{vb}}{\sin(2\alpha_{vt})}}$$

Some normal common pressure angles of bevel gears may be obtained from Figure 2.4.2.

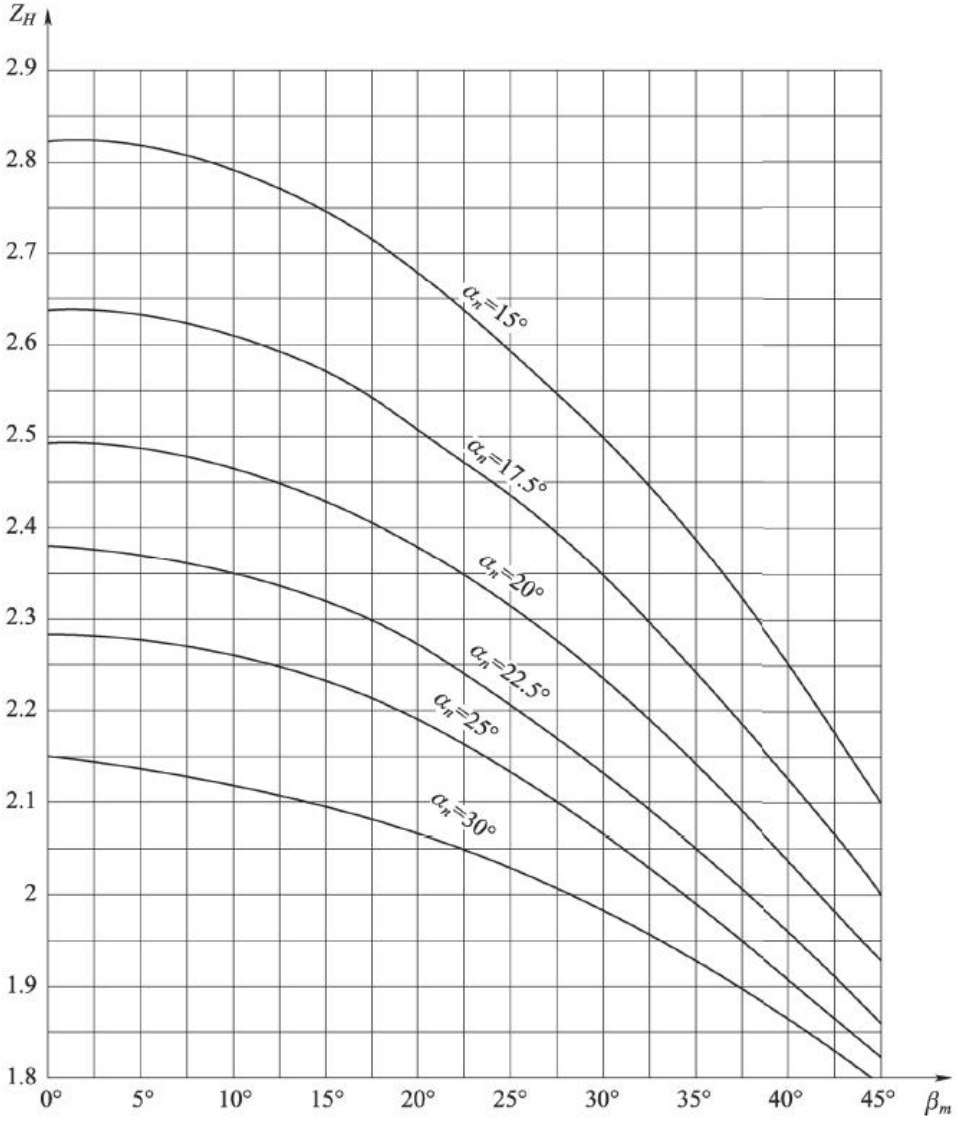


Figure 2.4.2 Zone Factor Z_H for X-Zero Bevel Gears

2.5 Elasticity factor Z_E

2.5.1 The elasticity factor, Z_E, accounts for the influence of the material properties E (modulus of elasticity) and v (Poisson's ratio) on the contact stress.

2.5.2 The factor Z_E is to be calculated as follows:

$$Z_E = \sqrt{\frac{1}{\pi\left(\frac{1-v_1^2}{E_1} + \frac{1-v_2^2}{E_2}\right)}}$$

For $E_1 = E_2 = E$ and $v_1 = v_2 = v$:

$$Z_E = \sqrt{\frac{E}{2\pi(1-v^2)}}$$

For $v = 0.3$ in respect to steel and hard aluminum alloys:

$$Z_E = \sqrt{0.175E}$$

Where the modulus of elasticity of the material of a pair is E_1 or E_2, the following applies:

$$E = \frac{2E_1E_2}{E_1 + E_2}$$

For steel gears (E = 206000 N/mm^2, v = 0.3):

$$Z_E = 189.8\ \sqrt{\text{N/mm}^2}$$

2.5.3 In other cases, reference is to be made to ISO 6336-2 standard.

2.6 Contact ratio factor Z_ε

2.6.1 The contact ratio factor, Z_ε, accounts for the influence of the transverse contact ratio and the overlap ratio on the specific surface load of gears.

2.6.2 The contact ratio factor Z_ε is to be calculated as follows:

Spur gears: $$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}}$$

Helical gears: $$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}(1-\varepsilon_\beta)+\frac{\varepsilon_\beta}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta < 1$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta \geq 1$$

2.7 Bevel gear load sharing factor Z_{LS}

2.7.1 The load sharing factor, Z_{LS}, accounts for the load sharing between two or more pairs of teeth in contact.

2.7.2 The load sharing factor, Z_{LS}, may be calculated as follows:

(1) $Z_{LS} = 1$ for $\varepsilon_{vr} \leq 2$ or $\varepsilon_{v\beta} < 1$.

(2) For $\varepsilon_{vr} > 2$ and $\varepsilon_{v\beta} > 1$, Z_{LS} is to be calculated as follows:

$$Z_{LS} = \left\{1+2\left[1-\left(\frac{2}{\varepsilon_{vr}}\right)^{1.5}\right]\sqrt{1-\frac{4}{\varepsilon^2_{vr}}}\right\}^{-0.5}$$

2.7.3 Where Z_{LS} obtained according to 2.7.2(2) is less than 0.837, Z_{LS} is to be taken as 0.837.

2.8 Bevel gear factor Z_K

2.8.1 The bevel gear factor Z_K is an empirical factor and accounts for the difference between bevel and cylindrical loading and adjusts the contact stresses so that the same permissible stresses may apply.

2.8.2 $Z_K = 0.8$ may be taken in lack of detailed data.

2.9 Helix angle factor Z_β

2.9.1 The helix angle factor, Z_β, accounts for the influence of helix angle on surface durability, allowing for such variables as the distribution of load along the lines of contact.

2.9.2 Z_β is to be calculated as follows:

(1) Cylindrical gears:

$$Z_\beta = \sqrt{\frac{1}{\cos\beta}}$$

(2) Bevel gears:

$$Z_\beta = \sqrt{\frac{1}{\cos\beta_m}}$$

2.10 Endurance limit for contact stress σ_{Hlim}

2.10.1 For a given material, σ_{Hlim} is the limit of repeated contact stress which can be permanently endured.

2.10.2 The value of σ_{Hlim} may be regarded as the level of contact stress which the material will endure without pitting for at least 5×10^7 load cycles. For this purpose, pitting is defined by:

(1) for not surface hardened gears: pitted area > 2% of total active flank area;

(2) for surface hardened gears: pitted area > 0.5% of total active flank area, or > 4% of one particular tooth flank area.

2.10.3 The σ_{Hlim} values are to correspond to a failure probability of 1% or less.

2.10.4 The endurance limit mainly depends on:

(1) material composition, cleanliness and defects;

(2) mechanical properties;

(3) residual stresses;

(4) heat treatment, depth of hardened zone, hardness gradient;

(5) material structure (forged, rolled bar, cast).

2.10.5 The endurance limit for contact stress $\sigma_{H\lim}$ is to be determined, in general, making reference to values indicated in ISO 6336-5 standard, for material quality MQ.

2.11 Life factor Z_N

2.11.1 The life factor Z_N accounts for the higher permissible contact stress in case a limited life (number of cycles) is required.

2.11.2 The factor Z_N mainly depends on:

(1) material and heat treatment;
(2) number N_L of load cycles (service life);
(3) lubrication;
(4) failure criterion;
(5) required operational smoothness;
(6) pitch line velocity;
(7) cleanliness of material;
(8) plasticity and fracture toughness of material;
(9) residual stresses;
(10) influence factors (Z_R, Z_V, Z_L, Z_W, Z_X).

2.11.3 The life factor Z_N is to be determined according to Method B outlined in the reference standard ISO 6336-2.

2.12 Influence factors of lubrication film on contact stress, Z_L, Z_V and Z_R

2.12.1 The lubricant factor, Z_L, accounts for the influence of the type of lubricant and its viscosity. The velocity factor, Z_V, accounts for the influence of the pitch line velocity. The roughness factor, Z_R, accounts for the influence of the surface roughness on the surface endurance capacity. The factors may be determined for the softer material where gear pairs are of different hardness.

2.12.2 The factors mainly depend on:

(1) viscosity of lubricant in the contact zone;
(2) the sum of the instantaneous velocities of the tooth surfaces;
(3) load;
(4) relative radius of curvature at the pitch point;
(5) surface roughness of teeth flanks;
(6) hardness of pinion and gear.

2.12.3 The lubricant factor Z_L is to be calculated as follows:

$$Z_L = C_{ZL} + \frac{4(1.0 - C_{ZL})}{(1.2 + 134/\nu_{40})^2}$$

where: C_{ZL} — factor:

for 850 N/mm² ≤ σ_{Hlim} ≤ 1,200 N/mm²,

$$C_{ZL} = 0.83 + 0.08\frac{\sigma_{H\lim} - 850}{350}$$

if σ_{Hlim} < 850 N/mm², take C_{ZL} = 0.83;
if σ_{Hlim} >1,200 N/mm², take C_{ZL} = 0.91;

ν_{40} — nominal kinematic viscosity of the oil at 40℃.

2.12.4 The velocity factor Z_V is to be calculated as follows:

$$Z_V = C_{ZV} + \frac{2(1.0 - C_{ZV})}{\sqrt{0.8 + 32/V}}$$

where: C_{ZV} — factor:

for 850 N/mm² ≤ σ_{Hlim} ≤ 1200 N/mm²,

$$C_{ZV} = C_{ZL} + 0.02$$

if σ_{Hlim} <850 N/mm², take C_{ZV} = 0.85;
if σ_{Hlim} >1,200 N/mm², take C_{ZV} = 0.93.

2.12.5 The roughness factor Z_R is to be calculated as follows:

$$Z_R = \left(\frac{3}{R_{Z10}}\right)^{C_{ZR}}$$

where: R_{Z10} — relative mean roughness (curvature radius relative to pitch point ρ_{red} = 10 mm):

$$R_{Z10} = \frac{R_{Z1} + R_{Z2}}{2} \sqrt[3]{\frac{10}{\rho_{red}}}$$

R_{Z1} and R_{Z2} —mean peak-to-valley roughness determined respectively for the pinion and the wheel (refer to ISO 6336-2 standard);

ρ_{red} — relative radius of curvature, to be determined from the following equation:

(1) for cylindrical gears:

$$\rho_{red} = \frac{\rho_1 \rho_2}{\rho_1 + \rho_2}$$

(2) for bevel gears:

$$\rho_{\text{red}} = \frac{\rho_{v1} \rho_{v2}}{\rho_{v1} + \rho_{v2}}$$

where: $\rho_{1,2} = 0.5 \times d_{b1,2} \times \tan \alpha_{tw}$;

$\rho_{v1,2} = 0.5 \times d_{vb1,2} \times \tan \alpha_{tw}$.

If the roughness stated is an arithmetic mean roughness, i.e. R_a value (= *CLA* value) (= *AA* value) the following approximate relationship can be applied:

$$R_a = CLA = AA = R_z/6$$

C_{ZR} — factor:

for 850 N/mm² ≤ σ_{Hlim} ≤ 1,200 N/mm², $C_{ZR} = 0.32 - 0.0002\sigma_{Hlim}$;

if σ_{Hlim} < 850 N/mm², take C_{ZR} =0.15;

if σ_{Hlim} > 1,200 N/mm², take C_{ZR} =0.08.

2.13 Hardness ratio factor Z_W

2.13.1 The hardness ratio factor, Z_W, accounts for the increase of surface durability of a soft steel gear meshing with a significantly harder gear (mean peak-to-valley roughness $R_Z \leq 6$ μm or rough arithmetic mean value $R_a \leq 1$ μm) with a smooth surface in the following cases.

(1) Surface-hardened pinion with through-hardened wheel

If $HB < 130$, $Z_W = 1.2 \times (\frac{3}{R_{zH}})^{0.15}$;

If $130 \leq HB \leq 470$, $Z_W = (1.2 - \frac{HB - 130}{1700}) \times (\frac{3}{R_{zH}})^{0.15}$;

If $HB > 470$, $Z_W = (\frac{3}{R_{zH}})^{0.15}$.

where: *HB* = Brinell hardness of the tooth flanks of the softer gear of the pair;

R_{zH} — equivalent roughness, μm

$$R_{zH} = \frac{R_{z1} \times (\frac{10}{\rho_{red}})^{0.33} \times (\frac{R_{z1}}{R_{z2}})^{0.66}}{(v \times v_{40} / 1500)^{0.33}}$$

ρ_{red}— relative radius of curvature.

(2) Through-hardened pinion and wheel

When the pinion is substantially harder than the wheel, the work hardening effect increases the load capacity of the wheel flanks. Z_W applies to the wheel only, not to the pinion.

If $HB_1/HB_2 < 1.2$, $Z_W = 1$

If $1.2 \leq HB_1/HB_2 \leq 1.7$, $Z_W = 1 + \left(0.00898 \frac{HB_1}{HB_2} - 0.00829 \right) \times (u - 1)$

If $HB_1/HB_2 > 1.7$, $Z_W = 1 + 0.00698 \cdot (u - 1)$

If gear ratio $u > 20$ then the value $u = 20$ is to be used.

In any case, if calculated $Z_W < 1$ then the value $Z_W = 1.0$ is to be used.

2.14 Size factor of contact stress, Z_X

2.14.1 The size factor, Z_X, accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

2.14.2 The factor mainly depends on:

(1) material and heat treatment;

(2) tooth and gear dimensions;
(3) ratio of case depth to tooth size;
(4) ratio of case depth to equivalent radius of curvature.

2.14.3 For through-hardened gears and for surface-hardened gears with adequate case depth relative to tooth size and radius of relative curvature, Z_x =1. When the case depth is relatively shallow, then a smaller value of Z_X is to be chosen.

2.15 Safety factor for contact stress, S_H

2.15.1 The safety factor for contact stress, S_H, can be assumed by taking into account the type of application. The safety factor for contact stress S_H is to satisfy the following guidance values:

Main propulsion gears: $1.20 \le S_H \le 1.40$;

Auxiliary gears: $1.15 \le S_H \le 1.20$.

For gearing of duplicated independent propulsion or auxiliary machinery, a reduced value can be assumed.

3 Tooth Root Bending Strength

3.1 Calculation requirements

3.1.1 The criterion for tooth root bending strength is the permissible limit of local tensile strength in the root fillet. The root stress σ_F is to be equal to or less than the permissible root stress σ_{FP}.

3.1.2 The root stress σ_F and the permissible root stress σ_{FP} are to be calculated separately for the pinion and the wheel.

3.1.3 The following formulae and definitions apply to gears having rim thickness greater than 3.5 m_n.

3.1.4 The result of rating calculations made by following this method are acceptable for normal pressure angles up to 25° and reference helix angles up to 30°. For larger pressure angles and large helix angles, the calculated results are to be confirmed by experience as by ISO 6336-3 Method A and the relevant standard.

3.2 Tooth root bending stress for pinion and wheel σ_F

3.2.1 Tooth root bending stress for pinion and wheel σ_F is to be calculated as follows:

(1) For cylindrical gears:

$$\sigma_F = \frac{F_t}{bm_n} Y_F Y_S Y_\beta Y_B Y_{DT} K_A K_\gamma K_v K_{F\alpha} K_{F\beta} \le \sigma_{FP}$$

(2) For bevel gears:

$$\sigma_F = \frac{F_{mt}}{bm_{mn}} Y_{Fa} Y_{Sa} Y_\varepsilon Y_K Y_{LS} K_A K_\gamma K_v K_{F\beta} K_{F\alpha} \le \sigma_{FP}$$

where: Y_F, Y_{Fa} — tooth form factor, see 3.3 of this Appendix;
Y_S, Y_{Sa} — stress correction factor, see 3.4 of this Appendix;
Y_β — helix angle factor, see 3.5 of this Appendix;
Y_ε — contact ratio factor, see 3.6 of this Appendix;
Y_K — bevel gear factor, see 3.7 of this Appendix;
Y_{LS} — load sharing factor, see 3.8 of this Appendix;
Y_B — rim thickness factor, see 3.15 of this Appendix;
Y_{DT} — deep tooth factor, see 3.16 of this Appendix;
for F_t, K_A, K_γ, K_V, K_{Fa} and $K_{F\beta}$, see 1.4 and 1.5 of this Appendix;
for b and m_n, see 1.2 of this Appendix.

3.2.2 Permissible tooth root bending stress for pinion and wheel, σ_{FP}, is to be calculated as follows:

$$\sigma_{FP} = \frac{\sigma_{FE} \times Y_N \times Y_d}{S_F} Y_{\delta relT} \times Y_{RrelT} \times Y_X \quad \text{N/mm}^2$$

where: σ_{FE} — bending endurance limit, see 3.9 of this Appendix;
Y_d — design factor, see 3.10 of this Appendix;
Y_N — life factor, see 3.11 of this Appendix;
$Y_{\delta relT}$ — relative notch sensitivity factor, see 3.12 of this Appendix;
Y_{RrelT} — relative surface factor, see 3.13 of this Appendix;
Y_X — size factor of bending stress, see 3.14 of this Appendix;
S_F — safety factor for tooth root bending stress, see 3.17 of this Appendix.

3.3 Tooth form factors Y_F, Y_{Fa}

3.3.1 The tooth form factors, Y_F and Y_{Fa}, represent the influence on nominal bending stress of the tooth form with load applied at the outer point of single pair tooth contact.

3.3.2 Y_F and Y_{Fa} are to be determined separately for the pinion and the wheel. In the case of helical gears, the form factors for gearing are to be determined in the normal section, i.e. for the virtual spur gear with virtual number of teeth z_n.

3.3.3 Tooth form factor of cylindrical gears, Y_F

For the pinion and the wheel, the tooth form factor is to be calculated as follows:

$$Y_F = \frac{6\frac{h_F}{m_n}\cos\alpha_{Fen}}{(\frac{S_{Fn}}{m_n})^2\cos\alpha_n}$$

where: h_F — bending moment arm for tooth root bending stress for application of load at the outer point of single tooth pair contact, in mm;

S_{Fn} — tooth root normal chord in the critical section, in mm;

α_{Fen} — pressure angle at the outer point of single tooth pair contact in the normal section, in º.

h_F, α_{Fen} and S_{Fn} are shown in Figure 3.3.3.

For the calculation of h_F, α_{Fen} and S_{Fn}, the procedure outlined in the reference standard ISO 6336-3 (Method B) is to be used.

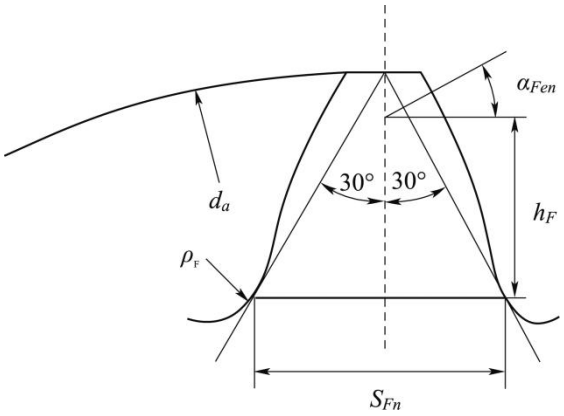


Figure 3.3.3 Dimensions of h_F, S_{Fn} and α_{Fen} for External Gear

3.3.4 Tooth form factor for bevel gears, Y_{Fa}

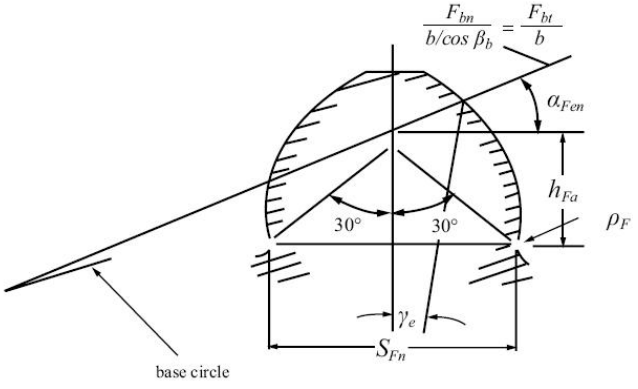
3.3.4.1 The tooth form factor Y_{Fa} represents the influence on nominal bending stress of the tooth form with load applied at the tooth tip. In calculation by this method, the section at 30° tangent point of the tooth root transition curve beyond the normal tooth profile of the equivalent cylindrical gear is the critical section.

3.3.4.2 The tooth form factor is to be determined separately for the pinion and the wheel. Depending on different manufacturing methods, specific equations are respectively given in 3.3.4.4 and 3.3.4.5, with relevant parameters being defined in Figure 3.3.4.

3.3.4.3 The tooth form factor of generated gears is also to comply with the following:

(1) the contact point of the 30° tangent lies on the fillet curve generated by cutter tip radius;

(2) the cutter must have a tip fillet radius ($\rho_{a0} \neq 0$).



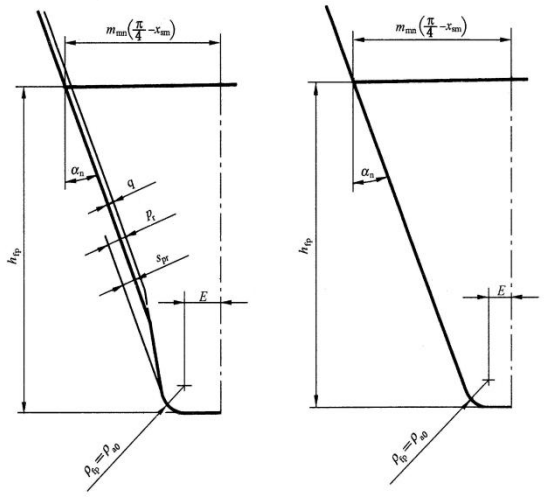


Figure 3.3.4 Factors Influencing Tooth Form of Bevel Gears

3.3.4.4 The tooth form factor of generated gears may be calculated as follows:

(1) Tooth form factor Y_{Fa}:

$$Y_{Fa}=\frac{6(\frac{h_{Fa}}{m_{mn}})\cos\alpha_{Fan}}{(\frac{S_{Fn}}{m_{mn}})^2\cos\alpha_n}$$

(2) For calculation of tooth root chord S_{Fn} in the critical section and bending moment arm h_{Fa}, the auxiliary values E, G, H and θ are first to be determined:

$$E=(\frac{\pi}{4}-x_{sm})m_{mn}-h_{ao}\tan\alpha_n-\frac{\rho_{ao}(1-\sin\alpha_n)-s_{pr}}{\cos\alpha_n}$$

$$G=\frac{\rho_{ao}}{m_{mn}}-\frac{h_{ao}}{m_{mn}}+x_{hm}$$

$$H=\frac{2}{z_{vn}}(\frac{\pi}{2}-\frac{E}{m_{mn}})-\frac{\pi}{3}$$

$$\theta=\frac{2G}{z_{vn}}\tan\theta-H$$

It is recommended to take the initial value $\theta=\pi/6$ to obtain θ by iterative method.

(3) Tooth root chord S_{Fn} in the critical section:

$$\frac{S_{Fn}}{m_{mn}}=Z_{vn}\sin(\frac{\pi}{3}-\theta)+\sqrt{3}(\frac{G}{\cos\theta}-\frac{\rho_{ao}}{m_{mn}})$$

(4) Tooth root fillet radius ρ_F in the critical section:

$$\frac{\rho_F}{m_{mn}}=\frac{\rho_{ao}}{m_{mn}}+\frac{2G^2}{\cos\theta(z_{vn}\cos^2\theta-2G)}$$

(5) Bending moment arm h_{Fa}:

$$\alpha_{an}=\arccos(d_{vbn}/d_{van})$$

$$\gamma_a=\frac{1}{z_{vn}}[\frac{\pi}{2}+2(x_{hm}\tan\alpha_n+x_{sm})]+inv\alpha_n-inv\alpha_{an}$$

$$\alpha_{Fan}=\alpha_{an}-\gamma_a$$

$$\frac{h_{Fa}}{m_{mn}}=\frac{1}{2}\left[(\cos\gamma_a-\sin\gamma_a\tan\alpha_{Fan})\frac{d_{van}}{m_{mn}}-z_{vn}\cos(\frac{\pi}{3}-\theta)-\frac{G}{\cos\theta}+\frac{\rho_{ao}}{m_{mn}}\right]$$

For gears having a basic rack profile of $\alpha_n=20°$, $h_{a0}/m_{mn}=1.25$, $\rho_{a0}/m_{mn}=0$ and $x_{sm}=0$, the tooth form factor may be obtained from Figure 3.3.4.4.

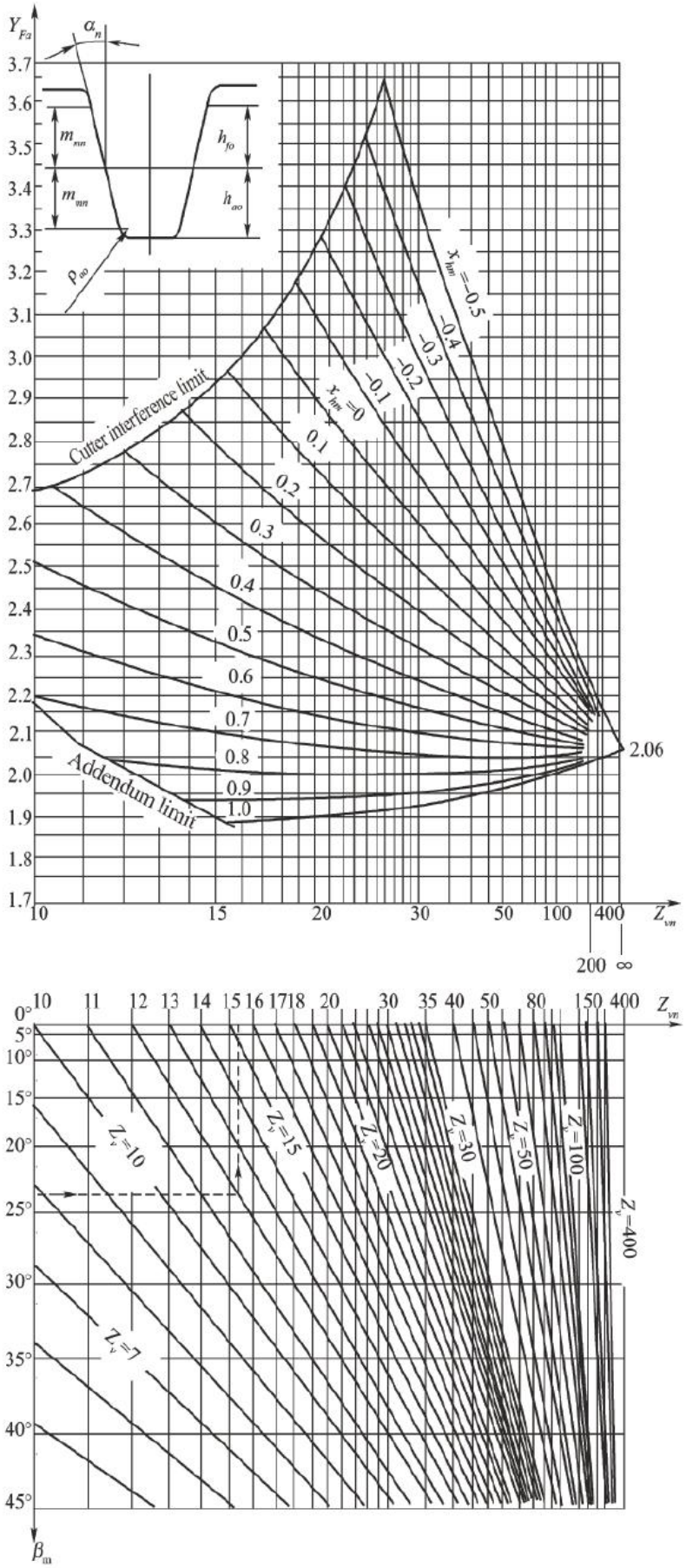


Figure 3.3.4.4 Tooth Form Factor of Generated Gears

3.3.4.5 Tooth form factor Y_{Fa} of form cutting

The tooth form factor of form cutting may be calculated as follows:

(1) Tooth root chord in the critical section

$$s_{Fn2} = \pi m_{mn} - 2E - 2\rho_{a02}\cos 30^{o}$$

where: E is to be calculated according to 3.3.4.4(2).

(2) Fillet radius at contact point of 30° tangent

$$\rho_{F2} = \rho_{a02}$$

(3) Bending moment arm

$$h_{Fa2} = h_{a02} - \frac{\rho_{a02}}{2} + m_{mn} - (\frac{\pi}{4} + x_{sx2} - \tan a_n) m_{mn} \tan a_n$$

(4) The tooth form factor is to be calculated as follows:

$$Y_{Fa} = \frac{6\frac{h_{Fa2}}{m_{mn}}}{(\frac{S_{Fn2}}{m_{mn}})^2}$$

3.4 Stress correction factors Y_S, Y_{Sa}

3.4.1 The stress correction factors are used to convert the nominal bending stress to the local tooth root stress, taking into account the effects of stress concentration at the tooth root transition curve and stresses other than bending stresses on the root stress.

3.4.2 The factors apply to the load application at the outer point of single tooth pair contact and are to be determined separately for the pinion and for the wheel.

3.4.3 Y_S value is to be determined with the following equation (having range of validity: $1 \le q_s < 8$):

(1) Stress correction factor Y_S of cylindrical gears:

$$Y_S = (1.2 + 0.13L) q_s^{(\frac{1}{1.21+2.3/L})}$$

(2) Stress correction factor Y_{Sa} of bevel gears:

$$Y_{Sa} = (1.2 + 0.13L_a) q_s^{(\frac{1}{1.21+2.3/L_a})}$$

where : q_s — notch parameter, $q_s = \frac{S_{Fn}}{2\rho_F}$

$$L = \frac{S_{Fn}}{h_F}$$

$$L_a = \frac{S_{Fn}}{h_{Fa}}$$

ρ_F = root fillet radius in the critical section, mm. For the calculation of ρ_F the procedure outlined in the reference standard ISO 6336-3 is to be used.

For bevel gears having the basic rack profile of the tooth with $\alpha_n = 20^{o}, h_{a0}/m_{mn} = 1.25, \rho_{a0}/m_{mn} = 0$ and x_{sm}= 0, the stress correction factors may be obtained from Figure 3.4.3.

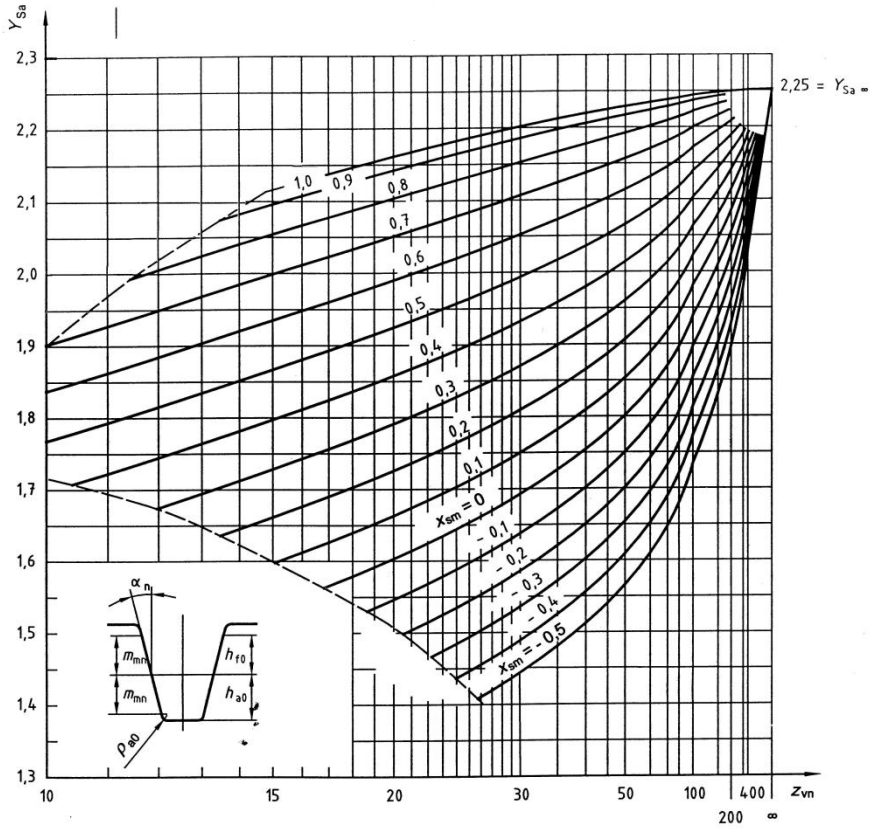


Figure 3.4.3 Stress Correction Factors for Tooth Form Factor of Generated Gear with Load Applied at Tooth Tip

3.5 Helix angle factor Y_β

3.5.1 The helix angle factor, Y_β, covers the effects of an oblique line of contact caused by the helix angle of cylindrical gears on the root stress.

3.5.2 The helix angle factor, Y_β is to be calculated as follows:

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120}$$

where: β — reference helix angle in degrees, 30° is substituted for $\beta > 30°$;

ε_β — overlap ratio, the value 1.0 is substituted for ε_β when $\varepsilon_\beta > 1.0$.

3.6 Contact ratio factor Y_ε

3.6.1 The contact ratio factor Y_ε covers the effects of an oblique line of contact caused by the helix angle of bevel gears on the root stress.

3.6.2 The contact ratio factor Y_ε may be calculated as follows:

(1) For $\varepsilon_{v\beta} = 0$:

$$Y_\varepsilon = 0.25 + \frac{0.75}{\varepsilon_{va}}$$

(2) For $0 < \varepsilon_{v\beta} \leq 1$:

$$Y_\varepsilon = 0.25 + \frac{0.75}{\varepsilon_{va}} - \varepsilon_{v\beta}\left(\frac{0.75}{\varepsilon_{va}} - 0.375\right)$$

For $\varepsilon_{v\beta} > 1$:

$$Y_\varepsilon = 0.625$$

3.6.3 Where Y_ε calculated according to 3.6.2 is less than 0.625, Y_ε is to be taken as 0.625.

3.7 Bevel gear factor Y_K

3.7.1 The bevel gear factor Y_K accounts for the differences between bevel and cylindrical gears in respect to root stress.

3.7.2 The bevel gear factor Y_K may be calculated as follows:

$$Y_K = (\frac{1}{2} + \frac{l'_{bm}}{2b})^2 \frac{b}{l'_{bm}}$$

$$l'_{bm} = l_{bm} \cos \beta_{vb}$$

where: l'_{bm} — projected length of the middle line of contact;

l_{bm} — length of the middle line of contact:

For $\varepsilon_{v\beta} < 1$: $l_{bm} = \frac{b\varepsilon_{va}}{\cos \beta_{vb}} \frac{\sqrt{\varepsilon_{vr}^2 - [(2 - \varepsilon_{va})(1 - \varepsilon_{v\beta})]^2}}{\varepsilon_{vr}^2}$;

For $\varepsilon_{v\beta} \geq 1$: $l_{bm} = \frac{b\varepsilon_{va}}{\cos \beta_{vb} \varepsilon_{vr}}$.

3.8 Load sharing factor Y_{LS}

3.8.1 The load sharing factor, Y_{LS}, accounts for the distribution of load between two or more pairs of teeth.

3.8.2 The factor Y_{LS} may be calculated as follows:

$$Y_{LS} = Z_{LS}^2$$

where: Z_{LS} — load sharing factor, see 2.7 of this Appendix.

3.8.3 Where Z_{LS} calculated according to 3.8.2 is less than 0.7, Z_{LS} is to be taken as 0.7.

3.9 Bending endurance limit σ_{FE}

3.9.1 For a given material, bending endurance limit σ_{FE} is the local tooth root stress which can be permanently endured. According to the reference standard the number of 3×10^6 cycles is regarded as the beginning of the endurance limit. The σ_{FE} values are to correspond to a failure probability 1% or less.

σ_{FE} is defined as the unidirectional pulsating stress with a minimum stress of zero (disregarding residual stresses due to heat treatment). Other conditions such as alternating stress or prestressing etc., are covered by the design factor Y_d.

3.9.2 The endurance limit σ_{FE} mainly depends on:

(1) material composition, cleanliness and defects;

(2) mechanical properties;

(3) residual stresses;

(4) heat treatment, depth of hardened zone, hardness gradient;

(5) material structure (forged, rolled bar, cast).

3.9.3 The bending endurance limit σ_{FE} is to be determined, in general, making reference to values indicated in ISO 6336-5 standard, for material quality MQ.

3.10 Design factor Y_d

3.10.1 The design factor, Y_d, takes into account the influence of load reversing and shrink fit prestressing on the tooth root strength, relative to the tooth root strength with unidirectional load as defined for σ_{FE}.

3.10.2 The design factor, Y_d, is to be determined as follows:

(1) for gears with unidirectional load: $Y_d = 1.0$;

(2) for gears with occasional part load in reversed direction, such as idler gear and planet wheel: $Y_d = 0.7$;

(3) for gears with performance in reversing: $Y_d = 0.9$;

(4) for gears shrinking on assembled gear rings: $Y_d = 0.8$.

3.11 Life factor Y_N

3.11.1 The life factor Y_N accounts for the higher tooth root bending stress permissible when a limited life (number of cycles) is required.

3.11.2 The factor Y_N mainly depends on:

(1) material and heat treatment;

(2) number of load cycles (service life);

(3) influence factors ($Y_{\delta relT}$, Y_{RrelT}, Y_X).

3.11.3 The life factor Y_N may also be determined according to Method B outlined in the reference standard ISO 6336-3.

3.12 Relative notch sensitivity factor $Y_{\delta relT}$

3.12.1 The relative notch sensitivity factor, $Y_{\delta relT}$, indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit.

3.12.2 The factor $Y_{\delta relT}$ mainly depends on:
(1) material;
(2) relative stress gradient.
3.12.3 $Y_{\delta relT}$ is to be determined as follows:

$$Y_{\delta relT}=\frac{1+\sqrt{0.2\rho'(1+2q_s)}}{1+\sqrt{1.2\rho'}}$$

where: q_s = notch parameter, see 3.4 of this Appendix;
ρ' = slip-layer thickness, mm, from Table 3.12.3.

Value of Slip-layer Thickness ρ' **Table 3.12.3**

Material		ρ'(mm)
Case hardened steels, flame or induction hardened steels		0.0030
Through-hardened steels①, yield point R_e	500 N/mm^2	0.0281
	600 N/mm^2	0.0194
	800 N/mm^2	0.0064
	1000 N/mm^2	0.0014
Nitrided steels		0.1005

Note: ① The given values of ρ' can be interpolated for values of R_e not stated above.

3.13 Relative surface factor Y_{RrelT}

3.13.1 The relative surface factor, Y_{RrelT}, takes into account the dependence of the root strength on the surface condition in the tooth root fillet, mainly the dependence on the peak-to-valley surface roughness.
3.13.2 The relative surface factor, Y_{RrelT} is to be determined from Table 3.13.2. The method applied here is only valid when scratches or similar defects deeper than $2R_z$ are not present.

Relative surface factor Y_{RrelT} **Table 3.13.2**

Material and heat treatment	$R_Z < 1$	$1 \le R_Z \le 40$
case hardened steels, through-hardened steels ($R_m \ge 800$ N/mm^2)	1.120	$1.674 - 0.529\ (R_Z + 1)^{0.1}$
normalised steels ($R_m < 800$ N/mm^2)	1.070	$5.306 - 4.203\ (R_Z + 1)^{0.01}$
nitrided steels	1.025	$4.299 - 3.259\ (R_Z + 1)^{0.0058}$

Notes: ① R_z — mean peak-to-valley roughness of tooth root fillets, in μm.
② If the roughness stated is an arithmetic mean roughness, i.e. R_a value (= *CLA* value) (= *AA* value) the following approximate relationship can be applied: $R_a = CLA = AA = R_Z/6$.

3.14 Size factor of bending stress Y_X

3.14.1 The size factor of bending stress, Y_X, takes into account the decrease of the strength with increasing size.
3.14.2 The factor Y_X mainly depends on:
(1) material and heat treatment;
(2) tooth and gear dimensions;
(3) ratio of case depth to tooth size.
3.14.3 The size factor Y_X is to be determined according to Table 3.14.3.

Size Factor of Bending Stress Y_X **Table 3.14.3**

Y_X	m_n	Status
1.00	$m_n \le 5$	Generally
$1.03 - 0.006\ m_n$	$5 < m_n < 30$	Normalized and through-hardened steels
0.85	$m_n \ge 30$	
$1.05 - 0.01\ m_n$	$5 < m_n < 25$	Surface hardened steels
0.80	$m_n \ge 25$	

3.15 Rim thickness factor, Y_B

The rim thickness factor, Y_B, is a simplified factor used to de-rate thin rimmed gears. For critically loaded applications, this method should be replaced by a more comprehensive analysis. Factor Y_B is to be determined as follows:
(1) for external gears:
If $S_R/h \ge 1.2$, $Y_B = 1$,
If $0.5 < \frac{S_R}{h} < 1.2$, $Y_B = 1.6 \cdot \ln(2.242 \frac{h}{S_R})$

where: S_R — rim thickness of external gears, in mm;
h — tooth height, in mm.
The case $S_R/h \leq 0.5$ is to be avoided.

(2) for internal gears:
If $S_R/m_n \geq 3.5$, $Y_B=1$;
If $1.75 < S_R/m_n < 3.5$, $Y_B = 1.15 \cdot \ln(8.324 \frac{m_n}{S_R})$
where: S_R— rim thickness of internal gears, in mm.
The case $S_R/h \leq 1.75$ is to be avoided.

3.16 Deep tooth factor, Y_{DT}

The deep tooth factor, Y_{DT}, adjusts the tooth root stress to take into account high precision gears and contact ratios within the range of virtual contact ratio $2.05 \leq \varepsilon_{\alpha n} \leq 2.5$, where:

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{\cos^2 \beta_b}$$

Factor Y_{DT} is to be determined as follows:
If ISO accuracy grade ≤ 4 and $\varepsilon_{\alpha n} > 2.5$, $Y_{DT} = 0.7$;
If ISO accuracy grade ≤ 4 and $2.05 < \varepsilon_{\alpha n} \leq 2.5$, $Y_{DT} = 2.366 - 0.666 \cdot \varepsilon_{\alpha n}$;
in all other cases, $Y_{DT} = 1.0$.

3.17 Safety factor for tooth root bending stress S_F

3.17.1 The safety factor for tooth root bending stress, S_F, can be assumed by taking into account the type of application. The safety factor for tooth root bending stress S_F is to comply with the following requirements:
main propulsion gears: $1.55 \leqslant S_F \leqslant 2.00$;
auxiliary gears: $1.40 \leqslant S_F \leqslant 1.45$.
For gearing of duplicated independent propulsion or auxiliary machinery, a reduced value can be assumed.

4 Alignment

4.1 Summary

At present, most gear box manufacturers require that during shaft alignment, static specific pressure of the gear bearing is not to exceed the specified value and static reaction difference of fore and aft bearings is not to exceed 20% of the total weight upon the two spans. Some manufacturers specify the dynamic limited pressure at the same time. It is proved through experience that under some circumstances, even if the conditions mentioned above are satisfied, the safety of the gearbox will not necessarily be ensured; on the contrary, even if the conditions mentioned above are not satisfied, it will not necessarily result in the failure of the gearbox. This covers design, alignment and installation of gearbox.
For gearbox is a part of the driving shafting, its alignment status is inevitably different with the different arrangement of shafting. Nevertheless, as a product, gearbox cannot be changed with the different arrangement of the shafting. The design of gearbox, such as arrangement of bearing, height of the bearing blocks, opening arrangement of sliding bearing pillow etc., is determined through dynamic resultant of gear force, so its safe operation when fitted onboard ship can be ensured.

4.2 Alignment calculation including gear force

4.2.1 The force of bearing in operation condition
When the gearbox is in static condition, only vertical static counterforce goes with the supporting bearing. Considering the influence of gearbox expansion in thermal state, the vertical static counterforce also goes with the supporting bearing. But when in operation condition, due to the influence of the gear force, not only supporting force changes, but the acting direction changes.
4.2.2 Calculation for dynamic resultants
Take the X-axis as along the gear shaft centerline, and the positive direction is from aft to fore wheel bearings. The Y-axis is perpendicular to the X-axis, with the upward direction as positive direction. The direction of Z-axis is determined by the right-hand rule.
Take the angle between the Y-axis and the line connecting gear engaged point and driven gear center as ψ, with the clockwise direction as positive direction.
θ_f and θ_a are angles between the Z-axis and the dynamic resultants on fore and aft bearings, with the counter-clockwise direction as positive direction.

L_1 is the distance between gear centerline and aft bearing; L_2 is the distance between gear centerline and fore bearing.
Take the upward direction (Y direction) as positive for counterforce on bearings; take the right direction (Z direction) as positive for counterforce on bearings while observed from aft to fore bearings.
Figure 4.2.2(1) shows the various forces that the final pinion with double gear ratio acts on wheel.

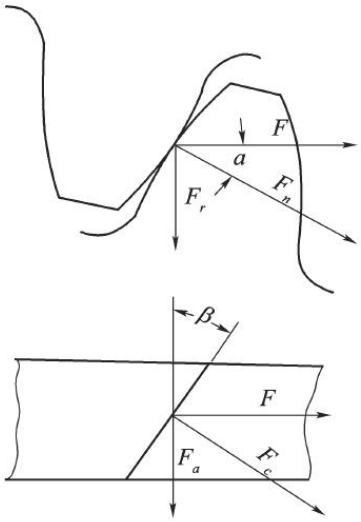


Figure 4.2.2(1) Forces acting on pinion

For spur gear and single helical gear, the dynamic resultants acting on bearings and acting directions are calculated in accordance with the following formulae:
(1) Counterforce which gear tangential force acts on fore and aft bearings
Tangential force F_t acting on wheel is:

$$F_t = 2T_1/d_1 \quad \text{kN} \tag{1}$$

where: T_1 — transmission torque acting on pinion, in N·m:

$$T_1 = 9550P\,u_2/n_e \tag{2}$$

where: P — propelling power transmitted by the reduction gear of the gearbox, in kW;
n_e — rated speed of the main engine, in r/min;
u_2 —gear ratio;
d_1 — working diameter of pinion, in mm.
The component of tangential force F_t acting on wheel in the Z direction, F_{tz}, is:

$$F_{tz} = F_t \cos\psi = 2T_1 \cos\psi/d_1 \quad \text{kN} \tag{3}$$

The component of tangential force F_t acting on wheel in the Y direction, F_{ty}, is:

$$F_{ty} = F_t \sin\psi = 2T_1 \sin\psi/d_1 \quad \text{kN} \tag{4}$$

The counterforce which gear tangential force acts on fore bearing in the Z direction, F_{tzf}, is:

$$F_{tzf} = \pm 2T_1 L_1 \cos\psi/((L_1+L_2)\,d_1) \quad \text{kN} \tag{5}$$

The counterforce which gear tangential force acts on aft bearing in the Z direction, F_{tza}, is:

$$F_{tza} = \pm 2T_1 L_2 \cos\psi/((L_1+L_2)\,d_1) \quad \text{kN} \tag{6}$$

The counterforce which gear tangential force acts on fore bearing in the Y direction, F_{tyf}, is:

$$F_{tyf} = \pm 2T_1 L_1 \sin\psi/((L_1+L_2)\,d_1) \quad \text{kN} \tag{7}$$

The counterforce which gear tangential force acts on aft bearing in the Y direction, F_{tya}, is:

$$F_{tya} = \pm 2T_1 L_2 \sin\psi/((L_1+L_2)\,d_1) \quad \text{kN} \tag{8}$$

Observed from aft to fore bearings, when the driven wheel rotates counter-clockwise, formulae (5) and (6) take positive, formulae (7) and (8) take negative; when it rotates clockwise, formulae (5) and (6) take negative, formulae (7) and (8) take positive.

(2) Counterforce which gear radial force F_r acts on fore and aft bearings
Radial force F_r is:

$$F_r = F_t \tan\alpha_n / \cos\beta \quad \text{kN} \tag{9}$$

where: α_n — normal engaged angle, in °.
β — helix angle at spur helical gear, in °.
The component of radial force F_r in the Z direction, F_{rz}, is:

$$F_{rz} = F_r \sin\psi = F_t \tan\alpha_n \sin\psi / \cos\beta \quad \text{kN} \tag{10}$$

The component of radial force F_r in the Y direction, F_{ry}, is:

$$F_{ry} = F_r \cos\psi = F_t \tan\alpha_n \cos\psi / \cos\beta \quad \text{kN} \tag{11}$$

The counterforce which gear radial force acts on fore bearing in the Z direction, F_{rzf}, is:

$$F_{rzf} = F_t L_1 \tan\alpha_n \sin\psi /((L_1 + L_2)\cos\beta) \quad \text{kN} \tag{12}$$

The counterforce which gear radial force acts on aft bearing in the Z direction, F_{rza}, is:

$$F_{rza} = F_t L_2 \tan\alpha_n \sin\psi /((L_1 + L_2)\cos\beta) \quad \text{kN} \tag{13}$$

The counterforce which gear radial force acts on fore bearing in the Y direction, F_{ryf}, is:

$$F_{ryf} = F_t L_1 \tan\alpha_n \cos\psi /((L_1 + L_2)\cos\beta) \quad \text{kN} \tag{14}$$

The counterforce which gear radial force acts on aft bearing in the Y direction, F_{rya}, is:

$$F_{rya} = F_t L_2 \tan\alpha_n \cos\psi /((L_1 + L_2)\cos\beta) \quad \text{kN} \tag{15}$$

(3) Counterforce which gear axial force F_a acts on fore and aft bearings
Axial force F_a is:

$$F_a = F_t \tan\beta \quad \text{kN} \tag{16}$$

The counterforce which gear axial force acts on fore bearing in the Z direction, F_{azf}, is:

$$F_{azf} = \pm F_t d_1 \tan\beta \sin\psi /(2(L_1 + L_2)) \quad \text{kN} \tag{17}$$

The counterforce which gear axial force acts on fore bearing in the Y direction, F_{ayf}, is:

$$F_{ayf} = \pm F_t d_1 \tan\beta \cos\psi /(2(L_1 + L_2)) \quad \text{kN} \tag{18}$$

For formulae (17) and (18), if, observed from aft to fore bearings, the wheel rotates counter-clockwise and is right-hand teeth, F_{azf} and F_{ayf} are positive; if the wheel rotates counter-clockwise and is left-hand teeth, F_{azf} and F_{ayf} are negative; if the wheel rotates clockwise and is right-hand teeth, F_{azf} and F_{ayf} are negative; if the wheel rotates clockwise and is left-hand teeth, F_{azf} and F_{ayf} are positive.

F_{aza}, the counterforce which gear axial force acts on aft bearing in the Z direction, and F_{azf} are equal in magnitude and opposite in direction; F_{aya}, the counterforce which gear axial force acts on aft bearing in the Y direction, and F_{ayf} are equal in magnitude and opposite in direction.

(4) Counterforce which gear weight acts on fore and aft bearings
The counterforce which gear weight acts on fore bearing, R_{f1}, is:

$$R_{f1} = 0.0098\ G_1 L_1 /(L_1 + L_2) \quad \text{kN} \tag{19}$$

The counterforce which gear weight acts on aft bearing, R_{a1}, is:

$$R_{a1} = 0.0098\ G_1 L_2 /(L_1 + L_2) \quad \text{kN} \tag{20}$$

where: G_1— gear weight, in kg.

(5) Counterforce which flange output shaft acts on fore and aft bearings
Case 1: if the center of gravity of flange output shaft is between the fore and aft bearings, then:
the counterforce which flange output shaft acts on fore bearing, R_{f2}, is:

$$R_{f2} = 0.0098\ G_2 L_3 /(L_3 + L_4) \quad \text{kN} \tag{21}$$

the counterforce which flange output shaft acts on aft bearing, R_{a2}, is:

$$R_{a2} = 0.0098\ G_2 L_4 /(L_3 + L_4) \quad \text{kN} \tag{22}$$

where, for formulae (21) and (22),

G_2—weight of flange output shaft, in kg;
L_3 —distance between the gravity center of flange output shaft and the aft bearing, in mm;
L_4—distance between the gravity center of flange output shaft and the fore bearing, in mm.

Case 2: if the center of gravity of flange output shaft is on the left of (behind) the aft bearing, then:
the counterforce which flange output shaft acts on fore bearing, R_{f2}, is:

$$R_{f2} = -0.0098 G_2 L_3/(L_4 - L_3) \quad \text{kN} \tag{23}$$

the counterforce which flange output shaft acts on aft bearing, R_{a2}, is:

$$R_{a2} = 0.0098 G_2 L_4/(L_4 - L_3) \quad \text{kN} \tag{24}$$

Dynamic resultants F_f, F_a acting on fore and aft bearings and acting direction θ_f, θ_a is:

$$F_f = \left[(F_{tzf} + F_{rzf} + F_{azf})^2 + (F_{tyf} + F_{ryf} + F_{ayf} + R_{f1} + R_{f2})^2\right]^{1/2} \quad \text{kN} \tag{25}$$

$$\theta_f = tg^{-1}\left[(F_{tyf} + F_{ryf} + F_{ayf} + R_{f1} + R_{f2})/(F_{tzf} + F_{rzf} + F_{azf})\right] \quad (°) \tag{26}$$

$$F_a = \left[(F_{tza} + F_{rya} + F_{aza})^2 + (F_{tya} + F_{rya} + F_{aya} + R_{a1} + R_{a2})^2\right]^{1/2} \quad \text{kN} \tag{27}$$

$$\theta_a = tg^{-1}\left[(F_{tya} + F_{rya} + F_{aya} + R_{a1} + R_{a2})/(F_{tza} + F_{rya} + F_{aza})\right] \quad (°) \tag{28}$$

where:

F_{tzf}, F_{tza}— counterforce which gear tangential force acts on fore and aft bearings in the Z direction, in kN, see formulae (5) and (6);

F_{tyf}, F_{tya}— counterforce which gear tangential force acts on fore and aft bearings in the Y direction, in kN, see formulae (7) and (8);

F_{rzf}, F_{rza}— counterforce which gear radial force acts on fore and aft bearings in the Z direction, in kN, see formulae (12) and (13);

F_{ryf}, F_{rya}— counterforce which gear radial force acts on fore and aft bearings in the Y direction, in kN, see formulae (14) and (15);

F_{azf}, F_{aza}— counterforce which gear axial force acts on fore and aft bearings in the Z direction, in kN, see formula (17);

F_{ayf}, F_{aya}— counterforce which gear axial force acts on fore and aft bearings in the Y direction, in kN, see formula (18);

R_{f1}, R_{a1}— counterforce which gear weight acts on fore and aft bearings, in kN, see formulae (19) and (20);

R_{f2}, R_{a2}— counterforce which flange output shaft acts on fore and aft bearings, in kN, see formulae (21), (22), (23) and (24);

F_f,F_a — dynamic resultants on fore and aft bearings, in kN;

θ_f, θ_a — acting angle of dynamic resultants on fore and aft bearings (°)

Obviously, due to the influence of gear force, under operation condition, dynamic resultants of fore and aft bearings of wheels and its acting direction are different from force of alignment calculation for shafting thermal state and its direction.

If the pinion is right above the wheel, then:

Dynamic resultants F_f, F_a acting on fore and aft bearings and acting direction θ_f, θ_a is:

$$F_f = \left[(F_{tzf})^2 + (F_{ryf} + F_{ayf} + R_{f1} + R_{f2})^2\right]^{1/2} \quad \text{kN} \tag{29}$$

$$\theta_f = \tan^{-1}\left[(F_{ryf} + F_{ayf} + R_{f1} + R_{f2})/F_{tzf}\right] \quad (°) \tag{30}$$

$$F_a = \left[(F_{tza})^2 + (F_{rya} + F_{aya} + R_{a1} + R_{a2})^2\right]^{1/2} \quad \text{kN} \tag{31}$$

$$\theta_a = \tan^{-1}\left[(F_{rya} + F_{aya} + R_{a1} + R_{a2})/F_{tza}\right] \quad (°) \tag{32}$$

where:

$$F_{tzf} = \pm 2T_1 L_1/((L_1+L_2)\, d_1) \quad \text{kN} \tag{33}$$

$$F_{tza} = \pm 2T_1 L_2/((L_1+L_2)\, d_1) \quad \text{kN} \tag{34}$$

$$F_{ryf} = F_t L_1 \tan\alpha_n/((L_1 + L_2)\cos\beta) \quad \text{kN} \tag{35}$$

$$F_{rya} = F_t L_2 \tan\alpha_n/((L_1 + L_2)\cos\beta) \quad \text{kN} \tag{36}$$

$$F_{ayf} = -F_{ayf} = \pm F_t d_1 \tan\beta\cos\psi/(2(L_1 + L_2)) \quad \text{kN} \tag{37}$$

Figure 4.2.2(2) shows the counterforce on fore and aft wheel bearings when the pinion is right above the wheel.

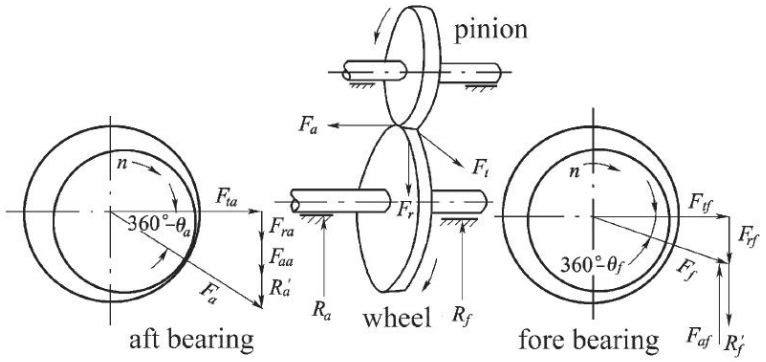


Figure 4.2.2(2) Counterforce on the wheel bearings

4.3 Influence of dynamic resultant

4.3.1 The interface of gear pillow is to be arranged in accordance with dynamic resultant direction.

(1) Bearing arrangement of straight tooth gear shaft

It may be seen from 4.2.2 that if it is straight tooth gear, there is no axial force, i.e., $F_a = 0$, then under the condition that bearing span is same or close, dynamic resultant and its direction is determined by the counterforce of shafting alignment and its direction. Where the counterforce of fore and aft bearings of delivery gear through alignment of shafting is positive value and is less than 20%, dynamic resultant of the two bearings and its direction is basically the same, and gear shaft will not be distorted. But due to the act of tangential force of gear, the direction of dynamic resultant is not on the vertical position, but within the IV quadrant (when the shaft rotates clockwise), as shown in Figure 4.3.1(1). Therefore, in order to ensure the establishment of lubricant film of bearing, and to avoid scorification of pillow, consideration is to be taken for the correct position of pillow entering oil groove, i.e., the interface of pillow is to be turned counter-clockwise to about 70° to 100° in accordance with the position of dynamic resultants.

(2) Bearing arrangement of helical gear shaft

For helical gear, $F_a \neq 0$, the strength and direction of dynamic resultant of fore and aft bearings are different, especially, the change of acting direction is great as shown in Figure 4.3.1(2). In this case, gear shaft will be distorted. Simultaneously, in order to ensure the normal establishment of lubricant film of bearing, and to avoid scorification of pillow, the position of dynamic resultants is to be calculated separately, and the interface of pillow is to be turned counter-clockwise to about 70° to 100°.

(3) Gear shafts other than delivery gear shaft

Where sliding bearings are adopted for other bearings in driving gears, the counter force of each bearing and gear force is to be calculated, and then dynamic resultant and direction of each bearing is to be calculated. The interface of pillow is also to be turned counter-clockwise to about 70° to 100° in accordance with the position of dynamic resultants.

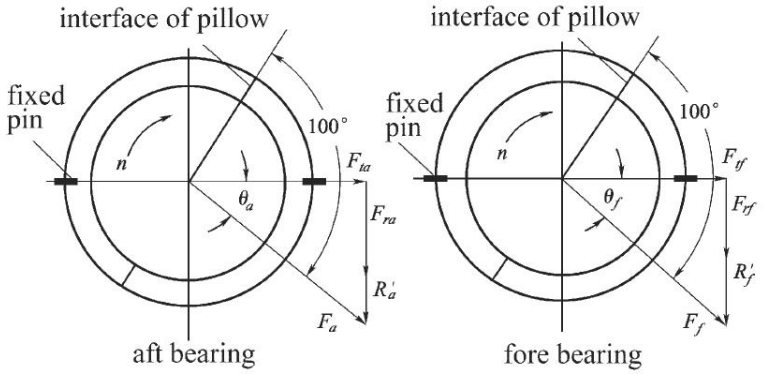


Figure 4.3.1(1) Stress of fore and aft bearings of spur gear

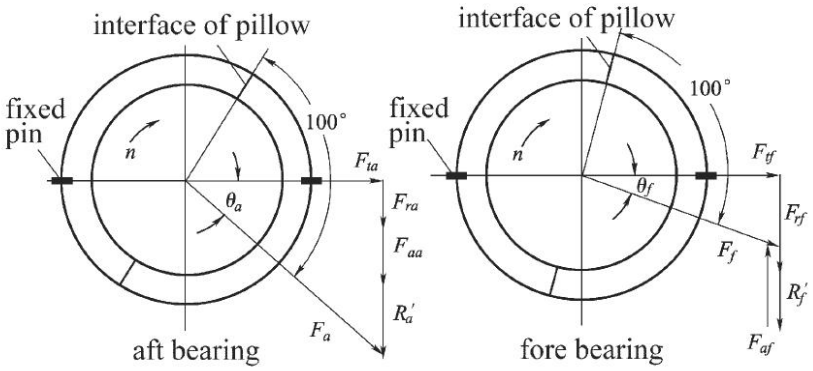


Figure 4.3.1(2) Stress of fore and aft bearings of helical gear

4.3.2 After the interface of pillows is determined according to the dynamic resultant, the counter force difference of alignment of two bearings may not be limited by 20% of the total weight.

When the driving shafting of gear is being aligned, the required load difference of fore and aft bearing of delivery gear is to be as little as possible. The maximum is not to exceed 20% of the total weight of the gear and shaft. Actually, if the interface of the gear pillow is determined in accordance with the dynamic resultant direction, the strength and direction of the dynamic resultant are mainly determined by the gear force under the condition that the alignment counterforce of two bearings is positive value (i.e., non-straight-line alignment). Therefore, during actual installation of shafting, it is safe even if the counter force difference of two bearings exceeds 20%. If the alignment counterforce of the fore bearing of delivery gear shaft on a ship is 28.95 kN, and the counterforce of the aft bearing is 10.61 kN, the difference is 2.7 times which greatly exceeds the defined 20%. However, the dynamic resultant of the fore bearing turns from 235 kN to 237 kN, and its acting angle turns from 348.2° to 346.4°; while the dynamic resultant of aft bearing turns from 283 kN to 277 kN, and its acting angle turns from 324.3° to 326.2°. Obviously, though the alignment counterforce difference of fore and aft bearing exceeds greatly the defined 20%, the influence of dynamic resultant and acting angle is little, i.e., the influence to dynamic specific pressure of the bearings and establishment of oil film is little, which is still safe.

4.3.3 Reducing the included angle of the dynamic resultants of fore and aft bearings can strengthen the engaging capability of gears and reduce noise.

The greater the included angle between dynamic resultant of fore and aft bearings, the greater the distorted angle of gear shaft; then the gear is distorted, which results in uneven contact along the facewidth, reducing the bearing capacity and increasing the contact stress of the gear. It will cause single side wearing of the gear, and even cause the gear broken event. Therefore, to ensure the parallel of the gear shaft, strengthen the engaging capability of gears and reduce noise, the included angle of the dynamic resultants of fore and aft bearings is to be reduced as far as possible. For driving shafting of the helical gear when it is being designed, the greater static counterforce value of the fore bearing is to be taken, so as to offset the influence of counterforce F_{af} of the axial force F_a acting upon the fore bearing.

In order to reduce the included angle of the dynamic resultants of fore and after bearing, when the gear is being designed, the F_a value is to be reduced as far as possible or $F_a = 0$, which may be achieved by the arrangement of herringbone gears, planetary gears or the symmetric arrangement of gears.

4.4 Alignment requirements to shafting

4.4.1 Parameters needed for alignment calculation of shafting

In order to facilitate alignment calculation of shafting, gearbox manufacturer is to provide following parameters:

Manufacturer:
Type:
Rated power: in kW
Rated speed: in r/min
Gear ratio:
Working diameter of pinion: in mm
Working diameter of wheel: in mm
Helix angle β of spur helical pinion, wheel: (°)
Normal engaged angle α_n: (°)
Structural size of pinion, wheel: in mm

Type of bearing:
Length of sliding bearing pillow: in mm
Open corner of sliding bearing pillow: (°)
Angle between the Y-axis and the line connecting gear engaged point and driven gear center ψ
Distance between gear centerline and fore bearing L_1
Distance between gear centerline and aft bearing L_2

4.4.2 The requirements to be satisfied for shafting alignment

(1) Rolling bearings

For rolling bearings, there is no need for establishment of lubricant film and the influence of gear force is considered during design, shafting alignment after the ship is loaded is to satisfy the following requirements:

① static load or dynamic load of bearing is not to exceed the permissible value;

② static counterforce difference or dynamic counterforce difference of fore and aft bearings is not to exceed the permissible value.

(2) Sliding bearings

For sliding bearings, due to establishment of lubricant film, if the gear force is included in design according to the requirements of this Chapter, shafting alignment after the ship is loaded is to satisfy the following requirements:

① not to exceed the dynamic specific pressure value of the bearing allowed for gearbox;

② changing of dynamic resultants not to affect the establishment of the lubricant film of gear bearing.

CHAPTER 11 SHAFTING AND PROPELLERS

Section 1 GENERAL PROVISIONS

11.1.1 Application

11.1.1.1 This Chapter is applicable to the shafting of ships propelled by diesel engines, steam turbines, gas turbines or electric propelling motors.

11.1.2 General requirements

11.1.2.1 Where the couplings are separate from the thrust shafts, intermediate shafts, tube shafts (i.e. the shaft which passes through the stern tube, but does not carry the propeller) and screwshafts, provision is to be made for the couplings to resist the astern pull so that no axial displacements of the couplings relative to the shafts may occur. Excessive stress concentration on the shafts is to be avoided.

11.1.2.2 Materials for shafting and propellers are to comply with the relevant requirements of CCS Rules for Materials and Welding.

The specified tensile strength of forgings for shafts is to be selected within the following general limits:

(1) for carbon and manganese steel, 400 to 760 N/mm^2. Where shafts may experience vibration stresses exceeding 90% permissible stresses for transient operation, the materials are to have a specified minimum ultimate tensile strength of 500 N/mm^2;

(2) for alloy steel, not exceeding 800 N/mm^2.

If the specified tensile strength exceeds the limitation value in 11.1.2.2(1) and (2) of this Chapter, calculation of shaft diameter is to comply with the provisions in 11.2.2.1 of this Chapter and calculation of permissible vibration stress is to comply with the provisions in 12.2.3.3, Chapter 12 of this PART.

For shaft couplings, nodular graphite cast iron may also be accepted.

11.1.2.3 The main propulsion shafting together with its transmission gears are to be capable of withstanding sufficient astern power.

For the main propulsion shafting with reduction gears, controllable pitch propellers or electric propelling motors, running astern are not to lead to the overload of main engines.

11.1.2.4 The sliding bearing temperature in the main propulsion shafting and transmission gearing is not to exceed 70℃, and not to exceed 80℃ if roller bearing is fitted.

11.1.2.5 The certificate requirements and product survey of shaft, bearing, coupling, propeller, transverse propulsion arrangement, Z propulsion arrangement and shafting connecting bolt are to comply with relevant requirements in Chapter 3, PART ONE of the Rules.

11.1.2.6 Alternative calculation methods may be considered by CCS. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections.

Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions, for example as given in Section 2 of Chapter 11 and Section 2 of Chapter 12.

11.1.3 Vibration and Alignment of Shafting

11.1.3.1 The shafting is also to comply with the requirements for shafting vibration and alignment in Chapter 12 of this PART.

11.1.4 Plans and documents

11.1.4.1 The following plans and documents of shafting and propellers are to be submitted for approval:

(1) Arrangement of Shafting;

(2) Thrust shaft, intermediate shaft, tube shaft (where applicable), and screwshaft;

(3) General arrangement of stern tube, including oil sealing gland and tube shaft bearings;

(4) Strength calculations for shafting, including calculations for the connection of couplings and strength calculations of bolts;

(5) Strength calculations for propellers;

(6) Propeller (including the clearances between the propeller and hull etc.);

(7) Oil shrink fitting of key or keyless propeller together with calculations (where applicable).

11.1.4.2 Detailed sizes and necessary parameters for verifying the calculations are to be indicated in plans.

Section 2 SHAFTING

11.2.1 General requirements

11.2.1.1 The minimum diameter of shafts determined by the formulae in this Section is to be checked for the allowable torsional vibration stress as specified in Chapter 12 of this PART.

11.2.2 Diameter of shafts

11.2.2.1 Low cycle fatigue criterion (typically < 10^4), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque if applicable.

The shaft diameter d is not to be less than the value determined by the following formula:

$$d = FC \sqrt[3]{\frac{N_e}{n_e}\left(\frac{560}{R_m + 160}\right)} \quad \text{mm}$$

where: F — factor for the type of propulsion installation:

F= 95 for intermediate shafts in turbine installations, diesel installations with hydraulic (slip type) couplings, electric propulsion installation;

F= 100 for all other diesel installations and all propeller shafts;

C — factor for the particular shaft design features (see Table 11.2.2.1) or calculated in accordance with the following formula;

$$C = \left[\frac{scf}{1.45}\right]^x$$

x — low cycle notch sensitivity. The chosen values are mainly representative for soft steels (R_m < 600), while the influence of steep stress gradients in combination with high strength steels may be underestimated;

scf — the stress concentration factors relative to the stress concentration for a flange with fillet radius of 0.08d (geometric stress concentration of approximately 1.45);

N_e — rated power transmitted through the shaft, in kW;

n_e — speed in revolution per minute of shaft at rated power, in r/min;

R_m — specified tensile strength of shaft material, in N/mm^2. For intermediate shaft, when carbon and manganese steel is used, it is to be taken as 760 N/mm^2 for R_m> 760 N/mm^2; when alloy steel is used, it is to be taken as 800 N/mm^2 for R_m> 800 N/mm^2. For special approval of alloy steel used for intermediate shaft material, the tensile strength of shaft material may be greater than 800 N/mm^2, but less than 950 N/mm^2, where such approval of the material comply with the relevant requirements for torsional fatigue test①, cleanliness②and inspection. The requirements of 5.1.1.1, 5.3.2.1, 5.3.2.3 and 5.3.4.5 for the cleanliness of material, and the requirements of 5.1.6 for the inspection in Chapter 5, PART ONE of CCS Rules for Materials and Welding are to be complied with. For screwshaft and tube shaft, it is to be taken as 600 N/mm^2 for R_m> 600 N/mm^2.

Factor *C* for different design features **Table 11.2.2.1**

Intermediate shafts with					Thrust shafts external to engines		Propeller shafts		
Integral coupling flange	Keyless couplings fitted by oil shrink method	keyway	Radial hole	Longitudinal slot	The portion of thrust shafts outside the thrust collar at a length equal to the thrust shaft diameter, the remainder may be tapered down to the diameter required for the intermediate shaft	In way of axial bearings where roller bearing is used as thrust bearing	Flange mounted or keyless taper fitted propeller shafts	Key fitted propeller shafts	The portion of the screwshaft and tube shaft forward of the length of screwshaft required by 11.2.2.3 till it reaches the aft peak bulkhead
1.0①	1.0⑦	1.10②⑤⑧	1.10③⑤	1.20④⑤	1.10	1.10	1.22	1.26	1.15

① Torsional fatigue test is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

② Cleanliness is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

Notes:

① The fillet radius at the base of the flange is not to be less than 0.08d.

② For over a length of at least 0.2d of the shaft from the ends of keyway and, the diameter of the shaft is to be increased by taking C = 1.10. The diameter of the shaft is to be decreased by taking C = 1.0 for the range beyond. The fillet radius in the transverse section at the bottom of the keyway are not to be less than 0.0125d.

③ For over a length of at least 0.2d of the shaft from the ends of hole and, the diameter of the shaft is to be increased by taking C = 1.10. The diameter of the shaft is to be decreased by taking C = 1.0 for the range beyond. The diameter of the hole is not to be greater than 0.3d. The intersection between a radial and an eccentric axial bore is not applicable, as shown in the figure below.

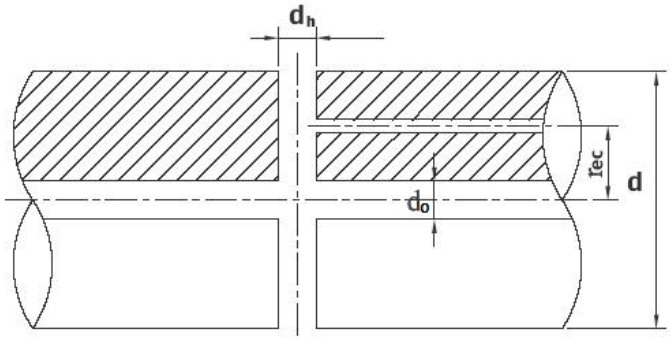


Figure 11.2.2.1 Intersection Between a Radial and an Eccentric Axial Bore

④ For over a length of at least 0.3d of the shaft from the longitudinal slot and its ends, the diameter of the shaft is to be increased by taking C = 1.20. The diameter of the shaft is to be decreased by taking C = 1.0 for the range beyond. In general, slot length is to be less than 0.8d, width is to be more than 0.15d and inner diameter is to be less than 0.7d. The end rounding of the slot is not to be less than half of the slot width and the quantity of slot is not to be more than 3. Slots at respectively 180º apart for 2 slots, and slots at respectively 120º apart for 3 slots. An edge rounding is preferably to be avoided as this increases the stress concentration slightly.

⑤ For shaft having several design features, the factor is to be the product of several factors.

⑥ Where, d is calculated with C = 1.0.

⑦ Where shafts may experience vibratory stresses exceeding 90% the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2%.

⑧ Keyways are in general not to be used in installations with a barred speed range.

11.2.2.2 Screwshafts or tube shafts forward of the aft peak bulkhead may be gradually reduced to the diameter of the intermediate shaft.

11.2.2.3 The diameter of the screwshaft determined in accordance with the formula in 11.2.2.1 is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2.5 times the diameter of the screwshaft, whichever is the greater.

11.2.2.4 Transitions of diameters are to be designed with either a smooth taper or a blending radius. For guidance, a blending radius equal to the change in diameter is recommended.

11.2.3 Hollow shafts

11.2.3.1 For shafts where the bore d_0 is greater than 0.4d, the actual external diameter d_a of the shaft is not to be less than that determined by the following formula:

$$d_a = d\sqrt[3]{\frac{1}{1-\left(\frac{d_0}{d_a}\right)^4}} \quad \text{mm}$$

where: d — shaft diameter determined by 11.2.2.1 of this Section, in mm;

d_0— actual bore of the shaft, in mm.

11.2.3.2 The edges of slots and holes in the shafts are to be smooth and without any traces of machining.

11.2.3.3 For ships engaged only in harbor service, the minimum diameter of the shafts may be reduced by 3%.

11.2.4 Shaft liners

11.2.4.1 The thickness t of bronze shaft liners shrunk on tube shafts or screwshafts, in way of the bushes, is not to be less than:

$$t = 0.03d + 7.5 \quad \text{mm}$$

where: d — diameter of tube shaft or screwshaft in way of the bushes, in mm.

The thickness of stainless steel liners, where fitted, is to be one-half that obtained above, but not less than 6

mm.
11.2.4.2 The thickness of a continuous liner between the bushes may be somewhat reduced, but is not to be less than 0.75*t*.
11.2.4.3 Continuous liners are to be generally cast in one piece. Where necessary, they may consist of two or more pieces, but these are to be butt-welded by reliable methods to prevent water ingress.
11.2.4.4 Where the portion of the shaft between any two lengths of the liner is protected with glass-reinforced plastics or other industrial plastics, the protection at the junction of the liner ends is to be of such a construction as to prevent the shaft from water ingress. In general, semicircular groove may be at the junction of the liner ends which is protected with several layers of glass-reinforced plastics or other industrial plastics and secured with copper wire or stainless steel wire. The connection portions are not to be located within the bearing range.
11.2.4.5 Shaft liners which are cast in one piece or consist of two or more lengths, are to be subject to hydraulic test to a pressure of 0.2 MPa after rough machining, and there is to be no crack or leakage.
11.2.4.6 Liners are to be carefully shrunk on, or forced on, to the shafts by hydraulic pressure. Pins are not to be used to secure the liners.
11.2.4.7 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

11.2.5 Stern tubes and bearings

11.2.5.1 The length of the bearing in the stern bush next to and supporting the propellers is to be as follows:
(1) For water lubricated bearings, the length of the bearing is not to be less than 4 times the rule calculated diameter for the screwshaft in way of the bearing. For water lubricated synthetic materials, if the design and materials of bearings comply with CCS provisions as demonstrated by tests, the length of the bearings may be appropriately reduced, but not less than 2 times the rule diameter of the shaft in way of the bearing. Synthetic materials of water lubricated stern tube bearings are to be type approved.
(2) For bearings which are white-metal lined and oil lubricated, the length of the bearing is not to be less than twice the rule calculated diameter for the screwshaft in way of the bearing. If the normal bearing pressure is less than 0.8 MPa as determined by static bearing reaction calculation taking into account shaft and propeller weight, the length of the bearings may be appropriately reduced. However, the minimum length is to be not less than 1.5 times the actual diameter.
(3) For bearings of synthetic rubber, reinforced resin or plastics materials which are approved for use as oil lubricated stern bush bearings, the length of the bearing is to be not less than twice the rule diameter of the shaft in way of the bearing. If the normal bearing pressure is less than 0.6 MPa as determined by static bearing reaction calculation taking into account shaft and propeller weight, the length of the bearings may be appropriately reduced. However, the minimum length is to be not less than 1.5 times the actual diameter. Synthetic materials for application as oil lubricated stern tube bearings are to be Type Approved.
Where the material has proven satisfactory testing and operating experience, consideration may be given to an increased bearing pressure.
(4) The length of a grease lubricated bearing is to be not less than 4.0 times the rule diameter of the shaft in way of the bearing.
(5) For bearings which are lined with other materials or lubricated by other methods, background for adopting its bearing length is to be provided, e.g. test results such as expansion characteristics and bearing capability of bearing material or service experience.
11.2.5.2 Forced water lubrication is to be provided for all bearings lined with rubber or plastics and for those lined with lignum vitae where the shaft diameter is 400 mm or over. A shut-off valve or cock controlling the supply of water is to be fitted direct to the after peak bulkhead or to the stern tube where the water supply enters the stern tube forward of the bulkhead.
11.2.5.3 Bearings which are oil lubricated are to be fitted with an approved oil sealing gland.
11.2.5.4 Where a gravity tank supplying lubricating oil to the stern bush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the engine room.
11.2.5.5 Where stern bush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the stern tube or by other suitable means.
11.2.5.6 Stern tubes are to be subject to hydraulic test to a pressure of 0.2 MPa before being fitted on board ship.

Section 3 SHAFT TRANSMISSION UNITS

11.3.1 Application

11.3.1.1 The requirements of this Section apply to couplings, hydraulic transmission arrangements, clutches, Z propulsion arrangement, transverse propulsion arrangement (if applying for additional notation) as well as controllable pitch propeller blade actuators. For transmission gearing, see Chapter 10 of this PART.

11.3.2 Couplings

11.3.2.1 Flange couplings are to comply with the following requirements:

(1) The thickness of coupling flanges is not to be less than 20% of the intermediate shaft diameter required in 11.2.2.1 of this Chapter, nor is it to be less than the diameter of the fitting coupling bolts whose minimum tensile strength is equivalent to that of the shafts. The fillet radius at the base of the coupling flange is not to be less than 8% of the actual diameter of the shaft at the coupling. Special consideration will be given for flanges having non-parallel faces, but in no case is the thickness of the flange to be less than the coupling bolt diameter.

(2) Where the propeller is attached to the screwshaft by means of a coupling flange, the thickness of the flange is not to be less than 25% of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of coupling flange is not to be less than 12.5% of the actual diameter of the shaft at the coupling.

(3) Fillets are to have a smooth finish and not to be recessed in way of nuts and bolt heads. The fillet may be formed of multiradii in such a way that the stress concentration factor is not to be greater than that for a circular fillet with radius 0.08 times the actual shaft diameter.

11.3.2.2 Where the coupling is fitted to the shaft with a key and the torque is transmitted through the key, the effective sectional area of the key in shear is not to be less than that determined by the following formula, and the tensile strength of the key material is to be equal to or greater than that of the shaft material:

$$BL \geq \frac{d^3}{2.6 d_m} \qquad \text{mm}^2$$

where: B — breadth of key, in mm;

L — effective length of key, in mm;

d — diameter of intermediate shaft determined in 11.2.2.1 of this Chapter, in mm;

d_m — diameter of shaft at mid-length of the key, in mm.

11.3.2.3 Keyless couplings fitted by oil shrink method are to meet the following requirements:

(1) Muff couplings are to have a capacity of transmitting a torque which is 2.8 times the mean torque and their equivalent stress of the maximum shrinkage allowance is not to be more than 70% of the yield stress of the muff material.

(2) For general couplings which are not covered in (1) above, the pull-up S or shrinkage allowance δ is to meet the following requirements:

$$S_1 \leq S \leq S_2 \qquad \text{mm}$$
$$\delta_1 \leq \delta \leq \delta_2 \qquad \text{mm}$$

$$S_1 = \frac{\delta_1}{K} = \frac{1}{K}\left[\frac{1672 N_e}{A n_e}(c_1 + c_2) + 0.03\right] \qquad \text{mm}$$

$$S_2 = \frac{\delta_2}{K} = \frac{0.034 \times 10^{-4}}{K} \mathrm{R}_{\mathrm{eH}} d_1 (c_1 + c_2) \frac{K_2^2 - 1}{\sqrt{3K_2^4 + 1}} \qquad \text{mm}$$

where: S_1 — minimum axial pull-up, in mm;

S_2 — maximum axial pull-up, in mm;

δ_1 — minimum shrinkage allowance, in mm;

δ_2 — maximum shrinkage allowance, in mm;

K — taper of the shaft for shrink-fit;

N_e — rated power transmitted by the shaft, in kW;

n_e — speed of the shaft at N_e, in r/min;

A — theoretical contact area of the shrinkage surface, in mm^2;

$c_1 = \frac{1 + K_1^2}{1 - K_1^2} - \mu_1$;

$$c_2 = \frac{K_2^2 + 1}{K_2^2 - 1} + \mu_2;$$

$$K_1 = \frac{d_0}{d_1};$$

$$K_2 = \frac{d_2}{d_1};$$

d_0 — bore diameter of the shaft, in mm;
d_1 — mean diameter of the shaft within the contact length, in mm;
d_2 — mean outside diameter of the coupling within the contact length, in mm;
$\mu_1 = \mu_2 = 0.3$;
R_{eH} — specified yield stress of the coupling material, in N/mm^2.

11.3.2.4 Clamp couplings are to meet the following requirements:
(1) Clamp couplings are to have a strength at least equal to the required strength of the intermediate shaft.
(2) The clamp coupling is to be provided with a key. For couplings transmitting thrust, a satisfactory axial locking device is to be provided.
(3) Torque is to be transmitted by the frictional moment resulting from clamping and the key. The frictional moment is not to be less than the rated torque to prevent track slip and the sizes of the key are not to be less than 2/3 of those determined by the formula in 11.3.2.2.
(4) The clamping length of the coupling is normally to be at least 2.4 times shaft diameter.
11.3.2.5 Where other types of couplings or connections are used for torque transmission, background of test results or service experience are to be provided for the purpose of examining their reliability.

11.3.3 Coupling bolts

11.3.3.1 For intermediate, thrust and propeller shaft couplings having all fitted coupling bolts, the coupling bolt diameter d_f is not to be less than that given by the following formula:

$$d_f = 0.65\sqrt{\frac{d^3(R_m + 160)}{DZR_{mb}}} \quad \text{mm}$$

where: d — Rule diameter of the solid intermediate shaft, in mm, in accordance with the requirements of Chapter 14 of this PART, taking into account ice strengthening requirements where applicable;
Z — number of bolts;
D — pitch circle diameter, in mm;
R_m — tensile strength of the intermediate shaft material for calculation, in N/mm^2;
R_{mb} — tensile strength of the fitted coupling bolts material taken for calculation, in N/mm^2, where: $R_m \le R_{mb} \le 1.7\ R_m$, but not higher than 1,000 N/mm^2.

11.3.3.2 Where it is proposed to use non-fitting bolts for connections, the diameter d_n at the root of thread of the bolts is not to be less than that determined by the following formula:

$$d_n = 25\sqrt{\frac{N_e \times 10^6}{n_e DZR_{mb}}} \quad \text{mm}$$

where: N_e — rated output transmitted by the shaft, in kW;
n_e — speed of the shaft at N_e, in r/min;
other symbols are as defined in 11.3.3.1 of this Section.
The prestressing force and workmanship of ordinary bolts are to be provided for information.

11.3.3.3 Bolts connecting propellers and screwshafts are to be fitting bolts, the diameter of which is to be increased by 5% of that determined in 11.3.3.1 of this Section.
11.3.3.4 For ships engaged only in harbour service, the diameter of the connecting bolts may be reduced by 4%.
11.3.3.5 The diameter of the fitting bolts at the joining faces of the couplings within the crankshaft and thrust shaft/crankshaft is to be increased by 5% of that determined by 11.3.3.1 of this Section.

11.3.4 Clutches and control devices

11.3.4.1 The friction elements of clutches for reversible gearing are not to give any slip in normal running. While the clutch is disengaged, the propulsion shafting is not to be dragged along by the driving shaft.
11.3.4.2 The maximum torque transmitted by the clutch is, in general, not to be less than 1.5 times the

rated torque of the main engine.
11.3.4.3 The flexible clutches controlled by air pressure are to be provided with air charging pressure gauges, signal devices for indicating clutching and declutching of the clutches and alarm devices for giving warning of high and low air pressures.
11.3.4.4 An emergency device for air charging is to be fitted to the system which supplies air to the pneumatic flexible clutch.
11.3.4.5 For reversible clutches, the time required for reversal is not to be more than 15 s.
11.3.4.6 In single screw ships having clutches, emergency mechanical means are to be provided to ensure that the ship can run at a reasonable speed in the event of failure of the clutches.
11.3.4.7 In case the control device of the clutch loses power, the clutch is to be able to maintain its current state until power is restored. Otherwise, an uninterrupted backup power source (e.g. electrical power source or air source) is to be provided.

11.3.5 Hydraulic transmissions

11.3.5.1 In single screw ships having emergency mechanical means are to be provided to ensure that the ship can run at a reasonable speed in the event of failure of the hydraulic transmission systems.
11.3.5.2 The lubricating oil system of hydraulic transmission arrangements is to be separate from other systems. The system is to consist of filters, coolers, drain tanks, etc. In the case of hydraulic gear transmission, in addition, magnetic filters are to be provided in the system.
11.3.5.3 Hydraulic transmission arrangements are to be provided with separate stand-by pumps. For propulsion systems with twin-engine and twin-screw, one stand-by pump may be accepted.
11.3.5.4 In addition to thermometers and pressure gauges, the lubricating oil system of hydraulic transmission arrangements is to be fitted with alarm devices for giving warnings of an excessive temperature and appreciable reduction in pressure of the oil supply.
11.3.5.5 The runners and impellers of hydraulic couplings are to be statically balanced. Furthermore, it is recommended that the runners and impellers be dynamically balanced.
11.3.5.6 Signal devices for indicating oil charging and discharging are to be fitted at the control positions of hydraulic transmission arrangement.
11.3.5.7 The hydraulic transmission arrangements may be controlled at the engine side and in the centralized control station or in the bridge. Where two or more control devices are fitted, they are to be interlocked one another.
11.3.5.8 In the case of multiple engines operating on one screwshaft, an interlocking device is to be provided in the control gear of the hydraulic transmission arrangement to prevent them from being filled with oil when the engines are in opposite directions.
11.3.5.9 At the centralized control station of hydraulic transmission, a tachometer showing the speed of the screwshaft and an indicator showing the direction of its rotation are to be fitted.

11.3.6 Transmission devices for controllable pitch propeller

11.3.6.1 The hydraulic transmission system of controllable pitch propeller blade actuators is to be provided with a separate stand-by pump having a capacity of not less than that required for power hydraulic oil pump during normal operation of one hydraulic transmission system of controllable pitch propeller. One independent stand-by pump may be common to hydraulic transmission system of controllable pitch propeller of duplicated propulsion shafting system. Where each hydraulic transmission system of controllable pitch propeller is provided with independent hydraulic pump, a complete spare pump may be accepted, provided that it is readily accessible and can easily be installed.
For propulsion plants up to 200 kW, one power-driven pump set is sufficient provided that, in addition, a hand-operated pump is fitted for controlling the blade pitch and that this enables the blades to be moved from the ahead to the astern position in a short enough time.
11.3.6.2 Pitch angle indicators are to be fitted both at the engine room control station and in the bridge. The deviation from the actual pitch angle is not to exceed ±1°.
11.3.6.3 The control system in the engine room is to be interlocked with that in the bridge. For control systems other than those actuated by mechanical devices, a stand-by manual control is to be fitted at the engine side.
11.3.6.4 The control system of hydraulic controllable pitch propeller blade actuators is to be such that the blade pitch can be altered efficiently and accurately.
11.3.6.5 Under any working conditions, the blade position of controllable pitch propellers is to be stable. Its fluctuation at 0° pitch angle is not to exceed ±0.5°.
11.3.6.6 At the rated speed of the propeller, the time required for the change of pitch angle from 1/3 positive maximum (or 1/3 negative maximum) to 1/3 negative maximum (or 1/3 positive maximum) is not

to exceed 15 s.

11.3.6.7 The pitch adjusting range of controllable pitch propeller is to ensure that the main engine will provide rated power under rated speed and specified astern power.

11.3.6.8 Thread core diameter d_k of blade fastening bolts is not to be less than the value obtained from following formula:

$$d_k = 2.6\sqrt{\frac{W_{0.35R} R_{P0.2} \alpha_A}{dZR_{eH}}} \quad \text{mm}$$

where: $W_{0.35R}$ — section modulus of cylindrical section at radius $0.35R$, in mm^3;

$$W_{0.35R} = 0.11\ (Bt^2)_{\ 0.35R}$$

where: B — breadth of blade on section at radius $0.35R$, in mm;

t — maximum thickness of blade on section at radius $0.35R$, in mm.

$R_{P0.2}$ — 0.2% proof stress of propeller material, in N/mm^2;

α_A — tightening factor for retaining bolts, = 1.2 to 1.6, depending on the method of tightening used;

d — diameter of pitch circle of bolt hole of fastening bolts, in mm;

Z — number of bolts;

R_{eH} — yield strength of fastening bolts, in N/mm^2.

11.3.6.9 Under following conditions, the controllable pitch propeller is to have alarm function:

(1) pressure of hydraulic system is too low;

(2) oil level of main hydraulic oil tank is too low;

(3) oil filter is blocked;

(4) pressure of boss lubricating oil is too low (except for grease lubricating method);

(5) temperature of hydraulic oil is too high;

(6) pitch adjusting function fails;

(7) power supply of control system fails.

11.3.6.10 Suitable devices are to be fitted to ensure that an alteration of the blade setting cannot overload the propulsion plant or cause it to stall.

11.3.6.11 Steps are to be taken to ensure that, in the event of failure of the control system, the setting of the blades does not change or assumes a final position slowly enough to allow the emergency control system to be put into operation.

11.3.6.12 Controllable pitch propeller systems are to be equipped with means of emergency control enabling the controllable pitch propeller to remain in operation should the remote control system fail. It is recommended that a device be fitted which locks the propeller blades in the “ahead” setting.

In case of emergent fixed propeller condition, effective measures are to be provided to prevent pitch adjustment.

11.3.6.13 Before being installed on board, the pipe lines and pressure elements of hydraulic transmission system and control system for controllable pitch propellers are to be subject to hydraulic tests to a pressure of 1.5 times the design pressure. On completion of installation, the system is to be tested to 1.25 times the working pressure for tightness, but need not exceed the design pressure plus 7 MPa.

11.3.6.14 Controllable pitch propeller and its main parts are to be subject to material test and non-destructive test according to the relevant requirements of CCS Rules for Materials and Welding.

11.3.6.15 A sealing is to be inserted between the propeller blade and the propeller boss to prevent the ingress of sea water and sand as well as the leakage of lubricating grease.

11.3.6.16 The inside of the propeller bosses is to be filled up with lubricating grease.

11.3.6.17 The pitch control system of CP propellers for main propulsion is to be tested and recorded in accordance with the following requirements, in order to demonstrate that the propelling thrust is not significantly altered when transferring control from one location to another and in case of failures in the control system, and that the pitch response times measured during the test do not exceed the maximum value.

(1) A full range of pitch response tests is to be carried out to get the pitch response and verify that it coincides with the combinator curve of the propeller. The tests are to be carried out for at least three positions of the control lever in ahead and astern directions (e.g., dead slow ahead / astern, half ahead / astern, full ahead / astern). The tests are to be carried out in normal and emergency operating conditions. Tests that are not affected by the control position may be carried out from one control position only.

(2) A test of the fail-to-safe characteristics of the propeller pitch control system is to be carried out to demonstrate that failures in the pitch command and control or feedback signals are alarmed and do not cause any change of thrust. Such failures are to be clearly identified and included in the test procedure.

(3) The test is to record: Position of the control handle; Actual pitch indication (local indication, remote

indications); Rotational speed of the propeller; Response time between the pitch change order (modification of the lever position) and the instant when the pitch and propeller speed have reached their final position; Propelling thrust variation during the transfer of the control from one location to another one.
(4) The test procedure, including the list of the parameters to be recorded and the maximum pitch response time, is to be prepared and submitted by the pitch control system manufacturer or integrator and agreed with CCS.

11.3.7 Z propulsion arrangement

11.3.7.1 Z propulsion arrangement is to be provided with means to control its propulsion direction from bridge, machinery control station (if any) and on the spot. Indicators of direction of thrust are to be provided in these control locations.

11.3.7.2 When the output shaft of main engine and input shaft of Z propulsion arrangement are not in the same level, universal couplings are to be provided in pair with same angle which is in general not to be more than 10°.

11.3.7.3 If Z propulsion arrangement has electric or electro-hydraulic power equipment of steering turning device , spare power equipment or other emergency control measures are to be provided.
If there are two or more Z propulsion arrangement on the ship, spare power equipment is not necessary.

11.3.7.4 The diameters of input shaft, vertical shaft and propeller shaft of Z propulsion arrangement are not to be less than the value obtained from calculation according to the formula in 11.2.2.1 of this Chapter.

11.3.7.5 Shafting vibration calculation of Z propulsion arrangement is to comply with the requirements in Chapter 12 of this PART.

11.3.7.6 Strength and installation of propeller of Z propulsion arrangement are to comply with the requirements in Section 4, Chapter 11 of this PART.

11.3.7.7 All alarms related to system failure are to be shown on maneuvering console. Z propulsion arrangement is to have alarm function under following conditions:
(1) low pressure of lubricating oil;
(2) high temperature of lubricating oil;
(3) low level of hydraulic oil;
(4) low pressure of hydraulic oil;
(5) high temperature of hydraulic oil (if fitted with oil cooler);
(6) too high pressure difference of hydraulic oil filter (if fitted with oil filter);
(7) low pressure of clutch.

11.3.7.8 On completion of manufacture of parts of Z propulsion arrangement such as upper and lower gearbox, rotating rudder gearbox and rudder post, 0.2 MPa hydraulic test is to be carried out and tightness test is to be carried out after assembly. Tightness test may be carried out using liquid with 0.1 MPa pressure, and 0.03 MPa compressed air may be used for test examination by means of applying soap liquid. No leakage is permitted.

11.3.7.9 Hydraulic pipes are to be subject to hydraulic tests to a pressure of 1.5 times the design pressure. On completion of installation, they are to be tested together with fittings to 1.25 times the design pressure for tightness.

11.3.7.10 Z propulsion arrangement together with its main parts and accessories are to be subject to material test and non-destructive test according to CCS Rules for Materials and Welding.

11.3.7.11 Steering gear of Z propulsion arrangement is to comply with the requirements of Section 1, Chapter 13 of this PART.

11.3.8 Transverse propulsion arrangement

11.3.8.1 Transverse propulsion arrangement is to have sufficient transverse thrust to satisfy the working requirements of navigation at low speed and docking and leaving wharf.

11.3.8.2 Material and test of transverse propulsion arrangement and its components are to comply with the relevant requirements of CCS Rules for Materials and Welding.

11.3.8.3 Diesel engines driving transverse propulsion arrangement are to comply with the relevant requirements in Chapter 9 of this PART.

11.3.8.4 Motor and distribution system of driving transverse propulsion arrangement are to comply with the relevant requirements in PART FOUR of the Rules.

11.3.8.5 The design of shafting together with its parts and propeller is to comply with the relevant requirements of this Chapter.

11.3.8.6 The thickness of tunnel of transverse propulsion arrangement is not to be less than the adjacent part of the hull.

11.3.8.7 The shaft sealing box is to be installed to prevent water so as to protect steel shafts from sea

water.
11.3.8.8 Alarm is to be in the bridge with individual or groupwise indicator for the following faults:
(1) overload of prime mover and servo unit;
(2) power failure of remote control system;
(3) power failure of alarm system;
(4) low level in lubrication oil tank (if fitted);
(5) low lubrication oil pressure (if forced lubrication oil system);
(6) low level in hydraulic supply tank;
(7) low pressure in hydraulic system.
11.3.8.9 Individual indication in the bridge is required for:
(1) running and stop of prime mover;
(2) propeller pitch for controllable pitch propeller plants;
(3) direction of rotation and r.p.m. for fixed propeller plants.
11.3.8.10 It is to be possible to stop the transverse propulsion arrangement from the bridge by means of a system independent of the remote control system.
11.3.8.11 Instrumentation and automation are also to comply with the relevant requirements of PART SEVEN of the Rules.

Section 4 PROPELLERS

11.4.1 General requirements

11.4.1.1 Propellers are to be subject to surface inspection and size verification as well as to static balancing test. For built-up propellers and controllable pitch propellers, the static balancing test is to be carried out respectively after machining and assembling.
11.4.1.2 Blade fastening studs of built-up propellers are to be made of forged steel having a tensile strength not less than 400 N/mm^2.
11.4.1.3 Fasteners (studs, nuts, etc.) for propellers and for their accessories are to be fitted with reliable devices to prevent loosening and corrosion.

11.4.2 Clearances between propeller and hull

11.4.2.1 For the purpose of modifying the effect of propeller excitation on hull, the necessary minimum clearances between the propeller and the hull are to be provided as specified in 2.14.4 of PART TWO of the Rules.

11.4.3 Thickness of propeller blades

11.4.3.1 The thickness of propeller blades t (at 0.25 *R* and 0.6 *R* for solid propellers, and at 0.35 *R* and 0.6 *R* for controllable pitch propellers) is not to be less than that calculated by the following formula:

$$t = \sqrt{\frac{Y}{K - X}} \quad \text{mm}$$

where: *Y* — power coefficient, to be obtained from 11.4.3.2 of this Section;
K — material coefficient given in Table 11.4.3.1;
X — speed coefficient, to be obtained from 11.4.3.3 of this Section.

Propeller material coefficient *K* **Table 11.4.3.1**

Material	tensile strength R_m (N/mm^2)	Material density *G* (g/cm^3)	Material coefficient *K*
Carbon steel and alloy steel	400	7.9	0.57
Ferritic and martensitic stainless steel	500	7.7	1.04
Austenitic stainless steel	450	7.9	1.04
Cu1 manganese bronze	440	8.3	1
Cu2 nickel-manganese bronze	440	8.3	1
Cu3 nickel-aluminum bronze	590	7.6	1.38
Cu4 manganese-aluminum bronze	630	7.5	1.17

Note: For materials other than specified in the above Table, the value *K* may be determined by making reference to those given in the Table.

11.4.3.2 Power coefficient *Y* is to be calculated by the following formula:

$$Y = \frac{1.36 A_1 N_e}{Zbn_e}$$

where: $A_1 = \frac{D}{P}(K_1 - K_2 \frac{D}{P_{0.7}}) + K_3 \frac{D}{P_{0.7}} - K_4$;

D — propeller diameter, in m;

P — pitch at the section under consideration, in m;

$P_{0.7}$— pitch at 0.7 R, in m;

R — propeller radius, in m;

K_1, K_2, K_3, K_4 — coefficients given in Table 11.4.3.2;

N_e— rated power of the main engine, in kW;

Z — number of blades;

b — blade width at the section under consideration, in m;

n_e— speed of the propeller at rated power of main engine, in r/min.

For aerofoil sections with trailing edge washback, the value of A_1 obtained from above formula is to be increased by 30%. The trailing edge washback is the offset of the trailing edge of the tangent plane of the propeller blade in respect to the pitch baseline (external chord) of the blade face, as shown in Figure 11.4.3.2, e.g. 0.6R without washback and 0.25R with washback.

Coefficient *K* values in way of different diameters of propeller **Table 11.4.3.2**

K / r	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8
0.25R	634	250	1410	4	82	34	41	380
0.35R	520	285	1320	16	64	28	57	420
0.60R	207	151	635	34	23	12	65	330

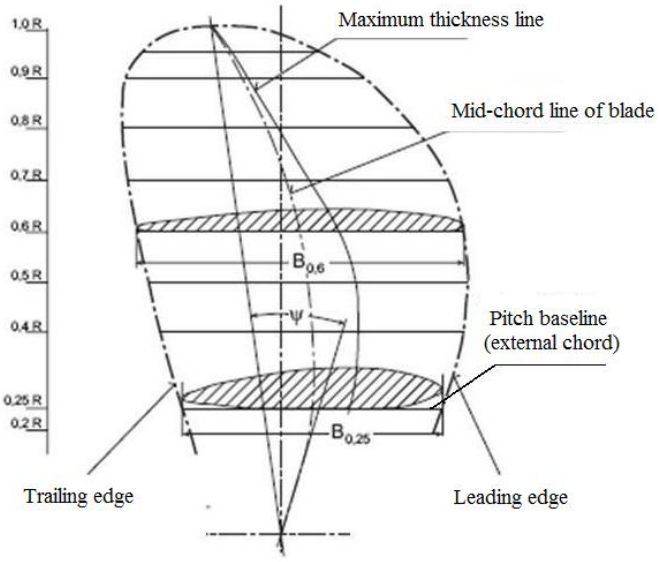


Figure 11.4.3.2

11.4.3.3 Speed coefficient X is to be calculated by the following formula:

$$X = \frac{A_2 G A_d n_e^2 D^3}{10^{10} Zb}$$

where: $A_2 = \frac{D}{P}(K_5 + K_6 \varepsilon) + K_7 \varepsilon + K_8$

D, P, n_e, Z and b as defined in 11.4.3.2 of this Section;

ε — rake angle of propeller blade, in degrees. The value of the rake angle is positive for backward rake and negative for forward rake. The rake angle is, as shown in the side view of propeller, is an angle taken in one of the following three conditions:

— ε_1 and ε_2 are backward rake angles: the more backward one is to be taken ($\varepsilon = \varepsilon_1$, as shown in Figure 11.4.3.3.3(1));

— ε_1 and ε_2 are forward rake angles: the less forward one is to be taken ($\varepsilon = \varepsilon_2$, as shown in

Figure 11.4.3.3.3(2));

— ε_1 and ε_2 are rake angles on both sides of the centreline: the backward one is to be taken ($\varepsilon = \varepsilon_1$, as shown in Figure 11.4.3.3.3(3)).

ε_1 is the angle measured from the line perpendicular to shaft centerline to the tangent to the backward thickness line at the radius 0.6R of the side projection of propeller blade;

ε_2 is the angle obtained by the following formula:

$$\varepsilon_2 = \tan^{-1}\frac{e}{R}$$

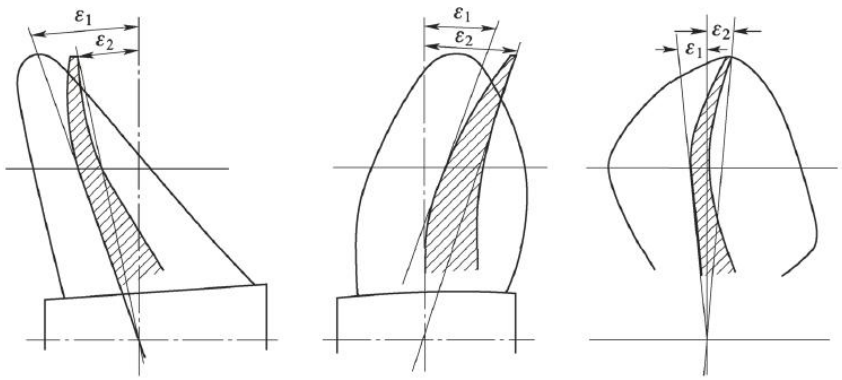
where: e — rake (radial inclination of blade section forward or backward from the reference line, taken as the distance between the blade tip projected on the propeller shaft and the intersection of the reference line and the propeller axis), in m;

R — the same as in 11.4.3.2.

K_5, K_6, K_7, K_8 — coefficients given in Table 11.4.3.2;

G — density of the propeller material, in g/cm^3;

A_d — expanded area ratio.



(1) (2) (3)

Figure 11.4.3.3 Rake Angle of Propeller Blade

11.4.3.4 The thickness of propeller blades is permitted to be calculated by some other appropriate methods, but background of test results or service experience is to be provided.

11.4.3.5 Depending on the condition of application of the propeller, detailed data of wake field in periphery of the propeller or blade thickness increase may be required.

11.4.4 Fitting of propellers to screwshafts

11.4.4.1 Where it is proposed to fit the propeller to the screwshaft with a flange, the diameter of flange bolts is to comply with the requirements of 11.3.3.1 and 11.3.3.3 of this Chapter, and the thickness of flanges is to comply with the provisions of 11.3.2.1(2) of this Chapter.

11.4.4.2 Where it is proposed to fit the propeller to the screwshaft with a key, the propeller boss is to be a good fit on the screwshaft cone. The length of the forward fitting surface is to be about the diameter of the screwshaft.

The taper of the coned end of screwshaft is not to exceed 1/10, and for keyless propellers fitted by oil injection method, such taper is not to exceed 1/15.

The intersection of cylindrical and conical portions of screwshafts is not to be shouldered or rounded. The forward end of the keyway in the screwshaft is to be smoothed and sled-runner shaped. In general, the shape and size may be in accordance with Figure 11.4.4.2, where $r_1 < r_2 < r_3 < r_4$, $AB = BC = CD = DF = x$ (x being depth of keyway).

For r_1, r_2, r_3 and r_4, refer to the following:

$r_1 = x/8$, $r_2 = 3x/8$, $r_3 = 3x/4$, $r_4 = x$.

The values of r_5 are given in Table 11.4.4.2.

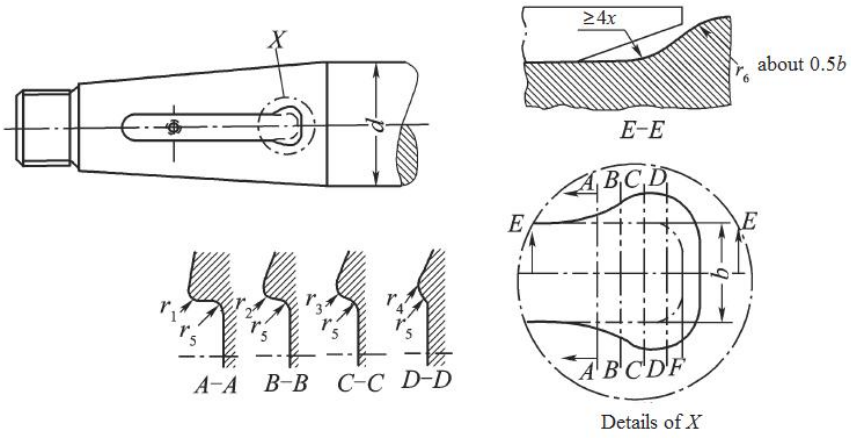


Figure 11.4.4.2

Values of r_5 **Table 11.4.4.2**

d (mm)	r_5 (mm)	d (mm)	r_5 (mm)
$d \leq 150$	3	$250 < d \leq 400$	5
$150 < d \leq 250$	4	> 400	6

The distance from the forward end of the keyway to the big end of conical portion of the shaft is not to be less than 0.2 times the diameter of the big end.

There is to be a clearance between the top of the key and the boss. The lateral sides of the key are to be in close contact with those of the keyways in the screwshaft and the propeller boss. The bottom of the keyways are to be provided with a smooth fillet, and the fillet radius is not to be less than 1.25% of the diameter of the big end of the cone.

Keys are to be secured to the shafts by screws. The forward screw is to be placed at least 1/3 of the length of the key from the end. The depth of the screw holes is not to exceed the diameter of screw holes, and the edges of the holes are to be beveled.

The outside diameter of the threaded end for the propeller retaining nut is not to be less than 60% of the calculated diameter of the propeller shaft.

11.4.4.3 Where the torques are transmitted completely by the keys, the effective sectional area of the key in shear is not to be less than the value determined by the following formula, and the tensile strength of the material is to be equal to or greater than that of the shaft material:

$$BL \geq \frac{d^3}{2.35 d_m} \qquad \text{mm}^2$$

where: B — breadth of the key, in mm;

L — effective length of the key, in mm;

d — diameter required for the intermediate shaft, in mm, to be taken as 800 N/mm^2 when the tensile strength of intermediate shaft material is greater than 800 N/mm^2 during calculation;

d_m — diameter of shaft at mid-length of the key, in mm.

11.4.4.4 The fitting of a keyed propeller is preferable to meet the following requirements, and the size of keys may be suitably reduced:

(1) the safety factor of friction force against sliding is not to be less than 1.0 at sea water temperature of 35°C;

(2) the inner surface pressure of propeller boss is not to be less than 20 MPa at sea water temperature of 15°C;

(3) the equivalent uniaxial stress at the inner surface of propeller boss is not to be more than 35% of the specified minimum yield stress of the material concerned at sea water temperature of 0°C.

11.4.5 Fitting of keyless propeller by oil shrink method

11.4.5.1 Where keyless fitting propellers with oil pressure, the axial pull-up length from propeller boss to shaft is to be in compliance with the requirements of 11.4.5.2.

11.4.5.2 The maximum equivalent uniaxial stress in the boss at 0°C based on the Mises-Hencky criterion is not to exceed 70% of the yield point or 0.2% proof-stress (0.2% offset yield strength) for the propeller

material based on the test piece value. For cast iron, the value is not to exceed 30% of the nominal tensile strength.

Where keyless fitting propellers with oil pressure, the axial pull-up length S from propeller boss to shaft may also meet the formulae given below:

Minimum required surface pressure at 35℃:

$$P_{35} = \frac{S_F T}{AB}\left(-\frac{S_F K}{2} + \sqrt{\mu^2 + B\left(\frac{F_v}{T}\right)^2}\right) \quad \text{N/mm}^2$$

Minimum pull-up length at 35℃:

$$S_{35} = P_{35}\frac{d_1}{K}\left(\frac{1}{E_2}\left(\frac{K_2^{\,2}+1}{K_2^{\,2}-1} + \mu_2\right) + \frac{1}{E_1}(1-\mu_1)\right) \quad \text{mm}$$

Minimum pull-up length at temperature t ($t < 35$℃):

$$S_t = S_{35} + \frac{d_1}{K}(a_2 - a_1)(35 - t) \quad \text{mm}$$

Corresponding minimum surface pressure at temperature t:

$$P_t = P_{35}\frac{S_t}{S_{35}} \quad \text{N/mm}^2$$

Minimum push-up load at temperature t:

$$W_t = AP_t\left(\mu + \frac{K}{2}\right) \quad \text{N}$$

Maximum permissible surface pressure at 0℃:

$$P_{\max} = \frac{0.7R_{eH}(K_2^2 - 1)}{\sqrt{3K_2^4 + 1}} \quad \text{N/mm}^2$$

Maximum pull-up length at 0℃:

$$S_{\max} = \frac{P_{\max}}{P_{35}}S_{35} \quad \text{mm}$$

Maximum pull-up length at 35℃:

$$S_{max} = \frac{P_{max}}{P_{35}}S_{35} - \frac{35(\alpha_2 - \alpha_1)d_1}{K} \quad \text{mm}$$

where: $B = \mu^2 - \dfrac{S_F^2 K^2}{4}$

$$F_v = \frac{2000CM_e}{d_1} \quad \text{N}$$

$$T = 1762\frac{N_e}{V} \quad \text{N}$$

S_F — factor of safety against friction slip at 35℃, not to be less than 2.8 under the action of rated torque (based on rated power r.p.m.) plus torque due to torsionals;

T — rated thrust, in N;

V — ship speed at rated horsepower, in kn;

μ — coefficient of friction between mating surfaces. For the oil injection method, the coefficient of friction is to be 0.13 for bosses made in copper-based alloy and steel;

F_v — shear force at interface, in N;

M_e — rated torque corresponding to N_e and n_e, in Nm;

C — constant:

C = 1 for turbines, geared diesel drives, electric drives and for direct diesel drives with a hydraulic or an electromagnetic or high elasticity coupling;

C = 1.2 for a direct diesel drive.

The c constant is increased if the shrinkage has to absorb an extreme high pulsating torque.

Maximum pull-up length at 35℃:

$$S_{\max} = \frac{P_{\max}}{P_{35}} S_{35} - 35(\alpha_2 - \alpha_1) d_1 / K \qquad \text{mm}$$

where: K — taper of the propeller shaft cone, $K \leq 1/15$;

N_e — rated output transmitted to the propeller shaft, in kW;

n_e —propeller speed at rated output Ne, in r/min;

A —100% theoretical contact area of propeller boss and propeller shaft, in mm^2, as read from drawings and disregarding oil grooves;

$$K_2 = \frac{d_2}{d_1}$$

d_1 —diameter of propeller shaft at the midpoint of the taper in the axial direction, in mm;

d_2 — mean outer diameter of the propeller boss at the axial position corresponding to d_1, in mm;

μ_1 — Poisson's ratio for shaft material, see Table 11.4.5.2;

μ_2 — Poisson's ratio for propeller material l, see Table 11.4.5.2;

E_1 — modulus of elasticity of propeller shaft material, see Table 11.4.5.2;

E_2 — modulus of elasticity of propeller material, see Table 11.4.5.2;

t — temperature at time of fitting propeller on shaft, in℃;

α_1 — coefficient of linear expansion of propeller shaft material, see Table 11.4.5.2;

α_2 — coefficient of linear expansion of propeller material, see Table 11.4.5.2;

R_{eH} — yield point or 0.2% proof stress of propeller material, in N/mm^2.

Material factor Table 11.4.5.2

Material	Modulus of elasticity	Poisson's ratio	coefficient of linear expansion (1/℃)
Cast and forged steel	20.6×10^4	0.29	12×10^{-6}
Cast iron	9.8×10^4	0.26	12×10^{-6}
Copper-based alloy Cu1 and Cu2	10.8×10^4	0.33	17.5×10^{-6}
Copper-based alloy Cu3 and Cu4	11.8×10^4	0.33	17.5×10^{-6}

11.4.5.3 Where keyless propellers are fitted by the oil shrink method at a temperature below 0℃, the ambient temperature for fitting the propeller to the shaft is not to be less than the value calculated by the following formula:

$$t_{\min} = \frac{KP_{\max}S_{35} - P_{35}KS_{35} - 35P_{35}d_1(\alpha_2 - \alpha_1)}{P_{35}d_1(\alpha_1 - \alpha_2)} \qquad ℃$$

11.4.5.4 Prior to final pull-up, the contact area between the mating surfaces is to be checked and is not to be less than 70% of the theoretical contact area (100%). Non-contact bands extending circumferentially around the boss or over the full length of the boss are not acceptable. After final pull-up, the propeller is to be secured by a nut on the propeller shaft. The nut is to be secured to the shaft.

11.4.5.5 Prior to final pull-up, the propeller and shaft are to be at the same temperature and the mating surfaces are to be clean and free from oil or grease. The bedding of the propeller with the shaft is to be demonstrated in the workshop to the satisfaction of the Surveyor.

11.4.5.6 A copy of the fitting curve relative to temperature, and data of corresponding loads are to be kept on board. Special tools for fitting and dismantling purposes are also to be provided on board.

11.4.5.7 The formulae given in 11.4.5.2, for the ahead condition, will also give sufficient safety in the astern condition. The formulae are applicable for solid shafts only and are not applicable for propellers where a sleeve is introduced between shaft and boss.

CHAPTER 12 SHAFT VIBRATION AND ALIGNMENT

Section 1 GENERAL PROVISIONS

12.1.1 General requirements

12.1.1.1 The arrangement of shafting and the scantlings of shafts are, in addition to the provisions of Chapter 11 of this PART, to comply with the requirements of this Chapter. The whole shafting could only be finally approved after the previous approval of the torsional, axial and lateral vibrations as well as the alignment of the said shafting.

12.1.1.2 Calculations for vibration and alignment of shafting are to be submitted for approval. Reports on measurements as deemed necessary are to be submitted for approval or information.

12.1.1.3 Novel and sophisticated shafting may be approved provided that measurement reports for similar installations are available and proved to be in compliance with the provisions of this Chapter.

12.1.1.4 Where changes are subsequently made to a shafting which has been approved, e.g. by fitting a highly flexible coupling, changing the size of shaft bearings and the engine type, or fitting a gearbox or a propeller of a different design, or changing the number of bearings etc. revised calculations of shaft vibration and alignment are to be made as appropriate and submitted for approval.

12.1.1.5 Calculations of shaft vibration and alignment are to include the detailed specifications and documents necessary for approval and checking.

12.1.1.6 In addition to shafting alignment requirements in Section 5 of this Chapter, ships complying with the provisions of Appendix 1 of this Chapter may be assigned the notation ESA upon request.

12.1.2 Restricted speed ranges

12.1.2.1 Restricted speed ranges will be imposed in the regions of resonant speeds n_c, where amplitudes or stresses or torques resulting from shaft vibration exceed the limiting values for continuous running as specified in this Chapter. The engine is not to be run continuously in such restricted speed ranges.

12.1.2.2 The following speed range is to be avoided:

$$\frac{16n_c}{18-r} \sim \frac{(18-r)n_c}{16}$$

where: $r = n_c/n_e$, n_e being the rated speed (r/min).

12.1.2.3 The restricted speed range for continuous operation may be suitably extended where amplitudes or stresses or torques resulting from vibration approach the limiting values for transient running as specified in this Chapter, and may be adequately reduced where they marginally exceed the limiting value for continuous running.

12.1.2.4 Restricted speed ranges may also be ascertained by measurements, i.e. the range of speed to be avoided for continuous running may be taken as that over which the measured values of amplitudes, or stresses, or torques resulting from shaft vibration are in excess of those allowed for continuous running, having regard to the tachometer accuracy.

12.1.2.5 Where the torsional vibration causes hammering of transmission gears or where the pulsatory torque of the elastic elements exceeds the allowable value for continuous running, restricted speed ranges are also to be imposed.

12.1.2.6 Where restricted speed ranges are imposed, the tachometer accuracy is to be within ±2% in way of the restricted speed range.

12.1.2.7 Restricted speed ranges are to be marked red on the tachometer, and notice boards are to be fitted in front of the control stations.

12.1.3 Measurements

12.1.3.1 Manufacturers are required to carry out torsional and axial (if required) vibration measurements on benches to their products of a new design or having undergone a major alteration, and to have all the equivalent parameters checked.

12.1.3.2 CCS may decide whether measurements are required for verification, depending upon the conditions of the method of calculation, the magnitudes of amplitudes or stresses or torques contained in the calculations submitted. The vibration measurements may be dispensed with provided that measurement reports for similar installations are submitted and proved to be in compliance with the provisions of this Chapter.

12.1.3.3 The instrumentation, measured points and a series of revolution step of vibration measurements are to be such that they can correctly demonstrate the characteristics of vibration mode to be measured.

Alternating torsional stresses are amplitudes of the maximum and minimum torsional stresses, which can be measured in relevant conditions of repetitive cycle process.

12.1.3.4 Where the difference between the measured and calculated values of natural vibration frequency is less than ±5%, the amplitudes or stresses (torque) at any cross-section of the system may be generally estimated by the measured amplitudes or stresses (torque) in accordance with the vibration mode under consideration.

12.1.3.5 The measurement reports of torsional vibration are to include order, angular amplitude or stress, natural frequency, torsional vibration of each shaft, vibratory torque of the gear and elastic couplings (where applicable) at each measuring point under test speed, and to make stress/torque and speed curves with the allowable value.

12.1.3.6 During measurement, the main engine is to start from the minimum steady speed to the rated speed, and the measurement is to be carried out under the condition of different speed and steady speed. Near the resonance speed, the speed separation is to be reduced appropriately.

12.1.3.7 In general, torsional vibration is to be measured in the following cases:

(1) the calculated torsional vibration stress has reached 70% of that permitted for continuous operation or over within the speed range of $r = 0.8$ to 1.0;

(2) the calculated torsional vibration stress is less than, but has reached 90% of that permitted for transient operation within the speed range of $r < 0.8$;

(3) certain novel shafting systems contain unconventional parts.

12.1.4 Miscellaneous

12.1.4.1 Where the bed-plates of machinery are installed on resilient mountings, the shafting is to be elastically connected.

12.1.4.2 The method of calculation and the particulars to be submitted in relation to the requirements of this Chapter may refer to CCS Guidelines for Vibration Control on Board Ships.

12.1.4.3 The pressure gauge and lower pressure alarm or amplitude monitoring device for oil supply are to be fitted for torsional or axial vibration dampers, for which the oil is supplied from the lubricating oil circulating system for main engine, unless effective measures are to be taken to identify the normal work of the vibration dampers.

12.1.4.4 The allowable stress of torsional vibration and allowable amplitude values of axial vibration may also be ascertained in accordance with Appendix 3, Chapter 9 of this PART.

Section 2 TORSIONAL VIBRATION

12.2.1 Application

12.2.1.1 The requirements of this Section are applicable to the following systems:

(1) main diesel engine propulsion systems, except in the case of ships classed for port service when fitted with engines having powers less than 110 kW.

(2) auxiliary diesel engine systems used for essential services, where the power developed by the auxiliary engines is 110 kW or over.

(3) propulsion systems formed by turbines;

(4) propulsion systems formed by electric motors.

12.2.2 Torsional vibration calculations

12.2.2.1 Torsional vibration calculation is to include: engine type, rated power, rated speed, shafting arrangement, tensile strength of shaft, equivalent parameters of torsional vibration for the dynamic system with necessary specification, Holzer tables for each vibration node under consideration and the associated vectorial sums of relative amplitudes, vibratory response calculation of main harmonics and the corresponding permissible values.

12.2.2.2 Where installations have different application conditions, e.g. combined with clutches, P.T.O. systems or having more than one engine, the torsional vibration calculations are to be carried out for each case.

12.2.2.3 Where there is considerable difference between the sizes of the spare propeller and the working propeller, torsional vibration is also to be calculated for the condition when the spare propeller is used.

12.2.2.4 The special speed requirements for prolonged periods in service are also to be indicated, e.g. the range of the service speed of a controllable pitch propeller and the range of the service speed of a P.T.O. system, etc.

12.2.2.5 Where controllable pitch propellers are fitted, torsional vibration calculations for zero and full

pitches are to be carried out.

12.2.2.6 Torsional vibration calculation is to be carried out with one cylinder misfiring in addition to that under normal working condition.

12.2.2.7 In general, the calculation is to cover the resonant conditions arising from all harmonic torque excitation up to order 12, in a speed range of 0.8 n_{min} to 1.2 n_e (n_{min} being the minimum steady speed, in r/min). For diesel engine propulsion system, if energy method is adopted to calculate torsional vibration, the calculation of non-resonant condition over 1.2 n_e, resulting from the main harmonic of one node vibration, is also to be carried out.

12.2.3 Allowable stresses

12.2.3.1 The allowable torsional vibration stresses for shafting are to be calculated based on the basic diameters of the shafts, i.e. the crankpin diameter for crankshafts, the minimum diameter for intermediate shafts and the minimum diameter between the aft bearing and the bulkhead gland for screwshafts, and the effect of the stress concentration on the plain sections of the shafting may be neglected.

12.2.3.2 The allowable torsional vibration stresses for main engine crankshafts are not to exceed the values given by the following formulae:

Continuous running $(0 < r \leq 1.0)$:

$$[\tau_c] = \pm [(52-0.031d)-(33.8-0.02d)\, r^2] \quad N/mm^2$$

$(1.0 < r \leq 1.05)$:

$$[\tau_c] = \pm [(18.1-0.0113d)+(87.3-0.052d)\sqrt{r-1}\,] \quad N/mm^2$$

Transient running $(0 < r < 0.8)$:

$$[\tau_t] = \pm 2.0\, [\tau_c] \quad N/mm^2$$

The symbols used in 12.2.3.2 to 12.2.3.4 are defined as follows:

$[\tau_c]$ — allowable torsional vibration stress for continuous running, in N/mm^2;

$[\tau_t]$ — allowable torsional vibration stress for transient running, in N/mm^2;

d — basic diameter of shafts, in mm;

$r = n_c/n_e$;

n_c — critical speed, in r/min;

n_e — rated speed, in r/min.

12.2.3.3 High cycle fatigue criterion (typically >> 10^7), i.e. torsional vibration stresses permitted for continuous operation as well as reverse bending stresses. The influence of reverse bending stresses is addressed by the safety margins, see the provisions of 11.2.2, Chapter 11 of this PART.

The allowable torsional vibration stresses for thrust, intermediate, tube shafts and screwshaft are not to exceed the values given by the following formulae:

Continuous running $(0 < r < 0.9)$:

$$[\tau_c] = \pm C_W C_K C_D (3-2\, r^2) \quad N/mm^2;$$

$(0.9 \leq r \leq 1.05)$:

$$[\tau_c] = \pm 1.38\, C_W C_K C_D \quad N/mm^2;$$

Transient running $(0 < r \leq 0.8)$:

$$[\tau_t] = 1.7\, [\tau_c] / \sqrt{C_K} \quad N/mm^2$$

where: C_W — material factor; $C_W = (R_m + 160)/18$;

R_m — specified tensile strength of shaft material, in N/mm^2. For intermediate shaft, when carbon and manganese steel is used, it is to be taken as 600 N/mm^2 for R_m> 600 N/mm^2; when alloy steel is used, it is to be taken as 800 N/mm^2 for R_m> 800 N/mm^2. For special approval of alloy steel used for intermediate shaft material, the tensile strength of shaft material may be greater than 800 N/mm^2, but less than 950 N/mm^2, where such approval of the material comply with the relevant requirements for torsional fatigue test①, cleanliness ② and inspection. The requirements of 5.1.1.1, 5.3.2.1, 5.3.2.3 and 5.3.4.5 for the cleanliness of material, and the requirements of 5.1.6 for the inspection in Chapter 5, PART ONE of CCS Rules for Materials and Welding are to be complied with. For screwshaft and tube shaft, it is to be taken as 600 N/mm^2 for R_m> 600 N/mm^2;

C_K — shape coefficient, see Table 12.2.3.3;

C_D — size factor: $C_D = 0.35+0.93\, d^{-0.2}$. The size factor being a function of diameter only does not

① Torsional fatigue test is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

② Cleanliness is to meet the requirements of 7.4.6 of Guidelines for Inspection of Forged Steel.

purely represent a statistical size influence, but rather a combination of this statistical influence and the notch sensitivity.

Shape coefficient C_K **Table 12.2.3.3**

Intermediate shafts						Thrust shafts		Propeller shafts and tube shafts		
Integral coupling flange	Shrink fit coupling	Keyway, tapered connection	Keyway, cylindrical connection	Radial hole	Longitudinal slot	On both sides of thrust collar	In way of axial bearings where roller bearing is used as thrust bearing	Flange mounted or keyless taper fitted propeller shafts	Key fitted propeller shafts	The portion of the screwshaft and tube shaft forward of the length of screwshaft required by 11.2.2.3 till it reaches the aft peak bulkhead
1.0①	1.0①	0.6	0.45	0.50	0.30②	0.85	0.85	0.55	0.55	0.8

Notes: ① For multiple-arc transition intermediate shaft, if C_K is greater than 1, the testing basis or service experience is to be provided and approved by CCS.

② C_K = 0.3 is a safe approximation within the limitations in note 4 of Table 11.2.2.1. More accurate estimate of the shape coefficient C_K may be determined by direct application of FE calculation or the following formula. In which case:

$$C_K = \frac{1.45}{scf}$$

where: *scf* — stress concentration factor, which is defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress (determined for the bored shaft without slots), to be calculated according to following formula:

$$scf = 2.3 + 0.8 \times \frac{(l-e)/d}{\sqrt{(1-d_0/d)\times e/d}}$$

l — length of slot, in mm;
e — width of slot, in mm;
d — basic diameter of shaft, in mm;
d_0 — actual bore of shaft, in mm.
This formula applies to:
- slots at 120 or 180 or 360 degrees apart.
- slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.
- slots with no edge rounding (except chamfering), as any edge rounding increases the scf slightly.

$$\alpha_{t(hole)} = 2.3 - 3\times\frac{e}{d} + 15\times\left(\frac{e}{d}\right)^2 + 10\times\left(\frac{e}{d}\right)^2 \times\left(\frac{d_i}{d}\right)^2$$

$\alpha_{t(hole)}$ represents the stress concentration of radial holes or simplified to 2.3.

12.2.3.4 The allowable torsional vibration stresses for the crankshafts and transmission shafts of diesel engines for generators and of auxiliary diesel engines for essential services and for the crankshafts of propulsion diesel engines running with constant speed are not to exceed the values given by the following formulae:

Continuous running $(0.9 \le r \le 1.10)$:

$$[\tau_c] = \pm (21.59 - 0.0132d) \quad \text{N/mm}^2;$$

Transient running $(0 < r < 0.95)$:

$$[\tau_t] = \pm 5.5\,[\tau_c] \quad \text{N/mm}^2.$$

12.2.3.5 For propulsion shafting running at constant speed, higher vibratory stress limits may be considered if background of service experience is provided.

12.2.3.6 Except the shafting material is of nodular graphite cast iron, the tensile strength of intermediate shaft material specified in 12.2.3.2 and 12.2.3.4 is greater than 430N/mm^2, the allowable stress τ' may be calculated by the following formula:

$$\tau' = \frac{R_m + 184}{614}\tau \quad \text{N/mm}^2$$

where: R_m — tensile strength of shaft material, in N/mm^2, to be taken as 600 N/mm^2 for R_m > 600 N/mm^2;
τ — allowable torsional vibration stress determined by 12.2.3.2 and 12.2.3.4 of this Section, in N/mm^2.

12.2.4 Additional requirements for generators

12.2.4.1 In the case of alternating current generators, the resultant vibration amplitudes at the rotor are not

to exceed 3.5° electrical degrees under rated load working conditions. Where the inverter provided with rectification can ensure the output of stable power supply to the grid for normal use, the electrical degree is not limited to 3.5°.

12.2.4.2 The vibratory inertia torques imposed on the generator rotors are to be limited to ± 2 M_e over the speed range of r = 0.95 to 1.10 (M_e being the torque at the rated speed), and to ± 6 M_e over the range of r < 0.95. Where a main engine drives two or more generators, the rated torque of each generator is to be taken into consideration separately.

12.2.5 Allowable vibratory torques for gearing and flexible coupling

12.2.5.1 The vibratory torque at gear engagement of the transmission gearing arrangements is not, in general, to exceed 1/3 of the rated full load mean torque in the range of r = 0.9 to 1.05. In cases where tooth surface contact stress and root bending stress of gears are less than the allowable values specified in Appendix 1, Chapter 10 of this PART, special consideration will be given to the acceptance of higher vibratory torque on the gears, but gear knock does not happen.

12.2.5.2 Flexible couplings are to be of such design that vibratory torque of the elastic elements is not to exceed the allowable pulsatory torque for continuous running and not to exceed the allowable pulsatory torque for transient running in the respective running conditions.

12.2.5.3 On the power output branch without load, the vibratory torque at gear engagement is not, in general, to exceed 20% of the rated full load mean torque.

12.2.6 Miscellaneous

12.2.6.1 No critical speed is to occur in the range of speed for normal service or in any special speed ranges required for service.

12.2.6.2 Restricted speed ranges in normal operating conditions (r = 0.8 to 1.0) are not acceptable. Restricted speed ranges in one-cylinder misfiring conditions of single propulsion engine ships are to enable safe navigation.

12.2.6.3 The torsional vibration stresses caused by the upper flank at r = 0.8 are not to exceed the allowable stress [τ_c].

12.2.6.4 Resulted stresses arising from resonance and major non-resonance are not to exceed 1.5 times the allowable torsional vibration stresses limited by this Section in the range of r = 0.8 to 1.05.

12.2.6.5 Where data from experience or detailed calculations are furnished by manufacturers, allowable torsional vibration stresses (or torques) as supplied by the manufacturers may be adopted.

12.2.6.6 The allowable torsional vibration stresses for crankshafts may also be obtained in accordance with the Unified Requirements of IACS. However the calculations are to be submitted in accordance with the requirements of Appraisal of Crankshaft Strength of Diesel Engines in Appendix 3, Chapter 9 of this PART.

Section 3 AXIAL VIBRATION

12.3.1 General requirements

12.3.1.1 For all main propulsion shafting systems, the ship-builders and designers are to ensure, so far as practicable, that excessive axial vibration amplitudes throughout the speed range are not to occur. Otherwise, restricted speed ranges are to be imposed or suitable means for reducing the amplitudes are to be provided as appropriate.

12.3.1.2 Documents of axial vibration characteristics of the slow-speed two-stroke diesel engine direct propulsion shafting systems and of the turbine propulsion shafting systems are to be submitted for approval.

12.3.2 Axial vibration calculations

12.3.2.1 Axial vibration calculations are to include: engine type, rated power, rated speed, shafting arrangement, equivalent parameters of systems and the necessary specification, the Holzer tables of 0-node and 1-node vibration and the associated vectorial sums of relative amplitudes difference, the vibratory response of major harmonics and the associated limits.

12.3.3 Allowable amplitudes

12.3.3.1 For diesel engine propulsion shafting systems, axial vibration amplitudes for continuous running arising from axial vibration in the range of r=0 to 1.0 are not to exceed the values calculated by following

formula:

$$[A_{a1}] = \frac{R[\Delta a_0]}{2(\Delta a_k)_{\max}(R + \frac{d_j}{2})} \quad \text{mm}$$

where: $[A_{a1}]$ — allowable axial vibration amplitude for continuous running at the free-end of the crankshaft, in mm;

$(\Delta_{ak})_{max}$ — the maximum relative amplitude difference in the crankshaft of the axial vibration mode under consideration, in mm;

d_j — the main journal diameter of the crankshaft, in mm;

$[\Delta_{a0}]$ — the maximum allowable difference between crank webs, in mm;

R — radius of the crank, in mm.

12.3.3.2 Allowable axial vibration amplitudes for transient running are in general, to be 1.5 times those for continuous running.

12.3.3.3 Where allowable values for continuous running are exceeded, restricted speed ranges are to be imposed. Generally, axial vibration amplitudes caused by resonance or the upper flank at r = 0.85 are not to exceed the allowable values for continuous running, and those caused by resonance or the lower flank at r = 1.0 are not to exceed the allowable values for continuous running.

12.3.3.4 Where data from experience or detailed calculations are furnished by manufacturers, allowable axial vibration amplitudes as supplied by the manufacturers may be adopted.

Section 4 WHIRLING VIBRATION

12.4.1 General requirements

12.4.1.1 For main propulsion shafting systems, the ship-builders and designers are to ensure, so far as practicable, that excessive amplitudes due to whirling vibration throughout the speed range are not to occur. Otherwise, restricted speed ranges are to be imposed or suitable means for frequency modulation are to be provided as appropriate.

12.4.1.2 For the propulsion shafting systems with brackets and cardan shafts, details of the whirling vibration characteristics are to be submitted for approval.

12.4.2 Whirling vibration calculations

12.4.2.1 Whirling vibration calculations are to include: engine type, rated power, rated speed, speed ratio (where applicable), shafting arrangement, lengths and positions of bearings, bearing materials, propeller mass and inertia, the resonant speed of 1 order and blade orders forward and backward whirling vibrations.

12.4.2.2 During whirling vibration calculation, bearing stiffness are to be taken into account, and the load distribution on bearings is also to be considered.

12.4.3 Speed ranges to be avoided

12.4.3.1 For the shafting systems with brackets and cardan shafts, the blade order forward whirling resonant speeds are not to appear in the range of r = 0.85 to 1.0, and 1 order forward whirling resonant speeds are to be 20% more than the rated speed.

Section 5 SHAFTING ALIGNMENT

12.5.1 General requirements

12.5.1.1 The alignment of main propulsion shafting systems is to comply with the requirements of this Section. For shafting systems using environmentally acceptable lubricants, the alignment of shafting systems is to additionally comply with the requirements of Chapter 4 of the Guidelines for Surveys on Implementation of the Requirements of U.S. Environmental Protection Agency on Environmentally Acceptable Lubricants.

12.5.1.2 The alignment of main propulsion shafting systems and the arrangement of bearings are to be such as to give reasonable bending moments and bearing reactions and minimize the effects of hull deformation or bearing weardown on shafting alignment.

12.5.1.3 For the shafting alignment of large ships, the effects of hull deformation when the ship is ballasted or fully loaded are to be taken into consideration.

12.5.1.4 Shafting alignment calculations together with shafting instructions for the following main propulsion shafting systems are to be submitted for approval:
(1) shafting systems where the propeller shaft has a diameter (hereinafter referred to as propeller shaft diameter) of 250 mm or greater in way of the aftermost sterntube bearing;
(2) shafting systems fitted with no sterntube forward bearing where the propeller shaft diameter is 200 mm or greater;
(3) shafting systems with speed reduction gear, of which the wheel is driven by two or more than two pinions;
(4) shafting systems for which the sterntube bearings are to be slope-bored or inclined;
(5) shaft generator or electrical motor as an integral part of the low speed shaft in diesel engine propulsion.
12.5.1.5 Shafting alignment instructions are to correctly reflect the calculation results for the alignment in cold condition, containing at least the contents of 12.5.4 and 12.5.5 of this Section.
12.5.1.6 In respect to shafting systems where the propeller shaft diameter is less than 250 mm, shafting alignment calculations are in general to be submitted for reference.
Where shafting alignment calculations are not submitted, the span of bearings etc. are to be included in the shafting strength calculations required by subparagraph 11.1.4.1(4), Chapter 11 of this PART, referring to the relevant requirements for shafting alignment in Chapter 9 of CCS Guidelines for Shipboard Vibration Control. In addition, the technological documents submitted by the shipyard regarding shafting alignment are to contain alignment instructions.

12.5.2 Shafting alignment calculations
12.5.2.1 Shafting alignment calculation results are to comply with the requirements of 12.5.3.
12.5.2.2 For a propulsion shafting system directly driven by a diesel engine, shafting alignment calculations are generally to be performed up to the 1st main bearing at the free end of the engine. For a gear-driven shafting system, shafting alignment calculations are to be performed up to the fore end of the gear wheel.
12.5.2.3 In shafting alignment calculations, the influence of thermal expansion of heated bearings (e.g. 55℃) during operation of the engine or gearbox and so far as possible, the influence of expansion of heated tanks (e.g. 45℃) in double bottom that are located below intermediate shaft bearings, are to be taken into account.
12.5.2.4 In shafting alignment calculations, the influence of different ambient temperatures (taken as 0℃, 10℃ or 20℃) on the installation of shafting systems is to be taken into account so far as practicable.
12.5.2.5 Shafting alignment calculations are to include engine type, rated power, rated speed, shafting arrangement, all point loads and their acting positions, positions and lengths of bearings, allowable bending moments and shearing forces at the output flange of diesel engines, allowable loads of individual bearings, bearing clearances, relative slope between the propeller shaft and the aftermost sterntube bearing, gearbox information and allowable load difference between fore and aft bearings of the gear wheel.
12.5.2.6 The shaft deflection, the bending moments or stresses, shear forces, and angles at different shaft sections, the loads and reaction force influence numbers of bearings obtained during reasonable shafting alignment in both cold and hot conditions are to be submitted. For shafting systems where the propeller shaft has a diameter of 500 mm or greater, or the design of multi-slope aftermost sterntube bearing is used, the shaft deflection, relative angle and bearing loads at the zero rudder angle as a minimum under rated speed are to be provided, taking into account hydrodynamics of propellers. The calculation results are to comply with the requirements of 12.5.3.2 and 12.5.3.7.
12.5.2.7 A bearing load measurement procedure is to be submitted, covering actual measurements, jacking positions and jack correction factors.
12.5.2.8 The sag and gap values of each couple of flanges for the installation of shafting systems (shaft flanges being not connected) are to be provided.
12.5.2.9 For slope-bored sterntube bearings or bearing inclinations, a detailed description of slope bores or bearing inclinations is to be provided.

12.5.3 Shafting alignment requirements
12.5.3.1 In the static condition, all bearing loads are to be positive, i.e. there is to be no voidable bearing load. The bearing load is generally not to be less than 20% of the sum of all weights between two adjacent spans.
12.5.3.2 Bearing loads are in general not to exceed the values specified below or by the manufacturer:
aftermost sterntube bearings: as specified in 11.2.5.1, Chapter 11 of this PART;
sterntube forward bearings: 0.8 N/mm^2;
nonmetallic sterntube bearings: 0.3 N/mm^2;

intermediate shaft bearings: 0.8 N/mm^2;
gear shaft bearings: 1 N/mm^2;
main bearings of diesel engines: as specified by the engine manufacturer.

12.5.3.3 Additional bending stresses of shafts are generally not to exceed the following values:
propeller shafts and sterntube shafts: 20 N/mm^2;
intermediate shafts: 20 N/mm^2;
thrust shafts: 15 N/mm^2;
gear wheel shafts: 10 N/mm^2 or as specified by the gearbox manufacturer.

12.5.3.4 The bending moments and shearing forces applied to the output flange of diesel engines are not to exceed those as specified by the engine manufacturer (if required). The minimum load of main bearings of main engines is in general not to be less than 10% of the allowable load on main bearings. Alternatively, the minimum value specified by the engine manufacturer may be accepted, but this is to be reflected in shafting alignment calculations.

12.5.3.5 The load difference between fore and aft bearings of the gear wheel of the gearbox is to meet the relevant requirements of the manufacturer, generally not exceeding 20% of the sum of the weight of the shaft portion between the two bearings and that of the gear wheel.

Where the alignment calculation results in running condition are provided and the bearing structure is confirmed to be determined according to the acting angle of the resultant force in the running condition, the load difference between fore and aft bearings may not be limited to 20% as specified above provided that the relevant requirements of Appendix 1, Chapter 10 of this PART are complied with.

12.5.3.6 The relative angle between the propeller shaft and the aftermost sterntube bearing at the supporting point of the bearing is not to exceed 3.0×10^{-4} rad in the static condition.

12.5.3.7 For shafting systems where the propeller shaft has a diameter of 500 mm or greater, or the design of multi-slope aftermost sterntube bearing is used, the relative angle between the propeller shaft and the aftermost sterntube bearing at the supporting point of the bearing is not to exceed 3.0×10^{-4} rad in the static condition and in the running condition considering hydrodynamics of propellers. Alternative recognized model technology may be accepted, e.g. multi-point support bearing model or fluid structure three dimensional FE model of interaction between bearing oil film and rotating shaft. Appropriate assumption and recognized modelling methods are to be indicated in the submitted report. The calculated oil film thickness in each analytical condition is not to be less than the minimum thickness value established for the oil film. Such criteria may replace aftermost bearing relative angle criteria.

12.5.4 Conditions for shafting alignment

12.5.4.1 The ship's superstructures, main engines, boilers, generators and other pieces of essential equipment are to have been hoisted to their respective places. There is to be no movement of essential equipment or change of ballasting during the alignment, installation and inspection on board.

12.5.4.2 The processing and welding of hull portions within shafting areas are to have been completed.

12.5.4.3 The temperatures of hull structures are to be stable and so far as practicable, uniform.

12.5.4.4 The installation of sterntube arrangements has been completed.

12.5.4.5 Where the ship is afloat, consideration is to be given to measures for preventing movement or rotation of the propeller shaft.

12.5.4.6 Where the ship is in a normal floating condition, the immersion of the propeller is to be so close as practicable to that indicated in calculations.

12.5.5 Shafting alignment procedure

12.5.5.1 Where the conditions specified in 12.5.4 are met, shafting alignment may be performed according to the approved alignment calculations or alignment technology (as specified in 12.5.1.4 or 12.5.1.6).

12.5.5.2 Where any noncompliance with calculation conditions (e.g. the ambient temperature, propeller immersion, ship's condition, load adjustment of main bearings of engines) may affect the alignment results during the installation of shafting systems, the alignment calculations together with alignment instructions are to be resubmitted for approval, unless such effects have been included in the calculations.

12.5.5.3 The shipyard is to give full consideration to the influence of deflection of boring equipment on the machining precision of stern tubes. After finishing machining of stern tubes, sizes of bores on stern tubes are to be measured to confirm the deviation of center lines of the stern tube body. Such deviation is to be taken into consideration during cylindrical grinding of stern bearing and compensation during machining is to be made for deviation from stern tube center line as appropriate.

12.5.5.4 After stern bearing is pressed and fitted, slope at stern bearing is to be measured. After the integrated stern tubes are poured and installed, slope at stern bearing is to be measured.

12.5.5.5 Where the load of the sterntube forward bearing is not positive for unconnected shafting flanges, the force applied downward from the propeller shaft forward flange is to comply with the calculations.
12.5.5.6 The axial distance of temporary supports, if fitted, is to comply with the calculations.
12.5.5.7 For shafting alignment, the propeller shaft forward flange is to be used as the reference for positioning bearings or temporary supports and the engine (or gearbox) from aft to fore by adjusting the sag and gap of unconnected flange pairs, in compliance with the relevant requirements.
12.5.5.8 The sag and gap tolerances of flange pairs for straight alignment shafting are to comply with the requirements of 12.5.6.1 and to be recorded.
12.5.5.9 The sag and gap values of flange pairs for the reasonable alignment shafting are to comply with the shafting alignment calculations and tolerances are to comply with the requirements of 12.5.6.1. After connection of flanges, at least a load verification is to be carried out on stern tube forward bearing (if any), intermediate bearing, last three bearings of the main engine (direct transmission propulsion system), wheel shaft bearing (if any) with the ship afloat, and tolerances are to comply with the requirements of 12.5.6.2 and appropriate records are to be made.
12.5.5.10 At the time of completing the shafting alignment, the gear engagement is to be examined or the difference between crank webs of engine measured, and the results are to comply with the requirements of 12.5.6.3 or 12.5.6.4 and appropriate records are to be made.
12.5.5.11 After completion of shafting alignment, coupling bolts are to be provided to flanges, chocks provided or epoxy resin cast to diesel engines (or gearboxes) and engine foundation bolts provided, followed by connection and fixing.

12.5.6 Shaft alignment survey

12.5.6.1 The sag and gap of flange pairs are to be examined, with tolerances generally not exceeding ±0.08 mm.
12.5.6.2 Where shafting alignment calculations are applied, actual bearing loads in cold condition may generally be measured by jacking up the loads. The jacking positions are to be the same as specified in calculations. Any deviation of measured loads from calculated ones is not to exceed 20% of the latter. For excessive tolerances, shafting alignment calculations may be carried out according to the measurement results which may be accepted where other requirements of 12.5.3 are still complied with. However, at least the loads of main bearings of the main engine are to be positive.
12.5.6.3 The gear engagement of gear-driven shafting systems is to be examined and the relevant requirements of the gearbox manufacturer are to be complied with.
12.5.6.4 For shafting systems directly driven by the diesel engine, the difference between crank webs of engine are to be examined and the relevant requirements of the engine manufacturer are to be complied with.

Appendix 1 ENHANCED SHAFT ALIGNMENT

1 General Provisions

1.1 Application

1.1.1 This Appendix applies to bearings which are white-metal lined and oil lubricated, and ships applying for enhanced shaft alignment (ESA) notation.

2 Calculation Conditions

2.1 When carrying out assessment of reasonable shafting alignment, the following calculation conditions are at least to be considered:

(1) ballast condition in both cold and hot conditions (empty tank and full tank are to be considered for aftpeak tank used as ballast tank); 3-5 (2) full load condition in both cold and hot conditions;

(3) ballast condition taking into account hydrodynamic propeller loads (zero rudder angle and full rudder angle under rated speed);

(4) full load condition taking into account hydrodynamic propeller loads (zero rudder angle and full rudder angle under rated speed).

3 Hull Deflections

3.1 Hull deflections are to be obtained by means of FE calculation or measurement data of similar ships (same type, similar ship size, similar double bottom height in engine room, similar sterntube and stern arrangement), and other recognized calculation methods.

3.2 Hull deflections in way of bearing position in the following conditions are to be provided:

(1) floating condition;

(2) ballast condition (empty tank and full tank are to be considered for aftpeak tank used as ballast tank);

(3) full load condition.

4 Hydrodynamic Propeller Loads

4.1 Hydrodynamic propeller loads may be obtained by means of calculation or empirical data.

4.2 In case the data of 4.1 is unavailable, hydrodynamic propeller loads may be selected in accordance with Table 4.2.

Hydrodynamic Propeller Loads **Table 4.2**

	Zero rudder angle	Full rudder angle
Single screw propulsion	-5% of Q +30% of Q	-30% of Q
Twin screw propulsion	+/-20% of Q	-40% of Q

Note: Q is rated torque;
Positive sign (+) implies upward bending moment;
Negative sign (-) implies downward bending moment.

5 Aftermost Sterntube Bearing Contact Analysis

5.1 The relative angle between the propeller shaft and the aftermost sterntube bearing at the supporting point of the bearing is not to exceed 3.0×10^{-4} rad in the static condition and in the running condition considering hydrodynamics of propellers. Alternative recognized model technology may be accepted, e.g. multi-point support bearing model or fluid structure three dimensional FE model of interaction between bearing oil film and rotating shaft. Appropriate assumption and recognized modelling methods are to be indicated in the submitted report. The calculated oil film thickness in each analytical condition is not to be less than the minimum thickness value established for the oil film. Such criteria may replace aftermost bearing relative 3-6 angle criteria.

6 Criteria

6.1 The calculation results of calculation conditions (1) and (2) in paragraph 2 of this Appendix are to satisfy applicable requirements of 12.5.3.1 to 12.5.3.6 of this Chapter.

6.2 The bearing load calculation results of calculation conditions (3) and (4) in paragraph 2 of this Appendix are to satisfy applicable requirements of 12.5.3.2 of this Chapter, and there is to be no voidable bearing load. The aftermost bearing relative angle is to satisfy applicable requirements of paragraph 5 of this Appendix.

7 Survey

7.1 The bearing actual load in cold or hot ballast conditions (empty tank and full tank are to be considered for aftpeak tank used as ballast tank) corresponding to the calculations may be generally measured by means of jack-up tests. The jack-up position is to be the same as the calculations. The actual load is to comply with provisions for bearing loads in 12.5.3.2.

CHAPTER 13 STEERING GEAR AND WINDLASSES

Section 1 STEERING GEAR

13.1.1 General requirements

13.1.1.1 The requirements of this Section apply to steering gear of vessel.

13.1.1.2 The certificate requirements and product survey of steering gear are to comply with relevant requirements in Chapter 3, PART ONE of the Rules.

13.1.2 Definitions

13.1.2.1 For the purpose of this Section:

(1) **Main steering gear** is the machinery, rudder actuators, the steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

(2) **Auxiliary steering gear** is the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

(3) **Steering gear power unit** is:

① **in the case of electric steering gear**, an electric motor and its associated electrical equipment;

② **in the case of electro-hydraulic steering gear**, an electric motor and its associated electrical equipment and connected pump;

③ **in the case of other hydraulic steering gear**, a driving engine and connected pump.

(4) **Power actuating system** is the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller, quadrant and rudder stock, or components serving the same purpose.

(5) **Rudder actuator** is the component which converts directly hydraulic pressure into mechanical action to move the rudder.

(6) **Steering gear control system** is equipment by which orders are transmitted from the navigating bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables. Steering gear control system also covers the equipment required to control the steering gear power actuating system.

(7) **Maximum ahead service speed** is the greatest speed which the ship is designed to maintain in service at sea at her deepest seagoing draught at maximum propeller RPM and corresponding engine MCR.

(8) **Maximum astern speed** is the speed which it is estimated the ship can attain at the designed maximum astern power at the deepest sea-going draught.

(9) **Maximum working pressure** is the maximum expected pressure in the system when steering gear is operated to comply with 13.1.5.2(1) of this Section.

(10) **Declared steering angle limits** are the operational limits in terms of maximum steering angle of propulsion and steering systems other than traditional arrangements for a ship's directional control (e.g. azimuth propulsion arrangements or water jet propulsion systems, but not limited to them), or equivalent, according to the manufacturer's guidelines for safe operation, also taking into account the ship's speed or propeller torque/speed or other limitation; the declared steering angle limits are to be declared by the directional control system manufacturer for each ship specific non-traditional steering means.

(11) **Hydraulic locking** are all situations where two hydraulic systems (usually identical) oppose each other in such a way that it may lead to loss of steering. It can either be caused by pressure in the two hydraulic systems working against each other or by hydraulic "bypass" meaning that the systems puncture each other and cause pressure drop on both sides or make it impossible to build up pressure.

13.1.3 Plans and documents

13.1.3.1 The following plans and documents are to be submitted for approval:

(1) details of steering gear construction, including documents of strength calculations for principal component parts and materials selected etc.;

(2) steering gear hydrostatic power system, including documents of relief valve's setting and delivery capacity etc.;

(3) power supply system;

(4) control, monitoring alarm system.

13.1.4 Materials

13.1.4.1 All the steering gear components such as hydraulic cylinders, pressure housings of rotary vane type actuators, hydraulic power piping valves, flanges and fittings, and all components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other ductile material, duly tested in accordance with the requirements of CCS Rules for Materials and Welding. In general, such material is not to have an elongation of less than 12% nor a tensile strength in excess of 650 N/mm^2.

If reliable basis for use and relevant background information can be provided, grey cast iron may be accepted for redundant parts with low stress levels, excluding cylinders.

13.1.4.2 Where flexibility is required, approved hose assemblies are to be installed between two points where torsional deflection (twisting) is not subjected to under normal operating conditions. In general, the hose is to be limited to the length necessary to provide for flexibility and for proper operation of machinery.

13.1.4.3 Hose assemblies are to be high pressure hydraulic hose fabricated according to the requirements of Chapter 2 of this PART and suitable for fluids, pressures, temperatures and relevant ambient conditions for which they intend.

13.1.4.4 Burst pressure of hoses is not to be less than four times the design pressure.

13.1.5 Basic performance

13.1.5.1 Unless the main steering gear is in compliance with 13.1.5.6 or 13.1.10.1, every ship is to be provided with a main steering gear and an auxiliary steering gear. The main steering gear and the auxiliary steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.

13.1.5.2 The main steering gear and rudder stock is to be:

(1) of adequate strength and capable of putting the rudder over from 35° on one side to 35° the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and under the same conditions, from 35° either side to 30° the other side in not more than 28 s. For the propulsion and steering systems other than traditional arrangements for a ship's directional control, the main steering arrangements (equivalent to the main steering gear) are to be capable of changing direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 2.3°/s with the ship running ahead at the maximum ahead service speed;

(2) operated by power where manual operation cannot meet the requirements above or in any case when, excluding strengthening for navigation in ice, a rudder stock is over 120 mm diameter in way of the tiller. For the propulsion and steering systems other than traditional arrangements for a ship's directional control, the main steering arrangements are to be operated by power;

(3) so designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

13.1.5.3 The auxiliary steering gear is to be:

(1) of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency;

(2) capable of putting the rudder over from 15° one side to 15° the other side in not more than 60 s with the ship at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater. For the propulsion and steering systems other than traditional arrangements for a ship's directional control, the auxiliary steering arrangements (equivalent to the auxiliary steering gear) are to be capable of changing direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 0.5°/s; with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater;

(3) operated by power where manual operation cannot meet the requirements above or in any case when, excluding strengthening for navigation in ice, a rudder stock is over 230 mm diameter in way of the tiller. For the propulsion and steering systems other than traditional arrangements for a ship's directional control, where the propulsion power exceeds 2,500 kW per thruster unit, the auxiliary steering arrangements are to be operated by power.

13.1.5.4 Manually operated gears are only acceptable when the operation does not require an effort exceeding 160 N and their constructions are to ensure that the hand wheels of the gears will not be damaged by counter-forces.

13.1.5.5 Main and auxiliary steering gear power units are to be:

(1) arranged to re-start automatically when power is restored after a power failure;

(2) capable of being brought into operation from a position in the navigation bridge;

(3) in the event of a power failure to any one of the steering gear power units, an audible and visual alarm is to be given in the navigation bridge.

13.1.5.6 Where the main steering gear comprises two or more identical power units, an auxiliary steering gear need not be fitted, provided that:
(1) in a passenger ship, the main steering gear is capable of operating the rudder as required in 13.1.5.2(1) of this Section while any one of the power units is out of operation;
(2) in a cargo ship, the main steering gear is capable of operating the rudder as required in 13.1.5.2(1) of this Section while operating with all power units;
(3) the main steering gear is so arranged that after a single failure in its piping system or in one of the power units the defect can be isolated so that steering capability can be maintained or speedily regained.
13.1.5.7 Steering gears, other than that of the hydraulic type, are to achieve the equivalent standards.
13.1.5.8 Steering gears are to be provided with positive rudder angle limiters. Power-operated steering gears are to be fitted with limit switches or similar devices, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronized with the gear itself and not with the steering gear control.
13.1.5.9 Effective means are to be fitted to the steering gear to keep the rudder steady.

13.1.6 Construction and design

13.1.6.1 Pressure cylinders of rudder actuators are to be designed in accordance with the relevant requirements of Chapter 6 of this PART for Class I pressure vessels, in addition to provisions of 13.1.10.3 and 13.1.10.4 of this Section. Accumulators, if fitted, are to comply with the relevant requirements of Chapter 6 of this PART.
13.1.6.2 Where the components subject to pressure are designed in accordance with the requirements of 13.1.6.1 of this Section, the permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{R_m}{A} \text{ or } \frac{R_{eH}}{B}$$

whichever is less.
where: R_m — specified tensile strength of material at ambient temperature, in N/mm^2;
R_{eH} — specified yield stress or proof stress of the material at ambient temperature, in N/mm^2;
A and B — safety coefficient given by Table 13.1.6.2.

Safety coefficient *A* or *B* **Table 13.1.6.2**

Safety coefficient	Steel (except cast steel)	Cast steel	Nodular graphite cast iron
A	3.5	4	5
B	1.7	2	3

13.1.6.3 All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength. The welding details and welding procedures are to be subject to approval of CCS.
13.1.6.4 The construction of steering gear components is to be such as to minimize local concentrations of stress.
13.1.6.5 When determining the scantlings of piping and other steering gear components subjected to internal hydraulic pressure, the design pressure is to be at least equal to the greater of the following:
(1) 1.25 times the maximum working pressure;
(2) the relief valve setting.
13.1.6.6 All the steering gear components and the rudder stock are to be of sound and reliable construction. Any essential component which is not duplicated, where appropriate, is to use anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which are to be permanently lubricated or provided with lubrication fittings.
13.1.6.7 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.
13.1.6.8 Oil seals between non-moving parts forming part of the external pressure boundary are to be of the metal upon metal type or of an equivalent type.
Oil seals between moving parts forming part of the external pressure boundary are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.
13.1.6.9 Pipes, joints, valves, flanges and other fittings are to comply with the requirements for Class I piping in Chapter 2 of this PART. The design pressure is to be in accordance with 13.1.6.5.

13.1.6.10 For relevant requirements to rudder, rudder stock, tiller and quadrant, refer to Chapter 3, PART TWO of the Rules.

13.1.7 Hydraulic system

13.1.7.1 Pipes, joints, valves, flanges and other fittings in hydraulic piping of hydraulic power steering gear are to comply with the requirements for Class I piping in Chapter 2 of this PART. The design pressure is to be in accordance with 13.1.6.5.

13.1.7.2 Relief valves

(1) Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The setting of the relief valves is not to exceed the design pressure. The valves are to be of adequate nominal diameter and so arranged as to avoid an undue rise in pressure above the design pressure.

(2) Relief valves fitted as required in 13.1.7.2(1) are to comply with the following:

① the setting pressure is not to be less than 1.25 times the maximum working pressure;

② the minimum discharge capacity of the relief valve(s) is not to be less than 110% of the total capacity of the pumps which can deliver through it (them).

Under such conditions the rise in pressure is not to exceed 10% of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

13.1.7.3 Isolating valves

For rudder actuators with non-duplicated units, isolating valves are to be fitted at the connection of pipes to the hydraulic cylinders, and are to be directly fitted on the hydraulic cylinders.

13.1.7.4 Filters

Arrangements to maintain the cleanliness of the hydraulic fluid are to be provided taking into consideration the type and design of the hydraulic system.

13.1.7.5 Level alarm

A low level alarm is to be provided for the circulating oil tank of each hydraulic system to give the earliest practicable indication of hydraulic fluid leakage. Audible and visual alarms are to be given in the navigation bridge and in the machinery space where they can be readily observed.

13.1.7.6 Arrangements for bleeding air

Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

13.1.7.7 Hydraulic locking

Where the steering gear is so arranged that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

13.1.7.8 Storage tank

A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the circulating oil tank is to be provided, where the main steering gear is required to be power operated. The storage tank is to be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and provided with a content gauge.

13.1.7.9 Arrangement

The power piping for hydraulic steering gears is to be so arranged that transfer between units can be readily effected.

13.1.8 Power supply and control systems

13.1.8.1 Steering gear control is to be provided:

(1) for the main steering gear, both in the navigation bridge and in the steering gear compartment;

(2) where the main steering gear is arranged according to 13.1.5.6 of this Section, by two independent control systems, both operable from the navigating bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not to be fitted, except in a tanker of 10,000 gross tonnage and upwards, a chemical carrier or a liquefied gas carrier;

(3) for the auxiliary steering gear, in the steering gear compartment and, if power operated, it is also to be operable from the navigating bridge and is to be independent of the control system for the main steering gear.

13.1.8.2 Main and auxiliary steering gear control systems operable from the navigating bridge are to comply with the following:

(1) Means are to be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves.

(2) The system is to be capable of being brought into operation from a position in the navigation bridge.

13.1.8.3 The angular position of the rudder is to be:
(1) if the main steering gear is power operated, indicated in the navigation bridge. The rudder angle indication is to be independent of the steering gear control system;
(2) recognizable in the steering gear compartment.
13.1.8.4 Where applicable, following standard signboard is to be fitted at a suitable place on steering control position in the bridge or incorporated into operating instruction mentioned in 13.1.11.3 of this Section.
"Caution:
In Some Circumstances When Two Power Units Are Running Simultaneously the Rudder May Not Respond to Helm. If This Happens Stop Each Pump in Turn Until Control Is Regained."
The above signboard is related to steering gears provided with two identical power units intended for simultaneous operation, and normally provided with either their own control systems or two separate (partly or mutually) control systems which are/may be operated simultaneously.
13.1.8.5 Source of electrical power and cable installation
(1) Means for indicating that motors of electric and electrohydraulic steering gear are running is to be installed in the navigation bridge and at a suitable main machinery control position.
(2) Each electrical or electrohydraulic steering gear comprising one or more power units is to be served by at least two exclusive circuits fed directly from the main switchboard, however, one of the circuits may be supplied through the emergency switchboard. Each power unit of electrical or electrohydraulic main steering gear complying with the requirements of 13.1.5.6 of this Section is to be served by one exclusive circuit fed directly from the main switchboard, and one of the afore-mentioned circuits may be fed from the emergency switchboard. An auxiliary electric or electrohydraulic steering gear associated with a main electrical or electrohydraulic steering gear may be connected to one of the circuits supplying this main steering gear. The circuits supplying an electrical or electrohydraulic steering gear are to have adequate rating for supplying all motors which can be simultaneously connected to them and may be required to operate simultaneously.
(3) When in a ship of less than 1,600 gross tonnage an auxiliary steering gear which is required in 13.1.5.3(3) of this Section to be operated by power is not electrically powered or is powered by an electrical motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard.
(4) Each main and auxiliary steering gear control system, if electrical and operable from the navigating bridge, is to be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment. Or alternatively, this control system may be supplied by a separate circuit directly from the same section of main or emergency switchboard bus-bars at a point on the switchboard adjacent to that supplying the said steering gear power circuit. For above-mentioned main and auxiliary steering gear, short circuit protection is only to be provided for power circuits of control system.
(5) The electrical power circuits and the steering gear control systems with their associated components, cables and pipes required in this Section are to be separated as far as practicable throughout their length.
13.1.8.6 Where the rudder stock is required to be over 230 mm diameter in way of the tiller (excluding strengthening for navigation in ice), or where the propulsion power exceeds 2,500 kW per thruster unit (applying to propulsion and steering systems other than traditional arrangements for a ship's directional control), an alternative power supply, sufficient at least to supply the steering gear power unit or the steering arrangements which complies with the requirements of 13.1.5.3(2) of this Section and also its associated control system and the rudder angle indicator, is to be provided automatically, within 45 s, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power is to be used only for this purpose. In every ship of 10,000 gross tonnage and upwards, the alternative power supply is to have a capacity for at least 30 min of continuous operation and in any other ship for at least 10 min.
13.1.8.7 Where the alternative power source for steering gear is an independent engine driven hydraulic pump located in the steering gear compartment, automatic starting arrangements for the engine are to comply with the relevant requirements relating to the automatic starting arrangements of emergency generators.

13.1.9 Monitoring and alarms

13.1.9.1 The alarm and monitoring requirements for the steering gear are to be in accordance with Table 13.1.9.1 and comply with the relevant requirements of Section 4, Chapter 2, PART SEVEN of the Rules. The failures likely to cause uncontrolled movements of rudder as indicated in the Table below are to be clearly identified. In the event of detection of such failure, the rudder is to stop in the current position without manual intervention or is to return to the midship/neutral poistion. For mechanical failures such as

sticking valves and failure of static components (pipes, cylinders), the system response without manual intervention is not mandatory, and the operator can follow instructions on the signboard in case of such failures, in accordance with the relevant requirements of 13.1.8.4 of this Section.

Alarm and Monitoring Requirements **Table 13.1.9.1**

No.	Item	Alarm and monitoring	Location	Note
1	Steering gear power unit	Power supply failure	Navigation bridge	–
2	Steering gear circuit and motor	Broken connections and overload	Navigation bridge and main control position in engine room	–
3	Steering gear motor	Indication of running		
4	Steering gear control system	Power supply failure	Navigation bridge	–
5		Earth fault on AC and DC circuits		If applicable (e.g. the control system is connected to main power supply through transformer)
6		Loop failures in closed loop systems (short circuit, broken connections and earth faults)		–
7		Data communication errors		If programmable electronic system is used
8		Computer hardware and software failures		
9		Deviation alarm		Deviation alarm is to be initiated if the rudder's actual position does not reach the set point within acceptable time limits for the closed loop control systems (e.g. follow-up control and autopilot). Deviation alarm may be caused by mechanical, hydraulic or electrical failures
10	Hydraulic oil tank of steering gear	Low level	Navigation bridge and machinery space	Each oil tank is to be monitored
11	Angular position of rudder	Rudder angle indication	Navigation bridge and steering gear compartment	See 13.1.8.3
12	Automatic rudder arrangement	Failure	Navigation bridge	—
13		Indication of operation		
14	Hydraulic oil	High temperature	Navigation bridge	If fitted with oil cooler
15	Hydraulic oil filter	High pressure difference	Navigation bridge	If oil filter is fitted
16	Steering gear (power or control) hydraulic system	Hydraulic locking	Navigation bridge	See 13.1.9.5

13.1.9.2 Short circuit protection and an overload alarm are to be provided for the circuits and motors referred to in 13.1.8.5(2) of this Section. Protection against excess current, including starting current, if provided, is to be for not less than twice the full load current of the motor or circuit so protected, and is to be arranged to permit the passage of the appropriate starting currents. Steering gear motor circuits obtaining their power supply via an electronic converter, e.g. for speed control, and which are limited to full load current are exempt from the requirement to provide protection against excess current. The required overload alarm is to be set to a value not greater than the normal load of the electronic converter. Normal load is the load in normal mode of operation that approximates as close as possible to the most severe conditions of normal use in accordance with the manufacturer's operating instructions. Where a three-phase supply is used, an alarm is to be provided that will indicate failure of any one of the supply phases. The alarms required in this Article are to be both audible and visual and are to be situated in a conspicuous position in the main machinery space or control room from which the main machinery is normally controlled. Audible and visual alarms are also required to be provided in the navigation bridge.

13.1.9.3 For any main and auxiliary steering gear control system operable from the navigation bridge an audible and visual alarm is to be given in the navigation bridge in the event of failure of electrical power supply to the control system, or in the event of a power failure to any one of the steering gear power units.

13.1.9.4 When in a ship of less than 1,600 gross tonnage an auxiliary steering gear which is required in 13.1.5.3(3) of this Section is powered by an electrical motor primarily intended for other services, the requirements of 13.1.9.2 of this Section may be waived by CCS if satisfied with protection arrangement together with the requirements of 13.1.5.5

and 13.1.8.1(3) of this Section applicable to auxiliary steering gear.
13.1.9.5 Where hydraulic locking, caused by a single failure, may lead to loss of steering, an audible and visual alarm, which identifies the failed system, is to be provided in the navigation bridge.
The alarm is to be activated whenever:
(1) position of the variable displacement pump control system does not correspond with given order; or
(2) incorrect position of 3-way full flow valve in constant delivery pump system is detected.

13.1.10 Additional requirements
13.1.10.1 For every oil tanker, chemical carrier and liquefied gas carrier of 10,000 gross tonnage and upwards, every other ship of 70,000 gross tonnage and upwards the main steering gear is to comprise two or more identical power units complying with the provisions of 13.1.5.6 of this Section.
13.1.10.2 For every oil tanker, chemical carrier and liquefied gas carrier of 10,000 gross tonnage and upwards, subject to the requirements specified in 13.1.10.3, the steering gear is to comply with the following requirements:
(1) The main steering gear is to be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems of the main steering gear, excluding the tiller, quadrant or components serving the same purpose, or seizure of the rudder actuators, steering capability is to be regained within 45 s after the loss of one power actuating system.
(2) The main steering gear is to comprise either:
① two independent and separate power actuating systems, each capable of meeting the requirements of 13.1.5.2(1) of this Section; or
② at least two identical power actuating systems which, acting simultaneously in normal operation, are capable of meeting the requirements of 13.1.5.2(1) of this Section. Where necessary to comply with these requirements, inter-connection of hydraulic power actuating systems is to be provided. Loss of hydraulic fluid from one system is to be capable of being detected and the defective system automatically isolated so that the other actuating system or systems remain fully operational.
(3) Steering gears other than that of the hydraulic type are to achieve equivalent standards.
13.1.10.3 For every oil tanker, chemical carrier and liquefied gas carrier of 10,000 gross tonnage and upwards but of less than 100,000 tons deadweight, solutions other than those set out in 13.1.10.2 of this Section which need not apply the single failure criterion to the rudder actuator or actuators, may be permitted provided that an equivalent safety standard is achieved and that:
(1) following loss of steering capability due to a single failure of any part of the piping system or in one of the power units, steering capability is regained within 45 s;
(2) where the steering gear includes only a single power actuator, stress analysis for the design including fatigue analysis and fracture mechanics analysis, as appropriate, the material used, the installation of sealing arrangements and the testing and inspection and provision of effective maintenance are to be submitted. See Appendix 1 to this Chapter for details.
13.1.10.4 Manufacturers of steering gear who intend their product to comply with the requirements of Appendix 1 of this Chapter are to submit corresponding information for approval by CCS.

13.1.11 Arrangement
13.1.11.1 In general, the steering gear is to be reliably secured to the seating with sufficient rigidity by fitting bolts or bolts and thrust plates.
13.1.11.2 The steering gear compartment is to be:
(1) readily accessible and, as far as practicable, separated from machinery spaces;
(2) provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.
13.1.11.3 Suitable operating instructions with a block diagram showing the change-over procedures for actuating systems and control systems of steering gear are to be permanently displayed in the navigation bridge and in the steering gear compartments.
13.1.11.4 A means of communication is to be provided between the navigation bridge and the steering gear compartment.

13.1.12 Testing
13.1.12.1 Testing at works
(1) The pipes, valves and other parts in hydraulic piping system of hydraulic power steering gear are to comply with the related requirements for class I piping in Chapter 2 of this PART.
(2) The pressure parts designed in accordance with 13.1.6.1 of this Section are to be tested in accordance

with the related requirements for class I pressure vessels in Chapter 6 of this PART.
(3) A hydraulic power unit pump is to be subject to a type test. The type test is to be carried out at workshop for a duration of not less than 100 h according to the following:

① the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure;

② during the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another is to occur at least as quickly as on board;

③ during the whole test, no abnormal heating, excessive vibration or other irregularities are permitted;

④ after the test, the pump is to be disassembled and inspected.

Type test may be waived for a power unit which has been proven to be reliable in marine service.
(4) For a diesel engine of a hydraulic power unit, see Chapter 9 of this PART.
(5) For an electric motor of a hydraulic power unit, see Chapter 3, PART FOUR of the Rules.
(6) After testing of each part and completion of general installation, the steering gear is to be subject to the final inspection and operation test.
13.1.12.2 Testing on board
After installation on board the vessel, the hydraulic steering gear is to be subject to a hydraulic tightness test under 1.25 times the design pressure and any kind of steering gear is to be subject to and a running test in mooring condition.
13.1.12.3 Sea trials
The steering gear is to be tried out on sea trial in order to demonstrate satisfaction that the requirements of this Section have been met. The trial is to include the operation of the following:
(1) the steering gear, including demonstration of the performances required in 13.1.5.2(1) and 13.1.5.3(2).
If the vessel cannot be tested at the deepest seagoing draught, steering gear trials are to be conducted at a displacement as close as reasonably possible to full-load displacement on either of the following conditions:

① where the rudder is fully submerged (zero speed waterline) and the vessel is in an acceptable trim condition; or

② where the rudder load and torque at the specified trial loading condition have been predicted and extrapolated to the full load condition.

In any case for the main steering gear trial, the speed of ship corresponding to the number of maximum continuous revolution of main engine could apply; for controllable pitch propellers, the propeller pitch is to be at the maximum design pitch approved for the maximum continuous ahead R.P.M. at the main steering gear trial;
(2) the steering gear power units, including transfer between steering gear power units;
(3) the isolation of one power actuating system, checking the time for regaining steering capability;
(4) the hydraulic fluid recharging system;
(5) the emergency power supply required in 13.1.8.6 of this Section;
(6) the steering gear controls, including transfer of control and local control;
(7) the means of communication between the wheelhouse, engine room and the steering gear compartment;
(8) the alarms and indicators required in this Chapter;
(9) where steering gear is designed to avoid hydraulic locking this feature is to be demonstrated.
The trials in (2), (3), (4), (7), (8) and (9) above may be carried out during mooring trial.

Section 2 WINDLASSES

13.2.1 General requirements

13.2.1.1 The requirements of this Section apply to windlasses of vessel.
13.2.1.2 The certification requirements and product survey of windlasses are to comply with the relevant requirements in Chapter 3, PART ONE of the Rules.
13.2.1.3 The design, construction and testing of windlasses are to conform to a standard or code of practice accepted by CCS. To be considered acceptable, the standard or code of practice is to specify criteria for stresses, performance and testing. The following are examples of standards recognized:

SNAME T & R Bulletin 3-15: 2018	Guide to the Design and Testing of Anchor Windlasses for Merchant Ships
ISO 7825: 2017	Deck machinery general requirements
ISO 4568: 2021	Shipbuilding - Sea-going vessels - Windlasses and anchor capstans

13.2.2 Definitions

13.2.2.1 For the purpose of this Section:

(1) **Working load** means the tension measured at wildcats, and is to be calculated in accordance with 13.2.5.2(1) of this Section.

(2) **Overload pull** means the capability of the windlass necessary to withstand an overload pull for a short time.

(3) **Mean speed** means the speed for raising two lengths of cable chains when three lengths of cable chains are in the water with the anchor hanged free.

(4) **Withstand load** means the maximum static load applied to chain cables which the windlass brake can withstand.

13.2.3 Plans and documents

13.2.3.1 The following plans showing the design specifications, the standard of compliance, engineering analyses and details of construction, as applicable, are to be submitted for approval:

(1) windlass arrangement plan showing all of the components of the anchoring/mooring system such as the prime mover, shafting, cable lifter, anchors and chain cables; mooring winches, wires and fairleads, if they form part of the windlass machinery; brakes; controls; etc.;

(2) dimensions, materials, welding details, as applicable, of all torque-transmitting (shafts, gears, clutches, couplings, coupling bolts, etc.) and all load bearing (shaft bearings, cable lifter, sheaves, drums, bed-frames, etc.) components of the windlass and of the winch, where applicable, including brakes, chain stopper (if fitted) and foundation;

(3) hydraulic system, to include: piping diagram along with system design pressure; safety valves arrangement and settings; material specifications for pipes and equipment; typical pipe joints, as applicable; and technical data and details for hydraulic motors;

(4) electric one line diagram along with cable specification and size; motor controller; protective device rating or setting; as applicable;

(5) control, monitoring and instrumentation arrangements;

(6) engineering analyses for torque-transmitting and load-bearing components demonstrating their compliance with recognized standards or codes of practice. Analyses for gears are to be in accordance with a recognized standard;

(7) plans and data for windlass electric motors including associated gears rated 50 kW and over;

(8) calculations demonstrating that the windlass prime mover is capable of attaining the hoisting speed, the required continuous duty pull, and the overload capacity are to be submitted if the “load testing” including “overload” capacity of the entire windlass unit is not carried out at the shop (see 13.2.6.1).

13.2.3.2 The following plans and documents are to be submitted for information:

(1) windlass design specifications; anchor and chain cable particulars; anchorage depth; performance criteria; standard of compliance;

(2) operation and maintenance procedures for the anchor windlass are to be incorporated in the vessel operations manual.

13.2.4 Material and welding

13.2.4.1 The materials for parts which are stressed by the pull of the chain when the cable lifer is disengaged (e.g. main shaft, driving gear, cable lifter, chain pulley, brake spindle, etc.) are generally to be made of steel. If chain cable passes through stopper, stopper is to be made of ductile material. Testing of material is to comply with the requirements of CCS Rules for Materials and Welding.

13.2.4.2 Materials used in the construction of torque-transmitting and load-bearing parts of windlasses and the testing of the materials are to comply with the requirements of CCS Rules for Materials and Welding. The proposed materials are to be indicated in the construction plans and are to be approved in connection with the design. All such materials are to be certified by the material manufacturers.

13.2.4.3 Weld joint designs are to be shown in the construction plans and are to be approved in association with the approval of the windlass design. Welding procedures and welders are to be qualified in accordance with the requirements of CCS Rules for Materials and Welding. Welding consumables are to be approved by CCS in the case they fall within the scope of CCS Rules for Materials and Welding; when they fall outside the scope of CCS Rules for Materials and Welding, they are to comply with national or international standards. The degree of non-destructive examination of welds and post-weld heat treatment, if any, are to be specified and submitted to CCS for consideration.

13.2.5 Design and requirements

13.2.5.1 Driving type

Windlasses are to be driven by prime movers or motors independent from other deck machinery. For hydraulic windlasses, the hydraulic pipes may be connected with the pipes for other deck machinery, provided that there is no interference to the operation of windlasses.

Where applicable, hand-operated windlasses may be accepted for ships having anchors of not more than 250 kg, and provision is to be made for prevention of injuring persons by handles.

13.2.5.2 Driving power

Windlasses are to be of sufficient power and are to be capable of working continuously, the working load and overload pull of which are to meet the following requirements:

(1) Windlasses are to be capable of working continuously for a period of 30 min at the mean speed as required in 13.2.6.3 of this Section. In general, stresses in each torque-transmitting component are not to exceed 40% of yield strength (or 0.2% proof stress) of the material under these loading conditions:

① where the design anchorage depth is less than or equal to 82.5 m:

$37.5\ d^2$, N for Class 1 stud link chains;

$42.5\ d^2$, N for Class 2 stud link chains;

$47.5\ d^2$, N for Class 3 stud link chains;

② where the design anchorage depth is greater than 82.5 m:

$37.5\ d^2 + (D - 82.5) \times 0.27\ d^2$, N for Class 1 stud link chains;

$42.5\ d^2 + (D - 82.5) \times 0.27\ d^2$, N for Class 2 stud link chains;

$47.5\ d^2 + (D - 82.5) \times 0.27\ d^2$, N for Class 3 stud link chains;

where: d — chain diameter, in mm;

D — design anchorage depth, in m.

The above working loads are based on the hoisting of one anchor at a time (for anchor weight, refer to the provisions of Section 2, Chapter 3, PART TWO of the Rules), and that the effects of buoyancy and the hawse pipes efficiency (assumed to be 70%) have been accounted for.

(2) Windlasses are to be capable of working continuously for a period of at least 2 min under an overload pull (without any requirements for hoisting speed) for breaking out the anchor. The overload pull is not less than 1.5 times the working load.

13.2.5.3 Other design loads

(1) Holding loads

Calculations are to be made to show that, in the holding condition (single anchor, cable lifter brake fully applied and chain cable lifter declutched), and under a load equal to 80% of the specified minimum breaking strength of the chain cable, the maximum stress in each load bearing component will not exceed yield strength (or 0.2% proof stress) of the material. For installations fitted with a chain cable stopper, 45% of the specified minimum breaking strength of the chain cable may instead be used for the calculation.

(2) Inertia loads

The design of the drive train, including prime mover, reduction gears, bearings, clutches, shafts, cable lifter and bolting is to consider the dynamic effects of sudden stopping and starting of the prime mover or chain cable so as to limit inertial load.

(3) Driving loads

Each transmission component is to be able to withstand the maximum output torque of the prime mover.

13.2.5.4 Reversing equipment

Power-operated windlasses are to be reversible.

13.2.5.5 Clutch

Windlasses are to be provided with a clutch located between the wildcat and driving shaft, and the clutches are to be provided with efficient locking devices. Hydraulically or electrically operated clutches are to be capable of being disengaged manually.

13.2.5.6 Brake

(1) Cable lifter brake

The wildcats or reels of windlasses are to be provided with efficient brakes to stop the anchor and chain cable when paying out the chain cable. The force-bearing parts of the brakes, when fully applied, are to withstand the following loads without permanent deformation and without brake slip.

① For windlasses fitted with a chain stopper, the brake is to be able to withstand a static pull equal to 45% of the breaking load of the cable or wire or the maximum static load of the cable or wire;

② For windlasses not fitted with a chain stopper, the brake is to be able to withstand a static pull equal to 80% of the breaking load of the cable or wire.

(2) Control brake

① Electric windlasses are to be provided with a fail-safe brake mechanism such that the brakes are automatically engaged when the operating device is in the stop or braking position, or when there is no power to the electric motors. The brake is to be able to function automatically and hold a load on the chain cable of 1.5 times the working load of the windlass.

② For other types of drives, a suitable fail-safe brake mechanism is to be used. The brake is to be able to hold a load on the chain cable of 1.3 times the working load of the windlass.

13.2.5.7 Chain cable stopper

Chain cable stopper, if fitted, along with its attachments is to be designed to withstand, without any permanent deformation, 80% of the specified minimum breaking strength of the chain cable.

13.2.5.8 Overload protection

Prime movers and transmission gears are to be provided with means for prevention of excessive moment and impact.

13.2.5.9 Protection of mechanical components

To protect mechanical parts including component housings, a suitable protection system is to be fitted to limit the speed and torque at the prime mover. Consideration is to be given to a means to contain debris consequent to a severe damage of the prime mover due to overspeed in the event of uncontrolled rendering of the cable, particularly when an axial piston type hydraulic motor forms the prime mover.

13.2.5.10 Hydraulic system

Hydraulic system of windlasses is also to comply with the relevant requirements of Section 7 of Chapter 2 and Section 7 of Chapter 4 of this PART.

13.2.5.11 Marking

Windlass is to be permanently marked with the following information:

(1) nominal size of the windlass (e.g. 100/3/45 is the size designation of a windlass for 100 mm diameter chain cable of Grade 3, with a holding load of 45 % of the breaking load of the chain cable);

(2) maximum anchorage depth, in metres.

13.2.5.12 For the strength requirements for anchors, chain cables and securing of windlasses, see the relevant requirements in Section 2, Chapter 3 of PART TWO of the Rules.

13.2.5.13 Electrical systems

(1) Electric motors are to meet the requirements in Section 2, Chapter 3 of PART FOUR of the Rules, and those rated 50 kW and over are to be certified. Motors exposed to weather are to have enclosures suitable for their location as provided for in the requirements in Table 1.3.2.2 of PART FOUR of the Rules. Where gears are fitted, they are to meet the requirements of ISO 6336-6 or other acceptable standards and those rated 100 kW and over are to be certified.

(2) Electric motors are to be protected in accordance with the requirements in 2.5.10 of PART FOUR of the Rules and cable sizing is to be in accordance with the requirements in Section 12, Chapter 2 of PART FOUR of the Rules. Electrical cables installed in locations subjected to the sea are to be provided with effective mechanical protection.

13.2.6 Testing

13.2.6.1 Testing at works

(1) The pumps, pipes, valves and fittings in piping system are to comply with the relevant requirements in Chapter 2 of this PART.

(2) For a diesel engine of a hydraulic power unit, see Chapter 9 of this PART.

(3) For an electric motor of a hydraulic power unit, see Chapter 3, PART FOUR of the Rules.

(4) After testing of each part and completion of general installation, the windlass is to be subject to final inspection and functional test to ensure that it complies with the design requirements in 13.2.5 above. Windlasses are to be inspected and witnessed by a Surveyor and include the following tests, as a minimum.

① No-load test

The windlass is to be run without load at nominal speed in each direction for a total of 30 minutes. If the windlass is provided with a gear change, additional run in each direction for 5 minutes at each gear change is required.

② Load test

The windlass is to be tested to verify that the continuous duty pull, overload capacity and hoisting speed as specified in 13.2.5.2 can be attained. For large windlass, where the manufacturing works does not have adequate facilities, load test (including the adjustment of the overload protection) can be carried out on board ship. In these cases, functional testing in the manufacturing works is to be performed under no-load conditions.

③ Brake capacity test.

The holding power of the cable lifter brake is to be verified either through testing or by calculation.

13.2.6.2 Testing on board

After installation on board the vessel, the hydraulic system of the windlass is to be subject to a hydraulic tightness test under 1.25 times the design pressure.

Each windlass is to be tested under working conditions after installation onboard to demonstrate satisfactory operation. Each unit is to be independently tested for braking, clutch functioning, lowering and hoisting of chain cable and anchor, proper riding of the chain over the cable lifter, proper transit of the chain through the hawse pipe and the chain pipe, and effecting proper stowage of the chain and the anchor. It is to be confirmed that anchors properly seat in the stored position and that chain stoppers function as designed if fitted. The braking capacity is to be tested by intermittently paying out and holding the chain cable by means of the application of the brake.

13.2.6.3 Sea trials

(1) In carrying out the trial of hoisting anchor by the windlass, a mean speed of hoisting one anchor from a depth of 82.5 m to a depth of 27.5 m is not to be less than 9 m/min (equivalent to hoisting two shots of chain cable). Where the depth of water in allowable trial areas is inadequate, the deepest sea area in allowable trial areas is to be selected for trial.

(2) Where the design anchorage depth is greater than 82.5 m, the windlass is also to be able to hoist one anchor from the design anchorage depth to a depth of 82.5 m at a mean speed not less than 3 m/min. Where the depth of waters for the anchoring test is not adequate for the design anchorage depth, consideration may be given to accepting an equivalent simulating test.

Appendix 1[①] GUIDELINES FOR THE ACCEPTANCE OF NON-DUPLICATED RUDDER ACTUATORS FOR TANKERS, CHEMICAL TANKERS AND GAS CARRIERS OF 10,000 GROSS TONNAGE AND UPWARDS BUT OF LESS THAN 100,000 TONS DEADWEIGHT

1.1 Materials

1.1.1 Parts subject to internal hydraulic pressure or transmitting mechanical forces to the rudder-stock are to be made of duly tested ductile materials complying with recognized standards. Materials for pressure retaining components are to be in accordance with recognized pressure vessel standards. These materials are not to have an elongation less than 12 per cent nor a tensile strength in excess of 650 N/mm^2.

1.2 Design

1.2.1 The design pressure should be assumed to be at least equal to the greater of the following:

(1) 1.25 times the maximum working pressure to be expected under the operating conditions required in 13.1.5.2(1);

(2) the relief valve(s) setting.

1.2.2 Analysis

In order to analyse the design, the following are required:

(1) The manufacturers of rudder actuators should submit detailed calculations showing the suitability of the design for the intended service.

(2) A detailed stress analysis of pressure retaining parts of the actuator should be carried out to determine the stresses at the design pressure.

(3) Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis may be required. In connection with these analyses, all foreseen dynamic loads should be taken into account. Experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations depending upon the complexity of the design.

1.2.3 Allowable stresses

For the purpose of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure, the allowable stresses should not exceed:

$$\sigma_m \leq f$$
$$\sigma_l \leq 1.5f$$
$$\sigma_n \leq 1.5f$$
$$\sigma_l + \sigma_n \leq 1.5f$$
$$\sigma_m + \sigma_n \leq 1.5f$$

where: σ_m — equivalent primary general membrane stress, in N/mm^2;

σ_l — equivalent primary local membrane stress, in N/mm^2;

σ_n — equivalent primary bending stress, in N/mm^2;

f = the lesser of R_m/A or R_{eH}/B;

R_m — specified minimum tensile strength of material at ambient temperature, in N/mm^2;

R_{eH} — specified minimum yield stress or proof stress of material at ambient temperature, in N/mm^2.

A and B are listed in Table 1.2.3.

Table 1.2.3

Numerical value	Forged steel	Cast steel	Nodular cast iron
A	4	4.6	5.8
B	2	2.3	3.5

1.2.4 Burst test

(1) Pressure retaining parts not requiring fatigue analysis and fracture mechanics analysis may be accepted on the basis of a certified burst test and the detailed stress analysis required in 1.2.2(2) need not be provided.

(2) The minimum bursting pressure is to be calculated as follows:

① This Appendix is from the Annex to IMO resolution A.467(XII).

$$P_b = PA(R_{ma}/R_m) \quad \text{MPa}$$

where: P_b — minimum bursting pressure, in MPa;
P — design pressure as defined in 1.2.1, in MPa;
A — selected from Table 1.2.3;
R_{ma} — actual tensile strength, in N/mm^2;
R_m — tensile strength as defined in.1.2.3, in N/mm^2.

1.3 Construction details

1.3.1 The construction is to be such as to minimize local concentrations of stress.

1.3.2 The welding details and welding procedures are to be approved.

1.3.3 All welded joints within the pressure boundary of a rudder actuator or connection parts transmitting mechanical loads should be full penetration type or of equivalent strength.

1.3.4 Oil seals forming part of the external pressure boundary are to comply with 13.1.6.8 of this Chapter.

1.3.5 Isolating valves are to be fitted at the connection of pipes to the actuator, and should be directly mounted on the actuator.

1.3.6 Relief valves for protecting the rudder actuator against over-pressure as required in 13.1.7.2 of this Chapter are to comply with the following:

(1) The setting pressure is not to be less than 1.25 times the maximum working pressure expected under operating conditions required in 13.1.5.2(1) of this Chapter.

(2) The minimum discharge capacity of the relief valve(s) is not to be less than 110% of the total capacity of all pumps which provided power for the actuator. Under such conditions the rise in pressure should not exceed 10% of the setting pressure. In this regard due consideration should be given to extreme foreseen ambient conditions in respect of oil viscosity.

1.4 Non-destructive testing

1.4.1 The rudder actuator should be subject to suitable and complete non-destructive testing to detect both surface flaws and volumetric flaws.

1.4.2 The procedure and acceptance criteria for non-destructive testing should be in accordance with requirements of recognized standards. If found necessary, fracture mechanics analysis may be used for determining maximum allowable flaw size.

1.5 Testing

1.5.1 Tests, including hydrostatic tests, of all pressure parts at 1.5 times the design pressure should be carried out.

1.5.2 When installed on board the ship, the rudder actuator should be subject to a hydrostatic test and a running test.

CHAPTER 14 STRENGTHENING FOR NAVIGATION IN ICE

Section 1 GENERAL PROVISIONS

14.1.1 General requirements

14.1.1.1 For ships with ice notations B1*, B1, B2, B3, the machinery installations are to additionally comply with the provisions of this Chapter. For ships with ice notation B, only the requirements of 14.1.1.2 and 14.1.1.4 need to be complied with.

14.1.1.2 For ships with ice notations B1*, B1, B2, B3 and B, the machinery installations are to be capable of assuring safe and normal operation under air temperatures below 0℃. Particular attention is to be paid to the functioning of hydraulic systems, anti-freezing of water piping and tanks, starting of emergency diesels at low temperatures.

14.1.1.3 The strengthening requirements for ice notations B1*, B1, B2 and B3 correspond respectively to the relevant provisions in the Finish-Swedish Ice Class Rules, 2021, as follows:

B1* — IA Super;
B1 — IA;
B2 — IB;
B3 — IC.

14.1.1.4 In addition to complying with the requirements of 14.1.1.2, ships with ice notation B are to be designed to ensure supply of cooling water when navigating in ice. For this purpose, at least one cooling water inlet chest is to be so arranged as to prevent its grating and sea suction from being blocked by brash ice.

14.1.1.5 In addition to the plans and documents required in other Chapters of this PART, for ships with ice notations B1*, B1, B2 and B3, main engine output calculations (including necessary diagrams) are to be submitted for approval.

14.1.2 Main engine output

14.1.2.1 The main engine output mentioned in this Chapter is the total maximum output the propulsion machinery can continuously deliver to propeller(s).

14.1.2.2 The main engine output is to be in no case less than 2,800 kW for Ice Class B1* and less than 1,000 kW for Ice Classes B1, B2 and B3.

14.1.2.3 For ships with ice notations B1*, B1, B2 and B3, the required main engine output N_r is to be determined by the following formula. The engine output requirement is to be calculated for two draughts. Draughts to be used are the maximum draught amidships referred to as UIWL and the minimum draught referred to as LIWL, as defined in 4.1.2 of PART TWO of the Rules. In the calculations, the ship's parameters which depend on the draught are to be determined at the appropriate draught, but L and B are to be determined only at the UIWL. The main engine output is not to be less than the greater of these two outputs.

$$N_r = K_e \frac{\left(\frac{R_{CH}}{1000}\right)^{3/2}}{D_p} \qquad \text{kW}$$

where: D_p — diameter of the propeller, in m;

K_e — propulsion coefficient, for conventional propulsion systems, to be taken from Table 14.1.2.3(1), for advanced propulsion systems, to be determined by ship model tests and other equivalent methods, but the requirements of 14.1.2.4 are to be complied with.

Propulsion Coefficient K_e **Table 14.1.2.3(1)**

Propeller type or machinery	CP or electric or hydraulic propulsion machinery	FP propeller
1 propeller	2.03	2.26
2 propellers	1.44	1.60
3 propellers	1.18	1.31

R_{CH} — the resistance of the ship in a channel with brash ice and a consolidated layer, in N, to be determined by the following formula:

$$R_{CH} = C_1 + C_2 + 845 C_\mu \left(H_F + H_M\right)^2 \left(B + C_\psi H_F\right) + 42 L_{PAR} H_F^2 + 825 \left(\frac{LT}{B^2}\right)^3 \frac{A_{wf}}{L}$$

where C_1 and C_2 are coefficients taking into account a consolidated upper layer of the brash ice and taken as zero for B1, B2 and B3; for B1*:

$$C_1 = 23\frac{BL_{PAR}}{\frac{2T}{B}+1} + (1+0.021\varphi_1)(45.8B + 14.7L_{BOW} + 29BL_{BOW});$$

$$C_2 = (1+0.063\varphi_1)(1530+170B) + (400+480\frac{T}{B})\frac{B^2}{\sqrt{L}};$$

$C_\mu = 0.15\cos\varphi_2 + \sin\psi\sin\alpha$, $C_\mu \geq 0.45$;

$C_\psi = 0.047\psi - 2.115$, and $C_\psi = 0$ if $\psi \leq 45°$;

$\left(\frac{LT}{B^2}\right)^3$ is not to be greater than 20 or less than 5;

$$\psi = \arctan\left(\frac{\tan\varphi_2}{\sin\alpha}\right);$$

A_{wf} — area of waterline of the bow, in m^2, see Figure 14.1.2.3;

B — maximum breadth of the ship, measured horizontally from outside of frame to outside of frame, in m;

H_M — thickness of the brash ice in mid channel, in m, to be taken as 1.0 for B1* and B1, 0.8 for B2 and 0.6 for B3;

H_F — thickness of the brash ice layer displaced by the bow, in m, $H_F = 0.26 + \sqrt{H_M B}$;

L_{BOW} — length of the bow, in m, see Figure14.1.2.3;

L_{PAR} — length of the parallel midship body, in m, see Figure 14.1.2.3;

L — length of the ship between the perpendiculars, in m, measured from the forward side of the stem to the after side of the rudder post, or to the center of the rudder stock if there is no rudder post;

T — actual ice class draughts of the ship, i.e. maximum draught amidships referred to as UIWL and the minimum draught referred to as LIWL, in m;

α — the angle of the waterline at B/4, in °, see Figure 14.1.2.3;

φ_1 — the rake of the stem at the centerline, in °, see Figure 14.1.2.3, for bulbous bow, φ_1 = 90°;

φ_2 — the rake of the bow at B/4, in °, see Figure 14.1.2.3.

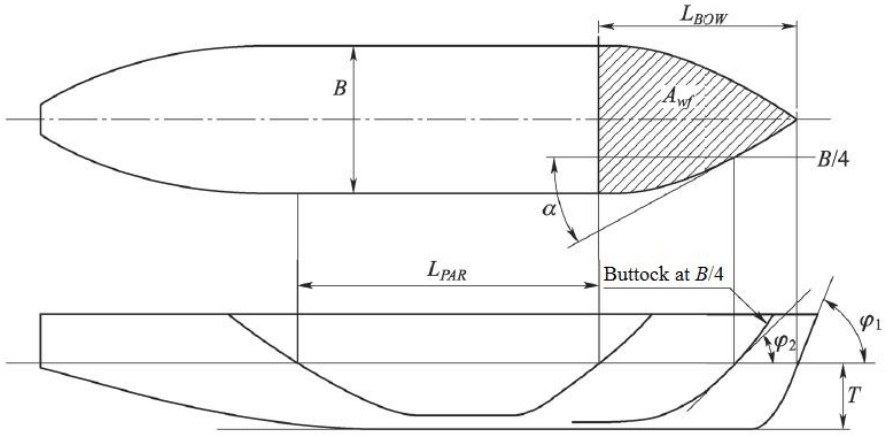


Figure 14.1.2.3

14.1.2.4 Where the value of K_e or R_{CH} is determined by ship model tests and other equivalent methods, the design requirement for ice classes is a minimum speed of 5 knots in the following brash ice channels:

B1* H_M=1.0 m and a 0.1 m thick consolidated layer of ice;

B1 H_M=1.0 m;

B2 H_M=0.8 m;

B3 H_M=0.6 m.

Section 2 PROPULSION MACHINERY

14.2.1 General requirements

14.2.1.1 These requirements apply to propulsion machinery, including controllable pitch (CP) or fixed pitch (FP) propellers and ducted-type propellers.The loads given are the expected ice loads for the ship's entire service life under normal operational conditions, including loads resulting from the changing rotational direction of fixed pitch propellers. However, these loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice.

14.2.1.2 These requirements also apply to azimuthing and fixed thrusters for main propulsion, considering loads resulting from propeller-ice interaction and loads on the thruster body/ice interaction. The given loads are the expected ice loads for the ship's entire service life under normal operational conditions. However, the load models do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially). The local strength of the thruster body is to be sufficient to withstand local ice pressure when the thruster body is designed for extreme loads. The thruster global vibrations caused by blade order excitation on the propeller may cause significant vibratory loads.

14.2.1.3 The given loads are intended for component strength calculations only and are total loads including ice-induced loads and hydrodynamic loads during propeller/ice interaction. The presented maximum loads are based on a worst case scenario that occurs once during the service life of the ship. Thus, the load level for a higher number of loads is lower.

14.2.1.4 If the highest point of the propeller is not at a depth of at least h_0 as specified in Table 4.2.4.2(1), Chapter 4, PART TWO of the Rules below the water surface when the ship is in ballast condition, the propulsion system is to be designed according to ice class B1 for ice classes B2 and B3.

14.2.2 Definitions of parameter symbols and loads

14.2.2.1 The main symbols, designations and units used for parameters in this Section are defined as follows:

c — chord length, in m, of blade section;

$c_{0.7}$ — chord length, in m, of blade section at 0.7 R propeller radius;

D — propeller diameter, in m;

d — external diameter, in m, of propeller hub;

D_{limit} — limit value, in m, for propeller diameter;

EAR — expanded blade area ratio;

F_b — maximum backward blade force, in kN, for the ship's service life;

F_{ex} — ultimate blade load, in kN, resulting from blade loss through plastic bending, referred to as blade failure load for short;

F_f — maximum forward blade force, in kN, for the ship's service life;

F_{ice} — ice load, in kN;

$(F_{ice})_{max}$ — maximum ice load, in kN, for the ship's service life;

h_0 — depth, in m, of the propeller centreline from lower ice waterline;

H_{ice} — thickness, in m, of maximum design ice block entering into propeller;

I — equivalent mass moment, in kgm^2, of inertia of all parts on engine side of component under consideration;

I_t — equivalent mass moment, in kgm^2, of inertia of the whole propulsion system;

k — shape parameter for Weibull distribution;

LIWL — lower ice waterline, in m;

m — slope for S-N curve in log/log scale;

M_{BL} — blade bending moment, in kN·m;

n — propeller rotational speed, in r/s;

n_n — nominal propeller rotational speed, in r/s, at maximum continuous rating (MCR) in free running condition;

N_{class} — reference number of impacts per propeller rotational speed per ice class;

N_{ice} — total number of ice loads on propeller blade for the ship's service life;

N_R — reference number of load for equivalent fatigue stress (10^8 cycles);

N_Q — number of propeller revolutions during a milling sequence;

$P_{0.7}$ — propeller pitch, in m, at 0.7 R radius;

$P_{0.7n}$ — propeller pitch, in m, at 0.7 R radius at MCR in free running condition;

$P_{0.7b}$ — propeller pitch, in m, at 0.7 R radius at MCR in bollard condition;

Q — torque, in kN·m;

Q_{emax} — maximum engine torque, in kN·m;
Q_{max} — maximum torque, in kN·m, on the propeller resulting from propeller-ice interaction;
Q_{max}^{n} — maximum torque, in kNm, on the propeller resulting from propeller/ice interaction reduced to the rotational speed in question;
Q_{motor} — electric motor peak torque, in kN·m;
Q_n — nominal torque, in kN·m, at MCR in free running condition;
Q_r — maximum response torque, in kN·m, along the propeller shaft line;
Q_{peak} — maximum of the response torque Q_r, in kNm;
Q_{smax} — maximum spindle torque, in kN·m, of the blade for the ship's service life;
Q_{sex} — maximum spindle torque due to blade failure caused by plastic bending F_{ex}, in kNm;
Q_{vib} — vibratory torque at considered component, taken from frequency domain open water torque vibration calculation (TVC) , in kNm;
R — propeller radius, in m;
r — blade section radius, in m;
T — propeller thrust, in kN;
T_b — maximum backward propeller ice thrust, in kN, for the ship's service life;
T_f — maximum forward propeller ice thrust, in kN, for the ship's service life;
T_n — propeller thrust, in kN, at MCR in free running condition;
T_r — maximum response thrust, in kN, along the shaft line;
t — maximum blade section thickness, in m;
Z — number of propeller blades;
α_i — duration of propeller blade/ice interaction expressed in rotation angle, in degrees;
a_1 — phase angle of propeller ice torque for blade order excitation component, in degrees;
a_2 — phase angle of propeller ice torque for twice the blade order excitation component, in degrees;
$\gamma_{\varepsilon 1}$ — the reduction factor for fatigue (scatter effect);
$\gamma_{\varepsilon 2}$ — the reduction factor for fatigue (test specimen size effect);
γ_v — the reduction factor for fatigue (variable amplitude loading effect);
γ_m — the reduction factor for fatigue (mean stress effect);
ρ — a reduction factor for fatigue correlating the maximum stress amplitude to the equivalent fatigue stress for 10^8 stress cycles;
$\sigma_{0.2}$ — proof yield strength, in MPa, of blade material;
σ_{exp} — mean fatigue strength, in MPa, of blade material at 10^8 cycles to failure in seawater;
σ_{fat} — equivalent fatigue ice load stress amplitude, in MPa, for 10^8 stress cycles;
σ_{fl} — characteristic fatigue strength, in MPa, for blade material;
σ_{ref} — reference stress, in MPa, $\sigma_{ref} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$;
σ_{ref2} — reference stress, in MPa, $\sigma_{ref2} = 0.7 \cdot \sigma_u$ or $\sigma_{ref2} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$, whichever is less;
σ_{st} — maximum stress, in MPa, resulting from F_b or F_f;
σ_u — ultimate tensile strength, in MPa, of blade material;
$(\sigma_{ice})_{bmax}$ — principal stress, in MPa, caused by the maximum backward propeller ice load;
$(\sigma_{ice})_{fmax}$ — principal stress, in MPa, caused by the maximum forward propeller ice load;
$(\sigma_{ice})_{max}$ — maximum ice load stress amplitude, in MPa.

14.2.2.2 The definitions and uses of loads used in these requirements are given in Table 14.2.2.2.

Definitions and Uses of Loads **Table 14.2.2.2**

Load	Definition	Use of the load in design process
F_b	The maximum lifetime backward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7 R chord line. See Figure 14.2.2.2. Ice contact pressure at the leading edge is shown with small arrows	Design force for strength calculation of the propeller blade
F_f	The maximum lifetime forward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7 R chord line	Design force for calculation of strength of the propeller blade.
Q_{smax}	The maximum lifetime spindle torque on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade	In designing the propeller strength, the spindle torque is taken into account because the propeller load is acting on the blade as distributed pressure on the leading edge or tip area

Load	Definition	Use of the load in design process
T_b	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction and the force is opposite to the hydrodynamic thrust	Used for estimation of the response thrust T_r. T_b can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in these requirements
T_f	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction acting in the direction of hydrodynamic thrust	Used for estimation of the response thrust T_r. T_f can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in these requirements
Q_{max}	The maximum ice-induced torque resulting from propeller/ice interaction on one propeller blade, including hydrodynamic loads on that blade	Used for estimation of the response torque (Q_r) along the propulsion shaft line and as excitation for torsional vibration calculations
F_{ex}	Ultimate blade load resulting from blade loss through plastic bending. The force may cause total failure of the blade so that plastic hinge is caused to the root area. The force is acting on 0.8 R. Spindle arm is to be taken as 2/3 of the distance between the axis of blade rotation and the leading/trailing edge (whichever is the greater) at the 0.8 R radius	Blade failure load is used to dimension the blade bolts, pitch control mechanism, propeller shaft, propeller shaft bearing and thrust bearing. The objective is to guarantee that total propeller blade failure should not cause damage to other components
Q_r	Maximum response torque along the propeller shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (torsional vibration) and hydrodynamic mean torque on propeller	Design torque for propeller shaft line components
T_r	Maximum response thrust along shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (axial vibration) and hydrodynamic mean thrust on propeller	Design thrust for propeller shaft line components
F_{ti}	Maximum response force caused by ice block impacts on the thruster body or the propeller hub	Design load for thruster body and slewing bearings
F_{tr}	Maximum response force on the thruster body caused by ice ridge/thruster body interaction.	Design load for thruster body and slewing bearings

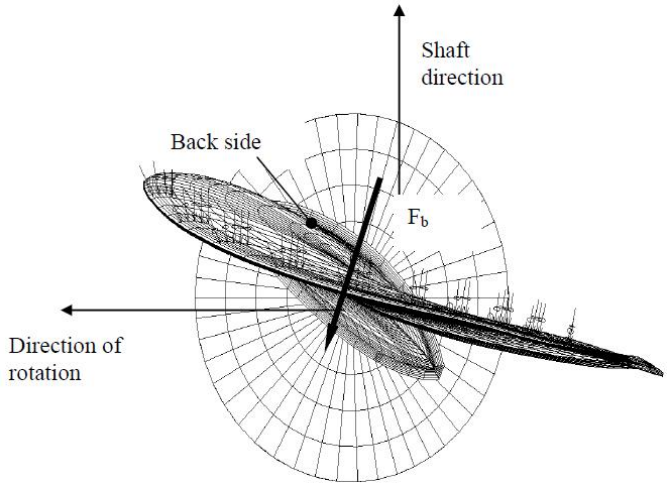


Figure 14.2.2.2 Direction of the backward blade force

14.2.3 Design ice conditions

14.2.3.1 In estimating the ice loads of the propeller for ice classes, different types of operation as given in Table 14.2.3.1 were taken into account.

Types of Operation for Ice Classes **Table 14.2.3.1**

Ice class	Operation of the ship
B1*	The ship may proceed by ramming for operation in ice channels and in level ice (not requiring ice breaker assistance)
B1, B2, B3	Operation in ice channels (if necessary, with ice breaker assistance)

14.2.3.2 For the estimation of design ice loads, a maximum ice block size is first to be determined. The maximum design ice block entering the propeller is a rectangular ice block with the dimensions H_{ice} × 2 H_{ice} × 3 H_{ice}. The design thickness of the ice block (H_{ice}) is given in Table 14.2.3.2.

Design Ice Thickness **Table 14.2.3.2**

Ice class	B1*	B1	B2	B3
Thickness of the design maximum ice block entering the propeller (H_{ice})	1.75 m	1.5 m	1.2 m	1.0 m

14.2.4 Materials

14.2.4.1 Materials exposed to seawater

Materials of components exposed to seawater, such as propeller blades, propeller hubs, and thruster body, are to have an elongation of not less than 15% on a test specimen, the gauge length of which is five times the diameter.

A Charpy-V impact test is to be carried out for materials other than bronze and austenitic stainless steel. An average impact energy value of not less than 20 J taken from three tests is to be obtained at minus 10℃.

For nodular cast iron, average impact energy of 10 J at minus 10 ºC is required accordingly.

14.2.4.2 Materials exposed to seawater temperature

Materials exposed to seawater temperature are to be of ductile material. An average impact energy value of not less than 20 J taken from three tests is to be obtained at minus 10℃. This requirement applies to the propeller shaft, blade bolts, CP mechanisms, shaft bolts, strut-pod connecting bolts etc. This does not apply to surface hardened components, such as bearings and gear teeth. The nodular cast iron of a ferrite structure type may be used for relevant parts other than bolts. The average impact energy for nodular cast iron is to be a minimum of 10 J at minus 10 ºC.

14.2.5 Design loads

14.2.5.1 Design loads on propeller blades

F_b is the maximum force experienced during the lifetime of the ship that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead. F_f is the maximum force experienced during the lifetime of the ship that bends a propeller blade forwards when the propeller mills an ice block while rotating ahead. These forces originate from different propeller/ice interaction phenomena, not acting simultaneously. Hence they are to be applied to one blade separately.

(1) Maximum backward blade force F_b for propellers

For $D \le D_{limit}$

$$F_b = 27(nD)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^2 \qquad \text{kN}$$

For $D > D_{limit}$

$$F_b = 23(nD)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} DH_{ice}^{1.4} \qquad \text{kN}$$

where: $D_{limit} = 0.85H_{ice}^{1.4}$, in m;

n — the nominal rotational speed (at MCR in free running condition) for a CP propeller and 85% of the nominal rotational speed (at MCR in free running condition) for an FP propeller.

(2) Maximum forward blade force F_f for propellers

For $D \le D_{limit}$

$$F_f = 250\frac{EAR}{Z}D^2 \qquad \text{kN}$$

For $D > D_{limit}$

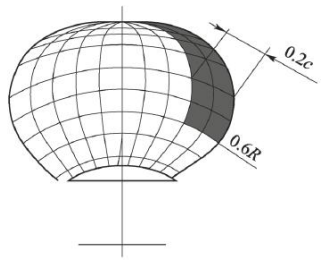
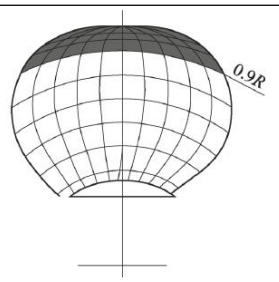
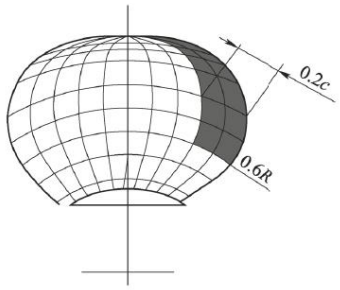
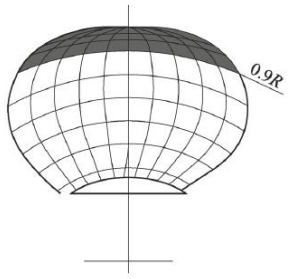
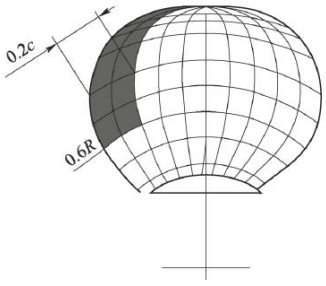
$$F_f = 500\frac{EAR}{Z}D\left(\frac{1}{1-\frac{d}{D}}\right)H_{ice} \qquad \text{kN}$$

where: $D_{limit} = \left(\frac{2}{1-\frac{d}{D}}\right)H_{ice}$, in m.

(3) Loaded area on the blade for propellers

Load cases 1 ~ 4 are to be covered, as given in Table 14.2.5.1(3), for CP and FP propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 is also to be covered for FP propellers.

Load Cases for Propellers **Table 14.2.5.1(3)**

Load case	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6 R to the tip and from the leading edge to 0.2 times the chord length	
Load case 2	50%F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside 0.9 R radius	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6 R to the tip and from the leading edge to 0.2 times the chord length	
Load case 4	50%F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside 0.9 R radius	
Load case 5	60%F_f or F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6 R to the tip and from the trailing edge to 0.2 times the chord length	

(4) Maximum backward blade ice force F_b for ducted propellers

For $D \leq D_{\text{limit}}$

$$F_b = 9.5(nD)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^2 \qquad \text{kN}$$

For $D > D_{\text{limit}}$

$$F_b = 66\left(nD\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^{0.6}H_{ice}^{1.4} \qquad \text{kN}$$

where: $D_{\text{limit}} = 4\,H_{ice}$, in m;

n — the nominal rotational speed (at MCR in free running condition) for a CP propeller and 85% of the nominal rotational speed (at MCR in free running condition) for an FP propeller.

(5) Maximum forward blade ice force F_f for ducted propellers

For $D \le D_{\text{limit}}$

$$F_f = 250\frac{EAR}{Z}D^2 \qquad \text{kN}$$

For $D > D_{\text{limit}}$

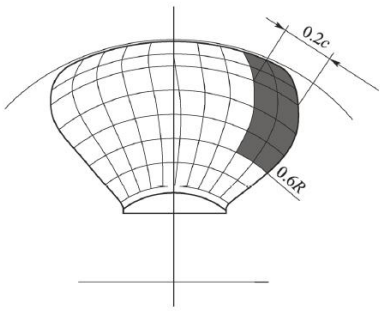
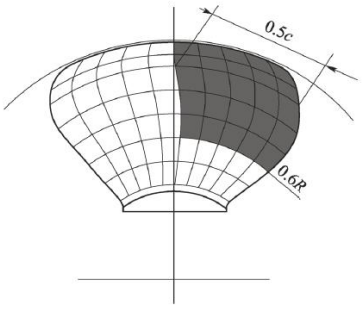
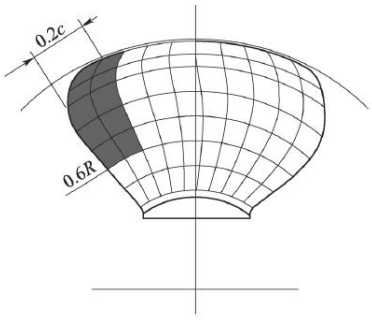
$$F_f = 500\frac{EAR}{Z}D\left(\frac{1}{1-\frac{d}{D}}\right)H_{ice} \qquad \text{kN}$$

where: $D_{\text{limit}} = \left(\frac{2}{1-\frac{d}{D}}\right)H_{ice}$, in m.

(6) Loaded area on the blade for ducted propellers

Load cases 1 and 3 are to be covered as given in Table 14.2.5.1(6) for all propellers, and load case 5 is to be additionally covered for an FP propeller to reflect ice loads when the propeller is reversed.

Load Cases for Ducted Propellers **Table 14.2.5.1(6)**

Load case	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6 R to the tip and from the leading edge to 0.2 times the chord length	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6 R to the tip and from the leading edge to 0.2 times the chord length	
Load case 5	60%F_f or F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6 R to the tip and from the trailing edge to 0.2 times the chord length	

(7) Maximum blade spindle torque for open and ducted propellers

The spindle torque around the axis of the blade fitting is to be calculated both for the maximum backward blade force F_b and forward blade force F_f, which are applied as in Table 14.2.5.1(3) and Table 14.2.5.1(6). The larger of the obtained torques is used as the dimensioning torque. If the above method gives a value which is less than the default value given by the formula below, the default value is to be used.

$$Q_{smax} = 0.25 F c_{0.7} \quad \text{kN·m}$$

where: F — F_b or F_f, whichever is greater.

(8) Load distributions for blade loads

The Weibull distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$), as given in Figure 14.2.5.2(8), is used for the fatigue design of the blade.

$$P\left(\frac{F_{ice}}{(F_{ice})_{\max}} \geq \frac{F}{(F_{ice})_{\max}}\right) = e^{\left(-\left(\frac{F}{(F_{ice})_{\max}}\right)^k \ln(N_{ice})\right)}$$

where: k — shape parameter of the spectrum, k = 0.75 for an open propeller and k = 1.0 for a ducted propeller;

N_{ice} — number of load cycles in the spectrum;

F_{ice} — random variable for ice loads on the blade, $0 \leq F_{ice} \leq (F_{ice})_{max}$.

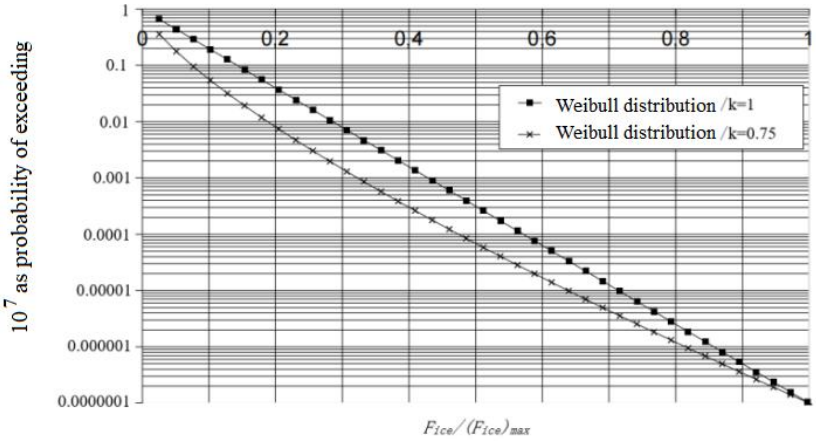


Figure 14.2.5.1(8) Weibull distribution (probability of exceeding) used for fatigue design

(9) Number of ice load cycles

The number of load cycles per propeller blade in the load spectrum is to be determined according to the following formula:

$$N_{ice} = k_1 k_2 k_3 N_{class} n_n$$

where: N_{class} — reference number of impacts per propeller rotational speed for ice classes, taken from Table 14.2.5.1(9);

k_1 — propeller location factor, k_1 = 1 for centre propellers bow first operation, k_1 = 2 for wing propellers bow first operation and k_1 = 3 for pulling propeller (wing and centre) bow propeller or stern first operation;

k_2 — submersion factor, determined as follows:

$k_4 = 0.8 - f$ for $f < 0$;

$k_4 = 0.8 - 0.4f$ for $0 \leq f \leq 1$;

$k_4 = 0.6 - 0.2f$ for $1 < f \leq 2.5$;

$k_4 = 0.1$ for $f > 2.5$;

where: $f = \dfrac{h_0 - H_{ice}}{D/2} - 1$

k_3 — propulsion machinery type factor, k_3 = 1 for fixed thrusters and k_3 = 1.2 for azimuthing thrusters;

Reference Number of Impacts per Propeller Rotational Speed for Ice Classes **Table 14.2.5.1(9)**

Ice class	B1*	B1	B2	B3
Reference number of impacts (during the service life)	9×10^6	6×10^6	3.4×10^6	2.1×10^6

For components that are subject to loads resulting from propeller/ice interaction with all the propeller blades, the number of load cycles (N_{ice}) is to be multiplied by the number of propeller blades (Z).

14.2.5.2 Axial design loads for open and ducted propellers

(1) Maximum ice thrust T_f and T_b on propeller for open and ducted propellers

The maximum forward and backward ice thrusts are:

$$T_f = 1.1F_f \quad \text{kN}$$

$$T_b = 1.1F_b \quad \text{kN}$$

(2) Design thrust along the propulsion shaft line for open and ducted propellers

The design thrust along the propeller shaft line is to be calculated with the formulae below. The greater value of the forward and backward direction loads is to be taken as the design load for both directions. The factors 2.2 and 1.5 take into account the dynamic magnification resulting from axial vibration.

In a forward direction:

$$T_r = T + 2.2\ T_f \quad \text{kN}$$

In a backward direction:

$$T_r = 1.5\ T_b \quad \text{kN}$$

If the hydrodynamic bollard thrust, T, is unknown, T is to be taken from Table 14.2.5.2(2).

Value of *T* **Table 14.2.5.2(2)**

Propeller type	T
CP propellers (open)	$1.25\ T_n$
CP propellers (ducted)	$1.1\ T_n$
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	$0.85\ T_n$
FP propellers driven by diesel engine (ducted)	$0.75\ T_n$

Note: T_n is the nominal propeller thrust at MCR in free running open water condition.

14.2.5.3 Torsional design loads

(1) Design ice torque Q_{max} on propeller for open propellers (maximum value during the service life of the ship)

For $D \le D_{limit}$

$$Q_{max} = 10.9\left(1 - \frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^3 \quad \text{kN·m}$$

For $D > D_{limit}$

$$Q_{max} = 20.7\left(1 - \frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9}H_{ice}{}^{1.1} \quad \text{kN·m}$$

where: $D_{limit} = 1.8\ H_{ice}$;

n — rotational propeller speed at MCR, in r/s, in bollard condition. If unknown, n is to be taken from Table 14.2.5.3(1):

Value of *n* **Table 14.2.5.3(1)**

Propeller type	n
CP propellers (open)	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine (open)	$0.85\ n_n$

Note: n_n is the nominal rotational speed at MCR in free running open water condition.

For CP propellers, the propeller pitch $P_{0.7}$ is to correspond to MCR in bollard condition, i.e. taken as $P_{0.7b}$. If unknown, $P_{0.7}$ is to be taken as $0.7 \cdot P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at MCR in free running condition.

(2) Design ice torque Q_{max} on propeller for ducted propellers (maximum value during the service life of the ship)

For $D \le D_{limit}$

$$Q_{max} = 7.7\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^3 \qquad \text{kN·m}$$

For $D > D_{\text{limit}}$

$$Q_{max} = 14.6\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9}H_{ice}{}^{1.1} \qquad \text{kN·m}$$

where: $D_{\text{limit}} = 1.8\ H_{\text{ice}}$;

n — rotational propeller speed at MCR, in r/s, in bollard condition. If unknown, n is to be taken from Table 14.2.5.3(1).

For CP propellers, the propeller pitch $P_{0.7}$ is to correspond to MCR in bollard condition, i.e. taken as $P_{0.7b}$. If unknown, $P_{0.7}$ is to be taken as $0.7 \cdot P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at MCR in free running condition.

(3) Design torque for non-resonant shaft lines

If there is no bladed secondary torsional resonance within a speed range of 20% above or below the maximum operating speed under bollard conditions (i.e., the nominal speed n_n at maximum sustained power free running without ice) and within the usual speed range, the maximum response torque estimated by the equation below can be used.

Directly coupled two stroke diesel engines without flexible coupling

$$Q_{peak} = Q_{e\max} + Q_{\text{vib}} + Q_{\max}\frac{I_{\text{e}}}{I_t} \qquad \text{kNm}$$

and other plants

$$Q_{peak} = Q_{e\max} + Q_{\max}\frac{I_{\text{e}}}{I_t} \qquad \text{kNm}$$

where all the torques and the inertia moments are to be converted to equivalent values at the rotation speed of the component being examined.

If the maximum torque Q_{emax} is unknown, it is to be taken from Table 14.2.5.3(3):

Value of Q_{emax} **Table 14.2.5.3(3)**

Propeller type	Q_{emax}
Propellers driven by electric motor	Q_{motor}
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	$0.75Q_n$

Note: Q_{motor} is the electric motor peak torque.

(4) Design torque for shaft lines having resonances

If there is bladed secondary torsional resonance within a speed range of 20% above or below the maximum operating speed under bollard conditions (i.e., the nominal speed n_n at maximum sustained power free running without ice) and within the usual speed range, the design torque (Q_{peak}) of the shaft component is to be determined by means of torsional vibration analysis of the propulsion line. There are two alternative ways of performing the dynamic analysis.

1. Time domain calculation for estimated milling sequence excitation
2. Frequency domain calculation for blade orders sinusoidal excitation.

The frequency domain analysis is generally considered conservative compared to the time domain simulation, provided that there is a first blade order resonance in the considered speed range.

① Time domain calculation of torsional response

Time domain calculations are to be calculated for the MCR condition, MCR bollard conditions and for blade order resonant rotational speeds so that the resonant vibration responses can be obtained.

The load sequence given in this chapter, for a case where a propeller is milling an ice block, is to be used for the strength evaluation of the propulsion line. The given load sequence is not intended for propulsion system stalling analyses.

The following load cases are intended to reflect the operational loads on the propulsion system, when the propeller interacts with ice, and the respective reaction of the complete system. The ice impact and system response causes loads in the individual shaft line components. The ice torque Q_{max} may be taken as a constant value in the complete speed range. When considerations at specific shaft speeds are performed, a relevant Q_{max} may be calculated using the relevant speed according to 14.2.5.3.

Diesel engine plants without an elastic coupling are to be calculated at the least favourable phase angle for ice versus engine excitation, when calculated in the time domain. The engine firing pulses are to be included in the calculations and their standard steady state harmonics can be used.
If there is a blade order resonance just above the MCR speed, calculations are to cover rotational speeds up to 105% of the MCR speed.
The propeller ice torque excitation for shaft line transient dynamic analysis is to be defined as a sequence of blade impacts which are of a half sine shape.The torque resulting from a single blade ice impact as a function of the propeller rotation angle is as follows:
For $\varphi = 0...\alpha_i$

$$Q(\varphi) = C_q Q_{\max} \sin[\varphi(180/\alpha_i)] \quad \text{kN·m}$$

For $\varphi = \alpha_i ....360$

$$Q(\varphi) = 0 \quad \text{kN·m}$$

Where φ is the rotation angle from when the first impact occurs; α_i is the duration of propeller blade/ice interaction expressed in terms of the propeller rotation angle (see Figure 14.2.5.3(4)①-1); the parameters C_q and α_i are given in Table 14.2.5.3(4)①.

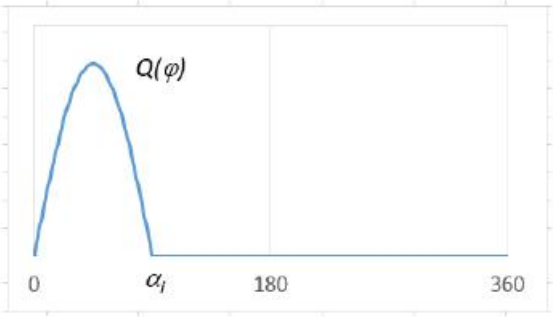


Figure 14.2.5.3(4)①-1 Schematic ice torque due to a single blade ice impact as a function of the propeller rotation angle

Values of Ice Impact Magnification Factor C_q and Duration Factor α_i **Table 14.2.5.3(4)①**

Torque excitation	Propeller/ice interaction	C_q	α_i(°)			
			Z=3	Z=4	Z=5	Z=6
Case 1	Single ice block	0.75	90	90	72	60
Case 2	Single ice block	1.0	135	135	135	135
Case 3	Two ice blocks (phase shift 360°/2/Z)	0.5	45	45	36	30
Case 4	Single ice block	0.5	45	45	36	30

The total ice torque is obtained by summing the torque of single blades, taking into account the phase shift 360°/Z, see Figure 14.2.5.3(4)①-2. In addition, at the beginning and at the end of the milling sequence a linear ramp function is to be used to increase C_q to its maximum value within one propeller revolution and vice versa to decrease it to zero (see the examples of different Z numbers in Figure 14.2.5.3(4)①-2).
The number of propeller revolutions during a milling sequence may be obtained as follows:

$$N_Q = 2H_{ice}$$

The number of impacts for blade order excitation is:

$$Z\,N_Q$$

An illustration of all excitation cases for different numbers of blades is given in Figure 14.2.5.3(4)①-2.
A dynamic simulation is to be performed for all excitation cases at the operational rotational speed range. For a fixed pitch propeller propulsion plant, a dynamic simulation is also to cover the bollard pull condition with a corresponding rotational speed assuming the maximum possible output of the engine.
If a speed drop occurs until the main engine is at a standstill, this indicates that the engine may not be sufficiently powered for the intended service task. For the consideration of loads, the maximum occurring torque during the speed drop process is to be used.

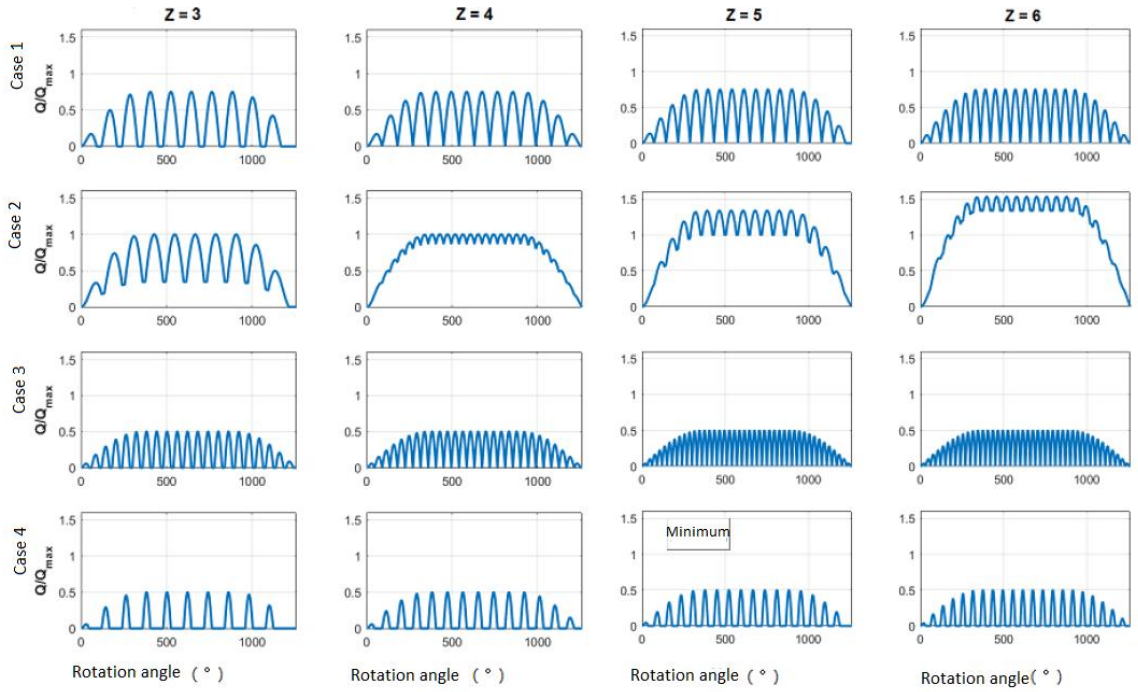


Figure 14.2.5.3(4)①-2 –The shape of the propeller ice torque excitation sequences for propellers with 3, 4, 5 or 6 blades

For the time domain calculation, the simulated response torque typically includes the engine mean torque and the propeller mean torque. If this is not the case, the response torques are to be obtained using the formula:

$$Q_{peak} = Q_{e\max} + Q_{\mathrm{rtd}} \qquad \text{kNm}$$

where: Q_{rtd} is the maximum simulated torque obtained from the time domain analysis.

② Frequency domain calculation of torsional response

For frequency domain calculations, blade order and twice-the-blade-order excitation may be used. The amplitudes for the blade order and twice-the-blade-order sinusoidal excitation have been derived based on the assumption that the time domain half sine impact sequences were continuous, and the Fourier series components for blade order and twice-the-blade-order components have been derived. The propeller ice torque is then:

$$Q_F(\varphi) = Q_{\max} \cdot \left[C_{q0} + C_{q1} \cdot \sin\left(Z \cdot E_0 \cdot \varphi + \alpha_1\right) + C_{q2} \cdot \sin\left(2Z \cdot E_0 \cdot \varphi + \alpha_2\right) \right] \qquad \text{kNm}$$

where: φ — rotation angle;

α_1, α_2— phase angles of the excitation component;

C_{q0} —mean torque parameter;

C_{q1} —the first blade order excitation parameter;

C_{q2} —the second blade order excitation parameter;

E_0 —the number of ice blocks in contact.

The values of the parameters for frequency domain excitation calculation are given in Table 14.2.5.3(4)②.

Coefficient values for frequency domain excitation calculation **Table 14.2.5.3(4)②**

Torque excitation	Z=3					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.375	0.375	-90	0	0	1
Excitation case 2	0.7	0.33	-90	0.05	-45	1
Excitation case 3	0.25	0.25	-90	0	0	2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=4					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.45	0.36	-90	0.06	-90	1
Excitation case 2	0.9375	0	-90	0.0625	-90	1
Excitation case 3	0.25	0.25	-90	0	0	2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=5					

	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.45	0.36	-90	0.06	-90	1
Excitation case 2	1.19	0.17	-90	0.02	-90	1
Excitation case 3	0.3	0.25	-90	0.048	-90	2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=6					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.45	0.375	-90	0.05	-90	1
Excitation case 2	1.435	0.1	-90	0	0	1
Excitation case 3	0.3	0.25	-90	0.048	-90	2
Excitation case 4	0.2	0.25	0	0.05	-90	1

The design torque for the frequency domain excitation case is to be obtained using the formula:

$$Q_{peak} = Q_{\max e} + Q_{vib} + \left(Q^n_{\max} C_{q0}\right) I_e / I_t + Q_{rf1} + Q_{rf2} \qquad \text{kNm}$$

where: $Q_{max}{}^n$ — the maximum propeller ice torque at the operation speed in consideration;

C_{q0} — mean torque parameter, see Table 14.2.5.3(4)②;

Q_{rf1} — the blade order torsional response from the frequency domain analysis;

Q_{rf2} — the second order blade torsional response from the frequency domain analysis.

If the prime mover maximum torque, Q_{emax}, is not known, it is to be taken as given in Table 14.2.5.3(3). All the torque values have to be scaled to the shaft revolutions for the component in question.

③ Guidance for torsional vibration calculation

The aim of time domain torsional vibration simulations is to estimate the extreme torsional load for the ship's lifespan. The simulation model can be taken from the normal lumped mass elastic torsional vibration model, including damping. For a time domain analysis, the model should include the ice excitation at the propeller, other relevant excitations and the mean torques provided by the prime mover and hydrodynamic mean torque in the propeller. The calculations should cover variation of phase between the ice excitation and prime mover excitation. This is extremely relevant to propulsion lines with directly driven combustion engines. Time domain calculations are to be calculated for the MCR condition, MCR bollard conditions and for resonant speed, so that the resonant vibration responses can be obtained.

For frequency domain calculations, the load should be estimated as a Fourier component analysis of the continuous sequence of half sine load sequences. First and second order blade components should be used for excitation. The calculation should cover the entire relevant rpm range and the simulation of responses at torsional vibration resonances.

14.2.5.4 Blade failure load

(1) Bending force, F_{ex}

The ultimate load resulting from blade failure as a result of plastic bending around the blade root is to be calculated with the formula below, or alternatively by means of an appropriate stress analysis, reflecting the non-linear plastic material behaviour of the actual blade. In such a case, the blade failure area may be outside the root section. The ultimate load is assumed to be acting on the blade at the 0.8 R radius in the weakest direction of the blade. A blade is regarded as having failed if the tip is bent into an offset position by more than 10% of propeller diameter D.

$$F_{ex} = \frac{0.3ct^2\sigma_{refl}}{0.8D - 2r} \times 10^3 \qquad \text{kN}$$

where: $\sigma_{refl} = 0.6\sigma_{0.2} + 0.4\sigma_u$;

c, t and r are respectively the chord length, maximum thickness, and radius of the cylindrical root section of the blade at the weakest section outside the root fillet.

(2) Spindle torque, Q_{sex}

The maximum spindle torque due to a blade failure load acting at 0.8R is to be determined.

The force that causes blade failure typically reduces when moving from the propeller centre towards the leading and trailing edges. At a certain distance from the blade centre of rotation, the maximum spindle torque will occur. This maximum spindle torque is to be defined by an appropriate stress analysis or using the equation given below.

$$Q_{sex} = \max(C_{LE0.8}, 0.8C_{TE0.8})C_{spex}F_{ex}$$

where: $C_{spex} = C_{sp}C_{fex} = 0.7\left[1-\left(4\frac{EAR}{Z}\right)^3\right]$;

C_{sp} — a non-dimensional parameter taking account of the spindle arm;

C_{fex} —a non-dimensional parameter taking account of the reduction of the blade failure force at the location of the maximum spindle torque;

C_{spex} —If C_{spex} is below 0.3, a value of 0.3 is to be used for C_{spex};

$C_{LE0.8}$ —the leading edge portion of the chord length at 0.8R;

$C_{TE0.8}$ —the trailing edge portion of the chord length at 0.8R.

Figure 14.2.5.4(2) illustrates the spindle torque values due to blade failure loads across the entire chord length.

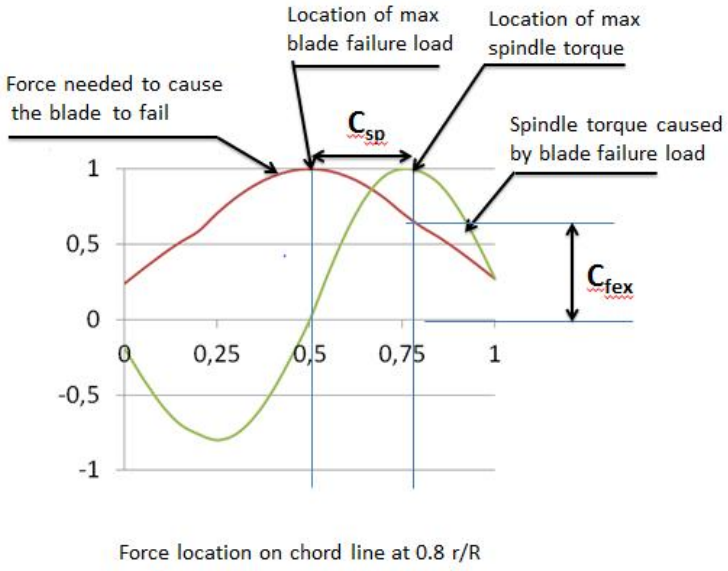


Figure 14.2.5.4(2) Schematic figure showing a blade failure load and the related spindle torque when the force acts at a different location on the chord line at radius 0.8*R*

14.2.6 Design

14.2.6.1 Design principle

The strength of the propulsion line is to be designed according to the pyramid strength principle. This means that the loss of the propeller blade is not to cause any significant damage to other propeller shaft line components.

14.2.6.2 Propeller blade

(1) Calculation of blade stresses

The blade stresses are to be calculated for the design loads given in paragraph 14.2.5.1. Finite element analysis is to be used for stress analysis of all propellers. The following simplified formulae can be used in estimating the blade stresses for all propellers at the root area ($r/R < 0.5$). The root area dimensions can be accepted even if the finite element analysis would show greater stresses at the root area.

$$\sigma_{st} = \mathrm{A}_1 \frac{M_{BL}}{100 \times ct^2} \quad \text{MPa}$$

where the constant A_1 is the ratio of the actual stress to the stress obtained with beam equation. If the actual value is not available, A_1 is to be taken as 1.6. $M_{BL} = (0.75 - r/R)RF$ for the relative radius $r/R < 0.5$, where F is F_b or F_f, whichever is greater.

(2) Acceptability criterion

The following criterion for calculated blade stresses is to be fulfilled:

$$\frac{\sigma_{ref2}}{\sigma_{st}} \geq 1.3$$

where: σ_{st} — calculated stress for the design loads. If finite element analysis is used in estimating the stresses, equivalent von Mises stresses are to be used;

σ_{ref2} — reference stress, taken as the lesser of $0.7\sigma_u$ and $(0.6\sigma_{0.2} + 0.4\sigma_u)$.

(3) Fatigue design of propeller blade

The fatigue design of the propeller blade is based on an estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress that produces the same fatigue damage as the expected load distribution is to be calculated and the acceptability criterion for fatigue should be fulfilled as given in this paragraph. The equivalent stress cycles are specified as 1×10^8.

For materials with a two-slope SN curve (see Figure 14.2.6.2(3)-1), if the following criterion is fulfilled, fatigue calculations according to this Chapter are not required:

$$\sigma_{\exp} \geq B_1 \cdot \sigma_{ref\,2}{}^{B_2} \cdot \log(N_{ice})^{B_3}$$

where coefficients B_1, B_2 and B_3 for open and ducted propellers are given in the Table 14.2.6.2(3).

Values of B_1, B_2 and B_3 **Table 14.2.6.2(3)**

Coefficient	Open propeller	Ducted propeller
B_1	0.00328	0.00223
B_2	1.0076	1.0071
B_3	2.101	2.471

Two types of S-N curves are available for calculation of equivalent stresses. The two-slope S-N curve (slopes 4.5 and 10) is shown in Figure 14.2.6.2(3)-1 and the one-slope S-N curve (the slope can be chosen) in Figure 14.2.6.2(3)-2.

The type of the S-N curve is to be selected to correspond to the material properties of the blade. If the S-N curve is unknown, the two-slope S-N curve is to be used.

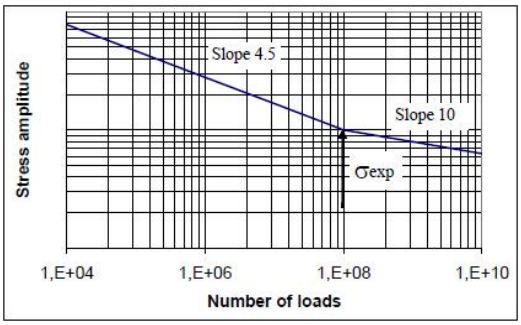


Figure 14.2.6.2(3)-1 Two-slope S-N curve

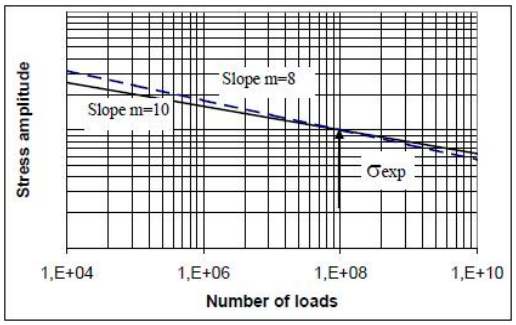


Figure 14.2.6.2(3)-2 One-slope S-N curve

① Equivalent fatigue stress

The equivalent fatigue stress for 10^8 stress cycles which produces the same fatigue damage as the load distribution for the service life of the ship is:

$$\sigma_{fat} = \rho \cdot (\sigma_{ice})_{\max} \quad \text{MPa}$$

where: $(\sigma_{ice})_{\max}$ — mean value of the principal stress amplitudes resulting from design forward and backward blade forces at the location being studied, determined as follows:

$$(\sigma_{ice})_{\max} = 0.5 \cdot \left((\sigma_{ice})_{f\,\max} - (\sigma_{ice})_{b\,\max}\right) \quad \text{MPa}$$

where $(\sigma_{ice})_{f\,\max}$ is the principal stress resulting from forward load and $(\sigma_{ice})_{b\,\max}$ the principal stress resulting from backward load.

In calculation of $(\sigma_{ice})_{\max}$, case 1 and case 3 (or case 2 and case 4) are considered as a pair for $(\sigma_{ice})_{f\max}$, and $(\sigma_{ice})_{b\max}$ calculations. Case 5 is excluded from the fatigue analysis.

② Calculation of ρ parameter for two-slope S-N curve

The parameter ρ relates the maximum ice load to the distribution of ice loads according to the regression formulae.

$$\rho = C_1 \cdot (\sigma_{ice})_{\max}{}^{C_2} \cdot \sigma_{fl}{}^{C_3} \cdot \log(N_{ice})^{C_4}$$

where: $\sigma_{fl} = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{\exp}$

where $\gamma_{\varepsilon 1}$ and $\gamma_{\varepsilon 2}$ are respectively the reduction factor for scatter and test specimen size effect, γ_v the reduction factor for variable amplitude loading, and γ_m the reduction factor for mean stress, and $\gamma_\varepsilon = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} = 0.67$, $\gamma_v = 0.75$, and $\gamma_m = 0.75$ if actual values are not available; $\sigma_{\exp}$ is the mean fatigue strength of the blade material at 10^8 cycles to failure in seawater.

The values of coefficients C_1, C_2, C_3 and C_4 are given in Table 14.2.6.2(3)②.

Values of C_1, C_2, C_3 and C_4 **Table 14.2.6.2(3)②**

Coefficient	Open propeller	Ducted propeller
C_1	0.000747	0.000534
C_2	0.0645	0.0533
C_3	-0.0565	-0.0459
C_4	2.22	2.584

③ Calculation of ρ parameter for one-slope S-N curve

For materials with a one-slope S-N curve, as shown in Figure 14.2.6.2(3)-2, the ρ factor is to be calculated as follows:

$$\rho = \left(G \frac{N_{ice}}{N_R} \right)^{1/m} (\ln(N_{ice}))^{-1/k}$$

where: k — shape parameter of the Weibull distribution, k = 1.0 for ducted propellers and k = 0.75 for open propellers;

N_R — reference number of load cycles, taken as10^8;

N_{ice} —range is $5\times10^6 \le N_{ice} \le 10^8$;

G — Values for the G parameter are given in Table 14.2.6.2(3)③; linear interpolation may be used to calculate the G value for other m/k ratios than given in the Table.

Values of the Parameter G for Different m/k Ratios **Table 14.2.6.2(3)③**

m/k	G	m/k	G	m/k	G	m/k	G
3	6	5.5	287.9	8	40320	10.5	11.899E6
3.5	11.6	6	720	8.5	119292	11	39.917E6
4	24	6.5	1871	9	362880	11.5	136.843E6
4.5	52.3	7	5040	9.5	1.133E6	12	479.002E6
5	120	7.5	14034	10	3.623E6		

④ Acceptability criterion for fatigue

The equivalent fatigue stress at all locations on the blade is to fulfill the following acceptability criterion:

$$\frac{\sigma_{fl}}{\sigma_{fat}} \ge 1.5$$

where: σ_{fl} — characteristic fatigue strength of the blade material, in MPa, calculated as in 14.2.6.2(3)②;

σ_{fat}— equivalent fatigue ice load stress amplitude, in MPa, for 10^8 stress cycles.

14.2.6.3 Propeller bossing and CP mechanism

The blade bolts, the CP mechanism, the propeller boss, and the fitting of the propeller to the propeller shaft are to be designed to withstand the maximum and fatigue design loads, as defined in paragraph 14.2.5. The safety factor against yielding is to be greater than 1.3 and that against fatigue greater than 1.5. In addition, the safety factor for loads resulting from loss of the propeller blade through plastic bending, as defined in paragraph 14.2.5.4, is to be greater than 1.0 against yielding.

14.2.6.4 Propulsion shaft line

The shafts and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings, are to be designed to withstand the propeller/ice interaction loads as given in paragraph 14.2.5. The safety factor is to be at least 1.3 against yielding for extreme operational loads, 1.5 for fatigue loads and 1.0 against yielding for the blade failure load.

(1) Shafts and shafting components

The ultimate load resulting from total blade failure, as defined in paragraph 14.2.5.4, should not cause yielding in shafts and shaft components. The loading is to consist of the combined axial, bending, and torsion loads. The minimum safety factor against yielding is to be 1.0 for bending and torsional stresses.

14.2.6.5 Azimuthing main propulsors

(1) Design principle

In addition to the above requirements for propeller blade dimensioning, azimuthing thrusters are to be designed for thruster body/ice interaction loads. Load formulae are given for estimating once in a lifetime extreme loads on the thruster body, based on the estimated ice condition and ship operational parameters. Two main ice load scenarios have been selected for defining the extreme ice loads. Examples of loads are illustrated in Figure 14.2.6.5(1). In addition, blade order thruster body vibration responses may be estimated for propeller excitation. The following load scenario types are considered:

① Ice block impact on the thruster body or propeller hub;
② Thruster penetration into an ice ridge that has a thick consolidated layer;
③ Vibratory response of the thruster at blade order frequency.

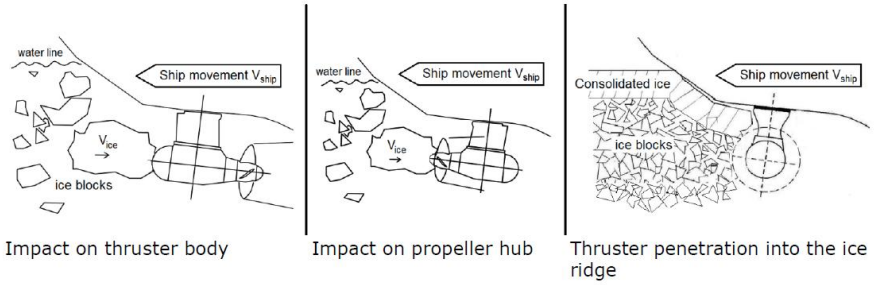


Figure 14.2.6.5(1) Examples of load scenario types

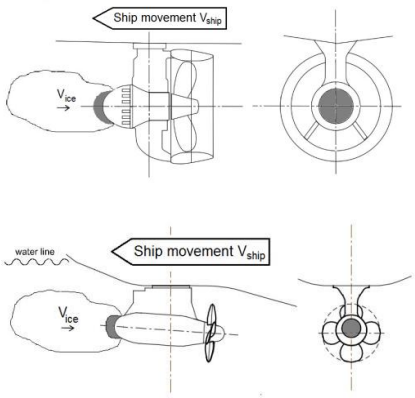
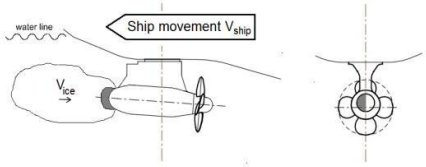
The steering mechanism, the fitting of the unit, and the body of the thruster are to be designed to withstand the plastic bending of a blade without damage. The loss of a blade is to be taken into account for the propeller blade orientation causing the maximum load on the component being studied. Top-down blade orientation typically places the maximum bending loads on the thruster body.

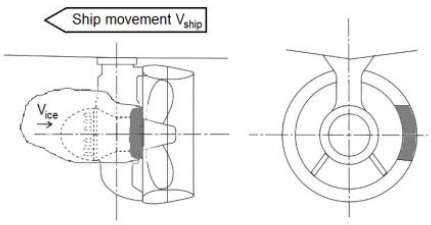
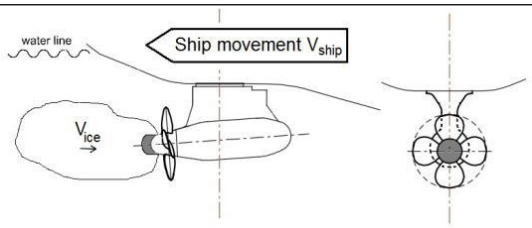
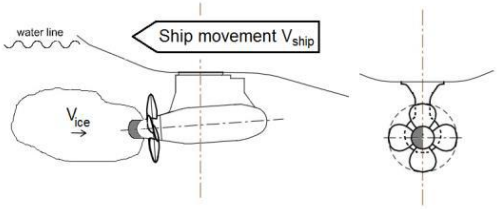
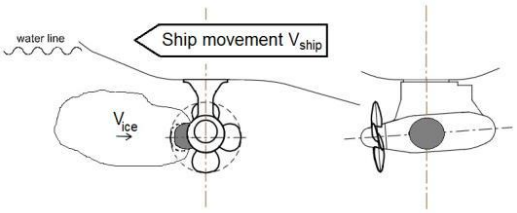
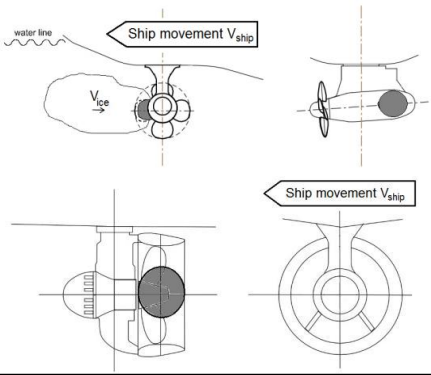
(2) Extreme ice impact loads

When the ship is operated in ice conditions, ice blocks formed in channel side walls or from the ridge consolidated layer may impact on the thruster body and the propeller hub. Exposure to ice impact is very much dependent on the ship size and ship hull design, as well as the location of the thruster. The contact force will grow in terms of thruster/ice contact until the ice block reaches the ship speed.

The thruster is to withstand the loads occurring when the design ice block defined in Table 14.2.3.2 impacts on the thruster body when the ship is sailing at a typical ice operating speed. Load cases for impact loads are given in Table 14.2.6.5(2)-1. The contact geometry is estimated to be hemi-spherical in shape. If the actual contact geometry differs from the shape of the hemisphere, a sphere radius is to be estimated so that the growth of the contact area as a function of penetration of ice corresponds as closely as possible to the actual geometrical shape penetration.

Load cases for azimuthing thruster ice impact loads **Table 14.2.6.5(2)-1**

Load case	Force	Loaded area	Figure
Load case T1a Symmetric longitudinal ice impact on thruster	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area	
Load case T1b Non-symmetric longitudinal ice impact on thruster	50% of F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area	

Load case	Force	Loaded area	Figure
Load case T1c Non-symmetric longitudinal ice impact on nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Contact area is equal to the nozzle thickness (H_{nz})*the contact height (H_{ice})	
Load case T2a Symmetric longitudinal ice impact on propeller hub	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area	
Load case T2b Non-symmetric longitudinal ice impact on propeller hub	50% of F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area	
Load case T3a Symmetric lateral ice impact on thruster body	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area	
Load case T3b Non-symmetric lateral ice impact on thruster body or nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Nozzle contact radius R to be taken from the nozzle length (L_{nz})	

The ice impact contact load is to be calculated using the formula below. The related parameter values are given in Table 14.2.6.5(2)-2. The design operation speed in ice can be derived from Tables 14.2.6.5(2)-3 and 14.2.6.5(2)-4, or the ship in question's actual design operation speed in ice can be used. The longitudinal impact speed in Tables 14.2.6.5(2)-3 and 14.2.6.5(2)-4 refers to the impact in the thruster's main operational direction. For the pulling propeller configuration, the longitudinal impact speed is used for load case T2, impact on hub; and for the pushing propeller unit, the longitudinal impact speed is used for load case T1, impact on thruster end cap. For the opposite direction, the impact speed for transversal impact is applied.

$$F_{ti} = 34.5 C_{DMI} R_c^{0.5} \left(m_{ice} v_s^2 \right)^{0.333} \text{kN}$$

where: R_C —impacting part sphere radius, see Figure 14.2.6.5(2), in m;

m_{ice} —ice block mass, in kg;

V_s —ship speed at the time of contact, in m/s;

C_{DMI}—dynamic magnification factor for impact loads.

C_{DMI} is to be taken from Table 14.2.6.5(2)-2 if unknown.

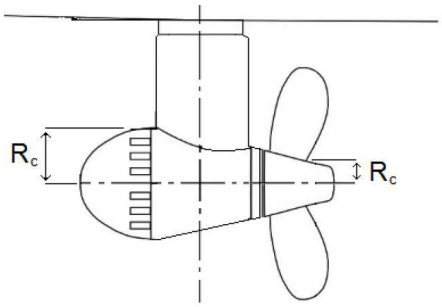


Figure 14.2.6.5(2) Dimensions used for R_c

For impacts on non-hemispherical areas, such as the impact on the nozzle, the equivalent impact sphere radius is to be estimated using the equation below.

$$R_{ceq} = \sqrt{\frac{A}{\pi}} \text{ m}$$

If the $2R_{ceq}$ is greater than the ice block thickness, the radius is set to half of the ice block thickness. For the impact on the thruster side, the pod body diameter can be used as a basis for determining the radius. For the impact on the propeller hub, the hub diameter can be used as a basis for the radius.

Parameter values for ice dimensions and dynamic magnification **Table 14.2.6.5(2)-2**

Ice class	B1*	B1	B2	B3
Thickness of the design ice block impacting thruster (2/3 of H_{ice}) (m)	1.17	1.0	0.8	0.67
Extreme ice block mass (m_{ice}) (kg)	8670	5460	2800	1600
C_{DMI} (if not known)	1.3	1.2	1.1	1

Impact speeds for aft centerline thruster **Table 14.2.6.5(2)-3**

Ice class	B1*	B1	B2	B3
Longitudinal impact in main operational direction (m/s)	6	5	5	5
Longitudinal impact in reversing direction (pushing unit propeller hub or pulling unit cover end cap impact) (m/s)	4	3	3	3
Transversal impact in bow first operation (m/s)	3	2	2	2
Transversal impact in stern first operation (double acting ship) (m/s)	4	3	3	3

Impact speeds for aft wing, bow centerline and bow wing thrusters **Table 14.2.6.5(2)-4**

Ice class	B1*	B1	B2	B3
Longitudinal impact in main operational direction (m/s)	6	5	5	5
Longitudinal impact in reversing direction (pushing unit propeller hub or pulling unit cover end cap impact) (m/s)	4	3	3	3
Transversal impact (m/s)	4	3	3	3

(3) Extreme ice loads on thruster hull when penetrating an ice ridge

In icy conditions, ships typically operate in ice channels. When passing other ships, ships may be subject to loads caused by their thrusters penetrating ice channel walls. There is usually a consolidated layer at the ice surface, below which the ice blocks are loose. In addition, the thruster may penetrate ice ridges when backing. Such a situation is likely in the case of B1* class ships in particular, because they may operate independently in difficult ice conditions. However, the thrusters in ships with lower ice classes may also have to withstand such a situation, but at a remarkably lower ship speed.

In this load scenario, the ship is penetrating a ridge in thruster first mode with an initial speed. This situation occurs when a ship with a thruster at the bow moves forward, or a ship with a thruster astern moves in backing mode. The maximum load during such an event is considered the extreme load. An event of this kind typically lasts several seconds, due to which the dynamic magnification is considered negligible and is not taken into account.

The load magnitude is to be estimated for the load cases shown in Table 14.2.6.5(3)-1, using the equation below. The parameter values for calculations are given in Table 14.2.6.5(3)-2 and Table 14.2.6.5(3)-3. The loads are to be applied as uniform distributed load or uniform pressure over the thruster surface. The design operation speed in ice can be derived from Table 14.2.6.5(3)-2 or Table 14.2.6.5(3)-3. Alternatively, the actual design operation speed in ice of the ship in question can be used.

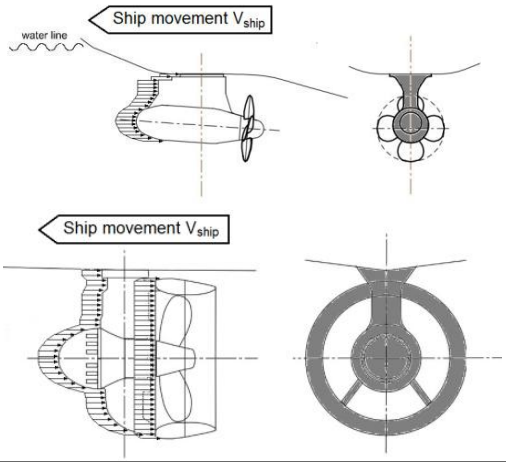
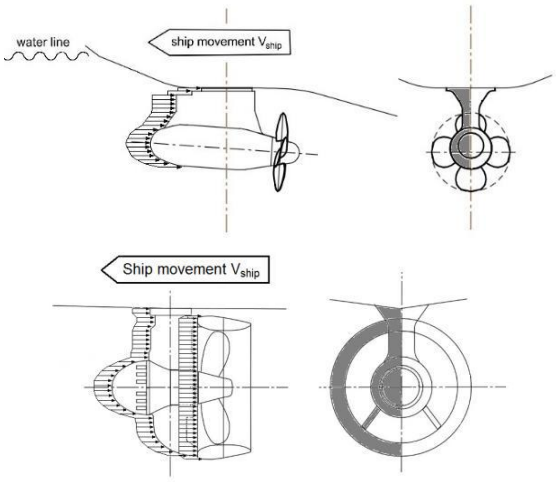
$$F_{tr} = 32 v_s^{0.66} H_r^{0.9} A_t^{0.74} \qquad \text{kN}$$

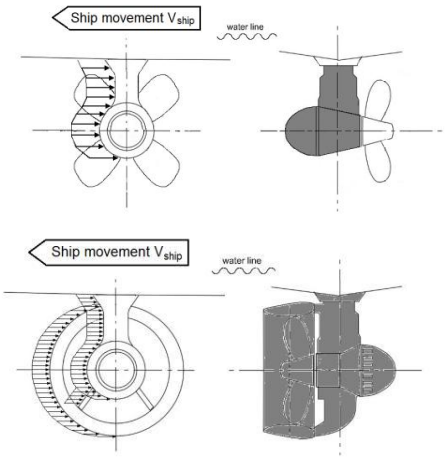
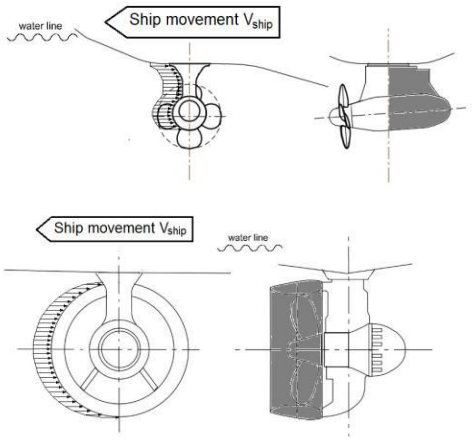
where: V_s— ship speed, in m/s;

H_r— design ridge thickness (the thickness of the consolidated layer is 18% of the total ridge thickness), in m;

A_t —projected area of the thruster, in m^2.

Load cases for ridge ice loads Table 14.2.6.5(3)-1

Load case	Force	Loaded area	Figure
Load case T4a Symmetric longitudinal ridge penetration loads	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area	
Load case T4b Non-symmetric longitudinal ridge penetration loads	50% of F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area	

Load case	Force	Loaded area	Figure
Load case T5a Symmetric lateral ridge penetration loads for ducted azimuthing unit and pushing open propeller unit	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the contact area	
Load case T5b Non-symmetric lateral ridge penetration loads for all azimuthing units	*50% of* F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area	

When calculating the contact area for thruster-ridge interaction, the loaded area in the vertical direction is limited to the ice ridge thickness, as shown in Figure 14.2.6.5(3).

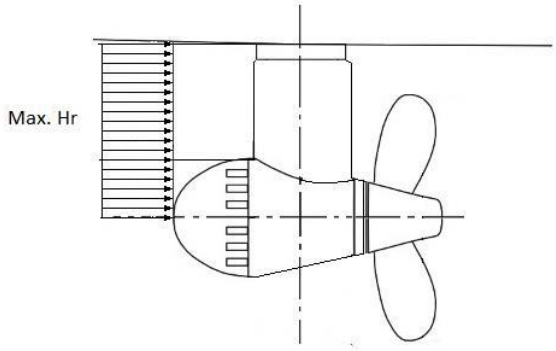


Figure 14.2.6.5(3) Schematic figure showing the reduction of the contact area by the maximum ridge thickness

Parameters for calculating maximum loads when the thruster penetrates an ice ridge (aft thrusters. bow first operation)

Table 14.2.6.5(3)-2

Ice class	B1*	B1	B2	B3
Thickness of the design ridge consolidated layer (m)	1.5	1.5	1.2	1.0
Total thickness of the design ridge, H_r (m)	8	8	6.5	5
Initial ridge	4	2	2	2

Ice class	B1*	B1	B2	B3
penetration speed (longitudinal loads) (m/s)				
Initial ridge penetration speed (transversal loads) (m/s)	2	1	1	1

Parameters for calculating maximum loads when the thruster penetrates an ice ridge (thruster first mode such as double acting ships)

Table 14.2.6.5(3)-3

Ice class	B1*	B1	B2	B3
Thickness of the design ridge consolidated layer (m)	1.5	1.5	1.2	1.0
Total thickness of the design ridge, H_r (m)	8	8	6.5	5
Initial ridge penetration speed (longitudinal loads) (m/s)	6	4	4	4
Initial ridge penetration speed (transversal loads) (m/s)	3	2	2	2

(4) Acceptability criterion for static loads

The stresses on the thruster are to be calculated for the extreme once-in-a-lifetime loads described in 14.2.6.5. The nominal von Mises stresses on the thruster body are to have a safety margin of 1.3 against the yielding strength of the material. At areas of local stress concentrations, stresses are to have a safety margin of 1.0 against yielding. The slewing bearing, bolt connections and other components are to be able to maintain operability without incurring damage that requires repair when subject to the loads given in 14.2.6.5(2) and 14.2.6.5(3) multiplied by a safety factor of 1.3.

(5) Thruster body global vibration

Evaluating the global vibratory behavior of the thruster body is important, if the first blade order excitations are in the same frequency range with the thruster global modes of vibration, which occur when the propeller rotational speeds are in the high power range of the propulsion line. This evaluation is mandatory and it is to be shown that there is either no global first blade order resonance at high operational propeller speeds (above 50% of maximum power) or that the structure is designed to withstand vibratory loads during resonance above 50% of maximum power.

When estimating thruster global natural frequencies in the longitudinal and transverse direction, the damping and added mass due to water are to be taken into account. In addition to this, the effect of ship attachment stiffness is to be modelled.

14.2.7 Alternative designs

14.2.7.1 Scope

As an alternative to paragraphs 14.2.5 and 14.2.6, a comprehensive design study may be carried out to the satisfaction of the Administration. The study is to be based on ice conditions given for different ice classes in paragraph 14.2.3, and is to include both fatigue and maximum load design calculations and fulfill the pyramid strength principle, as given in paragraph 14.2.6.1.

14.2.7.2 Loading

Loads on the propeller blade and propulsion system are to be based on an acceptable estimation of hydrodynamic and ice loads.

14.2.7.3 Design levels

The analysis is to indicate that all components transmitting random (occasional) forces, excluding propeller blades, are not subjected to stress levels in excess of the yield stress of the component material, with a reasonable safety margin.

Cumulative fatigue damage calculations are to indicate a reasonable safety factor. Due account is to be taken of material properties, stress raisers, and fatigue enhancements.

Vibration analysis is to be carried out and is to indicate that the complete dynamic system is free from

harmful torsional resonances resulting from propeller/ice interaction.

Section 3 STARTING ARRANGEMENTS AND COOLING WATER SYSTEM

14.3.1 Starting arrangements

14.3.1.1 The capacity of the air receivers is to comply with the provisions of 9.5.1.6 of this PART. If the air receivers serve any other services than starting the propulsion engine, their capacity is to be adequately increased.

14.3.1.2 The capacity of the air compressors is to comply with the provisions of 9.5.1.2 of this PART. If the ship is intended for Ice Class B1* and its propulsion engine is of reversible type, the charging time specified in 9.5.1.2 of this PART is not to be more than 0.5 h.

14.3.2 Cooling water system

14.3.2.1 The cooling water system is to be designed to ensure supply of cooling water when navigating in ice. For this purpose at least one cooling water inlet chest is to be arranged as follows:

(1) The sea inlet is to be situated near the centerline of the ship and well aft if possible.

(2) The chest is to have a sufficient volume. As a guidance for design, the volume of the chest is to be about one cubic metre for every 750 kW of engine output of the ship including the output of the auxiliary engines necessary for the ship's service.

(3) The chest is to be sufficiently high to allow ice to accumulate above the inlet pipe.

(4) A pipe, being of the same diameter as the cooling water discharge pipe, is to be connected between the chest and the cooling water discharge pipe.

(5) The area of the strum holes is not to be less than 4 times the inlet pipe sectional area.

14.3.2.2 If there are difficulties to meet the requirements of 14.3.2.1(2) and (3), two smaller chests may be arranged, but they must comply with the requirements of 14.3.2.1(1) to (5).

14.3.2.3 Heating coils may be installed in the upper part of the chest or chests where necessary.

14.3.2.4 Arrangements for using ballast water for cooling purposes may be used as a reserve in ballast condition but can not be accepted as a substitute for sea inlet chests as described above.

CHAPTER 15 VAPOUR CONTROL SYSTEM

Section 1 GENERAL PROVISIONS

15.1.1 Application

15.1.1.1 The requirements of this Chapter are applicable to ships fitted with systems for control of vapour emission from tanks and requesting sub-elements① as defined in 15.1.2, such as oil tankers and chemical tankers, etc.

15.1.1.2 In addition to the requirements of this Chapter, attention is to be given to any relevant regulations (if any) of the Administration of the flag States in which the ship is to be registered.

15.1.2 Sub-elements

15.1.2.1 Ships fitted with systems for control of vapour emission from cargo tanks complying with all requirements of this Chapter (other than Section 4) may be assigned to the following sub-elements:

VCS

15.1.2.2 Ships fitted with systems for control of vapour emission from cargo tanks complying with all requirements of this Chapter may be assigned to the following sub-elements:

VCS-T

15.1.3 Definitions

15.1.3.1 For the purpose of this Chapter:

(1) **Diluted** means a flammable gas or mixture is defined as diluted when its concentration in air is less than 50% of its lower explosive limit.

(2) **Flammable cargoes** are crude oils, petroleum products and chemicals having a flashpoint not exceeding 60℃ (closed cup test) and a Reid vapour pressure which is below the atmosphere pressure, and other substances having equivalent fire risk.

(3) **Inerted** is the condition in which the oxygen content in a flammable gas/air mixture is 8% or less by volume.

(4) **Independent** is suitable for two electrical systems which are considered independent when any one system may continue to operate with a failure of any part of the other system, except the power source and electrical feeder panels.

(5) **Maximum transfer rate** is the maximum volumetric rate at which a ship may receive cargo or ballast.

(6) **Service ship** is a ship which receives and transports liquid cargoes between a facility (shore station) and another ship and vice versa.

(7) **Lightering operation** is the operation of transferring liquid cargo from one ship to one service ship.

(8) **Topping-off** is the operation of transfer of liquid cargo from a service ship to another ship in order to load the receiving ship at a deeper draft.

(9) **Ship vapour connection** is the point of interface between the ship's fixed vapour collection system and the collection system of a facility or another ship. Hoses or loading arms on board, carried for the purpose of these Rules, are considered part of the vapour control system of the ship.

(10) **Terminal vapour connection** is that point at which the terminal vapour collection system is connected to a vapour collection hose or arm.

(11) **Vapour balancing** is the transfer of vapour displaced by incoming cargo from the tank of a ship receiving cargo into a tank of a facility delivering cargo via a vapour collection system.

(12) **Vapour collection system** is an arrangement of piping and hoses used to collect vapour emitted from a ship's cargo tank and to transport the vapour to a vapour processing unit.

(13) **Vapour processing unit** is that component of a vapour control system that recovers or destroys vapour collected from a ship.

15.1.4 Plans and documents

15.1.4.1 The following plans and documents are to be submitted for approval by ships for which the sub-elements of VCS or VCS-T is requested:

(1) Diagrammatic plan of the vapour piping system, indicating material specifications, scantlings, ratings, joining details and fittings;

(2) Diagrammatic plan of the gauging system and overfill protection, indicating manufacturer and type of

---

① Sub-elements: refer to Table 1.3.3.1 of Chapter 1 of Rules for Green Eco-ships.

the equipment or instruments, hazardous area locations, location of electrical equipment in gas–dangerous spaces and safe certificates of the electrical instruments intended to be used in hazardous locations, electrical schemes concerning the alarm system supply, electrical schemes concerning the intrinsically safe circuits;
(3) Diagrammatic plan of the venting system, indicating necessary data for verifying the venting capacity of the pressure/vacuum valves;
(4) Pressure drop calculation comparing cargo transfer rates versus pressure drops from the farthest tanks to the vapour connection, including any possible hoses;
(5) Calculations showing the time available between alarm setting and overfill at maximum loading rate for each tank;
(6) Instruction manual.
15.1.4.2 The following additional plans and documents are also to be submitted for reference by ships for which the sub-elements of VCS-T is requested:
Information on the anti-detonation devices, including manufacturer and type of the device employed as well as documentation on any acceptance tests carried out.

Section 2 VAPOUR PIPING SYSTEMS

15.2.1 General requirements

15.2.1.1 Each ship is to have vapour collection piping permanently installed, with the tanker vapour connection located as close as practical to the loading manifolds.
Chemical tankers are permitted to have a permanent vapour connection at each cargo tank for connection to a vapour hose which is to be kept as short as practicable, and in no case longer than 3 m.
15.2.1.2 If a tanker simultaneously collects vapour from incompatible cargoes, it is to keep these incompatible vapours separate throughout the entire vapour collection system.
15.2.1.3 Vapour collection piping is to be electrically bonded to the hull and is to be electrically continuous.
15.2.1.4 Means are to be provided to eliminate liquid condensate which may collect in the system. In general, a draining valve is to be fitted in each low point of the line and the condensate is led to an appropriate collection, such as catcher groove, slop tank.
15.2.1.5 When inert gas distribution piping is used for vapour collection piping, means to isolate the inert gas supply from the vapour collection system are to be provided. The isolation device is to comply with the requirements of Chapter 4, PART SIX of the Rules.
15.2.1.6 The vapour collection system is not to interfere with the proper operation of the cargo tank venting system. However, vapour collection piping may be partly common with the vent piping or the inert gas system piping.
15.2.1.7 External connection flange of the vapour collection system is to be fitted with a permanently protruding stud in way of 12 o'clock position on the pitch circle of bolt hole with 12.7 mm in diameter and at least 25.4 mm in length.

15.2.2 Vapour manifold

15.2.2.1 An isolation valve capable of manual operation is to be provided at the ship vapour connection, the valve position is to be readily determined visually (open/closed indication).
15.2.2.2 Each vapour manifold is to be for the last 1m in front of external connection flange painted on its exterior surfaces with red/yellow/red. The red bands are 100 mm wide, the yellow in the center is 800 mm wide and labeled "VAPOUR" in black letters at least 50 mm high.

15.2.3 Vapour hoses

15.2.3.1 Each hose used for transferring vapour is to have:
(1) a maximum working pressure of at least 0.035 MPa;
(2) the capacity of withstanding at least 0.014 MPa vacuum without collapsing or constricting;
(3) a design burst pressure of at least 0.175 MPa;
(4) electrical continuity with a maximum resistance of 10 kΩ;
(5) resistance to abrasion and kinking;
(6) the last 1 m of each end of the hose marked in accordance with 15.2.2.2.
15.2.3.2 Vapour hose handling equipment is to be provided with hose saddles which provide adequate support to prevent kinking or collapse of hoses.

15.2.4 High and low vapour pressure protection

15.2.4.1 The cargo tank venting system is to be capable of discharging cargo vapour at 1.25 times the maximum transfer rate in such a way that the pressure in the vapour space of each tank connected to the vapour collection system does not exceed the maximum working pressure of the tank or the operating pressure/burst pressure of a safety valve or rupture disk, if fitted.

15.2.4.2 It is not to relieve at a pressure corresponding to a pressure in the cargo tank vapour space of less than 0.007 MPa.

15.2.4.3 Means are to be provided to prevent a vacuum in the cargo tank vapour space that exceeds the maximum design vacuum for any tank which is connected to the vapour collection system, when the tank is discharged at the maximum rate.

15.2.4.4 It is not to relieve at a vacuum corresponding to a vacuum in the cargo tank vapour space less than 0.0035 MPa below the atmospheric pressure.

15.2.4.5 Pressure/vacuum safety valves are to be fitted with means to check that the device operates freely and does not remain in the open position.

15.2.4.6 Pressure/vacuum safety valves are to be fitted with a flame screen at their outlets, unless the vapour discharge velocity is not less than 30 m/s.

15.2.4.7 A venting testing is to be carried out for the pressure/vacuum safety valves before being fitted. Where it is intended to comply with the requirements of 15.2.4.6, a flame screen is to be fitted when in testing.

Section 3 INSTRUMENTATION

15.3.1 Cargo tank gauging equipment

15.3.1.1 Each cargo tank that is connected to a vapour collection system is to be equipped with a cargo gauging device which:

(1) provides a closed gauging arrangement which does not require opening the tank to the atmosphere during cargo transfer;

(2) allows the operator to determine the liquid level in the tank for the full range of liquid levels in the tank;

(3) indicates the liquid level in the tank, at the position where cargo transfer is located;

(4) if possible, is installed in tank during the entire transfer operation.

15.3.2 Cargo tank high level alarms

15.3.2.1 Each cargo tank that is connected to a vapour collection system is to be equipped with an intrinsically safe high level alarm system which alarms before the tank overfill alarm, but not lower than 95% of the tank capacity.

15.3.2.2 The high level alarm is to be capable of giving audible and visual alarm indications at the cargo transfer control room. It is to be identified with the black letters “HIGH LEVEL ALARM” with at least 50 mm high.

15.3.2.3 The high level alarm is to be independent of the overfill alarm.

15.3.2.4 The high level alarm is to alarm in the event of loss of power to the alarm system or failure of the electric circuits to the tank level sensors.

15.3.2.5 The high level alarm is to be able to be checked at the tank of proper operation prior to each transfer or contain an electronic self-testing feature which monitors the condition of the alarm circuits and sensors.

15.3.3 Cargo tank overfill alarms

15.3.3.1 Each cargo tank that is connected to a vapour collection system is to be equipped with an intrinsically safe overfill alarm which alarms early enough to allow the person in charge of transfer operation to stop such operation before the cargo tank overflows.

In general, the setting of cargo tank overfill alarm is not to exceed 98.5% of the tank capacity, and the time between alarm setting and overfill is not to be less than 1 min.

15.3.3.2 The overfill alarm is to be given audible and visual alarm indications at the cargo transfer control room and in the deck cargo area, and the audible and visual alarm indications can also be seen and heard at most positions. It is to be identified with the black letters “OVERFILL ALARM” with at least 50 mm high.

15.3.3.3 The overfill alarm is to be independent of both the high level alarm and the cargo gauging system.

15.3.3.4 The overfill alarm is to alarm in the event of loss of power to the alarm system or failure of the electric circuits to the tank level sensors.

15.3.3.5 The overfill alarm is to be able to be checked at the tank of proper operation prior to each transfer or contain an electronic self-testing feature which monitors the condition of the alarm circuits and sensors.

15.3.4 High and low vapour pressure alarms

15.3.4.1 Each vapour collection system is to be fitted with one or more pressure sensing devices that sense the pressure in the main collection line, and which:

(1) have a pressure indicator and audile and visual alarm indications located in the cargo transfer control room;

(2) alarm the high pressure at not more than 90% of the lowest relief valve setting in the tank venting system;

(3) alarm at a low pressure of not less than 0.001 MPa (100 mm WG) for an inerted tank, or the lowest vacuum relief valve setting in the cargo venting system for a non-inerted tank.

15.3.4.2 Pressure sensors fitted in each cargo tank are acceptable as equivalent to pressure sensors fitted in each main vapour collection line.

Section 4 ADDITIONAL REQUIREMENTS FOR VCS-T

15.4.1 Application

15.4.1.1 The requirements of this Section are applicable to service ships.

15.4.2 General requirements

15.4.2.1 If the cargo tanks on a ship discharging cargo and a ship receiving cargo are inerted, the service ship is to have a means to inert the vapour transfer hose prior to transferring cargo vapour and an oxygen analyzer with a sensor or sampling connection fitted within 3 m of the ship vapour connection which:

(1) activates an audible and visual alarm at the cargo transfer control room on the service ship where the oxygen content in the vapour collection system exceeds 8% by volume;

(2) has an oxygen concentration indicator at the cargo transfer control room on the service ship;

(3) has a connection for injecting a span gas of known concentration for calibration and testing of the oxygen analyzer.

15.4.2.2 If the cargo tanks on a ship discharging cargo are not inerted, the vapour collection line on the service ship is to be fitted with an approved detonation arrester located within 3 m of the ship vapour connection.

15.4.2.3 An electrical insulating flange or one length of non-conductive hose is to be provided between the ship vapour connection on the service ship and the vapour connection on the ship being lightered or topped off.

Section 5 INSTRUCTION MANUAL

15.5.1 General requirements

15.5.1.1 Each ship utilizing a vapour emission control system is to be provided with a detailed instruction manual.

15.5.1.2 Instructions are to encompass the purpose and principles of operation of the vapour emission control system and provide an understanding of the equipment involved and associated hazards. In addition, the instructions are to provide an understanding of the operating procedures, piping connection sequence, start-up procedures, normal operations and emergency procedures.

15.5.2 Content

15.5.2.1 The instructions are to contain:

(1) a line diagram of the tanker's vapour collection piping including the location of all valves, control devices, pressure-vacuum safety valves, pressure indicators, flame arresters and detonation arresters, if fitted;

(2) the maximum transfer rate for each group of cargo tanks having the same venting line, determined as the lowest of the following:

① 80% of the total venting capacity of the pressure relief valves in the cargo tank venting system;

② the total vacuum relieving capacity of the vacuum relief valves in the cargo tank venting system;

③ the rate based on pressure drop calculations at which, for a given pressure at the facility (shore station) vapour connection, or, if lightering, at the vapour connection of the service ship, the pressure in any cargo tank connected to the vapour collection system exceeds 80% of the setting of any pressure relief valve in the cargo tank venting system;

(3) the initial loading rate for each cargo tank, to be determined in such a way as to minimize the development of a static electrical charge, where applicable;

(4) tables or graphs of transfer rates (and corresponding vapour collection system pressure drops through the vapour hoses, if foreseen) determined from the most remote cargo tanks to the ship vapour connection as follows:

① for each cargo handled by the vapour collection system at the maximum and the lowest transfer rates;

② based on 50% cargo vapour and air mixture, and a vapour growth rate appropriate for the cargo being loaded.

CHAPTER 16 ADDITIONAL REQUIREMENTS FOR MACHINERY INSTALLATIONS OF SMALL SHIPS

Section 1 GENERAL PROVISIONS

16.1.1 Application

16.1.1.1 The provisions of this Chapter apply to the machinery installations of small ships and such provisions may substitute those fore-mentioned relevant provisions of this PART.

Section 2 ADDITIONAL REQUIREMENTS FOR MACHINERY INSTALLATIONS

16.2.1 Dead ship starting

16.2.1.1 Cargo ships of less than 500 gross tonnage may not be required by 1.2.6 of this PART.

16.2.2 Boiler arrangement

16.2.2.1 For cargo ships of less than 500 gross tonnage, if effective heat-insulating measures are taken, the clearance between the boilers and the fuel oil tank boundaries as required in 1.3.2.2 of this PART may be suitably reduced.

16.2.3 Bilge suction arrangement in machinery spaces

16.2.3.1 For ships of less than 500 gross tonnage, the number of direct bilge suctions in Table 3.3.2.1 of this PART may be changed to 1. The number of branch suction may be changed to 2.

For ships of less than 100 gross tonnage, the number of branch suction in Table 3.3.2.1 of this PART may be changed to 1.

16.2.3.2 For cargo ships of less than 500 gross tonnage or passenger ships of less than 100 gross tonnage engaged on non-international voyage or passenger ships of less than 500 gross tonnage and with service category 3 engaged on non-international voyage, emergency bilge suction as required in 3.3.3.1 of this PART may be dispensed with.

16.2.4 Bilge pumps and bilge piping

16.2.4.1 The number of power bilge pumps and drive modes for each ship as specified in Table 3.4.1.1 of this PART may be required for the following ships:

(1) for passenger ships engaged on non-international voyages of less than 100 gross tonnage, carrying not more than 100 passengers, 2 independent bilge pumps may be provided if navigation period is less than 4 h;

(2) for cargo ships of less than 100 gross tonnage, one of power driven type and one hand pump may be provided.

16.2.4.2 For ships of 25 m or less in length, the internal diameter of branch bilge pipes as required in 3.4.3.4 of this PART may be reduced to 40 mm.

16.2.4.3 For ships of 60 m or less in length, the internal diameter of branch bilge pipes to the tunnel wells as required in 3.4.3.6 of this PART may be reduced to 50 mm.

16.2.4.4 For ships of less than 500 gross tonnage, the capacity of bilge wells for machinery and boiler spaces and cargo holds as specified in 3.4.8.1 of this PART may be suitably reduced but not to be less than 0.10 m^3.

16.2.4.5 For ships of less than 100 gross tonnage, the ends of bilge suction in machinery spaces as specified in 3.4.8.2 of this PART may be fitted with a strum box instead of a mud box.

16.2.5 Fuel oil daily tank

16.2.5.1 The requirements of 4.2.1.8 of this PART do not apply to cargo ships of less than 500 gross tonnage.

16.2.6 Oil burning units of boilers

16.2.6.1 For cargo ships of less than 500 gross tonnage, for auxiliary boilers for essential services or auxiliary boilers supplying steam for heating heavy fuel oil as specified in 4.2.2.2 of this PART, one oil supply unit will be accepted.

16.2.7 Oil fuel booster pumps

16.2.7.1 For ships of less than 500 gross tonnage, the standby pump or spare pump as required in 4.2.3.1 of this PART may be dispensed with.

16.2.8 Feed water pumps for boilers

16.2.8.1 For cargo ships of less than 500 gross tonnage, for auxiliary boilers for essential services or auxiliary boilers supplying steam for heating heavy fuel oil and cargo oil as specified in 4.4.1.1 of this PART, only one feed water pump fitted is acceptable.

16.2.9 Feed water systems for boilers

16.2.9.1 For auxiliary boilers fitted with only one feed water pump as required in 16.2.8 of this Chapter, the requirements for provision of two independent feed water systems in 4.4.2.1 of this PART are not applicable.

16.2.10 Condensate pumps

16.2.10.1 For cargo ships of less than 500 gross tonnage, if not propelled by steam, for condensate pumps mentioned in 4.4.4.1 of this PART, the standby pump or spare pump is dispensed with.

16.2.11 Cooling water pumps

16.2.11.1 For cargo ships of less than 500 gross tonnage, the standby pump or spare pump as required in 4.5.1.1 of this PART is dispensed with.

16.2.12 Bilge lines of oil tankers

16.2.12.1 For oil tankers of less than 150 gross tonnage, the cargo pump room bilge specified in 5.3.2.1 of this PART may be drained by means of a hand pump having a 50 mm bore suction.

16.2.13 Oil tank air pipes

16.2.13.1 Paragraph 3.10.2.5 of this PART does not apply to cargo ships of less than 500 gross tonnage.

16.2.14 Oil tank short sounding pipes

16.2.14.1 For fuel oil tanks in double bottom tanks, when the sounding pipes are terminated in machinery spaces, only requirements of 3.10.10.1(2) and (3) are to be met for cargo ships of less than 500 gross tonnage.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2025

PART FOUR ELECTRICAL INSTALLATIONS

CONTENTS

CHAPTER 1 **GENERAL** 4-1
Section 1 GENERAL PROVISIONS 4-1
Section 2 OPERATING CONDITIONS 4-6
Section 3 DESIGN, CONSTRUCTION AND INSTALLATION 4-7
CHAPTER 2 **ELECTRICAL INSTALLATIONS IN SHIPS** 4-15
Section 1 MAIN SOURCE OF ELECTRICAL POWER 4-15
Section 2 EMERGENCY SOURCE OF ELECTRICAL POWER 4-17
Section 3 EXTERNAL SOURCE OF ELECTRICAL POWER 4-21
Section 4 POWER SUPPLY AND DISTRIBUTION 4-22
Section 5 PROTECTION 4-25
Section 6 AUXILIARY MACHINERIES 4-29
Section 7 LIGHTING AND NAVIGATION LIGHTS 4-32
Section 8 INTERNAL COMMUNICATION SYSTEMS 4-33
Section 9 SAFETY SYSTEMS FOR SHIPS AND PERSONS ONBOARD 4-35
Section 10 HEATING AND COOKING EQUIPMENT 4-39
Section 11 STORAGE BATTERIES 4-40
Section 12 CABLES 4-43
Section 13 LIGHTNING PROTECTION 4-54
Section 14 SPECIAL REQUIREMENTS FOR HIGH VOLTAGE ELECTRICAL INSTALLATIONS 4-55
Section 15 ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION MACHINERY 4-59
Section 16 ADDITIONAL REQUIREMENTS FOR OIL TANKERS 4-59
Section 17 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR OWN PROPULSION 4-62
Section 18 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING DANGEROUS GOODS 4-63
Section 19 DETECTION OF WATER INGRESS IN CARGO HOLDS 4-67
CHAPTER 3 **CONSTRUCTION AND TESTING OF ELECTRICAL EQUIPMENT** 4-70
Section 1 GENERAL PROVISIONS 4-70
Section 2 ROTATING MACHINES 4-70
Section 3 SWITCHGEAR ASSEMBLIES 4-75
Section 4 CONTROL GEAR 4-78
Section 5 CABLES 4-79
Section 6 POWER AND LIGHTING TRANSFORMERS 4-80
Section 7 STORAGE BATTERIES 4-82
Section 8 POWER SEMICONDUCTOR CONVERTORS 4-83
Section 9 UNINTERRUPTIBLE POWER SYSTEM 4-84
Section 10 OTHER ELECTRICAL EQUIPMENT 4-85
CHAPTER 4 **SUPPLEMENTARY REQUIREMENTS FOR CARGO SHIPS OF LESS THAN 500 GROSS TONNAGE** 4-87
Section 1 CARGO SHIPS OF LESS THAN 500 GROSS TONNAGE 4-87
APPENDIX 1 **SHORT-CIRCUIT CURRENTS CALCULATIONS WITH REGARD TO ELECTRICAL INSTALLATIONS** 4-89
Appendix A Examples of Calculation 4-101
Appendix B Conversion of Short-Circuit Breaking Capacity of Circuit Breaker 4-116
APPENDIX 2 **TYPE APPROVAL PROCEDURE FOR CABLE TRAYS/PROTECTIVE CASINGS MADE OF PLASTIC MATERIALS** 4-117

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 Unless otherwise specified, the requirements of this PART apply to electrical installations intended for sea-going ships.

1.1.1.2 Electrical propelling machinery and associated equipment together with auxiliary services essential for the safety of the ship are to be constructed and installed in accordance with the relevant requirements of this PART, inspected and tested by the Surveyors. In addition, construction and testing of the electrical equipment are to comply with the relevant acceptable standards.

1.1.1.3 The design and installation of the electrical equipment other than those specified in 1.1.1.2 of this Section is to be such that risk of fire due to its failure is minimized, and it is at least to comply with the acceptable standards to be revised where necessary for ambient conditions.

1.1.1.4 In addition, the electrical installations are to comply with the applicable requirements in PART ONE of the Rules.

1.1.1.5 The electrical installations are to be such that:

(1) all electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions will be ensured without recourse to the emergency source of electrical power;

(2) electrical services essential for safety will be ensured under various emergency conditions;

(3) the safety of passengers, crew and ship from electrical hazards will be ensured.

1.1.2 Definitions

1.1.2.1 For the purpose of this PART:

(1) Essential services are the equipment necessary for the propulsion, steering and safety of the ship and the special equipment on ships with special class notations, including:

① primary essential services which need to be in continuous operation for maintaining propulsion and steering:

(a) steering gear;

(b) controllable pitch propeller installation;

(c) scavenging air blowers, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines and turbines required for propulsion;

(d) forced draught fans, feed water pumps, water circulating pumps, vacuum pumps, condensate pumps and oil burning installations for auxiliary steam boilers for the operation of primary essential services and for steam plants on steam turbine ships;

(e) azimuth thrusters which are the sole means for propulsion/steering with lubricating oil pumps, cooling water pumps;

(f) electrical equipment for electric propulsion plant with lubricating oil pumps and cooling water pumps;

(g) electric generators and associated power sources supplying the equipment mentioned in (a) to (f) above;

(h) hydraulic pumps supplying the equipment mentioned in (a) to (f) above;

(i) viscosity control equipment for heavy fuel oil;

(j) fire pumps and other extinguishing medium pumps;

(k) navigation lights, aids and signals;

(l) internal safety communication equipment;

(m) lighting system;

(n) control, monitoring and safety devices/systems for equipment mentioned in (a) to (m) above;

② secondary essential services which need not necessarily be in continuous operation for maintaining propulsion and steering, but which are necessary for maintaining the ship's safety, e.g.:

(a) windlasses;

(b) fuel oil transfer pumps and fuel oil treatment equipment;

(c) lubricating oil transfer pumps and lubricating oil treatment equipment;

(d) pre-heaters for heavy fuel oil;

(e) starting air and control air compressors;

(f) bilge, ballast and heeling pumps;

(g) ventilating fans for engine and boiler rooms;

(h) equipment necessary for maintaining dangerous spaces in a safe condition;
(i) fire detection and alarm system;
(j) watertight closing appliances;
(k) refrigerating equipment for lowering ambient air temperature (see 1.2.1.2 of this Chapter);
(l) electric generators and associated power sources supplying the equipment mentioned in (a) to (k) above;
(m) hydraulic pumps supplying the equipment mentioned in (a) to (k) above;
(n) control, monitoring and safety systems for cargo containment systems;
(o) control, monitoring and safety devices/systems for equipment mentioned in (a) to (m) above;

③ special equipment of ships with a special class notation that may be regarded as essential services.

(2) Non-essential services are those whose temporary disconnection will not impair propulsion and steer of the ship, nor endanger the safety of passengers, crew, cargo, ship and machinery.

(3) Emergency consumer is a consumer which, after loss of the main source of electrical power, must be supplied by the emergency source of electrical power.

(4) Main source of electrical power is a source intended to supply electrical power to the main switchboard for distribution to all services necessary for maintaining the ship in normal operational and habitable condition.

(5) Emergency source of electrical power is a source of electrical power, intended to supply the emergency switchboard in the event of failure of the supply from the main source of electrical power.

(6) Dead ship condition is the condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting and operating the propulsion plant, the main source of electrical power and other essential auxiliaries is assumed to be available.

(7) Primary distribution system is a system having electrical connection with the generator.

(8) Secondary distribution system is a system having no electrical connection with the generator, e.g. isolated therefrom by a double-wound transformer.

(9) Low-voltage system is an alternating-current system operating with the maximum rated voltage not exceeding 1,000 V inclusive between conductors and with the rated frequency of 50 Hz or 60 Hz, or a direct-current system with the maximum instantaneous voltage under rated operating conditions does not exceed 1,500 V between conductors.

(10) High-voltage system is an alternating-current system operating with the rated voltage more than 1 kV but not exceeding 15 kV and with the rated frequency of 50 Hz or 60 Hz, or a direct-current system with the maximum instantaneous voltage under rated operating conditions exceed 1,500 V between conductors.

(11) Switch gear and control gear assembly is a combination of one or more switch gears and means of control, measurement, signal, protection and adjustment etc, assembled by the manufacturer together with all internal electrical and mechanical connectors and components.

(12) Main switchboard is a switchboard which is directly supplied by the main source of electrical power and is intended to control and distribute electrical energy to switch gear and control gear assemblies of the ship's services.

(13) Emergency switchboard is a switchboard which, normally supplied by the main switchboard, in the event of failure of the main electrical power supply system is directly supplied by the emergency source of electrical power or the transitional source of emergency power and is intended to control and distribute electrical energy to switch gear and control gear assemblies of the ship's emergency services.

(14) Distribution board is a switch gear and control gear assembly arranged for the control and distribution of electrical power to final sub-circuits.

(15) Final sub-circuit is that portion of a wiring system extending beyond the final over-current device of a board.

(16) Total discrimination (total selectivity) is an over-current discrimination where, in the presence of two or more over-current protection devices in series, the protective device on the load side effects the protection without causing the other protective devices to operate.

(17) Partial discrimination (partial selectivity) is an over-current discrimination where, in the presence of two or more over-current protective devices in series, the protective device on the load side effects the protection up to a given level of short-circuit current, without causing the other protective devices to operate.

(18) Back-up protection is the protection equipment or system which is intended to operate when a system fault is not cleared in due time because of failure or inability of the protective device closest to the fault to operate or because of failure of the other protective device.

(19) Continuity of power supply means that during and after a fault in a circuit, the supply to fault-free circuits is permanently ensured.

(20) Dangerous zone is a zone where flammable or explosive vapours, gases, dusts, or explosives may be

normally expected to accumulate.
(21) Enclosed space is a space enclosed by bulkheads and decks, which may be fitted with doors, windows or other openings capable of being closed.
(22) Semi-enclosed space is a space limited by top plates, wind breaks and bulkheads etc. in such a manner that the natural conditions of ventilation in the space are notably different from those obtained on open deck, and so arranged that the gas will not easily diffuse.
(23) A blackout situation means that the main and auxiliary machinery installations, including the main power supply, are out of operation, but the services for bringing them into operation (e.g. compressed air, starting current from batteries, etc.) are available.
(24) Shelf life of a battery means the duration of storage under specified conditions at the end of which a battery retains the ability to give a specified performance.
(25) An air-lock is to have two gastight steel doors which are self-closing without any hold-back arrangement, and the distance between which is not to be less than 1.5 m and not necessarily more than 2.5 m.
(26) Ripple voltage
The amplitude of the ripple voltage is represented in Figure 1.1.2.1(26) by the difference between U_{max} and U_{min}.

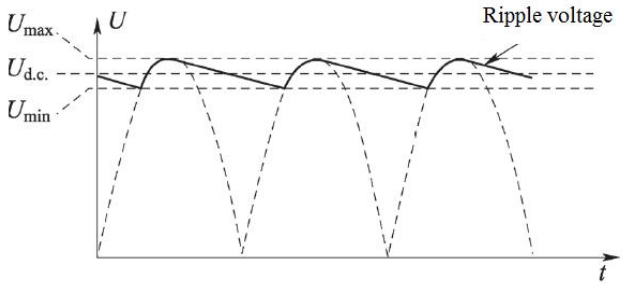
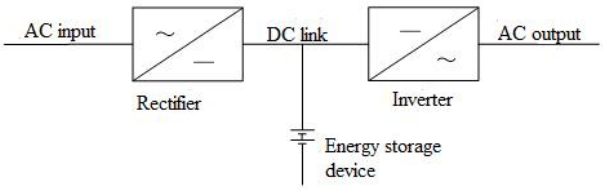


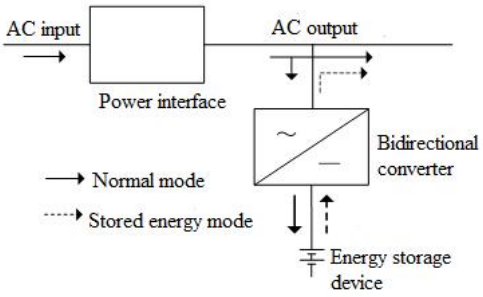
Figure 1.1.2.1(26) Ripple Voltage

(27) Uninterruptible power system (UPS)[①] is a combination of converters, switches and energy storage devices (such as batteries), constituting a power system for maintaining continuity of load power in case of AC input power failure.
(28) Double-conversion UPS topology[②] comprises an AC to DC converter, generally a rectifier, and DC to AC converter, generally an inverter. When the AC input power is out of UPS pre-set tolerances, the UPS enters stored energy mode.
(29) Line-interactive UPS topology[②] comprises bidirectional AC to DC power conversion, generally through a bidirectional converter and an AC power interface.When the AC input power voltage or frequency is out of UPS pre-set tolerances, the UPS enters stored energy mode.
(30) Standby UPS topology[②] comprises a battery charger, a DC to AC converter, generally a uni-directional inverter and a UPS switch. When the AC input power is out of UPS pre-set tolerances, the UPS enters stored energy mode.

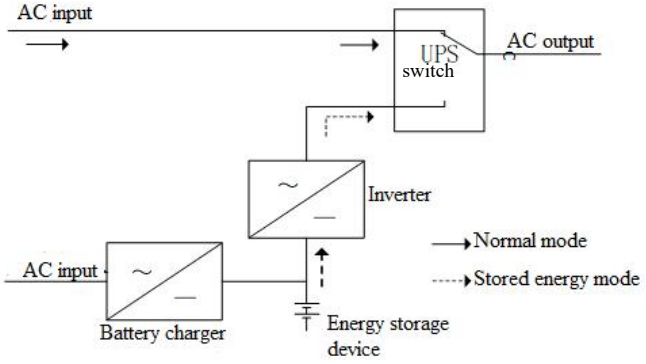
① Refer to IEC 62040-3 Uninterruptible power systems (UPS) - Part 3: Method of specifying the performance and test requirements.
② Refer to IEC 62040-3 Uninterruptible power systems (UPS) - Part 3: Method of specifying the performance and test requirements, Annex B.



Double-conversion UPS topology



Line-interactive UPS topology



Standby UPS topology

Notes:

① Energy storage device: system consisting of a single or multiple devices designed to provide power to the UPS inverter/converter.

②AC input power failure: variation in the AC input power which could cause the UPS to operate in stored energy mode.

③ Bidirectional converter: converter which has the functions of both a rectifier and an inverter, and which can reverse the flow of power from AC to DC and vice-versa.

Figure 1.1.2.1(28)(29)(30) UPS Topology

(31) Zone 0 is an area in which an explosive gas atmosphere is present continuously or for long periods.
(32) Zone 1 is an area in which an explosive gas atmosphere is likely to occur in normal operation.
(33) Zone 2 is an area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.

1.1.3 Plans and documents

1.1.3.1 The following plans and documents are to be submitted for approval:
(1) Electrical loading evaluation of main and emergency sources of electrical power.
(2) Calculations for short-circuit currents (for ships with operational conditions of generators having a total capacity (including single generator operation, long-term parallel operation and short-term parallel transferred load)of more than 250 kVA).
(3) Analysis for coordination of protective devices in compliance with the requirements of 2.5.1.1 and 2.5.4.1 of this PART (for ships with operational conditions of generators having a total capacity (including single generator operation, long-term parallel operation and short-term parallel transferred load) of more than 250 kVA,which may be omitted for non-self-propelled ships).
(4) Diagrams of power systems, in which the following are to be indicated:

① main ratings of motors, transformers, batteries, electrical and electronic equipment;
② all feeders connected to main and emergency switchboards;
③ section boards (if fitted) and distribution boards;
④ type, cross-sectional area and current loadings of cables;
⑤ rating and setting of protective devices (such as short-circuit, overloading, reverse power and unloading protection);
⑥ remote stops;
⑦ insulation level monitoring and alarm;
⑧ interlocks..

(5) Arrangement of main electrical equipment, in which the positions of the following items are to be indicated:

① main and emergency generators;
② main and emergency switchboards (or emergency accumulator battery charging and discharging boards);
③ emergency accumulator batteries;

④ electrical equipment for essential services (see 1.1.2.1 of this Chapter).

(6) Schematic diagrams of main lighting.

(7) Arrangement of main lighting.

(8) Schematic diagrams of emergency lighting, temporary emergency lighting (if fitted), and additional emergency lighting (if fitted).

(9) Arrangement of emergency lighting, temporary emergency lighting (if fitted), and additional emergency lighting (if fitted).

(10) Schematic diagrams (if supplied by emergency power) of low location lighting (if fitted).

(11) Schematic diagrams of internal communication systems, including:

① engine-room telegraph system;

② essential telephone system;

③ communication system for lifesaving;

④ engineers' alarm system.

(12) Arrangement of internal communication systems, including:

① engine-room telegraph system;

② essential telephone system;

③ communication system for lifesaving;

④ engineers' alarm system.

(13) Schematic diagrams of safety systems for the ship and persons on board, including:

① general emergency alarm system;

② public address system;

③ fire detection and fire alarm systems;

④ alarm system for closing watertight doors;

⑤ other alarm systems, e.g. for the release of fire extinguishing media (see Section 9, Chapter 2 of this PART).

(14) Arrangement of safety systems for the ship and persons on board, including:

① general emergency alarm system;

② public address system;

③ fire detection and alarm system;

④ alarm system for closing watertight doors;

⑤ other alarm systems, e.g. for the release of extinguishing media (see Section 9, Chapter 2 of this PART).

(15) Arrangement of main cable runs (for passenger ships and high voltage electrical installations).

(16) General arrangement of the ship showing dangerous zones and spaces (for oil tankers and other ships carrying dangerous explosive goods).

(17) Simplified circuit diagram of electrical propulsion system, in which the following are to be indicated:

① main ratings of motors, transformers, batteries, electrical and electronic equipment;

② type, cross-sectional area and current loadings of cables;

③ type and main rating of circuit breakers and fuses;

④ earth fault monitoring.

(18) Arrangement of control positions and stations of electrical propulsion machinery.

(19) List of monitoring and alarm items for electrical propulsion.

(20) Arrangement of semiconductor converters, including cooling system, for electrical propulsion system.

(21) Calculations of harmonic distortion for all main connectors, including main switchboards and distribution boards, in the electrical system of electrically propelled ships.

(22) Electrical system and general arrangement of water level detection systems for cargo holds, ballast tanks and dry spaces of bulk carriers.

(23) All electrical equipment located in hazardous areas together with the following associated information are to be included in their arrangement plan:

① type of protection, explosion group and temperature class;

② degree of protection;

③ hazardous classification of the area where the electrical equipment is installed.

(24) Verification information[①] of intrinsically safe circuits, including the verification of the voltage, current,

---

① The maximum inductance and capacitance which are the total of the cable out to the hazardous area plus the values of connected equipment are to be less than the rated values of associated apparatus. The values of permissible input voltage,

inductance and capacitance.
1.1.3.2 The specifications for all electrical systems of the ship may be submitted for information and additional plans and documents may be required as deemed necessary.

1.1.4 Testing

1.1.4.1 Electrical equipment specified in 1.1.1.2 and 1.1.2.1(1) of this Section is to be tested in accordance with the requirements of Chapter 3 of this PART at the manufacturer. Tests other than those specified in this PART may be required as deemed necessary.
1.1.4.2 On completion of installation on board, the electrical installations are to be subject to mooring and sea trials in accordance with the test programmes approved by CCS.

Section 2 OPERATING CONDITIONS

1.2.1 Environmental conditions

1.2.1.1 Unless otherwise specified (e.g. in 1.2.1.2 of this Section), all electrical installations are to operate satisfactorily under the following environmental conditions:
(1) The ambient air temperatures and primary cooling water temperatures are as given in Table 1.2.1.1(1), however the upper limit of ambient air temperatures for the electronic equipment is to be 55℃.

Ambient Temperature **Table 1.2.1.1(1)**

Medium	Location	Temperature (℃)	
		Unrestricted service	Restricted service except in tropical zones
Air	In enclosed spaces	0 ~ 45	0 ~ 40
	In spaces subject to temperatures over 45℃(or 40℃) or below 0℃	According to temperatures in such spaces	According to temperatures in such spaces
	On the open deck	-25 ~ 45	-25 ~ 40
Water		32	25

(2) The inclination and roll of the ship is as given in Table 1.2.1.1(2).

Angle of Inclination **Table 1.2.1.1(2)**

Installations, components	Angle (°) ①②			
	Athwartships		fore-and-aft	
	Static	Dynamic	Static	Dynamic
Emergency power installations, switchgear, electrical and electronic appliances	22.5	22.5	10	10
Electrical installations excluding items stated above	15	22.5	5	7.5

Notes: ① Athwartship and fore-and-aft inclinations may occur simultaneously.
② For ships carrying liquefied gases or chemicals, the emergency source of electrical power is also to remain operable with the ship being flooded to a final athwartship inclination up to a maximum of 30°.

(3) The vibration and shock likely to arise in normal service of the ship.
(4) Moisture, sea air, oil vapour and mould.
1.2.1.2 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable may be reduced from 45℃ to a value not less than 35℃ provided:
(1) the equipment is not for use for emergency services;
(2) temperature control is achieved by at least two cooling units so arranged that, in the event of loss of one cooling unit for any reason, the remaining unit(s) is capable of satisfactorily maintaining the design temperature;
(3) the equipment is able to be initially set to work safely within a 45℃ ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for a 45℃ ambient temperature;
(4) audible and visual alarms are provided, at a continually manned control station, to indicate any

input current of each intrinsically safe apparatus is to be greater than or equal to the values respectively of the associated apparatus. Refer to IEC publication 60079-14: “Explosive atmosphere-Part 14: Electrical installations design, selection and erection” or equivalent standards.

malfunction of the cooling units;
(5) it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.2.2 Voltage and frequency variations

1.2.2.1 The electrical equipment supplied from the main or emergency systems is to be capable of operating satisfactorily under normally occurring variations in voltage and frequency.

1.2.2.2 Unless otherwise stated in international standards, electrical equipment is to operate satisfactorily with the variations in voltage and frequency from the rated value shown in Table 1.2.2.2 (measured at input terminals of the equipment).

Voltage and Frequency Variations **Table 1.2.2.2**

Equipment	Parameters	Permanent (%)	Transient	
			%	Max. recovery time (s)
General AC equipment	Voltage	+6 ~ -10	±20	1.5
	Frequency	±5	±10	5
Direct current equipment supplied by DC generators or rectifiers	Voltage	±10	–	–
	Voltage cyclic variation deviation	5	–	–
	Voltage ripple	10	–	–
Equipment supplied by batteries: Connected to batteries during charging① Not connected to the batteries during charging	 Voltage Voltage	 +30 ~ -25 +20 ~ -25	–	–

Note: ① Different voltage variations as determined by the charging/discharging characteristics, including the ripple voltage from the charging device, are to be considered.

1.2.2.3 Any special system, e.g. electronic circuits, whose function cannot operate satisfactorily within the limits shown in Table 1.2.2.2 is not to be supplied directly from the system but by alternative means, e.g. through a stabilized supply.

1.2.3 Harmonic content

1.2.3.1 AC electrical equipment is to operate satisfactorily with a supply voltage containing a total harmonic content of the voltage waveform not exceeding 8%. Where the harmonic content may exceed 8%, attention is to be given in selecting the equipment to ensure its normal function.

Section 3 DESIGN, CONSTRUCTION AND INSTALLATION

1.3.1 General requirements

1.3.1.1 Electrical equipment is to be so designed, constructed and installed as to ensure safe operation and facilitate inspection and repair.

1.3.1.2 The distance between live parts of different potential and between live parts and earthed metal, whether across surfaces or in air, is to be adequate for the working voltage, having regard to the nature of the insulating material and the conditions of service.

1.3.1.3 Equipment is not to remain alive through the control circuits or pilot lamps when switched off by the control switch. This does not apply to synchronizing switches and/or plugs.

1.3.1.4 All nuts and screws used for the connection and fastening of electrical equipment are to be provided with means to ensure that they cannot work loose by vibration and shock.

1.3.1.5 The material used to make electrical equipment is to comply with the following requirements:
(1) It is, in general, to be durable, flame-retardant, moisture resistant unless it is adequately protected against the atmospheric environment and temperatures to which it is likely to be exposed.
(2) Insulating materials and insulated windings are to be resistant to moisture, sea air and oil vapour unless special precautions are taken to protect them.
(3) The current carrying parts of electrical equipment are, in general, to be made of copper or copper alloys.
(4) Metal parts of electrical equipment are to be covered with proper protective coating against corrosion unless they are made of satisfactory corrosion-resistant material.
(5) New installation of materials which contain asbestos is to be prohibited.

1.3.1.6 If electrical fittings, not of aluminium, are connected to aluminium, suitable means is to be taken to prevent electrolytic corrosion.

1.3.1.7 All electrical equipment with internal wiring is to be attached with schematic or wiring diagrams in which wiring codes are indicated. All terminals of electrical equipment are to be provided with durable markings or symbols corresponding to those indicated in the diagrams.
1.3.1.8 The controls for emergency alarms are to be marked in red and provided with durable nameplates indicating their purposes.
1.3.1.9 For the fitting of rheostats, starting and charging resistors, heating appliances and other electrical apparatus likely to cause high temperatures, means are to be provided against overheating or igniting of adjacent objects.
1.3.1.10 All electrical equipment is not to be fitted close to the external surfaces of oil compartments, oil tanks or double bottom tanks intended for carrying oils. If this is necessary, electrical equipment is to be installed at a minimum distance of 50 mm from these surfaces, provided that the electrical apparatuses mentioned in 1.3.1.9 are strictly prohibited to be installed on such surfaces.
1.3.1.11 Generating sets are to be installed with their shafts in parallel with the fore-and-aft direction of the ship, and horizontal motors are also to be installed, as far as practicable, with their shafts in parallel with the fore-and-aft direction of the ship.
1.3.1.12 For the electrical equipment other than that installed in a dedicated compartment, the live parts having a working voltage or a voltage to earth exceeding 50 V are to be so protected that they cannot be inadvertently touched.
1.3.1.13 Where the temperature of the enclosures of the electrical equipment is in excess of 80°C, suitable means are to be provided or suitable arrangement is to be made so as to protect the operators from injurious heating due to inadvertent touching.
1.3.1.14 Holes are not to be drilled in watertight bulkheads, decks or boundary plating of deckhouses for the purpose of fitting the screws used to securing the electrical equipment and cables.
1.3.1.15 Electrical equipment and cables are not to be fitted on the shell plating.
1.3.1.16 Conductors and equipment are to be placed at a suitable distance from the magnetic compass, or are to be so screened that the interfering external magnetic field is negligible.
1.3.1.17 The UPS unit for emergency services in 3.9.1.1, Section 9, Chapter 3 of this PART is to be suitably located for use in an emergency. UPS units utilising valve regulated sealed batteries may be located in compartments with normal electrical equipment, provided the ventilation arrangements are in accordance with the requirements of IEC 62040-1, IEC 62040-2, IEC 62040-3, IEC 62040-4 and/or IEC62040-5-3 publication (as applicable), or an acceptable and relevant national or international standard.

1.3.2 Protective enclosures

1.3.2.1 The type of protective enclosures for electrical equipment is to comply with IEC Publication 60529: Degrees of Protection Provided by Enclosures (IP Code) or equivalent standards.
1.3.2.2 The type of protective enclosures selected for electrical equipment is to be appropriate to the condition of the location at which such equipment is installed. The lowest degree of protection is to comply with the requirements given in Table 1.3.2.2 unless otherwise specified (e.g. in 1.3.2.3 and 1.3.2.4 of this Section).

Minimum Requirements for the Degree of Protection by Enclosure **Table 1.3.2.2**

(1)	(2)	(3)	(4)							
			Equipment							
Location	Condition of location	Degree of protection	Switchboards, control gear, motor starters	Generators	Motors	Transformers, semiconductor converters	Lighting fixtures	Heating appliances	Cooking appliances	Accessories (e.g. switches, connection boxes)
Dry accommodation spaces	Danger of touching live parts only	IP20	×	–	×	×	×	×	×	×
Dry control rooms			×	–	×	×	×	×	×	×
Control rooms	dripping water and/or moderate mechanical	IP22	×	–	×	×	×	×	×	×
Engine and boiler rooms above floor plates			×	×	×	×	×	×	×	IP44
Steering gear rooms			×	×	×	×	×	×	–	IP44

(1)	(2)	(3)	(4)							
			Equipment							
Location	Condition of location	Degree of protection	Switchboards, control gear, motor starters	Generators	Motors	Transformers, semiconductor converters	Lighting fixtures	Heating appliances	Cooking appliances	Accessories (e.g. switches, connection boxes)
Refrigerating machinery rooms (excluding ammonia plants)			×	–	×	×	×	×	–	IP44
Emergency machinery rooms			×	×	×	×	×	×	–	IP44
General storage rooms			×	–	×	×	×	×	–	×
Pantries			×	–	×	×	×	×	×	IP44
Provision rooms			×	–	×	×	×	×	–	×
Bathrooms and showers	Increased danger of water and/or mechanical damage	IP34	–	–	–	–	×	IP44	–	IP55
Engine and boiler rooms below floor plates			–	–	IP44	–	×	IP44	–	IP55
Closed fuel oil separator rooms			IP44	–	IP44	–	×	IP44	–	IP55
Closed lube oil separator rooms			IP44	–	IP44	–	×	IP44	–	IP55
Ballast pump rooms	Increased danger of water and mechanical damage	IP44	×	–	×	×	IP34	×	–	IP55
Refrigerated rooms			–	–	×	–	IP34	×	–	IP55
Galleys and laundries			×	–	×	×	IP34	×	×	×
Shaft or pipe tunnels in double bottom	Danger of water spraying, presence of cargo dust, serious mechanical damage, aggressive fumes	IP55	×	–	×	×	×	×	–	IP56
Holds for dry cargo			–	–	–	–	×	–	–	×
Open decks	Danger of water ingress in massive quantities	IP56	×	–	×	–	IP55	×	–	×

Notes: ① "×" means that the requirements of column (3) are to be complied with, or if impossible, the requirements of note ② are to be satisfied; "–" means that such equipment is generally not to be installed.

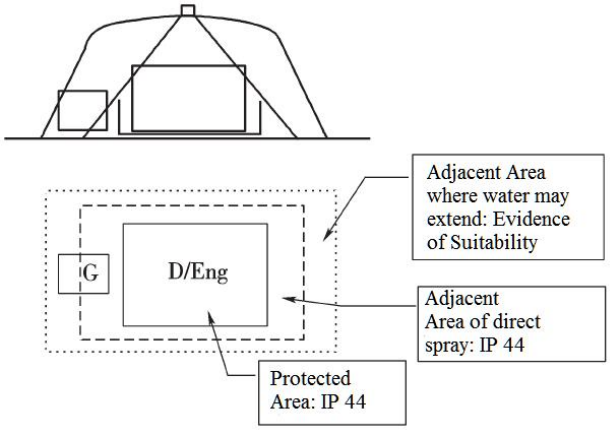
② Where the protection is not achieved by the equipment itself, other means are to be taken or the condition of the location for installing the equipment is to be improved to ensure the degree of protection required in the Table.

③ Where electrical equipment is installed in areas where explosive dusts may be present, the requirements of 1.3.3.7 of this Section are to be complied with.

④ Where the main and emergency switchboards are constructed and installed in accordance with the requirements of

Section 3 of Chapter 3 and Sections 1 and 2 of Chapter 2 of this PART respectively, the requirements of this Table may be dispensed with.

1.3.2.3 In the engine room, the electrical and electronic equipment located within areas protected by fixed water-based local fire-fighting systems and those within adjacent areas exposed to direct spray (see Figure 1.3.2.3) are to have a degree of protection not less than IP44, except where evidence of suitability is submitted to and approved by CCS.



G – generator; D/Eng – diesel engine

Figure 1.3.2.3 Areas Protected by Fixed Water-Based Local Application Fire-Fighting Systems

1.3.2.4 In the engine room, the electrical and electronic equipment within adjacent areas where water may extend and which are not covered by 1.3.2.3 above (see Figure 1.3.2.3) may have a lower degree of protection provided evidence of suitability for use in these areas is submitted taking into account the design and equipment layout, e.g. position of inlet ventilation openings, cooling airflow for the equipment is to be assured.

1.3.3 Explosion protection

1.3.3.1 Where electrical equipment is installed in areas where explosive gas or vapour atmospheres may be present, it is to be of a certified safe type complying with the following requirements:

(1) The construction and type testing of the safe type electrical equipment is to be in accordance with the relevant acceptable standards①.

(2) The safe type electrical equipment is to be certified by a competent testing authority approved by CCS.

1.3.3.2 The certified safe type equipment normally used on board ships includes the following types of protection:

(1) Intrinsically safe Ex “i”;
(2) Flameproof Ex “d”;
(3) Increased safety Ex “e”;
(4) Pressurized enclosure Ex “p”;
(5) Special protection Ex “s”;
(6) Powder filled Ex “q”;
(7) Encapsulated Ex “m”.

1.3.3.3 The electrical equipment allowed to be fitted in spaces subject to an explosion hazard, e.g. battery rooms, lamp stores and paint lockers (including ventilation ducts), is to comply with the following requirements:

(1) The electrical equipment is to be installed in paint stores and in ventilation ducts serving such spaces only when it is essential for operational services. Such equipment is to be of a certified safe type listed in 1.3.3.2(1) to (5) of this Section. For other spaces, the electrical equipment of certified safe types listed in 1.3.3.2 of this Section may be fitted, and the explosion groups and temperature classes of such equipment are at least to comply with the requirements in Table 1.3.3.3.

(2) Cables (through runs or terminating cables) of armoured type or installed in metallic conduits are to be used.

---

① Refer to IEC publication 60079: Electrical Apparatus for Explosive Gas Atmospheres, or an equivalent national standard. e.g., GB 3836: Electrical Apparatus for Explosive Gas Atmospheres.

(3) The switches, protective devices and motor control gear for the electrical equipment installed in such spaces are to interrupt all poles or phases and preferably are to be located in non-hazardous spaces.
In addition, the relevant requirements for paint locker ventilation openings, battery rooms, oil tankers and ships carrying vehicles with fuel in their tanks for their own propulsion are given in 1.3.3.4, 1.3.3.5 of this Section, and Sections 11, 16 and 17 of Chapter 2.

Explosion Group and Temperature Class **Table 1.3.3.3**

Location	Group①	Temperature class①
Battery rooms	II C②	T1
Paint lockers	II B	T3
Lamp stores	II A	T3
Ammonia plant rooms③	II A	T1
Acetylene storage rooms	II C	T2
Spaces carrying dangerous goods	According to the category of dangerous goods carried	According to the category of dangerous goods carried
Tunnels for pipes containing oil with a flash point of 60℃ or below	II A	T3

Notes: ① The explosion groups and temperature classes of electrical equipment listed in this Table and hereinafter in this PART are according to the relevant requirements of IEC Publication 60079: Electrical Apparatus for Explosive Gas Atmospheres or of GB 3836: Electrical Apparatus for Explosive Atmospheres.
② Explosion groups II A, II B and II C of electrical equipment listed in this PART are applicable only to intrinsically safe apparatus and flame-proof apparatus. For other types of explosion-proof electrical equipment, Group II is to be used.
③ Electrical equipment installed in R717 refrigerator room is to comply with the requirements in Section 5 of Chapter 2 of PART FIVE of the Rules.

1.3.3.4 In the areas on open deck within 1 m of inlet and exhaust ventilation openings or within 3 m of exhaust mechanical ventilation outlets of the paint locker, the following electrical equipment may be installed:
(1) certified safe type equipment listed in 1.3.3.2(1) to (5) of this Section, while cables and their installation are to comply with the requirements of 1.3.3.3(2);
(2) explosion-proof equipment of non-sparking construction (Ex “n”);
(3) appliances which do not generate arcs in service and whose surface does not reach unacceptably high temperature;
(4) appliances with simplified pressurized enclosures or vapour-proof enclosures (minimum degree of protection IP55) whose surface does not reach unacceptably high temperature.
1.3.3.5 The enclosed spaces giving access to the paint locker may be considered as non-hazardous, provided that:
(1) the door to the paint locker or the door of the paint locker is a gastight door with self-closing devices (a watertight door may be regarded as a gastight door) without holding back arrangements;
(2) the paint locker is provided with an acceptable, independent, natural ventilation system ventilated from a safe area;
(3) warning notices are fitted adjacent to the paint locker entrance stating that the locker contains flammable liquids.
1.3.3.6 Socket outlets are, unless expressly specified otherwise, not to be installed in spaces subject to an explosion hazard.
1.3.3.7 Where electrical equipment is to be installed in areas where explosive dusts may be deposited, it is to comply with the following requirements:
(1) the degree of protection by enclosures is to be at least IP55;
(2) the maximum surface temperature of the equipment in continuous service is to be at least 75 K lower than the glow temperature of a 5 mm thick layer of the dust.

1.3.4 Earthing

1.3.4.1 All accessible metal parts of the electrical equipment, other than current-carrying ones, are to be earthed, except for:
(1) lamp caps;
(2) shades, reflectors and guards supported on lamp holders or lighting fittings constructed of, or shrouded in, non-conducting material;
(3) metal parts on, or screws in or through, non-conducting material, which are separated by such material

from current-carrying parts and from earthed non-current-carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(4) portable appliances having double and/or reinforced insulation, provided that the appliances conform with recognized safety requirements;
(5) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(6) clips for fluorescent lamps;
(7) apparatus supplied at a working voltage not more than 50 V. For the alternating current, this voltage is a value of root mean square. Autotransformers are not to be used for the purpose of achieving this voltage;
(8) cable clips.

1.3.4.2 When the electrical equipment is directly fixed on the metal hull of the ship or securely fixed on bedplates (or supports) which have a good electrical contact with the metal hull of the ship, a special earthing conductor may not be required.

1.3.4.3 Whether the earthing is achieved through a special conductor or by bedplates (or supports) of the equipment, the surfaces in contact are to be clean, flat and bright so as to ensure an effective contact, and measures are to be taken to prevent the connection from loosening and corrosion.

1.3.4.4 When special earthing conductors are used, they are to be of copper or other corrosion-resistant materials of good conductivity, and are to be protected against mechanical damage and corrosion where necessary. The nominal cross-sectional area of various copper earthing conductors is not to be less than required in Table 1.3.4.4.

1.3.4.5 Bare metal parts of movable or portable appliances, other than current-carrying ones, are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket outlet, and the cross-sectional area of the earth conductor is to comply with the requirements of Table 1.3.4.4.

Size of Earthing Conductors **Table 1.3.4.4**

Type of earthing conductor	Cross-sectional area of associated current-carrying conductor S (mm^2)	Minimum cross-sectional area of copper earthing conductor Q (mm^2)
Earth-continuity conductor in flexible cable or flexible cord	$S \leq 16$	$Q = S$
	$S > 16$	$Q = S/2$, but at least 16
Earth-continuity conductor incorporated in fixed cable	$S \leq 16$	$Q = S$, but at least 1.5
	$S > 16$	$Q = S/2$, but at least 16
Special fixed earthing conductor	$S \leq 2.5$	$Q = S$, but at least 1.5
	$2.5 < S \leq 120$	$Q = S/2$, but at least 4
	$S > 120$	$Q = 70$

1.3.4.6 Metal coverings (braid or armour) of cables are to be effectively earthed at both ends of the run, except that final sub-circuits may be earthed at the supply end only. This does not necessarily apply to control and instrumentation cables or intrinsically safe circuit cables where single point earthing is permitted for technical or safety reasons.

1.3.4.7 The metal coverings of cables may be earthed by one of the means described below:
(1) gripped by metal clamps and connected to the metal hull of the ship by dedicated copper earthing conductors. The relationship between the cross-sectional area Q of the copper earthing conductors and the cross-sectional area S of the current-carrying conductors of the cables is to comply with Table 2 in IEC 60092-352 or as follows:

$$Q \geq 1.5 \text{ mm}^2, \text{ for } S \leq 25 \text{ mm}^2;$$
$$Q \geq 4 \text{ mm}^2, \quad \text{for } S > 25 \text{ mm}^2;$$

(2) by means of glands intended for this purpose and so designed as to ensure an effective earth connection;
(3) by means of clamps or clips of corrosion-resistant metal, enabling a good contact between the metal coverings of cables and the earthed metal.

1.3.4.8 The electrical continuity of metal coverings of cables is to be ensured throughout the length of the cables, particularly at joints and tappings.

1.3.4.9 Every connection of an earth-continuity conductor or a special earthing conductor to the hull structure is to be made in an accessible position, and is to be secured by a screw of brass or other corrosion-resistant material and having a diameter not less than 4 mm, which is to be used for this purpose only.

1.3.4.10 Where aluminium superstructures are secured to the steel hull of a ship with an insulation to prevent electrolytic corrosion between these materials, a separate bonding connection is to be provided between the superstructure and the hull which is to be made in such a manner that electrolytic corrosion is prevented and the connection points may readily be inspected.

1.3.4.11 In order to avoid the hazard of an incentive discharge due to the build-up of static electricity resulting from the flow of liquids/gases/vapours, all cargo tanks, process plants and piping systems that contain flammable liquids, evolve combustible gases and/or develop flammable dusts are to comply with the following requirements:
(1) The resistance between the above cargo tanks, process plants and piping systems and the hull of the ship is not to be greater than 1 MΩ.
(2) The requirements of 1.3.4.11(1) will be readily met without the use of bonding straps where cargo tanks, process plants and piping systems are directly or via their supports, either welded or bolted to the hull of the ship.
(3) Bonding straps are required for cargo tanks, process plants and piping systems which are not permanently connected to the hull of the ship, e.g.:
① independent cargo tanks;
② cargo tanks and piping systems which are electrically separated from the hull of the ship;
③ pipe connections arranged for the removal of spool pieces;
④ wafer-style valves with non-conductive (e.g. PTFE) gaskets or seals.
(4) Where bonding straps are required, they are to be:
① clearly visible so that any shortcomings can be clearly detected;
② designed and sited so that they are protected against mechanical damage and that they are not affected by high resistivity contamination, e.g. corrosive products or paint;
③ easy to install and replace.
(5) Bonding straps are to be made of copper or other corrosion-resistant materials of good conductivity, having a cross-sectional area of at least 10 mm^2.

1.3.5 Electromagnetic compatibility

1.3.5.1 Appropriate measures are to be taken to reduce the interference due to electromagnetic energy so that all electrical and electronic equipment can operate normally in a ship's electromagnetic environment.
1.3.5.2 The allowable value of the voltage (current) of the interference induced by electrical and electronic equipment and the means of interference suppression are to comply with the relevant provisions of acceptable standards①.

1.3.6 Visual and audible signals

1.3.6.1 Except those required in 1.3.6.2 of this Section, the colour of visual signals is to comply with the requirements of Table 1.3.6.1.
1.3.6.2 Except those required above, the visual and audible signals are to comply with the acceptable standards②.

Colours of Visual signals **Table 1.3.6.1**

Colour	Meaning	Explanation	Example
Red	Danger or alarm	Warning of danger or a situation which requires immediate action	Operation failure of essential services; Temperature or pressure of water, oil etc. reaching a critical value; Power failure of essential circuits
Yellow	Caution	Change or impending change of conditions	Temperature or pressure is abnormal, but not reaching a critical value
Green	Safety (normal operating or normal working conditions)	Indication of a safe situation	Normal operation of machinery; Normal circulation of liquids; Pressure, temperature and currents within limits
Blue	Instruction/information (specific meaning assigned according to the need in the case considered)	Blue may be given a meaning which is not covered by the three above colours: red, yellow and green	Motor begins to start; Unloading generator begins to switch on; Heating circuit of stopping motor is connected
White	No specific meaning assigned	Any meaning, used if red, yellow or green is considered not applicable	Earthing insulation indication; Synchronizing lamp; Telephone calling; Automated equipment

① Refer to IEC Publication 60533: Electromagnetic Compatibility of Electrical and Electronic Installations in Ships, or corresponding standards.
② Refer to Code on Alerts and Indicators, 2009 adopted by IMO resolution A.1021(26).

1.3.7 Harmonic Distortion for Ship Electrical Distribution System including Harmonic Filters①

1.3.7.1 Ships where harmonic filters are installed on main busbars of electrical distribution system are to meet the requirements of 1.3.7.2 to 1.3.7.6 below. However, harmonic filters installed for single application frequency drives such as pump motors and harmonic filters installed for enhancing electromagnetic compatibility of single equipment/system may be excluded from these requirements.

1.3.7.2 The total harmonic distortion (THD) of electrical distribution systems is not to exceed 8%. This limit may be exceeded where all installed equipment and systems have been designed for a higher specified limit and the harmonic distortion calculation report is to be provided and made available on board as a reference for the surveyor at each periodical survey.

1.3.7.3 Ships are to be fitted with facilities to continuously monitor the levels of harmonic distortion experienced on the main busbar as well as alerting the crew should the level of harmonic distortion exceed the acceptable limits. Where the engine room is provided with automation systems, this reading is to be logged electronically, otherwise it is to be recorded in the engine log book for future inspection by the surveyor.

1.3.7.4 The system integrator of the distribution system is to show, by calculation, the effect of a failure of a harmonic filter on the level of harmonic distortion experienced. The system integrator of the distribution system is to provide the ship owner with guidance documenting permitted modes of operation of the electrical distribution system while maintaining harmonic distortion levels within acceptable limits during normal operation as well as following the failure of any combination of harmonic filters. The calculation results and validity of the guidance provided are to be verified by the surveyor during sea trials.

1.3.7.5 A harmonic filter is to be arranged as a three-phase unit with individual protection of each phase. The activation of the protection arrangement in a single phase is to result in automatic disconnection of the complete filter. Additionally, a current unbalance detection system independent of the overcurrent protection alerting the crew in case of current unbalance is to be installed. This alarm is to be provided locally and/or in normally attended spaces.

1.3.7.6 Consideration is to be given to additional protection for the individual capacitor element (e.g. relief valve or overpressure disconnector) in order to protect against damage from rupturing. This consideration is to take into account the type of capacitors used.

---

① Applicable to new ships and ships where an application for a periodical or occasional machinery survey after the retrofit of harmonic filters is dated on or after 1 July 2017.

CHAPTER 2 ELECTRICAL INSTALLATIONS IN SHIPS

Section 1 MAIN SOURCE OF ELECTRICAL POWER

2.1.1 Generating sets

2.1.1.1 A main source of electrical power having sufficient capacity to supply all services mentioned in 1.1.1.5(1) of this PART is to be provided, and the following requirements are to be complied with.

(1) The main source of electrical power is to consist of at least two generating sets.

(2) The number and ratings of these generating sets are to be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide normal operational conditions of propulsion and safety of the ship and essential for ships with class notation for carrying refrigerated cargoes as specified in PART FIVE of the Rules. Furthermore, minimum comfortable conditions of habitability are also to be ensured, which include at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water.

(3) The generating sets are to be such as to ensure that with any one generator or its prime mover out of operation, the remaining generating sets are still capable of providing the electric services necessary to start the main propulsion plant from a dead ship condition.

(4) Where the main source of electrical power is necessary for propulsion and steering of the ship, the continuity of the power supply to the equipment necessary for the propulsion and steering and for ensuring the safety of the ship is to comply with the following requirements:

① Where the electrical power is normally supplied by more than one generating set simultaneously in parallel operation, means of protection, including automatic shedding (see 2.5.7.1 of this Chapter) of non-essential services and if necessary, automatic shedding of the arrangements for habitability and secondary essential services, are to be provided to ensure that in case of loss of any of these generating sets, the remaining ones are kept in operation to supply equipment necessary for propulsion and steering and for ensuring the safety of the ship.

② Where the electrical power is normally supplied by one generator, provision is to be made, upon loss of power, for automatic starting and connecting to the main switchboard of a stand-by generator(s) of sufficient capacity with automatic restarting of the essential auxiliaries, in sequential operation if required. Starting and connection to the main switchboard of the stand-by generator is to be as rapid as possible, preferably within 30 s, but in any case not more than 45 s, after loss of power.

(5) Where the main source of electrical power is necessary for propulsion of the ship, the main bus-bar is to be subdivided into at least two independent sections which are normally be connected by a circuit breaker without tripping mechanism or disconnecting link or switch by which the bus-bar can be split easily. So far as is practicable, the connection of generating sets and other duplicated equipment is to be equally divided between the sections.

(6) A common power plant may be provided as both the main source of electrical power and the electrical power for propulsion, and in this case the requirements of 15.2.1.9 of Chapter 15, PART EIGHT of the Rules are to be complied with.

2.1.1.2 The alternating current system is to be such that with one generating set out of action, the remaining sets have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any other device to fail due to excessive voltage drop on the system. Motors which have a very large capacity and are not essential to the safe navigation of the ship, such as thruster motors, may be started when all generators are put into operation without causing any essential services to stop.

2.1.1.3 The arrangement of the ship's main source of electrical power is to be such that the operation of the services referred to in 1.1.1.5(1) of this PART can be maintained regardless of the speed and direction of the propulsion machinery shafting.

2.1.1.4 For calculation of the capacity of generating sets, where the detailed power of refrigerated containers can not be provided, it is recommended that 11 kW be taken for each socket where the sockets of refrigerated containers are adaptable to power supply for 20 ft or 40 ft containers. It is also recommended that 7.5 kW be taken for each socket suitable only for power supply of 20 ft containers. A diversity factor of 0.6 may be taken for calculation of loading of containers.

2.1.1.5 A main source of electrical power may be provided as necessary for non-self-propelled ships. Where the main source of electrical power is the generator, the provisions of 2.1.1.1 to 2.1.1.3 of this Chapter need not be complied with.

2.1.2 Generators driven by main propulsion machinery (e.g. shaft-driven generators)

2.1.2.1 A generator driven by the ship's main propulsion machinery may be considered part of the ship's main source of electrical power, provided that:
(1) the generator is capable of operating normally under all weather conditions during sailing or maneuvering, also when the vessel is stopped, within the specified limits for the voltage variation in paragraphs 3.2.7 and 3.2.8 and for the frequency variation in 1.2.2.2;
(2) the rated capacity of the generator is in compliance with 2.1.1.1(2) upon loss of any other generator in service;
(3) the short circuit current of the generator and/or generator system is sufficient to trip the generator circuit breaker, taking into account the selectivity of the protective devices for the distribution system. Protection is to be arranged in order to safeguard the generator in case of a short circuit in the main bus-bar. The generator is to be suitable for further use after fault clearance;
(4) the automatic start of standby sets is in compliance with 2.1.1.1(4)②.
2.1.2.2 A generators and/or generating system driven by the ship's propulsion machinery and not forming part of the ship's main source of electrical power may be used, whilst the ship is at sea, to supply the electrical equipment necessary for normal operational and habitable conditions provided that:
(1) sufficient and adequately rated additional generators are fitted, which constitute part of the main source of electrical power required by 2.1.1.1 of this Section;
(2) arrangements are fitted to automatically start at least one of the generators, which constitute part of the main source of electrical power required by 2.1.1.1 of this Section, in compliance with 2.1.1.1(4)②, when frequency variations exceed the limits specified below:
Frequency variations (permanent): ±5.5%
Frequency variations (transient): ±11% (5 s);
(3) voltage variations are within the limits specified in 3.2.7 and 3.2.8 and frequency variations within the limits specified in 1.2.2.2;
(4) the short circuit current of the generator and/or generating system is sufficient to trip the generator and/or generating system circuit breaker, taking into account the selectivity of the protective devices for the distribution system;
(5) automatic load shedding arrangements are fitted in accordance with the requirements of 2.5.7 of this Chapter;
(6) on ships having remote control of the propulsion machinery from the navigation bridge, means are provided or procedures are in place to ensure that the power supply to essential services is maintained during maneuvering conditions in order to avoid a blackout situation.

2.1.3 Transformers
2.1.3.1 The number, capacity and arrangement of transformers are to meet the following requirements if they constitute the necessary parts of lighting system and main electric power source system as required in 2.1.1.1 of this Section.
(1) The transformers are to be such that, with any one transformer out of operation, the remaining transformers are sufficient to ensure the safe operation of the equipment necessary for normal propulsion and for safety of the ship. Furthermore, minimum comfortable conditions of habitability are also to be ensured, which include at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water.
(2) Each transformer is to be located as a separate unit with separate enclosure or equivalent, and is to be served by separate circuits on the primary and secondary sides.
(3) Each primary circuit is to be provided with switch gear and protection devices in each phase.
(4) Each of the secondary circuits is to be provided with a multi-pole isolating switch.

2.1.4 Installation of switchboards
2.1.4.1 The main switchboard is to be so placed relative to the main power plant that, as far as is practicable, the integrity of the normal electrical supply will be affected only by a fire or other casualty in one space. An environmental enclosure for the main switchboard, such as may be provided by a machinery control room situated within the main boundaries of the space, is not to be considered as separating the switchboard from the generators.
2.1.4.2 Water, oil or steam pipes, oil tanks or other liquid containers are not to be installed above or behind the switchboard. If this is unavoidable, suitable protection is to be provided in these positions.
2.1.4.3 Passages of an adequate width are to be left in front of and behind switchboards. The width of the front passage is to be at least 0.8 m. The width of passage behind the switch gear is to be at least 0.6 m, and at least 0.5 m at frames. If the construction of a switchboard is such as to permit maintenance, inspection and replacement of parts from the front or from the ends, the passageway behind the switchboard may be

dispensed with.
2.1.4.4 Where the length of the main switchboard is greater than 4 m, passageways are to be, as far as possible, provided at both ends of the switchboard. Except that the main switchboard is installed in the machinery control room, doors with locking devices are to be provided at both ends of the passageway behind the switchboard.
2.1.4.5 The passageways in front of and behind the main switchboard are to be covered by non-slipping and oil-proof insulating mats or insulated wood gratings.

2.1.5 Automatic connecting and disconnecting of main generating set

2.1.5.1 Requirements of paragraph 2.1.5.2 to 2.1.5.6 are to be met where start, stop and load sharing between generators, is controlled by an automation system.
2.1.5.2 The following alarms are to be arranged:
(1) variations in bus bar voltage from the rated value (high and low);
(2) variations in bus bar frequency from the rated value (high and low);
(3) automatic load shedding;
(4) failure in automatic switch-on of circuit breaker of generator;
(5) automatic tripping of circuit breaker of generator;
(6) failure in load distribution (with the necessary time delay, see paragraph 3.2.8.5 of Chapter 3 for the percentage of load distribution).
2.1.5.3 Means are to be provided to avoid two or more than two generating sets being switched on the common bus-bar of main switchboard simultaneously.
2.1.5.4 After a blackout due to short circuit, the generator circuit breaker is permitted to be switched on only once.
2.1.5.5 Where the standby generating set has been started as a result of a prolonged main bus-bar voltage or frequency fluctuation, the running generating set is to be stopped and disconnected from the switchboard prior to connection of the standby generating set.
2.1.5.6 Automatic starting attempts which fail are to be limited to restrict consumption of starting energy.

Section 2 EMERGENCY SOURCE OF ELECTRICAL POWER

2.2.1 General requirements

2.2.1.1 All passenger ships and cargo ships of more than 500 gross tonnage are to be provided with a self-contained emergency source of electrical power.
2.2.1.2 The emergency source of electrical power is to be so arranged as to comply with the following:
(1) The emergency source of electrical power, associated transforming equipment (if any), transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and are to be readily accessible from the weather deck. They are not to be located forward of the collision bulkhead, except where permitted by CCS for cargo ships in exceptional circumstance.
(2) The location of the emergency source of electrical power, associated transforming equipment (if any), the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment (if any), and the main switchboard is to be such as to ensure that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment (if any), and the main switchboard or in any machinery space of category A will not interfere with the supply, control and distribution of emergency electrical power. As far as practicable, the space containing the emergency source of electrical power, associated transforming equipment (if any), the transitional source of emergency electrical power and the emergency switchboard is not to be continuous to the boundaries of machinery spaces of category A or those spaces containing the main source of electrical power, associated transforming equipment (if any), or the main switchboard.
2.2.1.3 The emergency source of electrical power may be a generator, which is to comply with the following requirements:
(1) driven by a suitable prime mover with independent cooling system and supply of fuel as well as starting arrangements complying with the requirements of 9.5.3 of Chapter 9, PART THREE of the Rules;
(2) started automatically upon failure of the electrical supply from the main source of electrical power and connected automatically to the emergency switchboard, and those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section then transferred automatically to the emergency generating set, except for cargo ships fitted with a transitional source of emergency electrical power in

accordance with 2.2.1.5 of this Section. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 s.

2.2.1.4 The emergency source of electrical power may also be an accumulator battery, which is to comply with the following requirements:

(1) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage;

(2) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

(3) supplying those services (except as otherwise stated) referred to in 2.2.2.1 (for passenger ships) or 2.2.3.1 (for cargo ships) of this Section, and immediately supplying those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section.

2.2.1.5 Where the emergency source of electrical power is a generator, a transitional source of emergency electrical power which consists of an accumulator battery is to be provided in compliance with the following requirements, except for cargo ships fitted with an emergency generator capable of automatic starting in accordance with 2.2.1.3(2):

(1) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage;

(2) so arranged as to supply immediately and automatically in the event of failure of either the main or emergency source of electrical power those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section.

2.2.1.6 Where the emergency source of electrical power is required to restore propulsion from a dead ship condition, the capacity is to be sufficient to supply the following equipment within 30 min of the blackout (For steam turbine ships, the 30-min time limit is to be taken as the time from blackout/dead ship condition to light-off of the first boiler):

(1) equipment referred to in 2.2.2.1(1), (2) and (3) or in 2.2.3.1 (1), (2), (3) and (4) of this Section;

(2) restoring propulsion of the ship and operation of other machineries (as appropriate) from a dead ship condition.

2.2.1.7 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power and to comply with the following requirements:

(1) Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

(2) Where the emergency source of electrical power is an accumulator battery, the accumulator battery is not to be installed in the same space as the emergency switchboard.

(3) Water, oil or steam pipes, oil tanks or other liquid containers are not to be installed above or behind the emergency switchboard. If this is unavoidable, suitable protection is to be provided in these positions.

(4) The passageways in front of the emergency switchboard are to be covered by non-slipping and oil-proof insulating mats or insulated wood gratings.

2.2.1.8 An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or transitional source of emergency electrical power are being discharged.

2.2.1.9 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be protected according to the requirements of 2.5.9.6 and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.

2.2.1.10 In order to ensure ready availability of the emergency source of electrical power, arrangements are to be made, where necessary, to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that electrical power is to be available to the emergency circuits.

2.2.1.11 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits.

2.2.1.12 Where the emergency and/or transient emergency source of electrical power is an accumulator battery which supplies emergency loads via an electronic converter or inverter, the maximum permitted D.C voltage variations (taken as those on the load side of the converter or inverter) are to be within 12% above or below its nominal voltage; where DC is converted into AC the maximum variations are to comply with Table 1.2.2.2.

2.2.1.13 UPS units specified in Section 9, Chapter 3 of this PART may be used to provide an alternative power supply or transitional power supply to emergency services as defined in 2.2.2 and 2.2.3 of this Section.

2.2.2 Scope and period of supply of the emergency source in passenger ships

2.2.2.1 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(1) for a period of 36 h, emergency lighting:

① at every muster and embarkation station and over the sides as required in the SOLAS Convention in force;

② in alleyways, stairways and exits giving access to the muster and embarkation stations as required in the SOLAS Convention in force;

③ in all escape routes with their stairways and exits (including angles and intersections) placed not more than 0.3 m above the deck as required in the SOLAS Convention in force (where an emergency source of electrical power is required for the supply);

④ in all service and accommodation alleyways, stairways and exits, personnel lift cars;

⑤ in public spaces and in cabins accommodating more than 16 persons;

⑥ in the machinery spaces and main generating stations including their control positions;

⑦ in all control stations, machinery control rooms, and at each main and emergency switchboard;

⑧ at all stowage positions for firemen's outfits;

⑨ at the steering gear; and

⑩ at the fire pump, the sprinkler pump and the emergency bilge pump referred to in the subparagraph (4) and at the starting position of their motors;

(2) for a period of 36 h:

① the navigation lights and other signal lights required in the International Regulations for Preventing Collisions at Sea in force;

② VHF radio equipment, MF radio installation (if any), ship earth station (if any) and MF/HF radio equipment (if any) required in the SOLAS Convention in force;

(3) for a period of 36 h:

① all internal communication equipment required in an emergency;

② the navigational aids as required in the SOLAS Convention in force, where such provision is unreasonable or impracticable, this requirement may be waived for ships of less than 5,000 gross tonnage, subject to agreement of CCS;

③ the fire detection and fire alarm system, and the fire door holding and release system; and

④ for intermittent operation of the daylight signaling lamp, the ship's whistle, the manually operated call points and all internal signals that are required in an emergency (e.g. general emergency alarm system, alarms for warning of the release of extinguishing media),

unless such services mentioned above in ① to ④ have an independent supply for the period of 36 h from an accumulator battery suitably located for use in an emergency;

(4) for a period of 36 h:

① one of the fire pumps required in the SOLAS Convention in force;

② the automatic sprinkler pump, if any;

③ the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves;

(5) for the period of time required in 13.1.8 of PART THREE of the Rules, the steering gear if required to be so supplied by that paragraph;

(6) for a period of half an hour:

① any watertight doors required in the SOLAS Convention in force to be power operated together with their indicators and warning signals;

② the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency;

2.2.2.2 The transitional source of emergency electrical power required in 2.2.1.5 of this Section is to be of sufficient capacity to supply at least the following services, if they depend upon an electrical source for their operation:

(1) for half an hour:

① the lighting required in 2.2.2.1(1) (except for 2.2.2.1(1)③) and navigation lights and other signal

lights required in 2.2.2.1(2)① of this Section;

② all services required in 2.2.2.1 (3)①, ③ and ④ unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency;

(2) power to operate the watertight doors, but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided;

(3) power to the control, indication and alarm circuits for operation of watertight doors for half an hour.

2.2.2.3 In addition to the emergency lighting required above, passenger ships with ro-ro cargo spaces or special category spaces are to be provided with the following:

(1) all passenger public spaces and alleyways are to be provided with supplementary emergency lighting complying with the following:

① capable of operating for at least three hours when all other sources of electrical power have failed and under any condition of heel;

② the illumination provided is to be such that the approach to the means of escape can be readily seen;

③ the source of power for the supplementary lighting is to consist of accumulator batteries located within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Alternatively, other means of lighting which is at least as effective may be accepted by CCS;

④ the supplementary lighting is to be such that any failure of the lamp will be immediately apparent;

⑤ any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service;

(2) a portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required in (1) above, is provided.

2.2.3 Scope and period of supply of the emergency source in cargo ships

2.2.3.1 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(1) for a period of 3 h, emergency lighting at every muster and embarkation station and over the sides as required in the SOLAS Convention in force;

(2) for a period of 18 h, emergency lighting:

① in all services and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks;

② in the machinery spaces and main generating stations including their control positions;

③ in all control stations, machinery control rooms, and at each main and emergency switchboard;

④ at all stowage positions for firemen's outfits;

⑤ at the steering gear;

⑥ at the fire pump referred to in (5), at the sprinkler pump (if any), and at the emergency bilge pump (if any), and at the starting positions of their motors;

⑦ in all cargo pump rooms of tankers;

(3) for a period of 18 h:

① the navigation lights and other signal lights required in the International Regulations for Preventing Collisions at Sea in force;

② VHF radio installation, MF radio installation (if any), ship earth station (if any) and MF/HF radio installation (if any) required in the SOLAS Convention in force;

(4) for a period of 18 h:

① all internal communication equipment as required in an emergency;

② the navigational aids as required in the SOLAS Convention in force, where such provision is unreasonable or impracticable, this requirement may be waived for ships of less than 5,000 gross tonnage, subject to agreement of CCS;

③ the fire detection and fire alarm system;

④ intermittent operation of the daylight signaling lamp, the ships whistle, the manually operated call points and all internal signals that are required in an emergency (e.g. general emergency alarms system, alarms for warning of the release of extinguishing media, etc.),

unless such services mentioned above in ① to ④ have an independent supply for the period of 18 h from an accumulator battery suitably located for use in an emergency;
(5) for a period of 18 h, one of the fire pumps required in the SOLAS Convention in force if dependent upon the emergency generator for its source of power;
(6) for the period of time required in 13.1.8 of PART THREE of the Rules, the steering gear where it is required to be so supplied by that paragraph;
2.2.3.2 The transitional source of emergency electrical power required in 2.2.1.5 of this Section is to be of sufficient capacity to supply at least the following services for half an hour, if they depend upon an electrical source for their operation:
(1) the lighting required in 2.2.3.1(1) and (2), and navigation lights and other signal lights required in 2.2.3.1(3)①. For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and
(2) all services required in 2.2.3.1(4)①, ③ and ④, unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

2.2.4 Use of emergency generator in port
2.2.4.1 The emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements below are complied with:
(1) to prevent the generator or its prime mover from becoming overloaded when used in port, arrangements are to be provided to shed sufficient non-emergency loads to ensure its continued safe operation;
(2) the prime mover is to be fitted with fuel oil filters and lubrication oil filters, monitoring equipment and protection devices as required for the prime mover for main power generation and for unattended operation;
(3) the fuel oil supply tank to the prime mover is to be provided with a low level alarm, arranged at a level ensuring sufficient fuel oil capacity for the emergency services for the period of time as required in 2.2.2 or 2.2.3 of this Section;
(4) the prime mover is to be designed and built for continuous operation and to be subjected to a planned maintenance scheme verified by CCS ensuring that it is always available and capable of fulfilling its role in the event of an emergency at sea;
(5) fire detectors are to be installed in the location where the emergency generator set and emergency switchboard are installed;
(6) means are to be provided to readily change over to emergency operation;
(7) control, monitoring and supply circuits, for the purpose of the use of the emergency generator in port, are to be so arranged and protected that any electrical fault will not influence the operation of the main and emergency services. When necessary for safe operation, the emergency switchboard is to be fitted with switches to isolate the circuits;
(8) instructions, which are to contain information on required fuel oil tank level, position of harbor/sea mode switch, ventilation openings etc., are to be provided on board to ensure that when the vessel is under way all control devices (e.g. valves, switches) are in a correct position for the independent emergency operation of the emergency generator set and emergency switchboard. These instructions are to be posted in the emergency generator room.

Section 3 EXTERNAL SOURCE OF ELECTRICAL POWER

2.3.1 Shore connection system of rated voltage of 1 kV and less
2.3.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box complying with the requirements of 3.3.2.11 of this PART is to be installed in a position in the ship suitable for the convenient reception of flexible cables from the external source. Suitable cables having adequate ratings, permanently fixed, are to be provided for connection between the shore connection box and the main switchboard or emergency switchboard.
2.3.1.2 When a three-phase AC system with neutral earthed is adopted for shore and/or ship power, an earth terminal is to be provided for connecting the ship's hull to shore. In the case of DC systems with hull return, the negative terminal of the shore power must be connected to hull.
2.3.1.3 The shore connection is to be provided with an indicator at the main switchboard or emergency switchboard in order to show when the cables are energized.
2.3.1.4 Where an automatic control device is used for the connection and disconnection of shore supply, the device is to comply with the applicable requirements in Chapter 2 of PART SEVEN of the Rules.

2.3.1.5 In addition to the requirements of 2.3.1.6, an interlocking device between all main generators and emergency generators and the shore supply is to be provided to avoid simultaneous power supply.
2.3.1.6 Where the system has the function of load transfer executed via temporary parallel running between shore supply and ship power, the requirements of 19.2.5.3, 19.2.5.4 and 19.2.6, Chapter 19 of PART EIGHT are to be complied with.

2.3.2 Shore connection system of rated voltage above 1 kV
2.3.2.1 For the shore connection system where load transfer between the shore supply and ship power is executed via blackout, the requirements of 19.2.1.2, 19.2.2, 19.2.3, 19.2.4, 19.2.5.2 and 19.2.6 of Chapter 19, PART EIGHT of the Rules are at least to be complied with.
2.3.2.2 For the shore connection system having the function of load transfer executed via temporary parallel running between shore supply and ship power, the requirements of 19.2.1.2, 19.2.2, 19.2.3, 19.2.4, 19.2.5.3, 19.2.5.4 and 19.2.6 of Chapter 19, PART EIGHT of the Rules are at least to be complied with.
2.3.2.3 The shore supply equipment installed onboard the ship is to comply with the requirements of Section 3, Chapter 19, PART EIGHT of the Rules.

Section 4 POWER SUPPLY AND DISTRIBUTION

2.4.1 Power supply and distribution systems
2.4.1.1 The following systems of distribution may be used:
(1) DC
two-wire insulated system;
two-wire system with negative pole earthed;
single-wire system with negative to hull return.
(2) AC single phase
two-wire insulated system;
two-wire system with one pole earthed;
single-wire system with hull return.
(3) Three-phase AC
three-wire insulated system;
four-wire system with neutral earthed;
three-wire system with neutral earthed and the hull serving as neutral wire.
Other distribution systems than those mentioned above are to be subject to special consideration by CCS.
2.4.1.2 For power supply and distribution systems for high-voltage systems, refer to the requirements of 2.14.2.1 of this PART.
2.4.1.3 For the distribution systems of ships intended for the carriage of crude oil and petroleum products in bulk having a flash point (closed-cup test) below 60℃, refer to the requirements of 2.16.2.1 of this PART.

2.4.2 Insulated distribution systems
2.4.2.1 The neutrals of generating sets are not to be connected together in the insulated distribution system.
2.4.2.2 The insulated distribution systems for power, heating and lighting circuits, whether primary or secondary, are to be provided with a device capable of continuously monitoring the insulation level to earth and of giving an audible or visual indication in case of abnormally low insulation values.

2.4.3 Earthed and hull return systems of distribution
2.4.3.1 The hull return system of distribution is not to be used for power, heating or lighting in ships of 1,600 gross tonnage and upwards, but not excluding the following:
(1) impressed current cathodic protective systems;
(2) limited and locally earthed systems, provided that any possible resulting current will not directly flow through any hazardous areas;
(3) insulation level monitoring devices provided the circulation current does not exceed 30 mA under the most unfavourable condition.
2.4.3.2 Where the hull return system is used, all final sub-circuits are to have all poles or phases insulated, the hull return being achieved by connecting to the hull one of the bus-bars of the distribution board from which they originate.
2.4.3.3 The earthed distribution system in a high-voltage system is to be in compliance with the relevant

requirements of 2.14.2.1 of this PART.
2.4.3.4 The earthing conductors used in the hull return system are to be of the same cross-sectional area as the conductors in the insulated pole or phase, and bare conductors are not to be used.
2.4.3.5 Enclosures of equipment or their mounting bolts are not to be used as return conductors or connection to the conductors.
2.4.3.6 The cross-sectional area of earthing conductors which do not normally carry current in service is to be 50% of that of the current-carrying conductors, but not less than 1.5 mm^2.
2.4.3.7 The system earthing of earthed distribution systems is to be effected by means independent of any earthing arrangements of non-current-carrying parts of the electrical equipment.

2.4.4 Voltage and frequency

2.4.4.1 The maximum voltages of AC distribution systems are not to exceed the values given in Table 2.4.4.1.

Maximum Voltages of AC Distribution Systems **Table 2.4.4.1**

No.	Application	Max. voltage (V)
1	For power equipment permanently installed and connected by permanent wiring	15,000
2	(1) For heating and cooking equipment permanently installed and connected by permanent wiring, except space heaters. (2) For portable equipment, which is not hand-held during operation, and with connection by socket outlet which incorporates an earth continuity conductor of a size in accordance with 1.3.4.5 of this PART	1,000
3	(1) For lighting permanently installed (2) For socket outlets supplying the following (which are not specified in items 2 and 4 in the table): ① equipment with double insulation; ② equipment earthed by earth continuity conductors of a size in accordance with 1.3.4.5 of this PART	250
4	For socket outlets used in spaces where particular risks due to exposure and conductivity may exit: (1) supplied with or without the use of isolating transformers; (2) where a safety isolating transformer is used supplying one consuming device only. Both wires of such systems are to be insulated from earth	55① 250
5	Instrumentation and control equipment②	55③ 250

Note: ① For socket outlets with rated voltage up to 24V, the maximum voltage is 55V.
② For the control voltage of distribution systems operating at a voltage above 500 V, see 2.4.4.2 of this Section.
③ For instrumentation and control equipment with rated voltage up to 48V, the maximum voltage is 55V.

2.4.4.2 For distribution systems operating at a voltage above 500 V, the control voltage is to be limited to 230 V, except where all control devices of the distribution systems operating at a voltage not exceeding 1000 V are enclosed in appropriate control boxes.
2.4.4.3 The standard frequency for AC distribution systems is to be 50 Hz or 60 Hz.
2.4.4.4 The maximum voltages of DC distribution systems are not to exceed the values given in Table 2.4.4.4.

Maximum Voltages of DC Distribution Systems **Table 2.4.4.4**

No.	Application	Max. voltage (V)
1	Power equipment	1500
2	Cooking equipment, heating equipment, lighting and socket outlets	500
3	Communication equipment, instrumentation	250
4	Socket outlets supplying power for life boats/rafts	55

2.4.5 Balance of loads

2.4.5.1 For AC three-wire or four-wire systems, the electrical consumers are to be so grouped in the final sub-circuits that the load in each phase will, under normal conditions, be balanced as far as possible within

15% of its rated load at the individual distribution and section boards as well as the main switchboard.

2.4.6 Diversity factors

2.4.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

2.4.6.2 The diversity factor may be applied to the calculation of the cross-sectional area of conductors and the rating of switch gear and fuse gear.

2.4.6.3 For cargo winches, a diversity factor may be applied based on the information available from the manufacturer and the information agreed upon between the manufacturer and purchaser. If there is no exact information available, the diversity factors of Table 2.4.6.3 may be applied.

Diversity Factors **Table 2.4.6.3**

<table>
<tr><td rowspan="2">Number of motors</td><td colspan="2">Current to be provided for</td></tr>
<tr><td>Cases in which motors are of the same size</td><td>Cases in which motors are of different sizes</td></tr>
<tr><td>2</td><td colspan="2">100% of combined full load of motors</td></tr>
<tr><td>3</td><td>67% of combined full load of motors</td><td rowspan="3">100% of full load of the largest motor + 50% of full load of each one of the other motors</td></tr>
<tr><td>4</td><td>62% of combined full load of motors</td></tr>
<tr><td>5</td><td>60% of combined full load of motors</td></tr>
<tr><td>6 or more</td><td colspan="2">58% of combined full load of motors</td></tr>
</table>

2.4.6.4 For the diversity factors of socket circuits for refrigerated containers, refer to the requirements of Chapter 4, PART FIVE of the Rules.

2.4.7 Power supply to essential services

2.4.7.1 Unless expressly provided otherwise, the primary essential services are to be supplied directly from the main or emergency switchboard (if required), except for the total discrimination.

2.4.8 Power supply to radio equipment and navigation equipment

2.4.8.1 The power supply to the radio equipment as required in Chapter IV (hereinafter referred to as the radio equipment) and the electrical/electronic navigation equipment as required in Chapter V (hereinafter referred to as the navigation equipment) of the SOLAS Convention are to comply with the requirements of 2.4.8.2 to 2.4.8.4.

2.4.8.2 The distribution board of supplies to the radio equipment is to be independent of that of supplies to the navigation equipment.

2.4.8.3 The distribution board of the radio equipment and that of the navigation equipment supplied by the emergency source of electrical power are to be supplied by separate feeders from main and emergency switchboards, and each distribution board is to be provided with a device for changing over between main and emergency sources of electrical power, which is in general to be initiated automatically. In the event of any failure of the power supply of the radio distribution board, an audible and visual alarm is to be given in the navigation bridge.

2.4.8.4 Each consumer is to be supplied by an independent final sub-circuit from its distribution board.

2.4.9 Power supply to auxiliary machinery motors, etc.

2.4.9.1 In addition to the above-mentioned requirements, the power supply to auxiliary machinery motors, illumination, navigation lights, internal communication systems and safety system for ships and persons on board is to comply with the relevant requirements of this PART.

2.4.9.2 For AC distribution systems, final sub-circuits rated over 16A are not to supply more than one equipment, except that they only supply socket outlets with current rating not greater than 32A.

2.4.10 Sockets

2.4.10.1 The sockets for general portable appliances are to be in compliance with the requirements of No.3 and No.4 in Table 2.4.4.1 of this Section.

2.4.10.2 For the sockets of distribution systems operating at different voltages and/or frequencies, non-interchangeable plugs are to be used for connection.

2.4.10.3 No socket outlets are to be provided below floor plates in machinery spaces, or in enclosed fuel and lubrication oil separator rooms.

2.4.10.4 Where sockets are necessary in cargo holds, they are to be fitted in positions with sufficient protection against mechanical damage.

2.4.10.5 For sockets of refrigerated containers, refer to the relevant requirements of Chapter 4, PART FIVE of the Rules.
2.4.10.6 Socket outlets for power circuits rated over 16A (AC) or 10A (DC) are to be interlocked in such a way that the plug can be neither inserted nor withdrawn when the socket contacts are live.

2.4.11 Power supply with transformers operating in parallel
2.4.11.1 Transformers arranged for parallel operation are to comply with the following requirements:
(1) their winding connections are to be compatible;
(2) their rated voltage ratios are to be equal (with tolerances within permissible limits);
(3) their short-circuit impedance values are to be equal (if expressed in percentage, a ratio within 0.9 to 1.1 may be allowed);
(4) when transformers are intended for operation in parallel, the rated output of the smallest transformer in the group is not to be less than 50% of the rated output of the largest transformer in the group.

2.4.12 Power supply to safety, control and alarm systems of prime movers
2.4.12.1 The prime movers referred to in this paragraph mean diesel engines, gas turbines and steam turbines, etc. that drive the electric generators which comprise the main source of electric power.
2.4.12.2 The safety, control and alarm systems of prime movers are to be supplied by two independent power sources, which and associated wiring are to be such that the requirements of 2.1.1.1(2) of this Chapter can be met in case of single failure.

2.4.13 Power supply to electronic control system of diesel engines
2.4.13.1 The power supply to electronic control systems of diesel engines is to comply with the requirements of 2.2.4 of Appendix 2 to Chapter 9, PART THREE of the Rules.

Section 5 PROTECTION

2.5.1 General requirements
2.5.1.1 Electrical installations are to be suitably protected against overcurrents including short circuits, and other electric faults. The performance and arrangement of the protective devices are to provide complete and coordinated automatic protection to ensure the continuity of supply to available essential services through the discriminative action of the protective devices in the event of a fault elsewhere, and to ensure the elimination of the effects of the fault to reduce damage to the system and hazard of fire.
Coordination is to be provided:
(1) between main generator protective device, main bus-bar section breakers (if provided with trip), protective devices (if fitted) of feeders connected to the main bus-bar, and protective devices of feeders from the main bus-bar;
(2) between protective devices of feeders and branch circuits of the distribution board containing essential services, unless otherwise specified in 2.5.3.6 of this Section;
(3) between protective devices of feeders from the emergency generator and the emergency bus-bar, and between protective devices of feeders interconnecting main and emergency switchboards and feeders from the emergency bus-bar.
2.5.1.2 Short-circuit protection is to be provided in each non-earthed pole or phase of distribution systems.
2.5.1.3 Overload protection is to be provided in:
(1) insulated two-wire DC or single-phase AC systems: at least one pole or phase;
(2) insulated three-phase AC systems: at least two phases;
(3) earthed systems: each non-earthed pole or phase.
2.5.1.4 No fuse or non-linked switch is to be inserted in an earthed conductor of distribution systems.

2.5.2 Calculations of short-circuit current
2.5.2.1 In the calculation of the maximum prospective short-circuit current, consideration is to be given to:
(1) all generators which are possibly connected in parallel to reach the maximum required power;
(2) all motors which are normally simultaneously connected in the system.
2.5.2.2 When necessary, the prospective short-circuit power factor of the AC system is to be calculated. If the power factor so obtained is less than the specified one corresponding to the rated short-circuit making or breaking capacity of the selected switch gear, then the breaking capacity of such switch gear is to be

reduced accordingly.
2.5.2.3 Short-circuit calculations are to be referred to Appendix 1 of this PART: Short-Circuit Current Calculations with Regard to Electrical Installations, or performed by other methods acceptable to CCS.
2.5.2.4 In general, short-circuit calculations are to be carried out for the following:
(1) short circuit at the output terminal of generators;
(2) short circuit at the main bus-bar;
(3) short circuit at the bus-bars of the emergency switchboard, section switchboards and distribution switchboards;
(4) short circuit at the secondary side of power and lighting transformers.
For the determination of the discriminative action of protective devices, short-circuit calculations are, if necessary, to be additionally performed for short-circuit at terminals of the protected circuit, when only the smallest generator is in supply.

2.5.3 Choice of protective devices against short-circuit

2.5.3.1 Protection against short-circuit currents is to be provided by fuses or circuit-breakers.
2.5.3.2 Unless otherwise specified in 2.5.3.3 and 2.5.3.5, the breaking capacity of protective devices against short-circuit is to comply with the following requirements:
(1) The rated short-circuit breaking capacity of fuses and general circuit breakers is not to be less than the maximum prospective fault current at the point of installation. For the AC systems, the rated short-circuit breaking capacity is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the point of installation.
(2) The rated operating short-circuit breaking capacity (I_{cs}) of circuit breakers for relevant circuits of essential services is not to be less than the maximum prospective fault current at the point of installation. For the AC systems, the rated operating short-circuit breaking capacity is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the point of installation.
2.5.3.3 The rated short-time withstanding current of category B circuit breakers (with short time-lag) is not to be less than the maximum prospective short-circuit current at the instant of contact separation at the point of installation. For the AC systems, the rated short-time withstanding current is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the instant of contact separation at the point of installation.
2.5.3.4 Unless otherwise stated in 2.5.3.5 of this Section, the rated short-circuit making capacity of every circuit breaker or switch which will possibly be initiated for a short-circuit is not to be less than the maximum peak value of the prospective short-circuit current at the point of installation.
2.5.3.5 The use of a circuit-breaker having a short-circuit breaking and/or making capacity less than the maximum prospective short-circuit current at the point of installation is permitted, provided that it is backed up on the generator side by a fuse or by a circuit-breaker (not the generator circuit-breaker) having the necessary rated short-circuit breaking/making capacity.
The short-circuit performance of the back-up protective arrangement is to be at least as that required for a single circuit-breaker by a standard① acceptable to CCS. The circuit-breaker is to have the same utilization category as the circuit-breaker on the load side of the back-up arrangement and a rated short-circuit breaking/making capacity for the maximum prospective short-circuit current at the supply terminal of the arrangement.
2.5.3.6 The back-up protection complying with the requirements of 2.5.3.5 may be used for circuits of non-essential services and of duplicated essential services with automatic change-over. The same fuse or circuit-breaker may be used to back up more than one circuit-breaker when essential services are not involved.
2.5.3.7 Circuit-breakers with fuses connected to the load side may be used, provided the back-up fuse and circuit-breaker are designed for coordinated action, so as to ensure that the operation of the fuse takes place in due time to prevent arcing between poles or between poles and metal parts of the circuit breaker when they are subjected to an overcurrent involving the operation of the fuse.
2.5.3.8 When determining the short-circuit performance requirements for the above-mentioned back-up protection arrangement, the impedance of the elements of the arrangement may be taken into account, such as the impedance of a cable connection when the circuit-breaker on the load side is far away from the back-up circuit-breaker or fuse.

2.5.4 Selective protection for short-circuit

2.5.4.1 Unless otherwise stated in 2.5.3.6 of this Section, the short-circuit protection of essential services is to be selective and comply with the following:

---

① Refer to IEC Publication 60947-2: Low-Voltage Switch Gear and Control Gear – Part 2: Circuit-Breakers.

(1) to ensure that only the protective device nearest to the fault initiates disconnection of the defective circuit in the case of short-circuit;
(2) the tripping time of the protective devices connected in series is to be carefully coordinated;
(3) during the required time of selective protection, the protective device is to be capable of carrying the short-circuit current without breaking at the point of installation.

2.5.5 Choice of protective devices against overload

2.5.5.1 Circuit breakers provided for overload protection are to have a tripping characteristic (overcurrent − trip time) adequate for the overloading ability of protected elements and for any discrimination requirement of the system.
2.5.5.2 The use of fuses for overload protection is permissible up to 320 A, provided they have suitable characteristics, but the use of circuit breakers or similar devices for protection against overload above 200 A is recommended.

2.5.6 Protection of generators

2.5.6.1 Unless otherwise provided in 2.5.6.8 of this section, generators are to be protected against short-circuit and overloads by circuit breakers arranged to interrupt simultaneously all insulated poles, and the overload protection is to be adequate for the thermal capacity of the generator. In addition, the following requirements are to be complied with:
(1) for overloads between 10% and 50%, the circuit breaker is to be tripped with a time delay of less than 2 min. It is recommended that the circuit breaker be set within the limits of 125 to 135% of the rated current of the generator and with a time delay of 15 to 30 s;
(2) for overcurrents in excess of 50% but less than the steady short-circuit current of the generator, the circuit breaker is to be tripped after a short-time delay required for the discriminative protection of the system.
It is recommended that the pick-up current for tripping of the circuit-breaker after a short-time delay be set at 200% to 250% of the rated current of the generator and with a maximum time delay of 0.2 s (DC) or 0.6 s (AC);
(3) circuit breakers for three or more generators connected in parallel are also to be provided with instantaneous releases which are to be set slightly greater than the maximum short-circuit current of the generators protected so that the circuit-breaker may break instantaneously. Other equivalent means may also be accepted subject to the agreement of CCS.
2.5.6.2 For generators less than 50 kW (or kVA) in unit capacity and not arranged to operate in parallel, a multi-pole linked switch with a fuse in each insulated pole may be fitted for protection.
2.5.6.3 Generators having a capacity of 1,500 kVA or above are to be equipped with a suitable protective device or system which, in the event of a short-circuit in the generator or in the supply cable between the generator and its circuit breaker will de-excite the generator and open the circuit breaker. This does not apply to emergency generators.
2.5.6.4 AC generators arranged to operate in parallel are to be provided with a reverse-power protection, with a time delay set within 3 to 10 s. DC generators arranged for parallel operation are to be provided with instantaneous or short-time delayed (less than one second) reverse current protection. The setting of reverse power (or reverse current) protection of generators arranged for parallel operation, dependent on the type of the prime mover used, is to be as follows:
(1) for diesel engines − 8% to 15% of the rated power (or current) of the generator;
(2) for steam turbines − 2% to 6% of the rated power (or current) of the generator.
A fall of 50% in the applied voltage is not to render the reverse power (or reverse current) protection inoperative, although it may alter the amount of reverse power required to open the breaker.
For the reverse-current protection, due consideration is to be given to the reverse current resulting from the ship's network (e.g. cargo winches).
Where equalizer leads are provided, the reverse current protection is to be connected to the positive pole of DC generators.
2.5.6.5 Generators arranged to operate in parallel are to be provided with undervoltage protection as follows:
(1) the operation of undervoltage release is to be instantaneous, if used to prevent the circuit-breaker from closing when the generator is not generating electrical energy;
(2) when the voltage drops down to 70% ~ 35% of the rated voltage, the undervoltage release is to operate with a time delay for discrimination purpose.
2.5.6.6 Where turbine-driven DC generating sets are arranged to operate in parallel, means are to be provided for the purpose of opening simultaneously all circuit-breakers of the generators when the

overspeed tripping device of the driving turbine functions.
2.5.6.7 In the case of substantial reduction of speed of generators, the protective devices associated with generators are to remain effective.
2.5.6.8 Emergency generators are to be protected against short-circuit. Audible and visual alarm signals are to be given in the event of over-currents of emergency generators, which are not to lead to tripping of the circuit breakers of emergency generators.

2.5.7 Automatic load shedding

2.5.7.1 Proper load shedding or other equivalent arrangements are to be provided to automatically shed non-essential services, services for habitable conditions and where necessary, secondary essential services to ensure that the connected generator(s) is/are not overloaded. This load shedding may be carried out in one or more stages according to the overloading ability of the generator. In such case, the non-essential services are to be shed firstly.

2.5.8 Protection of power and lighting transformers

2.5.8.1 The primary windings of power and lighting transformers are to be protected against short-circuit and overload by multi-pole circuit-breakers or fuses. Overload protection may also be provided in the secondary windings.
2.5.8.2 When transformers are arranged to operate in parallel, means of isolation are to be provided on the secondary windings. Switches and circuit breakers used for this purpose are to be capable of withstanding surge currents.

2.5.9 Protection of feeder circuits

2.5.9.1 Each feeder circuit is to be protected against overload and short circuits by a multi-pole circuit breaker arranged to interrupt simultaneously all insulated poles, or a multi-pole switch with fuses, but for a transitional emergency lighting feeder circuit it may also be accepted to use fuses only.
2.5.9.2 When a multi-pole switch with fuses is used, the following requirements are to be complied with:
(1) the fuse in the feeder sub-circuit from the main switchboard is to be fitted between the bus-bar and the switch;
(2) where the final sub-circuit from the distribution board has a rated current not exceeding 60 A and the consumers supplied by it can be disconnected at a nearby position, the switch may be omitted.
2.5.9.3 Circuits supplying consuming devices protected individually against overload (e.g. motors) may be provided with short-circuit protection only.
2.5.9.4 The protection of the steering gear circuits is to comply with 13.1.9.2 of PART THREE of the Rules.
2.5.9.5 Permanently fixed cables between the shore connection box and the main or emergency switchboard are to be protected by a circuit-breaker or an isolating switch and fuses. Such protection is to be fitted in the shore connection box.
2.5.9.6 In general, the interconnector feeder supplying the emergency switchboard from the main switchboard is to be protected at the main switchboard against overload and short-circuit. Where the system is arranged also for reverse power supply, the interconnector feeder is to be additionally protected at the emergency switchboard at least against short-circuit.

2.5.10 Protection of motors

2.5.10.1 Motors rated at 1.0 kW or above and all motors for essential services are to be protected individually against overload and short-circuit, and against undervoltage as required in 2.5.10.6 of this Section. The short-circuit protection can be provided by the same protective device for both the motor and its supply cable.
2.5.10.2 Protection of steering gear motors is to comply with 13.1.9.2 of PART THREE of the Rules.
2.5.10.3 The protective devices are to be designed to allow the flow of currents during the normal accelerating period of motors under normal conditions of service. When the time-current characteristics of the overload protective device of a motor are not adequate for the starting period of the motor, the overload protecting device may be rendered inoperative during the accelerating period provided that the protection against short-circuit remains operative and that the suppression of the overload protection is only temporary.
2.5.10.4 For continuous duty motors, protective devices are to have a time delay characteristic which ensures reliable thermal protection of the motors for overload conditions. The maximum continuous current of the protective device is not to exceed 125% of the rated current of the protected motor.
2.5.10.5 For intermittent duty motors, the current setting and the delay characteristics for protective

devices are to be chosen after considering the actual service condition.
2.5.10.6 Motors are to be provided with either:
(1) undervoltage protection, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit until the motor is deliberately restarted; or
(2) undervoltage release, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit, but so arranged that the motor restarts automatically and without excessive voltage drop or starting current on restoration of voltage.
The protective devices are to allow the motor to start when the voltage is above 85% of the rated voltage, and are without fail to intervene when the voltage is lower than approximately 20% of the rated voltage, at the rated frequency and with time delay when necessary.
2.5.10.7 When fuses are used to protect poly-phase motor circuits, consideration is to be given to protection against single phasing.

2.5.11 Protection of lighting circuits
2.5.11.1 Each lighting circuit is to be protected against overload and short-circuit.

2.5.12 Protection of storage batteries
2.5.12.1 Storage batteries, other than engine starting batteries, are to be protected against short-circuit with devices placed as near as practicable to the batteries.
2.5.12.2 Each battery charger is to be properly protected against discharging of the battery due to the reduction or loss of charging voltage.

2.5.13 Protection of meters, pilot lamps and control circuits
2.5.13.1 Voltmeters, voltage coils of measuring instruments, earthing indicators and pilot lamps together with their connecting leads are to be protected by fuses. A pilot lamp need not be individually protected provided the following conditions are satisfied:
(1) the pilot lamp is installed with the equipment in the same enclosure;
(2) the pilot lamp is supplied from the interior circuit of the enclosure of the equipment;
(3) the protection device in the circuit is rated less than 25 A;
(4) a fault in the pilot lamp would not jeopardize the supply to essential services.
2.5.13.2 The voltage coils of control and protective devices and equipment are to be protected by fuses. The coils themselves need not be protected provided the following conditions are satisfied:
(1) the coils are installed with the equipment in the same enclosure and protected by a general protective device;
(2) the coils are supplied from circuits of the equipment and the protective device of such circuits is rated less than 25 A.

2.5.14 Protection of semiconductor equipment
2.5.14.1 Semiconductor equipment is to be protected against overload and short circuit.

Section 6 AUXILIARY MACHINERIES

2.6.1 General requirements
2.6.1.1 Motors rated at 1.0 kW or above and motors required for essential services are to be supplied from distribution boards by separate final sub-circuits.
2.6.1.2 Every electric motor is to be provided with efficient means of starting and stopping which are, in general, placed near the motor, so as to be easily operated by the person controlling the motor.
2.6.1.3 Means are to be provided for the disconnection of the full load from all live poles of supply of every motor rated at 0.5 kW or above and its control gear. Where the control gear is mounted on or adjacent to a main or other distribution switchboard, a disconnecting switch in the switchboard may be used for this purpose. Otherwise, a disconnecting switch within the control gear enclosure or a separate enclosed disconnecting switch is to be provided.
2.6.1.4 When the starter or any other apparatus for disconnecting the motor is remote from the motor, it is required that either:
(1) provision be made for locking the circuit disconnecting in the OFF position; or
(2) an additional disconnecting-switch be fitted near the motor; or
(3) the fuse in each live pole or phase be so arranged that it can be readily removed and retained by an authorized person.

2.6.1.5 Where a single master-starter system (i.e. a starter used for controlling a number of motors successively) is used, undervoltage and over-current protection, means of isolation and a running indicator are to be provided for each motor, not less effective than those required for systems using a separate starter for each motor. Where the starter system is of an automatic type, suitable alternative means are to be provided for manual operation. Where the starter is used for motors for essential services, the starting portion is to be duplicated, and means are to be provided for change-over in the event of failure of one of the starters.
2.6.1.6 All motors with field adjustment for speed control are to be provided with a device which renders the motors to be started only when the field is fully excited.
2.6.1.7 The undervoltage, overload and short-circuit protection for motors are to comply with the requirements of Section 5, Chapter 2 of this PART.

2.6.2 Steering gear
2.6.2.1 Electrical or electrohydraulic steering gears are to comply with the relevant requirements of Chapter 13, PART THREE of the Rules.

2.6.3 Permanently installed submersible bilge pumps
2.6.3.1 The motors of permanently installed submersible bilge pumps are to be connected to the emergency switchboard. The feeder cables are to be installed in continuous lengths from above the bulkhead to the motor terminals.
The cables are to be impervious-sheathed and armoured. Cables and their connections to such pumps are to be capable of operating under a head of water equal to the height of the bulkhead deck.
2.6.3.2 Under all circumstances it is to be possible to start the motor of a permanently installed submersible bilge pump from a position above the bulkhead deck. If an additional start-stop push button is provided near the motor, the circuits are to be so arranged as to ensure that all control circuits of the start-stop push button may be disconnected from the position above the bulkhead deck.
2.6.3.3 The power source of a permanently installed submersible bilge pump is also to comply with the relevant requirements of Section 5, Chapter 3, PART THREE of the Rules.

2.6.4 Deck machinery
2.6.4.1 Electromagnetic brakes for electrical deck machinery are to have, in addition, a hand release device.
2.6.4.2 If not otherwise specially required in their specifications, the duty of windlass motors and winch motors is to be rated for not less than 30 min.
2.6.4.3 Boat winch motors are to be provided with limit switches for cutting off the power supply upon returning of the boat to its original position.
2.6.4.4 The control device of boat winch motors is to be interlocked with the manual drive and manual brake.

2.6.5 Fire safety equipment
2.6.5.1 The electrical power supply to fire pump motors and fixed emergency fire pump motors is to comply with the relevant requirements of this PART.
2.6.5.2 The electrical power supply to automatic sprinkler systems and water-spraying systems is to comply with the relevant requirements of the International Code for Fire Safety Systems.

2.6.6 Stopping of ventilating fans and oil pumps
2.6.6.1 Power ventilation of accommodation spaces, service spaces, cargo spaces and control stations is to be capable of being stopped from an easily accessible position outside the space being served. This position is not to be readily cut off in the event of a fire in the space served.
The exhaust fans in the exhaust ducts from galley ranges are to be capable of being shut off within the galley.
2.6.6.2 Stopping of the ventilation fans and oil pumps in machinery spaces
(1) The means provided for stopping the power ventilation serving the machinery spaces are to be grouped so as to be operable from two positions outside the space served, one of which is to be easily accessible and close to such space, and is not to be readily cut off in the event of a fire in the space served.
The means provided for stopping the power ventilation of the machinery spaces are to be entirely separate from the means provided for stopping ventilation of other spaces.
(2) Means of control are to be provided for stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps, lubricating oil service pumps, thermal oil circulating pumps and oil separators

(purifiers). Except oil separators, such means of control are to be situated outside each related space so that it will not to be cut off in the event of a fire in the space served.

2.6.6.3 Additional requirements for passenger ships

(1) In passenger ships, the controls required in 2.6.6.2 of this Section are to be situated at one control position or grouped in as few positions as possible. Such positions are to have safe access from the open deck.

(2) In passenger ships carrying more than 36 passengers, power ventilation, except machinery space and cargo space ventilation and unless otherwise specified in PART SIX of the Rules, is to be fitted with controls so grouped that all fans may be stopped from either of two separate positions which are to be situated as far apart as practicable.

Fans serving power ventilation systems to cargo spaces are to be capable of being stopped from a safe position outside such spaces.

2.6.7 Integrated cargo and ballast systems on tankers

2.6.7.1 The following requirements are applicable to integrated cargo and ballast systems on tankers.

2.6.7.2 An integrated cargo and ballast system means any integrated hydraulic and/or electric system used to simultaneously drive both cargo and ballast pumps (including active control and safety systems and excluding passive components, e.g. piping).

2.6.7.3 The operation of the cargo and/or ballast systems may be necessary, in certain emergencies or during navigation, to enhance the safety of the tanker, and measures are to be taken to prevent cargo and ballast pumps becoming inoperative simultaneously due to a single failure in the integrated cargo and ballast system (including its control and safety systems).

2.6.7.4 The following design features are, inter alia, to be fitted:

(1) the emergency stop circuits of the cargo and ballast systems are to be independent from the circuits of the control systems. A single failure in the control system circuits or the emergency stop circuits is not to render the integrated cargo and ballast system inoperative;

(2) manual emergency stops of the cargo pumps are to be arranged in a way that they will not cause the stop of the power pack, rendering ballast pumps inoperable;

(3) the control systems are to be provided with backup power supply, which may be achieved by duplicated power supply from the main switch board. The failure of any power supply is to activate an audible and visual alarm at each location where the control panel is fitted;

(4) in the event of failure of an automatic or remote control system, a secondary means of control is to be available for the operation of the integrated cargo and ballast system. This may be achieved by manual overriding and/or redundancy control arrangements within the control system.

2.6.8 Vehicle ramp control system for ferries

2.6.8.1 The vehicle ramp control station is to be so arranged that the movement of the ramp can be observed by the operator.

2.6.8.2 An audible and visual alarm is to be given for power failure of the control system. At the same time, the ramp is to be kept at its position automatically. When the power supply is recovered, operation of the control mechanism is not to be continued until it its reset.

2.6.8.3 The indicator of ramp conditions is to be provided in the control station.

2.6.8.4 Devices for preventing control and driving circuits from action are to be provided under the following conditions:

(1) any of the covers is not taken off;

(2) enclosures of vehicles are not closed.

2.6.8.5 Audible and visual indications are to be given continuously at a conspicuous position by the ramp when the ramp is running.

2.6.8.6 Where the ramp is fixed by a retractable locking device, means are to be provided to ensure that the power will not be interrupted when the locking device is clutched and that no launching of the ramp is possible before the locking device is disengaged.

2.6.8.7 Where a ramp, in addition to that for the stern door, is provided for access from the wharf, its angle to the horizontal is to be less than 10° before the stern door is opened or closed.

2.6.8.8 The maximum inclination of the access ramp in operation to the horizontal is not to be more than the predetermined angle. An audible and visual alarm is to be given if the inclination exceeds the allowable angle.

2.6.8.9 Where a remote locking device is fitted, alternative means is to be provided for locking the ramp in case of failure of the locking control or locking mechanism.

Section 7 LIGHTING AND NAVIGATION LIGHTS

2.7.1 General requirements

2.7.1.1 The lighting fittings fitted in cargo holds, exterior passageways, or other spaces where they are liable to mechanical damage, are to be provided with robust protective grids.

The lighting fittings located in such spaces where they are liable to considerable vibration are to be provided with means for damping the vibration.

Where lighting fittings are directly fixed on wooden panelling or other inflammable materials, precautions are to be taken against overheating and fire.

2.7.1.2 The switches of lighting fittings for baggage rooms, mail rooms, provisions rooms, refrigerated spaces and other similar spaces are not to be fitted inside such spaces, and are to be provided with a pilot lamp. Switches for lighting used in wet spaces and in spaces where the risk of explosion might arise are to be capable of isolating all insulated poles.

2.7.1.3 The warning signs showing “DANGER! HIGH VOLTAGE!” are to be provided in the spaces adjacent to discharge lamps operating at a voltage over 250 V and elsewhere as necessary.

2.7.2 Supply and control

2.7.2.1 The lighting point supplied by each final sub-circuit of rating of more than 16 A at the lighting distribution board is not to exceed one. The number of lighting points supplied by each final sub-circuit of rating 16 A or less at the lighting distribution board is not to exceed:

10 for circuits of rating 55 V or less;

14 for circuits of rating 56 ~ 120 V circuits;

24 for circuits of rating 121 ~ 250 V circuits.

In final sub-circuits for cornice lighting, panel lighting and electrical signs where lampholders are closely grouped, the number of points supplied is unrestricted provided that maximum operating current in the sub-circuit does not exceed 10 A.

Final sub-circuits for lighting are not to supply heating and power appliances, except for small galley equipment (e.g. toasters, mixers, coffee makers), small motors (e.g. of desk and cabin fans, refrigerators), wardrobe heaters and similar items.

2.7.2.2 The lighting for main engine rooms, large machinery spaces other than main engine rooms, large galleys, passageways (including accesses), stairways leading to boat decks, public spaces and berthing compartments accommodating more than 16 passengers is to be supplied by at least two final sub-circuits, and one of which may be the final sub-circuit for emergency lighting so that in the event of failure of any one of the sub-circuits the other one could still maintain the necessary lighting for such spaces. The lighting points for main engine and boiler rooms are to be distributed alternately.

In machinery spaces, the oil fuel system containing heated oil under pressure exceeding 0.18 MPa are to be adequately illuminated so that defects and leakage will readily be observed. In machinery spaces of category A and whenever practicable in other machinery spaces, the arrangements for storage, distribution and utilization of oil used in pressure lubrication systems are also to be adequately illuminated.

2.7.2.3 Each main vertical fire zone is to be provided with at least two separate lighting feeders, one of which may be an emergency light feeder.

2.7.2.4 The permanently fixed lighting in cargo holds is to be controlled by switches located in a suitable position outside the cargo holds, capable of isolating all insulated poles and provided with a pilot lamp to indicate the power supply.

2.7.2.5 The degree of protection of lighting fittings located in various spaces in ships is to comply with the requirements of Table 1.3.2.2 of this PART. Lighting switches for spaces with special requirements are to be installed in accordance with the requirements of 2.7.1.2 of this Section.

2.7.2.6 Lighting circuits are to be provided with protection in accordance with the requirements of 2.5.11.1 of this Chapter.

2.7.2.7 A main electrical lighting system is to provide illumination throughout those parts of the ship normally accessible to and used by passengers or crew, and is to be supplied from the main source of electrical power.

2.7.2.8 In assessing the current rating of lighting circuits, in case of lack of accurate information, every lampholder is to be assessed at the maximum load likely to be connected to it, with a minimum of 60 W, unless the fitting is so connected as to take only a lamp rated at less than 60 W. 200VA are to be counted for each lighting socket in accommodation spaces.

2.7.3 Emergency lighting

2.7.3.1 The arrangement of emergency lighting and the supplementary emergency lighting for ro-ro passenger ships are to comply with the relevant requirements of Section 2 of this Chapter.
2.7.3.2 In passenger ships, the means of escape, including stairways and exits, are to be marked by lighting or photo-luminescent strip indicators complying with acceptable standards① and placed not more than 0.3 m above the deck at all points of the escape route including angles and intersections. The marking must enable passengers to identify the routes of escape and readily identify the escape exits.
If electric illumination is used, it is to be supplied by the emergency source of power (see 2.2.2.1(1)③ of this Chapter).
2.7.3.3 All emergency lighting fittings are to be provided with a prominent mark or structurally different from other luminaries.
2.7.3.4 No local switch is to be installed in the transitional emergency lighting feeders.
2.7.3.5 No local switch is to be installed in the emergency lighting circuits in the spaces so specified in 2.2.2.1(1) and 2.2.3.1(2) of this Chapter except for the emergency lights in the navigation bridge, at the stowage positions of lifeboats and life rafts.
2.7.3.6 Respective power sources of main and emergency switchboards, associated transforming equipment (if any), the main or emergency switchboard and lighting switchboard (excluding section board and distribution board) are not to be provided in the same space so that the two systems would not fail simultaneously in the event of a fire or other casualty in any space containing these appliances.
2.7.3.7 In passenger ships, supplementary lighting shall be provided in all cabins to clearly indicate the exit so that occupants will be able to find their way to the door. Such lighting, which may be connected to an emergency source of power or have a self-contained source of electrical power in each cabin, shall automatically illuminate when power to the normal cabin lighting is lost and remain on for a minimum of 30 min.

2.7.4 Navigation lights

2.7.4.1 Each navigation light is to be supplied by a sub-circuit connected separately to the control box fitted at an easily accessible position on the navigation bridge and is to be controlled and protected in each insulated pole by a switch and a fuse or by a circuit breaker fitted in the control box.
2.7.4.2 The control box for navigation lights is to be supplied directly from the main switchboard and emergency switchboard. Where the transitional source of emergency power is provided according to Section 2 of this Chapter, the control box is to be supplied directly from the emergency switchboard and transitional emergency charging and discharging switchboard.
2.7.4.3 The change-over switch for the supply circuits required in 2.7.4.2 of this Section is to be installed on the control box or at a suitable position on the navigation bridge.
2.7.4.4 Each navigation light is to be provided with an automatic indicator giving an audible and visual indication of failure of the light. If a visual signal is used and connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal, and the audible and visual alarms for failure of the power source of the control box are to be provided.
2.7.4.5 The power supply from the control box of navigation lights may be extended to the signal lights required in the International Regulations for Preventing Collisions at Sea, and other consumers are not to be connected to the box.

Section 8 INTERNAL COMMUNICATION SYSTEMS

2.8.1 Main engine telegraph system

2.8.1.1 At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the speed and direction of thrust of the propeller (hereinafter referred to as the normal control position of the propeller) are normally controlled. One of the means is to be the main engine telegraph system complying with the requirements of 2.8.1.2 of this Section.
2.8.1.2 The main engine telegraph system is to be in compliance with the following requirements:
(1) The controls of the transmitters and receivers are to be safeguarded by suitable means against being inadvertently moved.
(2) The engine telegraph is to be a two-way system in which the signal given by the receiver is also immediately discernible at the transmitter.

---

① Refer to the Guidelines for the Evaluation, Testing and Application of Low-Location Lighting on Passenger Ships adopted by IMO resolution A.752(18).

(3) In the case of installations with several control positions the acknowledged command must be indicated at all control positions. Where a control position is selected by switching, an additional indication is to be provided to show which one is in use.
(4) Both the transmitter and the receiver are to be equipped with a call-up device which remains in operation from the start of the command transmission till it is correctly acknowledged. The audible signal is to be audible at any position in the engine room. If necessary, a visual signal is to be provided in addition to the audible signal.
(5) An audible alarm is to be provided for wrong direction of rotation of the main engine (applicable to reversible main engines) in the normal control position of the propeller.
(6) Power is to be supplied by the independent final sub-circuit and audible and visual alarms are to be provided on the navigation bridge for the purpose of indicating the failure of power supply.
2.8.1.3 The other means for communicating orders required in 2.8.1.1 may be an emergency engine telegraph system, the functions of which are to be in compliance with the requirements of 2.8.1.2(1) and (2), and which is to be supplied by the emergency power source.
2.8.1.4 A telephone system required in 2.8.2.2(4) may be fitted instead of the emergency engine telephone system.

2.8.2 Important telephone systems

2.8.2.1 The important telephone systems are to be such as to ensure clear vocal intercommunication in all conditions of the ship.
2.8.2.2 The telephone system is to be provided in the following spaces:
(1) Bridge – Engine control room;
(2) Bridge – Steering gear control position in steering gear compartment;
(3) Bridge – Radio room, not required if communication can be made without telephone;
(4) Bridge – Normal control position of the propeller, not required if an emergency main engine telegraph system is provided;
(5) Bridge – Other control positions of the propeller, not required if a repeater of the main engine telegraph is provided in these positions;
(6) Engine control room – Other control positions of the propeller, not required if a repeater of the main engine telegraph is provided in these positions.
2.8.2.3 The telephone systems required in 2.8.2.2 are to be individual links, although a common telephone system may be used if it is ensured that the bridge can cut into existing conversations at all times.
2.8.2.4 The common telephone system described in 2.8.2.3 is to be an independent one and is allowed to provide voice communications, in addition to the spaces described in 2.8.2.2, only for those that are relevant to ship safety, such as the fire control station, CO_2 room and emergency generator room, etc.
2.8.2.5 Two-way calling equipment is to be provided for the telephone systems fitted in the engine room (except engine control room) and designed as being audible at any position in the engine room under full-power operation of the main propelling plant, and visual signals are to be provided in addition to the audible signals.
2.8.2.6 The important telephone system is to remain operable in case of failure of the main power supply.

2.8.3 Communication in an emergency

2.8.3.1 An intercommunication system is to be provided which enables commands to be transmitted between strategic positions, i.e. the emergency control station, the muster and embarkation station of survival craft and navigation bridge etc.
2.8.3.2 The communication system may comprise portable or permanently installed equipment, and is to remain operable in case of failure of the main power supply.

2.8.4 Engineers' alarms

2.8.4.1 An engineers' alarm is to be provided to be operated from the engine room or engine control room and is to be clearly audible in the engineers' accommodation.
2.8.4.2 The audible alarm may be mounted centrally in the passageway of the engineers' accommodation, or individually in the cabins and the mess.
Where a decentralized arrangement is used, it is to be possible to transmit the alarm to the engineers both individually and collectively.

Section 9 SAFETY SYSTEMS FOR SHIPS AND PERSONS ONBOARD

2.9.1 General emergency alarms

2.9.1.1 In order to sound general emergency signals, a general emergency alarm system comprised of the ship's whistle or siren and additionally an electrically operated bell or klaxon or other equivalent apparatus, is to be provided on all passenger ships and cargo ships of 500 gross tonnage and above. In passenger ships, the alarm is to be capable of being given separately or simultaneously to crew and passengers. Cargo ships of 500 gross tonnage and above may not be fitted with an independent general emergency alarm system when a public address system meeting the requirements of 2.9.2.1 (1) to (8) has already been provided.

2.9.1.2 The system is to be capable of operation from the navigation bridge and, except for the ship's whistle or siren, also from at least one other strategic points[①]. The alarm is to continue to function after it has been triggered until it is manually turned off or is temporarily interrupted by a message from the public address system. For passenger ships there is also to be an additional activation point in the safety centre.

2.9.1.3 Where the general emergency alarm system is in operation, the acoustic system for entertainment is to be interrupted automatically.

2.9.1.4 The general alarm system is to be supplied from special feeders, being capable of automatically converting to the emergency source of electrical power in the event of failure of the main source of electrical power. In passenger ships, the system is also to be capable of being supplied by a temporary emergency source of electrical power.

2.9.1.5 The system is to be audible throughout all the accommodation and normal crew working spaces, including open decks in passenger ships.

The minimum sound pressure level for the emergency alarm tone in interior and exterior spaces is to be 80 dB(A) and at least 10 dB(A) above ambient noise levels existing during normal equipment operation with the ship underway in moderate weather. The sound pressure levels at the sleeping position in cabins and in cabin bathrooms are to be at least 75 dB(A) and at least 10 dB(A) above ambient noise levels.

2.9.1.6 Each electrically operated bell or klaxon or other equivalent warning system is to be separately protected against short circuit.

2.9.2 Public address system

2.9.2.1 Cargo ships of 500 gross tonnage and above are to be provided with a public address system in compliance with the following requirements:

(1) capable of broadcasting messages from the navigation bridge and fire control station etc. to all spaces where crew are normally present and muster stations;

(2) no operation required of receivers to accept the broadcast message;

(3) protected against unauthorized use;

(4) amplifiers have sufficient output power so that all loudspeakers for the purpose of emergency announcement can be operated at the same time;

(5) arranged to prevent feedback or any other interference;

(6) with the ship underway in normal conditions, the minimum sound pressure level for broadcasting emergency announcements is to be:

① in interior spaces 75 dB(A) and at least 20 dB(A) above the speech interference level;

② in exterior spaces 80 dB(A) and at least 15 dB(A) above the speech interference level;

(7) capable of being supplied by both main and emergency power sources;

(8) if the public address system is used to give the general alarm, the following requirements are to be fulfilled:

① the performance requirements of 2.9.1 of this Section are to be complied with;

② at least two amplifiers are to be provided, each of them separately supplied;

③ the loudspeaker circuits are to be so arranged that an announcement at a reduced acoustic irradiation is maintained in the event of a failure of an amplifier or loudspeaker circuit;

④ where loudspeakers with built-in volume controls are used, the volume controls are to be disabled by the release of the alarm signal;

⑤ it is to be possible to transmit the clearly audible alarm signal at all times and other simultaneous signal transmissions are to be automatically interrupted;

⑥ an independent short-circuit protection is to be provided for each loudspeaker.

2.9.2.2 All passenger ships are to be provided with a public address system in compliance with the following requirements:

---

① Other strategic points are taken to mean those locations, other than the navigation bridge, from where emergency situations are intended to be controlled and the general alarm system can be activated. A fire control station or a cargo control station should normally be regarded as strategic points.

(1) capable of simultaneously broadcasting messages from bridge and central control station, etc. to all spaces where crew and passengers or both are normally present and muster stations, and capable of broadcasting messages to crew and passengers separately;
(2) complying with the requirements of 2.9.2.1(2) to (6);
(3) capable of interrupting at the control position on the navigation bridge any broadcast of the system from any other position onboard;
(4) the spaces where control units of the system are located are the control stations as defined in Chapter II-2 of the SOLAS Convention, and each of the control stations is to be provided with the following emergency function controls:

① clearly indicating any emergency function;

② automatically overriding any other input system or programme;

③ automatically overriding all volume controls and on/off controls so that the required volume for the emergency mode is achieved in all spaces;

(5) at least two independent and separate amplifiers are to be provided, each of them separately supplied;
(6) at least two loudspeaker circuits connected to their respective amplifiers are to be installed in each fire zone, and their cables are to be laid as widely apart as practicable for their entire length;
(7) independent short-circuit protection is to be provided for each loudspeaker;
(8) capable of being supplied by main, emergency and temporary emergency sources of electrical power;
(9) if the public address system is used to give the general emergency alarm, the requirements of 2.9.1 of this Section are also to be complied with.

2.9.3 Pre-discharge alarms of fire extinguishing medium

2.9.3.1 In any ro-ro spaces, container holds equipped with integral reefer containers, spaces accessible by doors or hatches (except general cargo holds), and other spaces in which personnel normally work or to which they have access, which are protected by fixed gas fire-extinguishing systems, means are to be provided for automatically activating audible and visual alarms for the release of fire-extinguishing medium. The alarms are to operate for the time required to evacuate the space, but in no case less than 20 s before the medium is released.
2.9.3.2 Machinery spaces, cargo pump-rooms, vehicle spaces, ro-ro spaces and special category spaces which are protected by fixed high-expansion foam fire-extinguishing systems are to be provided with audible and visual alarms for the release of fire-extinguishing medium in order to give warning of the release of the system. The alarms are to operate for the time required to evacuate the space, but in no case less than 20 s before the medium is released.
2.9.3.3 The above-mentioned alarm system is to be supplied by the emergency source of electrical power.
2.9.3.4 The fixed fire-extinguishing system for the protection of machinery spaces where main propulsion engine and main generator set are located is to be designed such that any action other than the release of fire extinguishing media are not to lead to automatic shutdown of ventilation fans and oil pumps in these machinery spaces,such as opening the release box (cabinet) door during fire drills.

2.9.4 Elevator alarms

2.9.4.1 Elevators having an internal control are to be fitted with an emergency audible call-up device capable of being operated in the car and the alarm signal is to be transmitted to the positions where persons are normally present.
2.9.4.2 The emergency audible call-up device is to be independent from the power and control circuits of the elevator and supplied by the emergency source of electrical power.

2.9.5 Alarms for closing refrigerated spaces

2.9.5.1 Where the doors to refrigerated spaces such as refrigerated holds and refrigerating food chambers cannot be opened from the inside, an alarm capable of being activated within the spaces upon inadvertent closing of such doors is to be fitted and the alarm transmitted to normally manned positions.

2.9.6 Fire detection and fire alarm systems

2.9.6.1 The fire detection and fire alarm systems are to comply with the relevant requirements of Chapter II-2 of the SOLAS Convention in force and Chapter 9 of the International Code for Fire Safety Systems.
2.9.6.2 There are to be not less than two sources of power supply for the fixed fire detection and fire alarm system, one of which is to be an emergency source. The supply is to be provided by separate feeders reserved solely for that purpose. Such feeders are to run to an automatic change-over switch situated in or adjacent to the control panel for the fire detection system. The main (respective emergency) feeder shall run from the main (respective emergency) switchboard to the change-over switch without passing through any

other distributing switchboard.
2.9.6.3 Operation of the automatic changeover switch or a failure of one of the power supplies is not to result in permanent or temporary degradation of the fixed fire detection and fire alarm system.
2.9.6.4 Where the fixed fire detection and fire alarm system would be degraded by the momentary loss of power, a source of stored energy having adequate capacity is to be provided to ensure the continuous operation during changeover between power supplies.
2.9.6.5 Connection of electrical power supplies to an automatic changeover switch is to be arranged such that a fault will not result in the loss of all supplies to the automatic changeover switch.
2.9.6.6 The fixed fire detection and fire alarm system emergency power may be supplied by an accumulator battery. Where the system is supplied from an accumulator battery, the arrangements are to comply with the following requirements:
(1) The accumulator battery is to have the capacity to operate the fire detection system under normal and alarm conditions during the period required by 2.2.2 or 2.2.3 of this Chapter for the emergency source of power supply.
(2) The rating of the charge unit, on restoration of the input power, is to be sufficient to recharge the batteries while maintaining the output supply to the fire detection system.
(3) The accumulator batteries are to be suitably located for use in an emergency.
(4) The feeders are to run from the accumulator battery or the accumulator battery charging and discharging board to the automatic changeover switch without passing through any other distributor.

2.9.7 Fire doors
2.9.7.1 The power, control, indication and alarm systems of fire doors as required in Chapter II-2 of the SOLAS Convention in force are to be supplied by the emergency source of electrical power.
2.9.7.2 For passenger ships, an indicator to show whether each door operated by remote control is opened or closed is to be provided in the normally manned control station.
2.9.7.3 For passenger ships, the control and indication systems for the fire doors are to be designed on the fail-safe principle, provided with a release system having manual reset capable of being operated from either side of the door.

2.9.8 Watertight doors in passenger ships
2.9.8.1 The power circuit and its associated control, indication and alarm circuits for power-operated sliding watertight doors are to be supplied either directly by the emergency switchboard or by a dedicated distribution board connected with the emergency switchboard above the bulkhead deck.
2.9.8.2 Where a motor is provided for the opening and closing of the watertight doors, unless an independent reserve energy is provided, the power source is to be capable of being automatically changed over to the transitional source of emergency electrical power in the event of failure of either the main or the emergency source of electrical power. The capacity of the motor is to be sufficient to operate the watertight door at least three times, i.e. closed – open – closed.
2.9.8.3 A single electrical failure in the operating or control system of a power-operated sliding watertight door is not result in a closed door opening or interrupt any manual operation of the watertight door.
2.9.8.4 Availability of the power supply is to be continuously monitored at a point in the electrical circuit as near as practicable to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console on the navigation bridge.
2.9.8.5 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a watertight door are not result in a loss of power operation of that door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.
2.9.8.6 The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water as follows:
(1) electric motors, associated circuits and control components: IPX7;
(2) door position indicators and associated circuit components: IPX8.
Where the water pressure testing is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 h;
(3) door movement warning signals: IPX6.
2.9.8.7 Electrical controls of watertight doors, including their cables, are to be kept as close as practicable to the bulkhead in which the doors are fitted and so arranged as to minimize the likelihood of them being involved in any damage which the ship may sustain.
2.9.8.8 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is

closed remotely by power and sound for at least 5 s but not more than 10 s before the door begins to move and is to continue sounding until the door is completely closed. In passenger areas and areas where ambient noise level exceeds 85 dB(A), the audible alarm is to be supplemented by an intermittent visual signal.
2.9.8.9 The central operating console is to be fitted on the navigation bridge, having a "master mode" switch with the following two modes of control:
(1) "Local control" mode for normal use, which is to allow any door to be locally opened and locally closed after use without automatic closure; and
(2) "Door closed" mode for emergency use, which is to automatically close any door that is opened while still permitting any door to be opened locally but with automatic reclosure upon release of the local control mechanism.
2.9.8.10 The central operating console at the navigation bridge is to be provided with a diagram showing the location of each door. Visual indicators showing whether the doors are open or closed are to be provided both on the central operating console and at hand operation positions above the bulkhead deck for watertight doors. A red light is to indicate a door is fully open and a green light is to indicate a door is fully closed. When the door is closed remotely, a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.
2.9.8.11 It is not to be possible to remotely open any watertight door from the central operating console.

2.9.9 Watertight access doors and hatch covers, etc. in cargo ships

2.9.9.1 For sliding watertight doors provided to ensure the watertight integrity of internal openings which are used while at sea, their operation, control and indicators are to comply with the following requirements:
(1) capable of being closed remotely at the navigation bridge and operated at either side of the bulkhead;
(2) an indicator to show whether the door is open or closed is to be provided in the control position;
(3) audible and visual alarms are to be given as the door is closed;
(4) each power-operated door is to be provided with an individual hand-operated mechanism, and it is to be possible to open and close the door by hand from each side.
2.9.9.2 Access doors and hatch covers normally closed at sea to ensure the watertight integrity of internal openings are to be provided with means of indication showing locally and on the navigation bridge whether these doors or hatch covers are open or closed.
2.9.9.3 All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, except for cargo hatch covers, are to be fitted with indicators on the navigation bridge to show whether the openings are open or closed.
2.9.9.4 The electrical power, control, indication and audible and visual alarms required in 2.9.9.1 are to remain operable in the event of the failure of the main source of electrical power.

2.9.10 Boundary doors of special category spaces and ro-ro spaces

2.9.10.1 The requirements below are applicable to boundary doors of special category spaces or ro-ro spaces as defined in Chapter 9, PART TWO of the Rules. These spaces may be flooded through the doors.
In cargo ships, where no part of a side shell door or stern door is under the highest waterline and the open area of the door is not greater than 6 m^2, the requirements from 2.9.10.2 to 2.9.10.5 of this Section are not applicable.
2.9.10.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to show that the doors are closed and that their securing and locking devices are properly positioned.
The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator lights.

2.9.10.3 The indicator system is to be designed① on the fail-safe principle and is to show by a visual alarm if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply from the emergency source of electrical power or other secure power supply (e.g. UPS).
The sensors of the indicator system are to be protected from water, icing and mechanical damage.
2.9.10.4 The indication panel on the navigation bridge is to be equipped with a mode selection function "harbor/sea voyage", so arranged that an audible alarm is given on the navigation bridge if the vessel leaves harbor with the bow door or inner door not closed or with any of the securing devices not in the correct position.
2.9.10.5 For side shell doors or stern doors, a water leakage detection system② with audible alarm and television surveillance is to be arranged on passenger ships to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors. A water leakage detection system② with audible alarm is to be arranged on cargo ships to provide an indication to the navigation bridge.
2.9.10.6 For inner doors, a water leakage detection system② with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the doors.
2.9.10.7 Between the bow door and the inner door a television surveillance system② is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to monitor the position of the doors and a sufficient number of their securing devices. Special consideration is to be given for the lighting and contrasting colour of objects under surveillance.
2.9.10.8 A drainage system② is to be arranged in the area between the bow door and ramp, or where no ramp is fitted, between the bow door and inner door. The system② is to be equipped with an audible alarm on the navigation bridge being set off when the water levels in these areas exceed 0.5 m or the high water level alarm threshold, whichever is lesser.
2.9.10.9 For ro-ro passenger ships, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means (e.g. television surveillance) so that any movement of vehicles in adverse weather conditions, or unauthorized access by passengers thereto, will be detected whilst the ship is underway.

2.9.11 Emergency dumping system of dredgers and barges

2.9.11.1 For dredgers and hopper barges of which the operation draft is marked according to Section 13, Chapter 1, PART TWO of the Rules, emergency devices, controlled from the navigating bridge, are to be fitted so that the discharge of spoil is possible in case of failure of the main electric power supply or the main hydraulic unit and/or a single failure of the normal control systems.

Section 10 HEATING AND COOKING EQUIPMENT

2.10.1 General requirements

2.10.1.1 All electric space heaters are to be installed permanently.
2.10.1.2 Heating appliances are not to be installed in positions where combustible gases and dusts are likely to accumulate.
2.10.1.3 Heating appliances are to be so mounted that there will be no risk of excessive heating of

---

① The indicator system is considered designed on the fail-safe principal when the following are provided:
a. The indication panel is provided with:
– a power failure alarm;
– an earth failure alarm;
– a lamp test;
– separate indication for door closed, door locked, door not closed and door not locked.
b. Limit switch electrically closed when the door is closed (when more limit switches are provided, they may be connected in series).
c. Limit switch electrically closed when securing arrangements are in place (when more limit switches are provided, they may be connected in series).
d. Two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked.
e. In the case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place, as appropriate.

② The system is to be designed on the fail-safe principle, see footnote of 2.9.10.3 of this Section.

adjacent decks, bulkheads or other surroundings.

2.10.2 Control and installation of heating and cooking equipment

2.10.2.1 Each item of heating or cooking equipment is to be controlled as a complete unit by a multi-pole linked switch mounted in the vicinity of the equipment. In the case of cabin heaters, a single-pole switch will be acceptable.

2.10.3 Supply of heating equipment

2.10.3.1 Each heater is to be connected to a separate final sub-circuit for heating except that up to ten small heaters of total connected current rating not exceeding 16 A may be connected to a single final sub-circuit for heating.

Section 11 STORAGE BATTERIES

2.11.1 Arrangement and installation

2.11.1.1 Storage batteries are not to be installed in spaces where they are exposed to excessively high or low temperatures, water splattering, steam or other factors which will impair their serviceability or shorten their service life. They are to be installed in such a way that persons will not be endangered and equipment will not be damaged by escaping gases or electrolytic leakage.

2.11.1.2 Storage batteries are to be so installed as to ensure accessibility for replacing cells, inspection, testing, topping-up and cleaning.

2.11.1.3 Storage batteries are not to be installed in the accommodation area. An exception may be granted for gastight cells, where charging does not result in the development of harmful gases.

2.11.1.4 Suitable protection measures are to be provided where the storage batteries are exposed to the risk of mechanical damage or falling objects.

2.11.1.5 Storage batteries connected to a charging device with a power output① of more than 2 kW are to be housed in a room assigned to the batteries only, or in a box or a locker on open deck.

2.11.1.6 Storage batteries connected to a charging device with a power output of 0.2 kW to 2 kW are to be installed in accordance with 2.11.1.5. They also may be installed in a box or a locker within a suitable space, or may be installed in an open position in a well ventilated machinery space.

2.11.1.7 Storage batteries connected to a charging device with a power output of less than 0.2 kW may be installed in an open position or in a battery box in any suitable space.

2.11.1.8 A gap of more than 20 mm is to be provided around each battery, and non-hygroscopic and electrolyte-resistant insulating material is to be used for the separation, dunnage and fixing of the battery. Measures are to be taken to prevent any leaking electrolyte from entering in contact with the ship's structure.

2.11.1.9 Any surface of dedicated battery rooms, boxes, lockers and associated ventilation ducts, etc., liable to corrosion, by the electrolyte or by the gas escaped from the electrolyte, are to be protected against corrosion.

2.11.1.10 Prime mover starter batteries are to be installed as close as practicable to the primer mover served.

2.11.1.11 Storage batteries used as emergency and temporary emergency source of electrical power are to be installed in accordance with the requirements of 2.2.1.2 of this PART.

2.11.1.12 A warning notice of "NO SMOKING OR NAKED LIGHTS" is to be displayed adjacent to doors of battery rooms and covers of battery boxes or lockers.

2.11.2 Ventilation

2.11.2.1 Battery rooms, boxes and lockers are to be ventilated to prevent the accumulation of flammable gases.

2.11.2.2 Natural ventilation may be employed if the required number of air changes is small and the duct can be run directly from the top of the battery room, box or locker to the open air above, with no part of the duct more than 45° from the vertical.

2.11.2.3 For natural ventilation of the battery room, the cross-sectional area A of the inlet is to be equal to that of the outlet, not less than:

(1) for vented type batteries

---

① Power output of the charging device is to be calculated from the maximum charging current multiplied by the rated voltage of batteries.

$$A = \frac{50 \times U_n \times Q \times n}{1000} \quad \text{cm}^2$$

(2) for valve-regulated sealed batteries

$$A = \frac{20 \times U_n \times Q \times n}{1000} \quad \text{cm}^2$$

where: U_n — nominal voltage of the battery, in V;
Q — battery capacity, in Ah;
n — number of cells in series.

2.11.2.4 Mechanical ventilation is to be provided for the battery room, box or locker containing vented type batteries with a total charging power higher than 2 kW.

2.11.2.5 Except those boxes and lockers on open deck or within the spaces required in 2.11.1.6 and 2.11.1.7 of this Section, the ventilation system for battery rooms, boxes or lockers is to be separate from other ventilating systems. The exhaust ducting is to be led to a location where any flammable gas can be safely diluted, away from any source of ignition, and the inlet ducting is to be led into spaces where flammable gases may accumulate. The outlet is to be situated at the top and the inlet at the bottom with the means to prevent the ingress of water and flame.

2.11.2.6 Mechanical ventilators for battery rooms, boxes or lockers are to be provided with means to prevent sparking in case of the impeller touching the casing. Non-metal impellers are to be of an antistatic material.

2.11.2.7 All openings of battery rooms, other than ventilation openings, are to be effectively sealed to prevent the explosive gas from entering adjacent compartments.

2.11.2.8 The quantity Q of air expelled from the rooms, boxes or lockers containing vented type batteries is not to be less than:

$$Q = 0.11\, In \quad \text{m}^3/\text{h}$$

where: I — the maximum charging current during the development of gas, but not less than 25% of the maximum charging current output by the charging device, in A;
n — number of battery cells.

2.11.2.9 The quantity of air expelled from the rooms, boxes or lockers containing valve-regulated sealed batteries may be reduced to 25% of that required in 2.11.2.8.

2.11.3 Charging facilities

2.11.3.1 Charging facilities are to be provided for all storage batteries such that the completely discharged battery can be recharged to the rated capacity in not more than 10 h, having regard to the service requirements.

2.11.3.2 Suitable means are to be provided for controlling and monitoring charging of storage batteries, and to protect them in accordance with the requirements of 2.5.12.2 of this PART.

2.11.3.3 For floating circuits or any other conditions where the load is connected to the storage battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

2.11.4 Electrical equipment

2.11.4.1 The installation of electrical equipment is to be avoided in battery rooms. Where this is necessary, the explosion-proof electrical equipment required in 1.3.3.3 of this PART is to be selected.

2.11.5 Recording of the type, location and maintenance cycle of batteries

2.11.5.1 A schedule of batteries used for essential and emergency services is to be compiled and maintained. The schedule, which is to be reviewed by the CCS attending Surveyor, is to include at least the following information regarding the batteries:

— type and manufacturer's type designation;
— voltage and ampere-hour rating;
— location;
— equipment and/or system(s) served;
— maintenance/replacement cycle dates;
— date(s) of last maintenance and/or replacement;
— for replacement batteries in storage, the date of manufacture and shelf life.

2.11.5.2 Procedures are to be put in place to ensure that, where batteries are replaced, they are of an equivalent performance type.

2.11.5.3 Where valve-regulated sealed batteries are replaced by vented type batteries, it is to be ensured that there is adequate ventilation as so required in 2.11.2.4 and 2.11.2.8 of this Section, and that the requirements in

2.11.1 of this Section relevant to the location and installation of vented type batteries are complied with.
2.11.5.4 Details of the schedule reviewed by the Surveyor and of the procedures, as mentioned above, are to be included in the ship's safety management system. Details of the schedule and of the procedures are to be integrated into the ship's operational maintenance routine as appropriate and be inspected at appropriate intervals, and to be verified by the surveyor.

Section 12 CABLES

2.12.1 General requirements

2.12.1.1 Cables are to be selected according to the environmental conditions of the space where the cables will be installed, methods of installation, rated current, duty, diversity factor, etc.

2.12.1.2 The rated voltage of any cable is not to be lower than the nominal voltage of the circuit for which it is used.

2.12.1.3 Portable electrical equipment is to be provided with movable flexible cables.

2.12.1.4 Cables used in the non-earthing system are to be provided with suitable rating so as to sustain the additional stress of the cable insulation in the event of failure.

2.12.2 Choice of insulating material and voltage rating

2.12.2.1 The rated maximum operating temperature of the insulating material is to be at least 10℃ higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

2.12.2.2 The insulating material of cables is generally to be selected in accordance with Table 2.12.2.2. The selection of other insulating materials is to comply with IEC publication 60092.

Maximum Rated Conductor Temperature of Insulating Material Table 2.12.2.2

Insulating material	Abbrev.	Max. rated conductor temp. (℃)	
		Normal operation	Short circuit
Ethylene propylene rubber	EPR	90	250
High modulus or hard grade ethylene propylene rubber	HEPR	90	250
Cross-linked polyethylene	XLPE	90	250
Silicone rubber	S95	95②	350①
Cross-linked polyolefin material for halogen-free cables	HF90	90	250

Notes: ① Applicable only to power cables and not appropriate for tinned copper conductors.

② The maximum rated conductor temperature for silicone rubber is 180℃, but the practical maximum working temperature is limited by the sheathing materials.

2.12.2.3 The rated voltage of a cable is expressed in U_0/U, where U_0 is the rated power voltage between conductor and "earth" (or metallic screen or surrounding medium of cables) and U is the rated power voltage between conductors. The choice of rated voltage of the cables depends on the system voltage and the system earthing arrangements, which is not to be lower than that given in Table 2.12.2.3.

Choice of Rated Voltage of Cables for AC Systems Table 2.12.2.3

Rated (between phases) voltage (kV) of Systems	Rated voltage U_0/U (kV) of cables	
	Category I distribution system	Category II distribution system
≤0.25	0.15/0.25	0.15/0.25
≤1.0	0.6/1.0	0.6/1.0
≤3.0 (3.3)	1.8/3.0	3.6/6.0
≤6.0 (6.6)	3.6/6.0	6.0/10.0
≤10.0 (11)	6.0/10.0	8.7/15.0

Notes:

① Category I distribution system: Protective devices are to be provided to automatically disconnect the circuits having earth faults.

② Category II distribution system: In AC insulation systems or in AC systems with high-resistance earthed neutral, circuits having earth faults are not to be automatically disconnected.

2.12.3 Choice of protective covering

2.12.3.1 Cables are to be provided with appropriate sheath that satisfies the fluid resistance requirements according to their installation locations. For example, cables permanently fitted on decks exposed to the weather, in bathrooms, cargo holds, refrigerated spaces, machinery spaces or in any other location where water condensation or harmful vapour (e.g. oil vapour) may be present are to have an impervious sheath. The nature of the impervious sheath is to satisfy the requirements for environmental conditions.

2.12.3.2 When choosing different types of protective coverings, consideration is to be given to the mechanical actions to which each cable may be subjected during installation and in service. If the mechanical strength of the protective covering is considered insufficient, the cable is to be fitted in pipes or

conduits or trunking or otherwise protected.

2.12.3.3 All cables and wiring external to electrical equipment are to be at least of a flame-retardant type. In general, cables which have passed the test of bunched flame-retardant cables in accordance with acceptable standards① are to be used. Where cables which have individually passed the test of a single flame-retardant cable in accordance with acceptable standards② are to be bunched, means are to be provided to limit the propagation of fire along the bunched cables (see 2.12.10).

2.12.3.4 Where cables for services, required to be operable under fire conditions, including their supply cables, pass through high fire risk areas③, and in addition for passenger ships, main vertical fire zones, other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the service in any other area or zone. This may be achieved by either of the following:

(1) Cables being of a fire resistant type④ complying with the requirements of 3.5.1.1 of this PART are installed and run continuously to keep the fire integrity within the high fire risk area, as shown in Figure 2.12.3.4.

(2) At least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

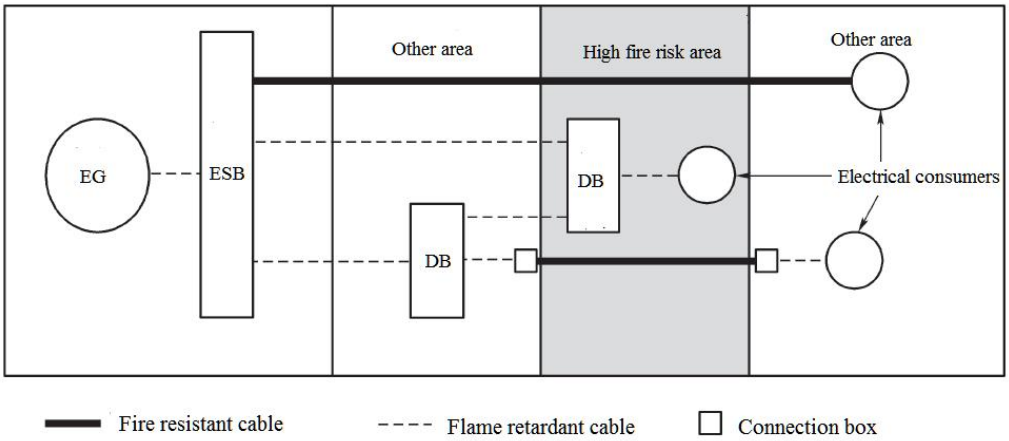


Figure 2.12.3.4 Cables for Services under Fire Conditions

2.12.3.5 Services required to be operable under fire conditions include:

(1) general emergency alarm system;

(2) fire detection and fire alarm system;

(3) fire extinguishing system and fire extinguishing medium release alarm;

(4) public address system;

(5) control and power systems of power operated fire doors and status indication systems for all fire doors;

(6) control and power systems of power operated watertight doors and their status indication systems;

(7) emergency lighting;

(8) low location lighting;

(9) remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion;

(10) emergency fire pump.

---

① Refer to IEC Publication 60332-3-22: Tests on electric and optical fibre cables under fire conditions – Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A, or the equivalent standards.

② Refer to IEC Publication 60332-1-2: Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame and IEC 60332-2-2: Tests on electric and optical fibre cables under fire conditions – Part 2-2: Test for vertical flame propagation for a single small insulated wire or cable – Procedure for diffusion flame, or the equivalent standards.

③ The "high fire risk areas" are defined as follows:

(1) machinery spaces as defined in SOLAS Reg. II-2/3.30, excluding spaces having little or no fire risk as defined in SOLAS Reg. II-2/9.2.2.3.2.2 (10) (including the interpretations for tables 9.3, 9.4, 9.5, 9.6, 9.7 and 9.8 given in MSC/Circ.1120 as amended by MSC.1/Circ.1436 and MSC.1/Circ.1510);

(2) spaces containing fuel treatment equipment or other highly flammable substances;

(3) galley and pantries containing cooking appliances;

(4) laundry containing drying equipment;

(5) spaces as defined in SOLAS Reg. II-2/9.2.2.3.2.2(8), (12), and (14) for ships carrying more than 36 passengers.

④ Fire resistant type cables are to be easily distinguishable.

2.12.3.6 The electrical cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source(s) of power and/or prime mover(s). When cables pass through high fire risk areas, the cables are to be of a fire resistant type.
2.12.3.7 Where necessary for particular applications, CCS may permit the use of special types of cables which do not comply with the requirements of 2.13.3.3 of this Section, such as radio frequency cables or digital computer information transmission system cables.
2.12.3.8 In passenger spaces and in service areas only halogen-free cables are to be used.

2.12.4 Determination of the cross-sectional area of conductors

2.12.4.1 The maximum continuous load carried by a cable is not to exceed its current rating corrected by correction factors. The diversity factor of the individual loads and the duration of the maximum load may be taken into account in estimating the maximum continuous load.
2.12.4.2 Cables supplying cargo winches, revolving cranes, windlasses and capstans are to be suitably rated for their duty.
2.12.4.3 The cross-sectional area of the conductors of equalizer leads for DC generators is not to be less than 50% of that of the main circuit cables. The cross-sectional area of neutral conductors in three-phase four-wire distribution systems is to be equal to at least 50% of that of phase conductors. If the cross-sectional area of phase conductors is 16 mm^2 or less, the cross-sectional area of the neutral conductors is to be the same.

2.12.5 Continuous service current rating

2.12.5.1 The maximum continuous load carried by a cable is not to exceed the values as given in Table 2.12.5.1.
Where a more precise evaluation of current rating has been carried out based on empirical or calculated data, details may be submitted to CCS for approval.

Current Ratings for Cables during Continuous Working Time
(Based on Ambient Temperature of 45℃) (A) **Table 2.12.5.1**

Nominal cross-section	Maximum rated conductor temp 90℃			Maximum rated conductor temp 95℃		
mm^2	Single core	2 cores	3 or 4 cores	Single core	2 cores	3 or 4 cores
1	18	15	13	20	17	14
1.5	23	20	16	26	22	18
2.5	30	26	21	32	27	22
4	40	34	28	43	37	30
6	52	44	36	55	47	39
10	72	61	50	76	65	53
16	96	82	67	102	87	71
25	127	108	89	135	115	95
35	157	133	110	166	141	116
50	196	167	137	208	177	146
70	242	206	169	256	218	179
95	293	249	205	310	264	217
120	339	288	237	359	305	251
150	389	331	272	412	350	288
185	444	377	311	470	400	329
240	522	444	365	553	470	387
300	601	511	421	636	541	445

2.12.5.2 The continuous service of cables required in this Section is the service that the continuous service period of current with constant loading are three times longer than the time constant of cables, i.e. more than the critical duration (see Figure 2.12.5.2).

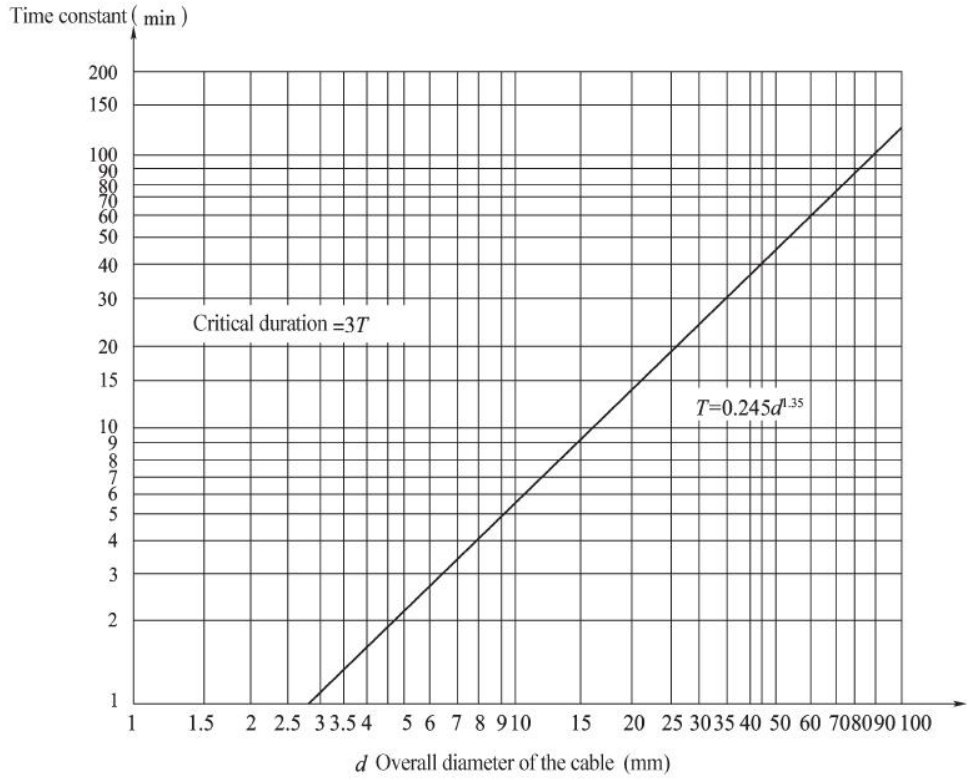


Figure 2.12.5.2 Time Constant of Cables

2.12.6 Correction factors for current rating

2.12.6.1 Correction factors for different ambient temperatures.

When it is known that the ambient temperature is different from 45℃, correction factors given in Table 2.12.6.1 are to be applied.

Correction Factor for Ambient Temperature **Table 2.12.6.1**

Max. operating conductor temp. (℃) \ Ambient temp. (℃)	35	40	45	50	55	60	65	70	75	80	85
60	1.29	1.15	1.00	0.82	–	–	–	–	–	–	–
65	1.22	1.12	1.00	0.87	0.71	–	–	–	–	–	–
70	1.18	1.10	1.00	0.89	0.77	0.63	–	–	–	–	–
75	1.15	1.08	1.00	0.91	0.82	0.71	0.58	–	–	–	–
80	1.13	1.07	1.00	0.93	0.85	0.76	0.65	0.53	–	–	–
85	1.12	1.06	1.00	0.94	0.87	0.79	0.71	0.61	0.50	–	–
90	1.10	1.05	1.00	0.94	0.88	0.82	0.74	0.67	0.58	0.47	–
95	1.10	1.05	1.00	0.95	0.89	0.84	0.77	0.71	0.63	0.55	0.45

2.12.6.2 Correction factors for bunched cables

(1) For cables laid in one of the following manners and so arranged as to ensure free circulation of cooling air around each bunch, the current ratings in Table 2.12.5.1 may be directly applied:

① not more than six cables bunched together on cable trays, in cable conduits, pipes or trunking;

② more than six cables arranged in the following manners:

distance between any two sextuplets is at least equal to the diameter of the thickest cable

○○○○○○ ○○○○○○ ○○○○○○

or distance between any two triplets both horizontally and vertically is at least equal to the diameter of the thickest cable

○○○ ○○○ ○○○

○○○ ○○○ ○○○

(2) Where more than six cables, which may be expected to operate simultaneously at their rated capacity, are laid close together in a cable bunch① in such a way that there is an absence of free air circulation around

① Cables are said to be bunched when two or more are contained within a single conduit, trunking or duct, or if not enclosed, are not separated from each other.

them, a correction factor of 0.85 is to be applied. When a corrector factor of 0.85 is used, care is to be taken that there are in general not more than two layers in each cable bunch.

2.12.6.3 Correction factors for non-continuous service

(1) For half-hour and one-hour services, the corresponding correction factors given by Figure 2.12.6.3(1) may be applied. These correction factors are applicable only if the periods of no load are longer than the critical duration given in Figure 2.12.5.2.

(2) For repetitive short-time services, the corresponding correction factors given in Figure 2.12.6.3(2) may be applied.

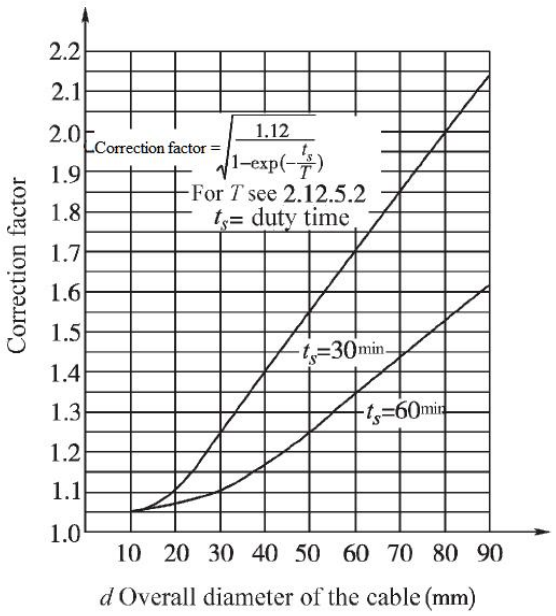
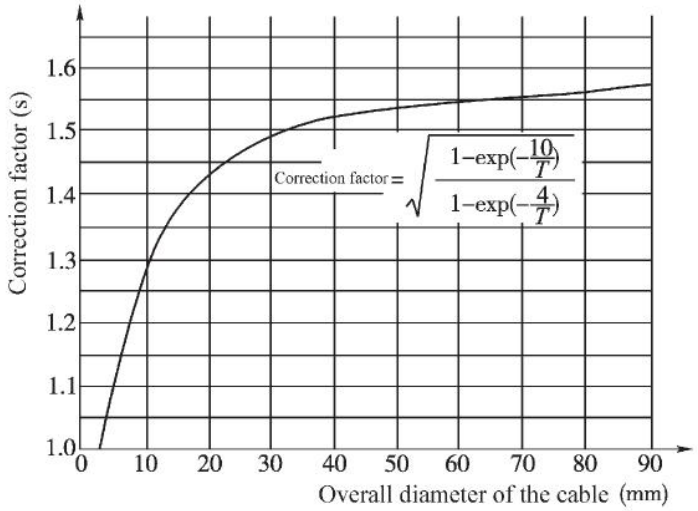


Figure 2.12.6.3(1) Correction Factors for Half-Hour and One-Hour Services



Note: The correction factors given in the Figure are roughly calculated for periods of 10 min, with a constant load for 4 min and without load for 6 min.

Figure 2.12.6.3(2) Correction Factors for Repetitive Short-Time Services

2.12.7 Parallel connection of cables

2.12.7.1 Parallel connection of cables will be permitted only for cables having a cross section of 10 mm^2 or more. The current rating of cables connected in parallel is the sum of the current ratings of all parallel conductors provided the cables have equal impedance, cross section and rated maximum operating conductor temperature.

2.12.8 Short-circuit capacity

2.12.8.1 Cables and their insulated conductors are to be capable of withstanding the mechanical and thermal effects of the maximum short-circuit.

2.12.9 Cable runs

2.12.9.1 Cable runs are to be, as far as possible, straight and accessible for inspection.

2.12.9.2 Cable runs are to be so arranged as to avoid the harmful effects from moisture or condensed water.

2.12.9.3 Cable runs are to be, as far as possible, away from the sources of heat such as boilers, hot pipes, resistors, etc., and are to be protected against mechanical damage.

2.12.9.4 Cables are not to be installed across expansion joints in any structure. Where this is unavoidable, a loop of cable having a length sufficient to accommodate the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

2.12.9.5 Cables having insulating materials with different maximum rated conductor temperatures are not to be bunched together. Where this is unavoidable, the cables are to be so installed that no cable reaches a temperature higher than that permitted for the cable with the lowest temperature rating in the bunch.

2.12.9.6 Cables having a protective covering or sheathing which may damage the covering or sheathing of other cables are not to be bunched together.

2.12.9.7 Where the main bus-bar is subdivided into two or more independent sections in accordance with the requirements of 2.1.1.1(5) of this Chapter, cables from different main generators to main switchboards are to follow at least two routes which are to be as far apart as practicable, for example from port and starboard or from different deck platforms.

2.12.9.8 Where a duplicate supply is required for essential electrical equipment, such as the two cables for the supply of the control box of navigation lights, the two cables are to follow different routes which are to be as far apart as practicable, both vertically and horizontally.

2.12.9.9 In the case of duplicated essential services, or systems which could operate as each other's stand-by for an essential function (such as duplicated power equipment of steering gears), the supply and any associated control cables are to follow different routes which are to be as far apart as practicable, both vertically and horizontally.

2.12.9.10 In passenger ships, distribution systems are to be so arranged that fire in any main vertical zone as defined in PART SIX of the Rules will not interfere with supply to services essential for safety in any other such zone. The requirement is considered satisfied if main and emergency feeders passing through any such zone are separated both vertically and horizontally as widely as is practicable.

2.12.9.11 Cables serving essential services or emergency power equipment, emergency lighting and internal communications or signals used in an emergency are to be as far as practicable routed clear of galleys, laundries, machinery spaces and their casings and other high fire risk areas, except for supplying equipment in these spaces.

Where possible, these cables are to be run in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

2.12.9.12 Main cable runs and cables for the supply and control of essential services are to be kept away from the machinery and machinery parts① having an increased fire risk unless:

(1) the cables serve such installations;

(2) the cables are separated by a steel bulkhead or deck from such installations;

(3) the cables are of a fire-resisting type.

2.12.9.13 Where trunk cables are laid in concealed manner, the panelling in way of which is to be arranged for easy removal.

2.12.9.14 Cables are not to be directly embedded in the thermal or sound insulation made of combustible material. Where cables are separated by non-combustible covering, they may be laid in the insulation, but the load carried is to be reduced accordingly.

2.12.9.15 The arrangement and run of fire resistant cables are to be in compliance with the following:

(1) Cables are to be so arranged that the loss of these services due to a localized fire at any one area or zone specified in 2.12.3.4 of this Section is minimized.

(2) Cables are to be run as straight as is practicable.

2.12.9.16 Cables of intrinsically safe circuits are to be laid apart from those for non-intrinsically safe circuits, e.g. neither bundled together or placed in the same casing or pipe, nor fixed by common clamps. The outer sheath of the cable is to be coloured blue or alternatively black with clearly visible blue stripes.

Intrinsically safe circuits of "ia" and "ib" class are not to be run in the same cable and to have their own separate cables.

2.12.10 Means to limit the propagation of fire along bunched cables

2.12.10.1 Where cables which have individually passed the test of a single flame-retardant cable in

① Machinery, machinery parts or equipment containing combustibles are considered to have an increased fire risk.

accordance with acceptable standards (see 2.12.3.3) are to be bunched, means are to be provided to limit the propagation of fire along the bunched cables[①], as required in 2.12.10.2 to 2.12.10.4.

2.12.10.2 Fire dampers are to be provided (see Figure 2.12.10.2).

(1) Cables laid vertically in enclosed or semi-enclosed spaces are to be provided with fire dampers in the following locations:

① at every second deck or approximately 6 m, except cables installed within the fully-closed trunking;

② at cable entrances of main switchboard and emergency switchboard;

③ at cable entrances of engine control room;

④ at cable entrances of centralized control panels for propulsion machinery and essential auxiliary machinery;

⑤ at each end of the fully-closed cable duct.

(2) Cables laid horizontally in closed or semi-enclosed spaces are to be provided with fire dampers in the same locations required in (1), but the maximum spacing of fire dampers may be increased to 14 m.

(3) In the passageways having a height lower than the neck of a standing person within cargo holds and cargo areas, fire dampers can only be fitted on the boundaries of compartments.

2.12.10.3 The fire dampers are to be designed to meet the following requirements:

(1) The fire resistance of cables passing through fire stops must meet the requirements for class B-0 divisions.

(2) Fire dampers are to be made of steel plate with the thickness of at least 3 mm.

(3) Where cables are laid vertically in the non-fully-closed trunking, the fire damper is to cover the sectional area of the trunking.

(4) Where cables are laid open, the fire damper is to extend around to twice the maximum laying size of cables, but not to penetrate ceilings, decks, bulkheads or the rigid sidewall of trunking.

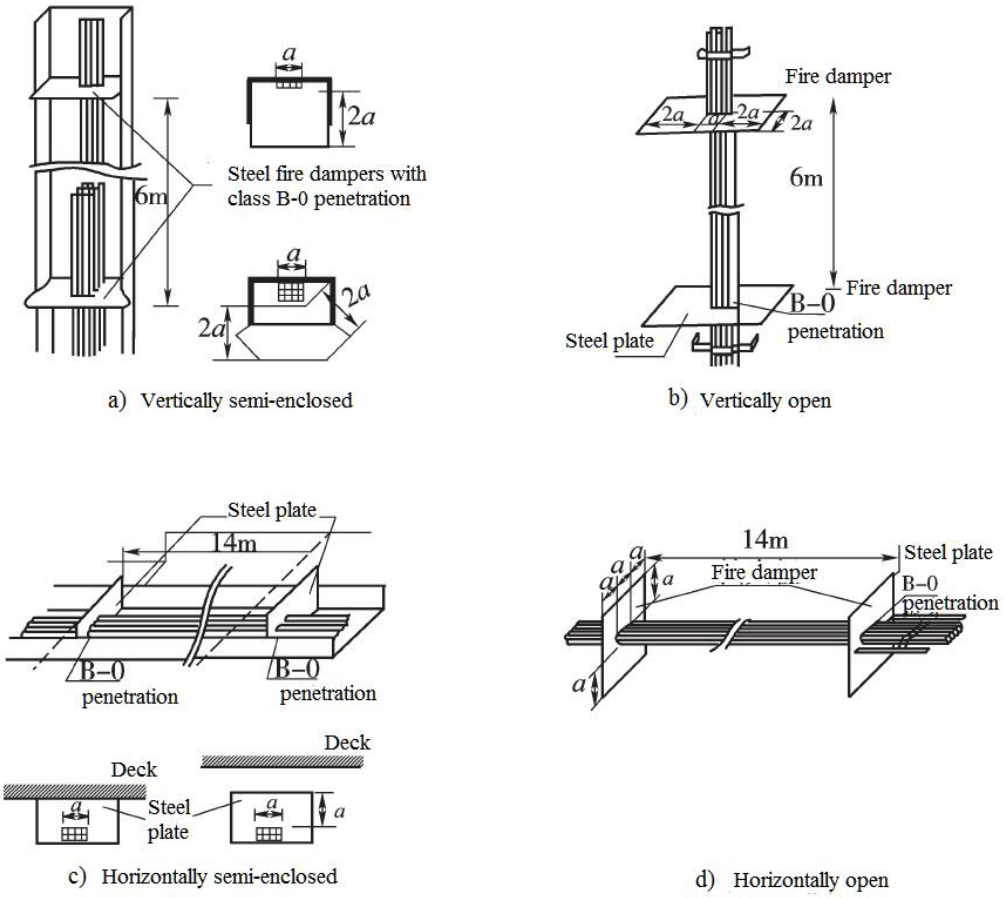


Figure 2.12.10.2 Locations of Fire Dampers

2.12.10.4 Instead of the fire dampers required above, installed cable bunches may be provided with

① The bunched cables mentioned here are 5 or more cables from machinery spaces and high fire hazard spaces and more than 10 cables from other spaces are laid close together in the cable trunking.

flameproof coating:
(1) over a length of 1 m in every 14 m for horizontal cable runs (see Figure 2.12.10.4a);
(2) over the entire length of vertical cable runs (see Figure 2.12.10.4b).

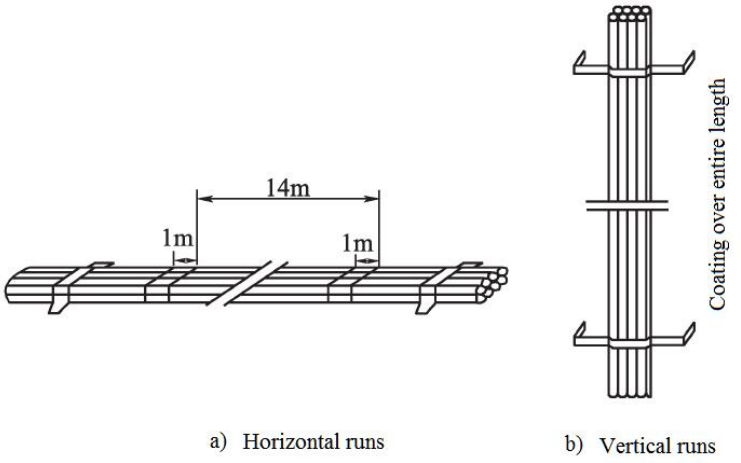


Figure 2.12.10.4 Location of Flameproof Coating

2.12.11 Mechanical protection of cables

2.12.11.1 Cables exposed to risk of mechanical damage are to be protected by metal channels or casings or enclosed in steel conduits, unless the protective sheathing of cables is sufficient to withstand the possible damage.

2.12.11.2 Cables in cargo holds and other spaces where there is exceptional risk of mechanical damage are to be suitably protected, even if armoured.

2.12.11.3 Metal casings for mechanical protection of cables are to be efficiently protected against corrosion.

2.12.11.4 Where cables are placed underneath the floor plates in machinery spaces, reliable precautions are to be taken to prevent such cables from being soaked in oil or water, or being exposed to mechanical damage.

2.12.12 Radius of bend

2.12.12.1 The minimum internal radius of bend of installed cables is to be generally in accordance with the manufacturer's recommendations, and is not to be less than the provisions of Table 2.12.12.1(1) and Table 2.12.12.1(2).

Minimum Internal Radius of Bends in Cables Rated up to 1.8/3kV Table 2.12.12.1(1)

Cable construction		Overall diameter of cable *D* (mm)	Minimum internal radius of bend *F*
Insulation	Outer covering		
Thermoset material (circular copper conductor)	Not armoured or not braided	≤ 25	4*D*
		> 25	6*D*
	Metal sheathed, braided or armoured	Any	6*D*
	Metal thread armoured, metal strip armoured	Any	6*D*
	Synthetic polyester/metal sheathed slice or combined sheathed	Any	8*D*
Thermoset material (circular copper conductor)	Any	Any	8*D*

Minimum Internal Radius of Bends in Cables Rated at 3.6/6.0(7.2) kV and above
Table 2.12.12.1(2)

Cable construction	Overall diameter of cable *D* (mm)	Minimum internal radius of bend *F*
Single core cable	Any	12*D*
3-core cable	Any	9*D*

2.12.13 Securing of cables

2.12.13.1 Cables are to be effectively supported and secured with the exception of cables for portable appliances and of those installed in pipes, conduits, trunking or special casings.

2.12.13.2 Clips or straps are to be robust and are to have a sufficient surface area and a certain shape so that the cables may remain tight without their covering or sheathing being damaged.

2.12.13.3 Clips, supports and accessories are to be made of corrosion-resistant material or suitably corrosion inhibited before erection.

2.12.13.4 The distance between supports is to be suitably chosen according to the type of cables and the possible vibration, and is generally to be in accordance with Table 2.12.13.4.

External Diameter of Cable and Distance between Supports Table 2.12.13.4

External diameter of cable (mm)		Distance between supports (mm)	
Exceeding	Not exceeding	Non-armoured cables	Armoured cables
–	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	–	400	450

2.12.13.5 When cables are fixed by means of non-metallic clips or straps, and are not laid on top of horizontal cable trays or supports, suitable metal cable clips or straps are to be added at regular distances not greater than 1 m in order that in the event of a fire, cables are prevented from falling and causing an injury to personnel or an obstruction to any escape route.

2.12.14 Penetration of bulkheads and decks by cables

2.12.14.1 Penetration of watertight bulkheads or decks may be carried out with either individual watertight glands or with packed watertight boxes carrying several cables, provided that the watertight integrity of the bulkheads or decks is to be maintained.

2.12.14.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material.

If the steel is 6 mm or more in thickness, adequately rounded edges may be accepted as the equivalent of bushing.

2.12.14.3 Penetration of bulkheads and decks requiring a certain fire integrity is to be so effected as to ensure that the required fire integrity is not impaired.

2.12.14.4 Cables passing through decks are to be protected by deck tubes or ducts having a suitable height.

2.12.14.5 Materials used for glands and bushings are to be such that there is no risk of corrosion to cables or hull structures.

2.12.14.6 Where rectangular holes are cut in bulkheads or structural steel, the corners of the holes are to be radiused.

2.12.14.7 Where a cable transit seal system is used, a register is to be developed according to Appendix 3, Chapter 4, PART ONE of the Rules.

2.12.15 Installation of cables in pipes, conduits or trunking

2.12.15.1 When cables are installed in metal pipes, conduits or trunking, the following requirements are to be complied with:

(1) The internal surfaces of the pipes, conduits or trunking are to be smooth and protected against corrosion.

(2) Provision is to be made at the ends of pipes, conduits or trunking so as to protect the sheathing or covering of cables from being damaged.

(3) The internal sectional area and radius of bend of pipes or conduits are to be such as to permit easy drawing in and out the cables contained therein; the internal radius of bend of pipes or conduits is not to be less than that allowed for cables, provided that for pipes equal to or above 63 mm in external diameter, the internal radius of bend is not less than twice the external diameter of the pipe.

(4) The drawing-in factor (ratio of the sum of the cross-sectional areas of the cables to the internal cross-sectional area of the pipe) is not to exceed 0.4.

(5) Pipes, conduits or trunking are to be effectively earthed.

(6) Pipes, conduits or trunking are to be so arranged that water will not accumulate inside them (consideration being given to possible condensation).

(7) If necessary, ventilation openings are to be provided, preferably at the highest and lowest points, so as

to permit air circulation and to prevent possible accumulation of water at any part of the pipes, conduits or trunking. This may be done only if the fire risk will not be increased thereby.
(8) Expansion joints are to be provided where necessary for long pipe run.
2.12.15.2 Where cables are laid in trunks, the trunks are to be so constructed as not to afford passage for fire from one 'tween deck or compartment to another.
2.12.15.3 Cables used for cold cathode luminous discharge lamps are not to be installed in metal conduits unless protected by metal screen.

2.12.16 Installation of cables in refrigerated spaces
2.12.16.1 Cables not serving refrigerated spaces are not to pass through such spaces. Cables installed in refrigerated spaces are to have an impervious sheath and are to be protected against mechanical damage. If an armoured cable is used, the armour is to be protected against corrosion by a further moisture-resisting covering.
2.12.16.2 Cables are to be run in the open in refrigerated spaces.
2.12.16.3 Metal supports used for securing the cables are to be galvanized or otherwise protected against corrosion.

2.12.17 Relief of tension
2.12.17.1 Cables are to be so installed that the tension stress applied to them either by their own weight or for any other reason is minimized. This is particularly important for cables of small cross-sections and for cables laid vertically or in vertical pipes.

2.12.18 Electrodynamic forces
2.12.18.1 In order to guard against the effects of electrodynamic forces in the event of short-circuit, single-core cables are to be firmly fixed and the strength of supports is to be sufficient to withstand the electrodynamic forces corresponding to the prospective short-circuit currents.

2.12.19 Installation of single-core cables for alternating current
2.12.19.1 For AC power systems, two-core or multi-core cables are to be used as far as practicable. Where it is necessary to use single-core cables for circuits rated in excess of 20 A, the following requirements are to be complied with:
(1) Cables are to be either non-armoured or armoured and covered with non-magnetic material.
(2) Cables belonging to the same circuit are to be contained in the same pipe, conduit or trunking. Cable clips are to include cables of all phases of a circuit, unless the clips are of non-magnetic material.
(3) In the installation of two, three or four single-core cables forming respectively single-phase, three-phase, or three-phase four-wire circuits, the cables are to be as far as possible in contact with one another. In any event, the distance between adjacent cables is not to be greater than one cable diameter.
(4) When it is necessary to install single-core cables of current rating greater than 250 A near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm, unless the single-core cables belonging to different phases are installed in trefoil formation.
(5) Magnetic material is not to be placed between single-core cables of a group for the same circuit. Where cables pass through steel plates, all conductors of the same circuit are to pass through a plate or gland so constructed that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless single-core cables belonging to different phases are installed in trefoil formation.
(6) In order to equalize to some degree the impedance of three-phase circuits of considerable length consisting of single-core cables having a cross sectional area of 185 mm^2 or over, the phases are to be transposed at regular intervals of not exceeding 15 m. Alternatively, the three single-core cables of different phases may be installed in a trefoil formation. The above precautions are, however, not necessary when the length of the run is less than 30 m.
(7) In circuits with several single-core cables in parallel for each phase, all cables are to follow the same route and have the same cross-sectional area.
In addition, cables belonging to the same phase are, as far as practicable, to be alternated with those of other phases so that an unequal division of current is avoided. For instance, in the case of six cables for each phase, the correct dispositions are as shown in Table 2.12.19.1.

Disposition of Cables **Table 2.12.19.1**

Cables in parallel for each phase	1-layer disposition	2-layer disposition
2	ABC CBA	ABC CBA
3		ABCA BCABC
4		ABCABC CBACBA
5		ABCABCA BCABCABC
6		ABCABCABC CBACBACBA

2.12.20 Installation of cables with respect to prevention of electromagnetic interference

2.12.20.1 In order to minimize the effects of unwanted electromagnetic interference, cables are to be installed in accordance with the relevant standards① accepted by CCS.

2.12.21 Earthing of metal protective coverings of cables

2.12.21.1 The earthing of metal protective coverings (braid or armour) of cables is to be in accordance with the relevant requirements of Section 3, Chapter 1 of this PART.

2.12.22 Cable ends

2.12.22.1 The ends of all conductors of a cross-sectional area greater than 4 mm^2 are to be fitted with soldered sockets, compression type sockets or mechanical clamps. Corrosive fluxes are not to be used.

2.12.22.2 The temperature of cable sockets and terminals is, in general, not to exceed the maximum operating temperature of insulated cables.

2.12.22.3 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and dynamic effects of short-circuit currents.

2.12.23 Joints and tappings

2.12.23.1 Cable runs are normally not to include joints. If a joint is necessary in the case of repair or sectional construction of the ship, the joint is to be such that the electrical continuity, insulation, mechanical strength and protection, earthing and fire-resisting or flame-retardant characteristics are not inferior to those required for the cables.

2.12.23.2 Tappings are to be made in suitable boxes of such a design that the conductors remain suitably insulated, protected from atmospheric action and fitted with terminals or bus-bars of dimensions appropriate to the current rating.

2.12.23.3 Joints and tappings are to be clearly marked.

2.12.24 Connection boxes

2.12.24.1 Connection boxes are to be made of flame-retardant material. Mountings of live parts are to be robust, durable, flame-retardant and moisture-resistant, having permanently insulation resistance with high dielectric strength.

2.12.24.2 Live parts within the box are to be suitably spaced or provided with shielding by flame-retardant insulating material so that a short-circuit will not occur between conductors of different polarity or between conductors and earthed metal.

2.12.24.3 Each connection box is to be provided with a nameplate indicating its purpose or a durable no. mark corresponding to the wiring diagram. Where the connection boxes are installed in a concealed manner, the panelling in way of the boxes is to be arranged for easy removal.

2.12.25 Cable trays/protective casings made of plastic materials

2.12.25.1 Cable trays/protective casings② made of plastic③ materials are to be type tested in accordance with Appendix 2 of this PART − "Type Approval Procedure for Cable Trays/Protective Casings Made of Plastic Materials".

---

① Refer to IEC Publication 60533: Electrical and Electronic Installations in Ships – Electromagnetic Compatibility, or the relevant requirements in relevant standards.

② "Protective casing" means a closed cover in the form of a pipe or other closed ducts of non-circular shape.

③ "Plastic" means both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastics - FRP.

2.12.25.2 Cable trays/protective casings made of plastic materials are to be supplemented by metallic fixing and straps such that in the event of a fire they, and the cables affixed, are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. When plastic cable trays/protective casings are used on open deck, they are additionally to be protected against UV light.
2.12.25.3 The load on the cable trays/protective casings is to be within the Safe Working Load (SWL). The support spacing is not to be greater than the manufacturer's recommendation nor in excess of spacing at the SWL test. In general the spacing is not to exceed 2 m. The selection and spacing of cable tray/protective casing supports are to take the following into account:
(1) cable trays/protective casings' dimensions;
(2) mechanical and physical properties of their material;
(3) mass of cable trays/protective casings;
(4) loads due to weight of cables, external forces, thrust forces and vibrations;
(5) maximum accelerations to which the system may be subjected;
(6) combination of loads.
2.12.25.4 The sum of the cables' total cross-sectional area, based on the cables' external diameter, is not to exceed 40% of the protective casing's internal cross-sectional area. This does not apply to a single cable in a protective casing.

Section 13 LIGHTNING PROTECTION

2.13.1 Protection against primary structural damage

2.13.1.1 A protective system need not be fitted to a ship of metallic construction where a low resistance path to earth will be inherently provided by masts, structural members and the hull.
2.13.1.2 A protective system is to be fitted to any ship having a substantial number of non-metallic structural members.
2.13.1.3 The protective system is to be comprised of air terminal, down conductor and earth termination.
2.13.1.4 Metallic masts and metallic structural members may form part or all of any protective system.
2.13.1.5 The metal rigging, such as stays, shrouds, etc., are to be bonded to the protective system.
2.13.1.6 Joints in down conductors are to be accessible and be located or protected so as to minimize accidental damage. They are to be made by means of copper rivets or clamps. Clamps may be of copper or of copper alloy and are to preferably be of the serrated contact type and effectively locked. No connection is to be dependent on a soldered joint.
2.13.1.7 The resistance between air terminals and earth terminations is not to exceed 0.02 Ω.
2.13.1.8 Suitable means are to be provided to enable ships when in dry dock, or on a slipway, to have their protective systems or metal hull connected to an efficient earth on shore. Connecting cables to the shore earth is to be external to the earth throughout their length.
2.13.1.9 Air terminals of the protective system are to comply with the following requirements:
(1) An air terminal is to be fitted to each non-metallic mast.
(2) Air terminals are to be made of copper or copper alloy conducting bar of not less than 12 mm diameter, and are to project at least 300 mm beyond the top of the mast. Other materials may be used, for example stainless steel or aluminium alloys, or steel bar effectively protected against corrosion, subject to the requirement of 2.13.1.7. The material is to be resistant to sea water.
(3) Vent outlets for flammable gases located at or near the top of masts on tankers are to be protected by air terminals which extend at least 2 m above the vent outlet. A steel mast may serve as the air terminal if it extends 2 m above the outlet.
2.13.1.10 Down conductors of the protective system are to comply with the following requirements:
(1) Down conductors are to be made of copper, or copper alloy tape or cable. Cable is preferred as both the insulation and the circuit shape inhibit surface discharge. Other materials may be used, for example stainless steel or aluminium alloys, subject to the requirement of 2.13.1.7. The material is to be resistant to sea water.
(2) Down conductors of copper are to have a minimum cross-section of 70 mm^2, be firmly secured to the structure and be run as straight as possible between the air terminal and the earth termination. Bends, where necessary, are to have a minimum radius of at least 10 times the equivalent diameter of the conductor.
2.13.1.11 The ends of down conductors are to be reliably bonded to the earth terminations of the metallic construction of the ship nearby. Where necessary, measures are to be taken for preventing electrochemical corrosion.

2.13.2 Protection against secondary damage

2.13.2.1 On all ships, equipment is to be so installed as to minimize the effect of secondary damage caused by lightning to the electrical system.
2.13.2.2 Metallic enclosures are to be reliably earthed. Particular attention is to be paid to navigation lights and other equipment at the top of masts and on other elevated structures.
2.13.2.3 Cable screens or armour, though normally earthed for signal interference suppression, are not to provide the sole lightning path to earth for equipment. Separate earthing, as required in 2.13.2.2, is to be provided.
2.13.2.4 The formation of cable loops, or metallic loops such as pipework, in proximity to down conductors of the protective system required in 2.13.1.2 is to be avoided. Cables in close proximity to down conductors are to be installed in metal pipes.
2.13.2.5 Cables along decks are to be installed close to the deck and advantage is to be taken of the screening effect of earthed metallic structures near to or above the cable runs, for examples handrails, pipes, etc.
2.13.2.6 Means are to be provided for the discharging to earth of any lightning energy that may be induced in for example radio and navigational equipment antennas. Consideration is to be given to installing devices such as spark gaps or surge diverters to provide protection from voltage transients.

Section 14 SPECIAL REQUIREMENTS FOR HIGH VOLTAGE ELECTRICAL INSTALLATIONS

2.14.1 General requirements

2.14.1.1 This Section applies to AC three-phase systems with nominal voltage (voltage between phases) exceeding 1 kV. If not otherwise stated herein, construction and installation applicable to low voltage equipment generally apply to high voltage equipment.
2.14.1.2 The nominal system voltage is not to exceed 15 kV. Where necessary for special application, higher voltages may be accepted by CCS.
2.14.1.3 Equipment with voltage above about 1 kV is not to be installed in the same enclosure as low voltage equipment, unless segregation or other suitable measures are taken to ensure that access to low voltage equipment is obtained without danger.

2.14.2 System design

2.14.2.1 The distribution of high-voltage electrical installations is to comply with the following:
(1) It is to be possible to split the main switchboard into at least two independent sections, by means of at least one circuit breaker or other suitable disconnecting devices, each supplied by at least one generator. If two separate switchboards are provided and interconnected with cables, a circuit breaker is to be provided at each end of the cable.
Services which are duplicated are to be divided between the sections.
(2) For earthed neutral systems in case of earth fault, the current is not to be greater than full load current of the largest generator on the switchboard or relevant switchboard section and not less than three times the minimum current required to operate any device against earth fault.
It is to be assured that at least one source neutral to ground connection is available whenever the system is in the energized mode. Electrical equipment in directly earthed neutral or other neutral earthed systems is to withstand the current due to a single phase fault against earth for the time necessary to trip the protection device.
(3) Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance and for insulation resistance measurement.
(4) All earthing impedances are to be connected to the hull. The connection to the hull is to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.
(5) In the systems with neutral earthed, connection of the neutral to the hull is to be provided for each separate section of the main switchboard.
2.14.2.2 The degrees of protection provided by enclosures for the high-voltage electrical equipment is to be appropriate to the location of installation, as a minimum in compliance with the requirements of Table 1.3.2.2 of this PART and in addition the following:
(1) The degree of protection by enclosures for rotating electrical machines is to be at least IP23. The degree of protection of terminals is to be at least IP44. For motors installed in spaces accessible to unqualified personnel, a degree of protection against approaching or contact with live or moving parts of at least IP4X is required.

(2) The degree of protection by enclosures for transformers is to be at least IP23. For transformers installed in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.
For transformers not contained in enclosures, 2.14.7.1 of this Section is to be complied with.
(3) The degree of protection of metal enclosed switchgear, control gear assemblies and static convertors is to be at least IP32. For switchgear, control gear assemblies and static converters installed in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.
2.14.2.3 The air clearances and creepage distances are to comply with the following:
(1) In general, for non-type-tested equipment phase-to-phase air clearances and phase-to-earth air clearances between non-insulated parts are not to be less than those specified in Table 2.14.2.3.
Where intermediate values of nominal voltages are accepted, the next higher air clearance is to be observed. In the case of smaller clearances, appropriate voltage impulse test is to be applied.

Minimum Air Clearances **Table 2.14.2.3**

Nominal voltage (kV)	Minimum air clearance (mm)
3 (3.3)	55
6 (6.6)	90
10 (11)	120
15	160

(2) Creepage distances between live parts and between live parts and earthed metal parts for standard components are to be in accordance with IEC publication 60092-503 for the nominal voltage of the system, the nature of the insulation material and the transient overvoltage developed by switch and fault conditions.
2.14.2.4 For protection of the high-voltage electrical system, the following special requirements are to be complied with:
(1) Protective devices are to be provided against phase-to-phase faults in the cables connecting the generators to the main switchboard and against interwinding faults within the generators. The protective devices are to trip the generator circuit breaker and automatically de-excite the generator.
In distribution systems with a neutral earthed, phase to earth faults are also to be treated as above.
(2) Any earth fault in the system is to be indicated by means of a visual and audible alarm. In low impedance or direct earthed systems (a system is defined effectively earthed when the earthing factor① is lower than 0.8), provision is to be made to automatically disconnect the faulty circuits. In high impedance earthed systems (a system is defined non-effectively earthed when the earthing factor is higher than 0.8), where outgoing feeders will not be isolated in case of an earth fault, the insulation of the equipment is to be designed for the phase to phase voltage.
(3) Power transformers are to be provided with overload and short circuit protection. When transformers are connected in parallel, tripping of the protective devices at the primary side has to automatically trip the switch connected at the secondary side.
(4) Voltage transformers are to be provided with overload and short circuit protection on the secondary side.
(5) Fuses are not to be used for overload protection.
(6) Lower voltage systems supplied through transformers from high voltage systems are to be protected against overvoltages. This may be achieved by:
① direct earthing of the lower voltage system;
② appropriate neutral voltage limiters;
③ earthed screen between the primary and secondary windings of transformers.

2.14.3 Rotating machinery

2.14.3.1 Generator stator windings are to have all phase ends brought out for the installation of the differential protection.
2.14.3.2 Rotating machinery is to be provided with temperature detectors in their stator windings to actuate a visual and audible alarm in a normally attended position whenever the temperature exceeds the permissible limit.
If embedded temperature detectors are used, means are to be provided to protect the circuit against overvoltage.
2.14.3.3 In addition to the tests normally required for rotating machinery, a high frequency high voltage

① Earthing factor is defined as the ratio between the phase to earth voltage of the health phase and the phase to phase voltage. This factor may vary between $1/\sqrt{3}$ and 1.

test in accordance with acceptable standard(s)[①] is to be carried out on the individual coils in order to demonstrate a satisfactory withstand level of the inter-turn insulation to steep fronted switching surges.

2.14.4 Power transformers

2.14.4.1 Dry type transformers are to comply with acceptable standard(s)[②], and liquid cooled transformers are also to comply with acceptable standard(s)[③].

2.14.4.2 Oil immersed transformers are to be provided with the following alarms and protections:

(1) liquid level (Low) – alarm;
(2) liquid temperature (High) – alarm;
(3) liquid level (Low) – trip or load reduction;
(4) liquid temperature (High) – trip or load reduction;
(5) gas pressure relay (High) – trip.

2.14.5 Cables

2.14.5.1 Cables are to be constructed in accordance with acceptable standards[④].

2.14.6 Switchgear and control gear assemblies

2.14.6.1 Switchgear and control gear assemblies are to be constructed according to acceptable standards[⑤].

2.14.6.2 Switchgear and control gear assemblies are to be constructed in accordance with the following requirements:

(1) Switchgear is to be of metal-enclosed type or of the insulation-enclosed type in accordance with acceptable standard(s)[⑥].

(2) Withdrawable circuit breakers and switches are to be provided with mechanical locking facilities in both service and disconnected positions. For maintenance purposes, key locking of withdrawable circuit breakers and switches and fixed disconnectors is to be possible.

Withdrawable circuit breakers are to be located in the service position so that there is no relative motion between fixed and moving portions.

(3) The fixed contacts of withdrawable circuit breakers and switches are to be so arranged that in the withdrawable position the live contacts are automatically covered. Shutters are to be clearly marked for incoming and outgoing circuits. This may be achieved with the use of labels or colours.

(4) For maintenance purposes an adequate number of earthing and short-circuiting devices is to be provided to enable circuits to be worked upon with safety.

(5) Switchgear and controlgear assemblies are to be internal arc classified (IAC). Where switchgear and controlgear assemblies are accessible by authorized personnel only, Accessibility Type A is sufficient (refer to IEC 62271-200; Annex AA; AA 2.2). Accessibility Type B is required if accessible by non-authorized personnel. Installation and location of the switchgear and controlgear assemblies are to correspond with their internal arc classification and classified sides (F, L and R).

2.14.6.3 Requirements for auxiliary systems

(1) If electrical energy and/or physical energy is required for the operation of circuit breakers and switches, a store supply of such energy is to be provided for at least two consecutive operations of all the components.

However, the tripping due to overload or short-circuit, and under-voltage is to be independent of any stored electrical energy sources. This does not preclude shunt tripping provided that alarms are activated upon lack of continuity in the release circuits and power supply failures.

(2) When external source of supply is necessary for auxiliary circuits, at least two external sources of supply are to be provided and so arranged that a failure or loss of one source will not cause the loss of more

---

① Refer to IEC Publication 60034-15 Rotating electrical machines – Part 15: Impulse voltage withstand levels of rotating AC machines with form-wound stator coils, or other equivalent standards.

② Refer to IEC Publication 60076-11 Dry-type power transformers, or other equivalent standards.

③ Refer to the applicable Parts of the IEC 60076 Series, or other equivalent standards.

④ Refer to IEC Publication 60092-353 Electrical installations in ships – Part 353: Power cables for rated voltages 1 kV and 3 kV and IEC Publication 60092-354 Electrical installations in ships – Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV (Um = 7.2 kV) up to 30 kV (Um = 36 kV).

⑤ Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV, or other equivalent standards.

⑥ Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV, and compliance with IEC Publication 62271-201: AC insulation-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV.

than one generator set and/or set of essential services. Where necessary, one source of supply is to be from the emergency source of electrical power for the start-up from dead ship condition.
2.14.6.4 A power-frequency voltage test is to be carried out on any switchgear and control gear assemblies. The test procedure and voltages are to be according to acceptable standard(s)[①].

2.14.7 Installation
2.14.7.1 Where equipment is not contained in an enclosure but a room forms the enclosure of the equipment, the access doors are to be so interlocked that they cannot be opened until the supply is isolated and the equipment earthed down.
At the entrance of the spaces where high-voltage electrical equipment is installed, a suitable marking is to be placed which indicates danger of high-voltage. As regards the high-voltage electrical equipment installed outside a.m. spaces, the similar marking is to be provided.
An adequate, unobstructed working space is to be left in the vicinity of high voltage equipment for preventing potential severe injuries to personnel performing maintenance activities. In addition, the clearance between the switchboard and the ceiling/deckhead above is to meet the requirements of the internal arc classification[②].
2.14.7.2 Run of high-voltage cables is to comply with the following:
(1) In accommodation spaces, high voltage cables are to be run in enclosed cable transit systems.
(2) High voltage cables are to be segregated from cables operating at different voltage ratings each other; in particular, they are not to be run in the same cable bunch, nor in the same duct or pipe, or, in the same box.
Where high voltage cables of different voltage ratings are installed on the same cable tray, the air clearance between cables is not to be less than the minimum air clearance for the higher voltage side in 2.14.2.3(1) of this Section. However, high voltage cables are not to be installed on the same cable tray for the cables operating at the nominal system voltage of 1 kV and less.
(3) High-voltage cables, in general, are to be installed on carrier plating when they are provided with a continuous metallic sheath or armour which is effectively bonded to earth; otherwise they are to be installed for their entire length in metallic casings effectively bonded to earth.
(4) Terminations in all conductors of high voltage cables are to be, as far as practicable, effectively covered with suitable insulating material. In terminal boxes, if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating materials. High voltage cables of the radial field type, i.e. having a conductive layer to control the electric field within the insulation, are to have terminations which provide electric stress control.
Terminations are to be of a type compatible with the insulation and jacket material of the cable and are to be provided with means to ground all metallic shielding components (i.e. tapes, wires etc.).
(5) High-voltage cables are to be readily identifiable by suitable marking.
(6) Before a new high voltage cable installation, or an addition to an existing installation, is put into service, a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories. After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge. An insulation resistance test is then repeated. The voltage withstand test is to be carried out in accordance with the following methods:

① For cables with rated voltage above 1.8/3 kV (U_m[③]=3.6 kV) an a.c. voltage withstand test may be carried out upon advice from high voltage cable manufacturer. One of the following test methods may be used: test for 5 min with the phase-to-phase voltage of the system applied between the conductor and the metallic screen/sheath, or test for 24 h with the normal operating voltage of the system; alternatively, a d.c. test voltage equal to 4 U_0 may be applied for 15 min.

② For cables with rated voltage up to 1.8/3 kV (U_m=3.6 kV) a d.c. voltage equal to 4 U_0 is to be applied for 15 min.

---

① Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV – Part 7: Routine test, or other equivalent standards.

② Refer to 6.2.5 of IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV.

③ *U*m is the maximum value of the "highest system voltage" for which the equipment may be used. Highest system voltage is the highest value of voltage which occurs under normal operating conditions at any time and at any point on the system. It excludes voltage transients, such as those due to system switching, and temporary voltage variations.

Section 15 ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION MACHINERY

Electrical propulsion machinery is to comply with the applicable requirements of this PART and the requirements of Chapter 15, PART EIGHT of the Rules.

Section 16 ADDITIONAL REQUIREMENTS FOR OIL TANKERS

2.16.1 General requirements

2.16.1.1 Electrical installations on tankers carrying crude oil and oil products are to comply with the provisions of this Section and other provisions of this PART as appropriate.

2.16.1.2 The classification of typical hazardous areas of oil tankers is carried out in accordance with zone 0, zone 1 and zone 2 based on the provisions of IEC60092-502 in this Section. For areas or spaces not mentioned in this Section, the classification of hazardous areas may be carried out in accordance with the principles given in IEC60079-10-1.

2.16.1.3 Electrical equipment and cables are, in principle, not to be installed in any hazardous areas. If it is impracticable to avoid doing so, the relevant provisions of this Section are to be complied with.

2.16.2 Distribution systems

2.16.2.1 The following distribution systems may be used:

(1) DC, two-wire, insulated;

(2) AC, single-phase, two-wire, insulated;

(3) AC, three-phase, three-wire, insulated.

2.16.2.2 No direct electrical connection is allowed between power networks operating at different voltages.

2.16.2.3 All circuits of generation, supply and distribution systems are not to be earthed, and hull return system is not permitted with the following exceptions:

(1) intrinsically safe circuits;

(2) power supplied control circuits and instrumentation circuits where technical or safety reasons preclude the use of a system with no connection to earth, provided the current in the hull is limited to not more than 5 A in both normal and fault conditions;

(3) limited and locally earthed systems, provided that any possible resulting current does not flow directly through any of the hazardous spaces;

(4) AC distribution systems with 1,000 V (root mean square) and over between phases, provided that any possible resulting current does not flow directly through any of the hazardous spaces.

2.16.3 Cables and their installation

2.16.3.1 All cables, other than those of intrinsically safe circuits, installed in zone 0 and zone 1, are to be provided with an impervious sheath in combination with braiding or other metallic covering.

2.16.3.2 Cables of intrinsically safe circuits are to have a metallic shielding with at least an impervious sheath.

2.16.3.3 Where cables are subject to lengthy immersion in the cargo, the construction of the cables is to be such as to withstand the substances to which they can be exposed, or the cables are to be enclosed in casings (such as metallic pipes) capable of withstanding such substances.

2.16.3.4 Where corrosion may be expected, an impervious sheath is to be applied over the metal braid or armour of the cable.

2.16.3.5 Where cables pass through gastight bulkheads or decks separating hazardous areas from non-hazardous areas, arrangements are to be such that the gastight integrity of the bulkhead or deck is not impaired.

2.16.3.6 Cables installed on deck or on fore and aft gangways are to be protected against mechanical damage. Cables are to be so installed as to avoid strain or chafing and due allowance is to be made for expansion or working of the structure. Where ring-type expansion bends are fitted, they are to be accessible for maintenance.

2.16.3.7 Cables installed in pump rooms are to be suitably protected against mechanical damage.

2.16.3.8 Flexible cables or wires for portable electrical appliances are not to pass through hazardous areas or spaces, with the exception of flexible cables or wires of intrinsically safe type.

2.16.4 Electrical equipment in hazardous areas

2.16.4.1 For electrical equipment installed in hazardous areas, the appropriate certified explosion-proof equipment is to be selected in accordance with the category of hazardous areas, and the explosion group and temperature class are not to be lower than II A T3.

2.16.4.2 The following equipment is allowed to be installed in zone 0:

(1) certified intrinsically-safe apparatus of category "ia";

(2) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category "ia", not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14;

(3) submersible pumps, having at least two independent methods of shutting down automatically in the event of low liquid level.

2.16.4.3 The following equipment is allowed to be installed in zone 1:

(1) electrical equipment specified in 2.16.4.2 of this Section;

(2) certified intrinsically-safe apparatus of category "ib";

(3) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category "ib", not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14;

(4) certified flameproof (type "d");

(5) certified pressurized (type "p");

(6) certified increased safety (type "e");

(7) certified encapsulated (type "m");

(8) certified sand filled (type "q");

(9) certified specially (type "s")[①];

(10) anodes or electrodes of an impressed current cathodic protection system, or transducers such as those for depth-sounding or log systems, provided that such fittings are housed within a gastight enclosure, and are not located adjacent to a cargo tank bulkhead;

(11) through runs of cable.

2.16.4.4 The following equipment is allowed to be installed in zone 2:

(1) electrical equipment specified in 2.16.4.3 of this Section;

(2) non-sparking electrical equipment "n";

(3) the type which ensures the absence of sparks and arcs and of "hot spots" during its normal operation.

2.16.4.5 Transmitting aerials and any associated riggings are to be sited well clear of gas and vapour outlets.

2.16.4.6 For the electrical equipment permitted in hazardous areas or spaces, all switches and protective devices are to be capable of interrupting all poles or phases and are to be located in a non- hazardous area or space. Such equipment, switches and protective devices are to be clearly and durably labelled for identification purposes.

2.16.5 Earth connection and static electricity protection

2.16.5.1 The metal casings of all electrical equipment in any hazardous areas or spaces, regardless of the working voltage, are to be reliably earthed.

2.16.5.2 Cargo tanks, process plants and piping systems are to be earthed in accordance with 1.3.4.11 of this PART for the control of static electricity.

2.16.5.3 All rigging is to be effectively bonded to ship's hull.

2.16.6 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) not exceeding 60℃

2.16.6.1 Zone 0 is to include the following areas or spaces:

(1) cargo tanks, slop tanks, any pipework of pressure-relief or other venting systems for cargo and slop tanks;

(2) interior spaces containing the pipes and equipment containing cargo oil.

2.16.6.2 Zone 1 is to include the following areas or spaces:

(1) cofferdams and ballast tanks adjoining cargo tanks;

(2) cargo pump rooms and the mechanical ventilation is to comply with the following requirements:

① audible and visual alarms are to be given at a manned location in case of failure of the mechanical

---

① Where explosion-proof types (flameproof, increased safety, intrinsically-safe, pressurized, oil filled, sand filled, encapsulated and non-sparking) not included in the special standards are used for electrical equipment, they may be treated as electrical equipment certified specially (type "s").

ventilation in the cargo pump room;

② actions are to be taken to restore ventilation immediately after failure of the mechanical ventilation;

③ where the mechanical ventilation can not be restored for an extended period, the remaining electrical equipment other than those mentioned below is to be capable of being disconnected outside of hazardous areas and provided with means against unauthorized re-connections:

(a) intrinsically safe equipment;

(b) flameproof lighting;

(c) general emergency alarm sounder of flameproof type, without internal sparking contacts;

④ where the mechanical ventilation has been stopped for an extended period or it is initially used, the cargo pump room is to be purged for at least five air changes before connecting the electrical equipment (except the intrinsically safe equipment, flameproof lighting and general emergency alarm sounder of flameproof type);

(3) enclosed or semi-enclosed spaces immediately above cargo tanks (e.g. 'tween-deck spaces) or having bulkheads above and in line with cargo tank bulkheads;

(4) spaces other than cofferdams adjoining to and below the top of a cargo oil tank (e.g. trunks, passageways and general cargo holds), and double bottom and pipe tunnels below cargo tanks;

(5) areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, gas or vapour outlet①, cargo manifold valve, cargo valve, cargo pipe flange, cargo pump-room ventilation outlets and cargo tank pressure/vacuum relief valve provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

(6) areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of large volumes of gas or vapour mixture during cargo loading and ballasting or during discharging, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet, and within a hemisphere of 6 m radius below the outlet;

(7) areas on open deck, or semi-enclosed spaces on open deck, within 1.5 m of cargo pump room entrances, cargo pump room ventilation inlet, openings into cofferdams or other zone 1 spaces;

(8) areas on open deck over all cargo tanks (including all ballast tanks within the cargo tank area) where structures are restricting the natural ventilation and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck;

(9) areas on open deck within spillage coamings surrounding cargo manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;

(10) compartments for cargo hoses;

(11) enclosed or semi-enclosed spaces in which pipes containing cargoes are located;

(12) fore peak tank and vent pipe openings as defined in 3.4.13.1, Chapter 3, PART SIX of the Rules.

2.16.6.3 Zone 2 is to include the following areas or spaces:

(1) areas of 1.5 m surrounding the open spaces or semi-enclosed spaces in zone 1 as specified in 2.16.6.2, if not otherwise specified in this standard;

(2) spaces 4 m beyond the area defined in 2.16.6.2(6);

(3) areas within 2 m beyond areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, cargo tank pressure/vacuum relief valve provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

(4) the spaces forming an air-lock leading to zone 1;

(5) areas on open deck extending to the coamings fitted to keep any spills on deck and away from the accommodation and service areas and 3 m beyond these up to a height of 2.4 m above the deck;

(6) areas on open deck over all cargo tanks (including all ballast tanks within the cargo tank area) where unrestricted natural ventilation is guaranteed and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck surrounding open or semi-enclosed spaces of zone 1;

(7) spaces forward of the open deck areas to which reference is made in 2.16.6.2(8) and 2.16.6.3(6) of this Section, below the level of the main deck, and having an opening on to the main deck or at a level less than 0.5 m above the main deck, unless:

① the entrances to such spaces do not face the cargo tank area and, together with all other openings to the spaces, including ventilating system inlets and exhausts, are situated at least 5 m from the foremost cargo tank and at least 10 m measured horizontally from any cargo tank outlet or gas or vapour outlet; and

② the spaces are mechanically ventilated.

---

① Such areas are sight ports, tank cleaning openings, ullage openings, sounding pipes, cargo vapour outlets.

2.16.6.4 The hazards in some hazardous areas or spaces, e.g. those having direct openings into hazardous areas or spaces, may be reduced or these zones or spaces may be regarded as non-hazardous areas or spaces, provided that the arrangements of ventilation, pressurization, doors at openings, and other safety precautions are in compliance with relevant acceptable standards①.

2.16.7 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) exceeding 60℃ and not heated or heated to a temperature more than 15℃ below their flash point

2.16.7.1 The interiors of cargo tanks, slop tanks, any pipework of pressure/vacuum relief valve or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo or handling flammable gas or vapour belong to zone 2.

2.16.8 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) exceeding 60℃ and heated to a temperature above their flash point or heated to a temperature within 15℃ of their flash point

2.16.8.1 Such tankers are to comply with the requirements for oil tankers carrying cargo oils having a flash point (closed cup) not exceeding 60℃, as specified in 2.16.6 of this Section.

Section 17 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR OWN PROPULSION

2.17.1 General requirements

2.17.1.1 This Section applies to the electrical installations of ships with spaces for carrying vehicles with fuel in their tanks for their own propulsion.

2.17.1.2 The certified explosion-proof equipment required by this Section is to comply with the provisions of 1.3.3 of this PART, and the explosion group and temperature class are not to be lower than II A, T3.

2.17.2 Carriage of vehicles in special category spaces above the bulkhead deck of passenger ships and in closed ro-ro spaces and closed vehicle spaces (with not less than 10 air changes per hour) of passenger ships and cargo ships

2.17.2.1 The electrical equipment fitted within a height of 450 mm above the vehicle deck or any platform on which vehicles are carried and within the exhaust ventilation trunking for the spaces is to be of certified safe type.

2.17.2.2 In spaces other than those specified in 2.17.2.1, where electrical equipment other than that of certified safe type is fitted, the enclosure of which is to be of at least IP55 type.

2.17.3 Carriage of vehicles in special category spaces below the bulkhead deck of passenger ships and in closed ro-ro spaces and closed vehicle spaces (with less than 10 air changes per hour) of passenger ships and cargo ships

2.17.3.1 The electrical equipment fitted within such spaces and their exhaust ventilation trunking are to be of certified safe type.

2.17.4 Carriage of vehicles in cargo spaces other than vehicle, special category or ro-ro spaces

2.17.4.1 On all ships, when vehicles with fuel in their tanks for their own propulsion are carried in cargo spaces other than vehicle, special category or ro-ro spaces, the requirements of SOLAS regulation II-2/20.2.1.2 are to be complied with.

2.17.5 Carriage of vehicles in open ro-ro spaces, open vehicle spaces and an area on weather deck of passenger ships and cargo ships

2.17.5.1 For the electrical equipment fitted in the area, the degrees of protection by enclosures are to comply with the relevant requirements of Table 1.3.2.2 of this PART.

① See IEC publication 60092-502: Electrical installations in ships –Part 502: Tankers – Special Features.

Section 18 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING DANGEROUS GOODS

2.18.1 General requirements

2.18.1.1 The electrical installations onboard ships fitted with cargo spaces intended for carrying dangerous goods specified in 2.18.1.2 are to comply with the requirements of this Section and other applicable requirements of this PART.

2.18.1.2 Dangerous goods, for which safety measures are required with respect to the electrical equipment, are grouped into the following classes in accordance with IMO International Maritime Dangerous Goods Code (IMDG Code) and International Maritime Solid Bulk Cargoes (IMSBC) Code:

(1) Dangerous goods in packaged form

Class 1 Explosives, except goods in division 1.4, compatibility group S of IMDG Code;

Class 2.1 All flammable gases, compressed, liquefied or dissolved under pressure;

Class 2.3 All toxic gases having a subsidiary risk class 2.1;

Class 3 All flammable liquids having a flashpoint below 23℃ (closed-cup test);

Class 4.3 Liquids having a flashpoint below 23℃, which in contact with water, emit flammable gases;

Class 6.1 All toxic substances having a flashpoint below 23℃ (closed-cup test);

Class 8 All corrosive liquids having a flashpoint below 23℃ (closed-cup test);

Class 9 Miscellaneous dangerous substances emitting flammable gases.

(2) Solid dangerous goods in bulk

Class 4.1 Flammable solids;

Class 4.2 Substances liable to spontaneous combustion;

Class 4.3 Substances, which in contact with water, emit flammable gases;

Class 5.1 Oxidizing substances;

Class 9 Miscellaneous dangerous substances, that is, any other substance which experience has shown, or may show, to be of such a dangerous character that the provisions of this Section apply to it;

MHB Materials which may possess chemical hazards when transported in bulk other than materials classified as dangerous goods in the IMDG Code.

2.18.1.3 Possible hazardous areas for carrying the dangerous goods specified in this Section comprise the following:

(1) Zones and spaces, in which an explosive atmosphere① is likely to occur in normal operation, are defined as hazardous areas.

(2) Zones and spaces, in which an explosive atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only, are defined as extended hazardous areas.

2.18.1.4 Electrical equipment is to be installed in hazardous areas only when it is essential for the safety and operation of the ship. The explosion protection of the installed and operated electrical equipment is to be suitable for the characteristics of the dangerous goods.

2.18.2 Carriage of explosives class 1 in packaged form as specified in 2.18.1.2 (1) (except goods in division 1.4, compatibility group S)

2.18.2.1 The following zones or spaces are hazardous areas:

(1) closed cargo spaces, and closed or open ro-ro cargo spaces;

(2) permanently fixed containers (e.g. magazines).

2.18.2.2 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required in Table 2.18.2.2 are permitted in the hazardous areas specified in 2.18.2.1 of this Section.

Permitted Electrical Equipment **Table 2.18.2.2**

Environment	Electrical equipment			
	Type	Explosion group	Temperature class or maximum surface temperature	Degree of protection
Explosive dust	General electrical equipment		100℃	IP65
Explosive gas	Intrinsically safe Ex “i”	IIA	T5	
	Flameproof Ex “d”	IIA		

① An explosive atmosphere may exist due to gas and/or dust.

Environment	Electrical equipment			
	Type	Explosion group	Temperature class or maximum surface temperature	Degree of protection
	Increased safety Ex “e” (only for lighting)	II		
Explosive gas and dust	Intrinsically safe Ex “i”	IIA	T5	IP65
	Flameproof enclosure Ex “d”	IIA		
	Increased safety Ex “e” (only for lighting)	II		

2.18.3 Carriage of solid dangerous goods in bulk, including classes 4.1, 4.2, 5.1, 9 and MHB creating explosive dust atmosphere

2.18.3.1 The following zones or spaces are hazardous areas:

(1) closed cargo spaces;

(2) ventilation ducts (if any) for hazardous areas;

(3) enclosed or semi-enclosed spaces having a direct opening into any of the spaces listed in (1) or (2) above, without appropriate measures to prevent flammable dust from entering.

2.18.3.2 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required as follows are permitted in the hazardous areas specified in 2.18.3.1 of this Section (unless otherwise specified in 2.18.5):

(1) general electrical equipment

— degree of protection IP55;

— maximum surface temperature 200℃; or

(2) certified explosion-proof electrical equipment

— degree of protection IP55;

— temperature class T3.

2.18.3.3 Where dangerous goods are to be carried which require a lower surface temperature than that given in 2.18.3.2 of this Section, the relevant requirements are to be complied with (see also 2.18.7).

2.18.3.4 Where ammonium nitrate (UN1942) and ammonium nitrate fertilizer (UN2067) of class 5.1, ammonium nitrate fertilizer (UN2071) of class 9, ammonium nitrate-based fertilizer and ammonium nitrate-based fertilizer MHB are to be carried, all electrical equipment, other than that of certified safe type, in hazardous areas are to be electrically disconnected from the power source in accordance with the requirements of 2.18.8.1.

2.18.4 Carriage of flammable liquids having a flashpoint below 23 ℃ (classes 3, 6.1 and 8), flammable gas in packaged form (class 2.1), miscellaneous dangerous substances emitting flammable gases in packaged form (class 9) and substances emitting flammable gases in contact with water (solid class 4.3 and MHB generating flammable gases in contact with water)

2.18.4.1 The following zones or spaces are hazardous areas:

(1) closed cargo spaces and closed ro-ro cargo spaces;

(2) ventilation ducts (if any) for hazardous areas;

(3) areas on weather deck, or semi-enclosed spaces on weather deck, within 1.5 m of any exhaust ventilation outlet of a hazardous area;

(4) enclosed or semi-enclosed spaces having a direct opening into any of the spaces listed in (1) and (2) above, and without appropriate measures to prevent flammable gas from entering.

2.18.4.2 The following zones or spaces are extended hazardous areas:

(1) spaces which are separated by self-closing gastight doors (watertight doors may be regarded as gastight) from the hazardous areas as mentioned in 2.18.4.1(1) and (2), and have natural ventilation;

(2) inside the air lock (if any) adjoining the hazardous areas as mentioned in 2.18.4.1;

(3) open or semi-enclosed spaces within 1.5 m of the hazardous areas as specified in 2.18.4.1(3).

2.18.4.3 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required in Table 2.18.4.3 are permitted in the hazardous areas specified in 2.18.4.1 and 2.18.4.2 of this Section (unless otherwise specified in 2.18.5).

Permitted Electrical Equipment **Table 2.18.4.3**

Type of hazardous areas	Electrical equipment		
	Type	Explosion group	Temperature class or maximum surface temperature
Hazardous areas	Intrinsically safe Ex “i”	IIC	T4
	Flameproof Ex “d”	IIC	
	Pressurized enclosure Ex “p”	II	
	Encapsulated Ex “m”	II	

Type of hazardous areas	Electrical equipment		
	Type	Explosion group	Temperature class or maximum surface temperature
Extended hazardous areas	Electrical equipment permitted in the above hazardous areas	IIC or II	T4
	Non-sparking Ex “n”	II	
	Appliances which do not generate sparks or arcs during normal operation		135℃

2.18.4.4 If cargoes to be carried do not include hydrogen gases, hydrogen mixtures or bulk cargo which may produce hydrogen under certain conditions, the explosion group required above may be IIB.

2.18.5 Carriage of solid dangerous goods in bulk and MHB only

2.18.5.1 Where solid dangerous goods in bulk (solid dangerous goods capable of creating explosive gas atmosphere) and MHB are to be carried, electrical equipment of certified safe type installed in hazardous areas are to be in compliance with the minimum requirements of Table 2.18.5.1.

Characteristics of Electrical Equipment for Use in Hazardous Areas (Example)

Table 2.18.5.1

Dangerous goods	IMO class	Dominant risk①	Protection against explosive dust atmosphere	Protection against explosive gas atmosphere	
			Degree of protection	Explosion group	Temperature class
Aluminium ferrosilicon powder UN1395	4.3	H_2	—	IIC	T2
Aluminium silicon powder uncoated UN1398	4.3	H_2	—	IIC	T2
Aluminium smelting by-products or Aluminium remelting by-products UN3170	4.3	H2	—	IIC	T2
Aluminium smelting/remelting by-products, processed	MHB(WF and/or WT and/or CR)	H2	—	IIC	T1
Ammonium nitrate UN1942	5.1	—	—	—	T4
Ammonium nitrate-based fertilizer UN2067	5.1	—	—	—	T4
Ammonium nitrate-based fertilizer UN2071	9	—	—	—	T4
Ammonium nitrate-based fertilizer	—	—	—	—	T4
Ammonium nitrate-based fertilizer MHB	MHB(OH)	—	—	—	T4
Brown coal briquettes	MHB (CB and/or SH)	Dust, methane	IP55	IIA	T4
Coal	MHB (CB and/or SH and/or WF and/or CR)	Dust, methane	IP55	IIA	T4
Direct reduced iron (A)	MHB (SH and/or WF)	H_2	—	IIC	T2
Direct reduced iron (B)	MHB (SH and/or WF)	H_2	—	IIC	T2
Direct reduced iron (C)	MHB (SH and/or WF)	H_2	—	IIC	T2
Direct reduced iron (D)	MHB (SH and/or WF)	H_2	—	IIC	T2
Ferrophosphorus (including briquettes)	MHB (WF and/or WT)	H_2	—	IIC	T1
Ferrosilicon, with at least 25% but less than 30% silicon, or 90% or more silicon	MHB (WF and/or WT)	H_2	—	IIC	T1

Dangerous goods	IMO class	Dominant risk①	Protection against explosive dust atmosphere	Protection against explosive gas atmosphere	
			Degree of protection	Explosion group	Temperature class
Ferrosilicon UN1408, with 30% or more but less than 90% silicon(including briquettes)	4.3	H_2	—	IIC	T1
Iron oxide, spent or sponge iron, spent UN1376	4.2	Dust	IP55	IIA	T2
Seed cake, containing vegetable oil UN1386(b)	4.2	Hexane	—	IIA	T3
Seed cake UN2217	4.2	Hexane	—	IIA	T3
Seed cakes and other residues of processed oily vegetables	MHB (SH)	Dust	IP55	IIA	T3
Silicomanganese (low-carbon)	MHB(WF and/or WT and/or TX)	H_2	—	IIC	T1
Solidified fuels recycled from paper and plastics	MHB (SH)	Combustible	IP55	—	T3
Sugarcane biomass pellets	MHB(CB and/or WF and/or WT and/or OH)	Combustible, dust	IP55	IIA	T3
Sulphur UN1350 (crushed lump and coarse grained)	4.1	Combustible, dust	IP55	—	T4
Zinc Ashes UN1435	4.3	H_2	—	IIC	T2
Wood torrefied	MHB(CB and/or SH and/or CR)	Combustible, dust	IP55	—	T3
Wood pellets, containing additives and/or binders	MHB(WF)	Dust	IP55	—	T3
Wood pellets, not containing any additives and/or binders	MHB(OH)	Dust	IP55	—	T3

Note: ① The term “risk” relates only to the risk of explosion due to dangerous goods and electrical appliances.

2.18.6 Pressurized protection and air locks

2.18.6.1 Spaces having openings into adjacent hazardous spaces or areas (such as the hazardous areas specified in 2.18.4.1(4) of this Section) may be regarded as non-hazardous spaces provided they are pressurized as indicated in the acceptable standards①.

2.18.6.2 Where air locks are fitted adjacent to a hazardous area specified in 2.18.4.1, the external spaces adjacent to the air locks and fitted with natural ventilation may be regarded as non-hazardous spaces.

2.18.7 Special requirements

2.18.7.1 If no details of the characteristics of the prospected cargo are available, or if a ship is intended for the carriage of all the materials defined in 2.18.1.2, the electrical equipment permitted in hazardous areas are to be in compliance with the following requirements:

— degree of protection provided by enclosure IP65;
— maximum surface temperature 85℃;
— explosion group IIC;
— temperature class T6.

2.18.8 Installation of electrical system in hazardous areas

2.18.8.1 If the electrical equipment installed is not suitable for use in areas where a risk of explosion

① See IEC publication 60092-506: Special features – Ships carrying specific dangerous goods and materials hazardous only in bulk.

exists, the equipment is to be capable of being disconnected and protected against unauthorized re-connection. Disconnection is to be made outside the hazardous areas and be effected with isolating links or lockable switches.
2.18.8.2 Cables are to be armoured or braided, or to be laid in metallic conduits.
2.18.8.3 Cable joints in cargo spaces are to be avoided where possible. Where joints are unavoidable, they are to be enclosed in explosion-proof metallic or high strength plastic junction boxes, or encapsulated crimp sleeve cable joints.
2.18.8.4 Cable penetrations of decks and bulkheads are to be sealed against the passage of inflammable gas or vapour.

2.18.9 Portable electrical appliances in hazardous areas

2.18.9.1 Portable electrical appliances, which must be used in hazardous areas for operation of the ship, are to be of a certified safe type suitable for such areas and except for intrinsically safe circuits, generally provided with their own power source.

2.18.10 Carriage of flammable liquids having a flashpoint below 23℃ in packaged form (classes 3, 6.1 and 8), aluminium smelting by-products or aluminium remelting by-products (UN 3170), aluminium smelting or remelting by-products processed (MHB), ferrosilicon (MHB) and ferrosilicon (UN 1408)

2.18.10.1 The bilge pipes with flanges, valves, pumps, etc., constitute a source of release and the enclosing spaces (e.g. pipe tunnels, bilge pump rooms, etc.) are to be classified as an extended hazardous area (comparable with Zone 2) unless these spaces are continuously mechanically ventilated with a capacity for at least six air changes per hour.
2.18.10.2 Except where the space is protected with redundant mechanical ventilation capable of starting automatically, equipment not certified for Zone 2 are to be automatically disconnected following loss of ventilation while essential systems such as bilge and ballast systems are to be certified for Zone 2.
2.18.10.3 Where redundant mechanical ventilation is employed, equipment and essential systems not certified for Zone 2 are to be interlocked so as to prevent inadvertent operation if the ventilation is not operational. Audible and visual alarms are to be provided at a manned station if failure occurs.

Section 19 DETECTION OF WATER INGRESS IN CARGO HOLDS

2.19.1 Application

2.19.1.1 This Section applies to all bulk carriers, single hold cargo ships other than bulk carriers and multiple hold cargo ships other than bulk carriers and tankers of 500 gross tonnage and upwards engaged on international voyages. Bulk carriers mentioned in this Section are bulk carriers as defined in SOLAS Chapter XII.

2.19.2 Water level detector system

2.19.2.1 Water level detectors installed in cargo holds, ballast tanks and dry spaces are to comply with the relevant requirements of acceptable standards① in addition to the provisions of this Section, and are to be subject to type approval.
2.19.2.2 All bulk carriers to which this Section is applicable are to be fitted with water level detectors and the following requirements are to be satisfied:
(1) Audible and visual alarms are to be given in each cargo hold, one when the water level above the inner bottom in any hold reaches a height of 0.5 m and another at a height not less than 15% of the depth of the cargo hold but not more than 2.0 m. On bulk carriers to which SOLAS regulation XII/9.2 applies, detectors with only the latter alarm need be installed. For cargo holds which are used for water ballast, an alarm overriding device may be installed. The audible and visual alarms are to clearly discriminate between the two different water levels detected in each hold.
(2) In any ballast tank forward of the collision bulkhead required by SOLAS regulation II-1/12, an audible and visual alarm is to be given when the liquid in the tank reaches a level not exceeding 10% of the tank capacity. An alarm overriding device may be installed to be activated when the tank is in use.
(3) In any dry or void space other than a chain cable locker, any part of which extends forward of the foremost cargo hold, an audible and visual alarm is to be given at a water level of 0.1 m above the deck.

① See resolution MSC.188(79)/Rev.2 adopted by IMO − Performance standards for water level detectors on ships subject to SOLAS regulations II-1/25, II-1/25-1 and XII/12.

Such alarms need not be provided in enclosed spaces the volume of which does not exceed 0.1% of the ship's maximum displacement volume.

2.19.2.3 Single hold cargo ships having a length of less than 80 m and a single cargo hold below the freeboard deck or cargo holds below the freeboard deck which are not separated by at least one bulkhead made watertight up to that deck are to be fitted in such space or spaces with water level detectors, which are to give an audible and visual alarm at the navigation bridge when the water level above the inner bottom in the cargo hold reaches a height of not less than 0.3 m, and another when such level reaches not more than 15% of the mean depth of the cargo hold. The audible and visual alarms are to clearly discriminate between the two different water levels detected in each hold. The water level detectors required by this paragraph need not be fitted in ships having watertight side compartments each side of the cargo hold length extending vertically at least from inner bottom to freeboard deck.

2.19.2.4 Multiple hold cargo ships other than bulk carriers and tankers are to be fitted with water level detectors in each cargo hold intended for dry cargoes. Water level detectors are not required for cargo holds located entirely above the freeboard deck. The following requirements are to be satisfied:

(1) Giving audible and visual alarms at the navigation bridge, one when the water level above the bottom of the cargo hold reaches a height of not less than 0.3 m, and another at a height not less than 15% of the depth of the cargo hold but not more than 2 m. For cargo holds which are occasionally used for water ballast, an alarm overriding device may be installed. The visual alarms are to clearly discriminate between the two different water levels detected in each hold.

(2) As an alternative to the water level detector at a height of not less than 0.3 m as per (1) of this paragraph, a bilge level sensor serving the bilge pumping arrangements required by SOLAS regulation II-1/35-1 and installed in the cargo hold bilge wells or other suitable location is considered acceptable, subject to:

① the fitting of the bilge level sensor at a height of not less than 0.3 m at the aft end of the cargo hold;

② the bilge level sensor giving audible and visual alarm at the navigation bridge which is clearly distinctive from the alarm given by the other water level detector fitted in the cargo hold.

2.19.2.5 The audible and visual alarms specified in 2.19.2.2 to 2.19.2.4 are to be located on the navigation bridge.

2.19.2.6 Detection equipment is to be suitably corrosion resistant for all intended cargoes. Detection equipment includes the sensor and any filter and protection arrangements for the detector installed in cargo holds and other spaces.

Equipment which is to be used in refrigerated cargo spaces is to satisfy the requirements of a suitable industry standard covering the relevant service temperatures.

2.19.2.7 Detection equipment is to be electrical equipment of a certified safe type complying with the requirements of 1.3.3.1, Chapter 1 of this PART. The explosion groups and temperature classes are determined in accordance with carried cargoes. The part of the water level detector system which has circuitry in the cargo area is to be of an intrinsically safe type and explosion protection type as specified in acceptable standards①. Where a ship is designed only for the carriage of cargoes that cannot create a combustible or explosive atmosphere, then the requirement for electrical equipment of certified safe type may not be mandatory provided that this is specified in the operation manual of the water level detector system, the ship's cargo book and the certificate relating to the carriage of specially identified cargoes.

2.19.2.8 Where the characteristics of the dust and gas are unknown, the explosion group of electrical equipment used in dust and/or gas hazardous space is not to be lower than IIIC and/or IIC and the temperature class is to be T6.

2.19.2.9 The electrical power supply for the water level detector system is to comply with the following:

(1) It is to be supplied from two independent sources of electrical power:

① the main source of electrical power and the emergency source of electrical power; or

② the main source of electrical power, and a continuously charged dedicated accumulator battery of which the arrangement, location and endurance for power supply (18 h) are equivalent to those of the emergency source of electrical power. The battery may be an internal battery of the water level detector system;

(2) The changeover of supply from one source of electrical power to another need not be integrated into the water level detector system;

(3) Failure of any of the two electrical power supplies is to be indicated by an alarm.

2.19.2.10 The degree of protection provided by enclosures for electrical components installed in cargo holds, ballast tanks and dry spaces are to satisfy the requirements of IP 68.

2.19.2.11 Where the cargo hold is used as water ballast, sensors provided in the hold are to be suitable for the maximum pressure that might occur in the hold.

---

① See IEC publication 60079.

2.19.3 Installation requirements for water level detectors

2.19.3.1 The sensors are to be located in a protected position that is in communication with the specified part of the cargo hold (usually the aft part) such that the position of the sensor detects the level that is representative of the levels in the actual hold space. These sensors are to be located either as close to the centerline as practicable, or at both the port and starboard sides of the cargo hold.

The sensors are to be placed at a distance not exceeding 1 corrugation spacing or 1 bulkhead vertical stiffener spacing from the centerline, otherwise sensors are to be located at both the port and starboard sides of the cargo hold.

2.19.3.2 The sensors are to be located at the specified height. These heights are to be measured from the upper surface of the inner bottom. For bilge level sensors in 2.19.2.4(2) of this Section, if the bottom of the bilge well is below the upper surface of the inner bottom, the heights of those sensors are to be measured from the bottom of the bilge well.

2.19.3.3 When a lining or insulation is fitted, if the lining or insulation is not constructed to a watertight standard, then the height is to be measured from the upper surface of the inner bottom. If the lining or insulation is tested as watertight, then the heights may be measured from the upper surface of the lining/insulation.

2.19.3.4 The detector installation is not to inhibit the use of any sounding pipe or other water level gauging device for cargo holds or other spaces.

2.19.3.5 Detectors and equipment are to be installed where they are accessible for survey, maintenance and repair.

2.19.3.6 Any filter element fitted to detectors is to be capable of being cleaned before loading.

2.19.3.7 Electrical cables and any associated equipment installed in cargo holds are to be protected from damage by cargoes or mechanical handling equipment associated with bulk carrier operations, such as in tubes of robust construction or in similar protected locations.

2.19.3.8 Any change/modification to the ship’s structure, electrical systems or piping systems that involves cutting and/or welding are to be approved by CCS prior to commencement of work.

CHAPTER 3 CONSTRUCTION AND TESTING OF ELECTRICAL EQUIPMENT

Section 1 GENERAL PROVISIONS

3.1.1 General requirements

3.1.1.1 This Chapter applies to class-related electrical equipment. The additional requirements for high voltage electrical installations are given in Section 14, Chapter 2 of this PART, and additional requirements for electrical propulsion machinery are given in Chapter 15, PART EIGHT of the Rules.

3.1.1.2 Class-related electrical equipment is to be provided with certificates corresponding to its type. The specific requirements for certificates are given in Chapter 3, PART ONE of the Rules.

Section 2 ROTATING MACHINES

3.2.1 General requirements

3.2.1.1 The characteristics of the prime movers of generators and their governors are to comply with the relevant requirements of Chapters 7, 8 and 9, PART THREE of the Rules.

3.2.1.2 For generating sets operating in parallel, the governing characteristics of the prime mover are to be such as to ensure the load sharing specified in 3.2.7.5 and 3.2.8.5 of this Section. Facilities are to be provided to adjust the governor sufficiently fine to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

3.2.1.3 Shaft material for electrical propulsion motors and for main engine driven generators where the shaft is part of the propulsion shafting is to be certified by CCS.

3.2.1.4 Electrical machines are to be protected against ill effects of shaft current.

3.2.1.5 For non-closed-type bearings of electrical machines, consideration is to be to the fitting of grease cups or oil holes and corresponding oil drainage so as to ensure efficient lubrication.

3.2.2 Plans and documents

3.2.2.1 The following plans and documents are to be submitted for approval:

(1) General plan;

(2) Detailed drawings of main parts including assembly of stators, assembly of rotors, drawing of rotating shaft, assembly of slip rings or commutators, drawing of bedplate, and structural drawing of connection boxes;

(3) Technical specifications of the products;

(4) Front panel arrangement and system control flow diagram (applicable to electrical propulsion motors and their controls);

(5) Electrical schematic diagram (applicable to electrical generators and their excitation systems, electrical propulsion motors and their controls);

(6) External wiring diagram (applicable to electrical generators and their excitation systems, electrical propulsion motors and their controls).

3.2.2.2 The following plans and documents are to be submitted for information:

(1) Specifications of associated electrical appliances (applicable to electrical generators and their excitation systems, electrical propulsion motors and their controls).

3.2.3 Temperature rise

3.2.3.1 The limits of temperature rise of air-cooled machines based on an ambient air temperature of 45℃ are given in Table 3.2.3.1.

3.2.3.2 Where the ambient air temperature for motor operation is more than 45℃, the permissible temperature rise is to be reduced by an amount equal to the difference between the actual air ambient temperature and 45℃, based on the specified value given in Table 3.2.3.1.

Where the ambient air temperature for motor operation is less than 45℃, the permissible temperature rise is to be increased by a value equal to the difference between the actual ambient air temperature and 45℃, based on the specified value given in Table 3.2.3.1, and the increased value is not to be more than 15 K.

For motors fitted with water-cooled heat exchanger, the temperature of cooling water at the inlet of the heat exchanger may be regarded as the ambient air temperature for motor operation.

Limits of Temperature Rise (K) of Air-Cooled Machines **Table 3.2.3.1**

Thermal classification		B			F			H		
Method of measurement		Th	R	ETD	Th	R	ETD	Th	R	ETD
Item	Part of machine									
1a)	AC windings of machines having output of 5,000 kW (or kVA) or more	–	75	80	–	100	105	–	120	125
1b)	AC windings of machines having output above 200 kW (or kVA), but less than 5,000 kW (or kVA)	–	75	85	–	100	110	–	120	135
1c)	AC windings of machines having output of 200 kW (or kVA) or less, other than those of items 1d) or 1e)	–	75	–	–	100	–	–	120	–
1d)	AC windings of machines having rated output of less than 600 W (or VA)	–	80	–	–	105	–	–	125	–
1e)	AC windings and/or encapsulated windings of self-cooled machines without a fan (IC410)	–	80	–	–	105	–	–	125	–
2	Windings of armatures having commutators	65	75	–	80	100	–	100	120	–
3	Field windings of AC and DC machines other than those of item 4	65	75	–	80	100	–	100	120	–
4a)	Field windings of synchronous machines with cylindrical rotors having DC excitation windings embedded in slots, excluding synchronous induction motors	–	85	–	–	110	–	–	130	–
4b)	Stationary field windings of DC machines having more than one layer	65	75	85	80	100	110	100	120	135
4c)	Single-layer low-resistance field windings of AC and DC machines and compensating windings of DC machines having more than one layer	75	75	–	95	100	–	120	120	–
4d)	Single-layer windings of AC and DC machines with exposed bare or varnished metal surfaces and single-layer compensating windings of DC machines	85	85	–	105	110	–	130	130	–

Notes:
1) The temperature rise or the temperature of any part of machine is not to be detrimental to the insulation of that part or to any other part adjacent to it.
2) With application of the superposition test method to windings of machines in items 1c), 1d) and 1e) with insulation classes B and F, the limits of temperature rise given for the resistance method may be exceeded by 5 K.
3) Multi-layer windings are to comply with the requirements of item 4d) where the under layers are all in contact with the circulating primary coolant.
4) Th – thermometer, R – resistance, and ETD – embedded temperature detector.

3.2.3.3 Main and emergency generators, including their exciters, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air temperature for an unlimited period, without the limits of temperature rise in Table 3.2.3.1 being exceeded.
Other generators and motors are to be rated in accordance with the duty which they have to perform and when tested under rated load conditions, the temperature rise is not to exceed the values given in Table 3.2.3.1. For intermittent service S2 machines, the limits of temperature rise of windings may be 10 K above the values given in Table 3.2.3.1.

3.2.4 Sparking

3.2.4.1 Direct current motors and generators are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.
3.2.4.2 Alternating current commutator motors are to work over the specified range of load and speed without injurious sparking.

3.2.5 Overloads

3.2.5.1 Machines are to withstand, on test, the following overcurrents or excess torques without injury:
DC generators: 50% overcurrent for 15 s;
AC generators: 50% overcurrent for 2 min;
DC motors: 50% excess torque for 15 s;
Polyphase asynchronous motors: 60% excess torque for 15 s;
Polyphase salient synchronous motors: 50% excess torque for 15 s;
Polyphase non-salient synchronous motors: 35% excess torque for 15 s;
Polyphase synchronous motors of asynchronous construction (wound rotor): 35% excess torque for 15 s.

3.2.6 Short-circuits

3.2.6.1 Ship's service generators are to be capable of withstanding the mechanical and thermal effects of a short-circuit current for the duration of any time delay for discrimination purposes when tripping a protective device. AC generators and their excitation systems are to be capable of maintaining, under steady-state short-circuit conditions, a current of at least 3 times the full load rated current for a duration of 2 s or where precise data are available, for the duration of any time delay which may be provided by a tripping device.

3.2.6.2 For determining the discrimination settings in the distribution system where the generator is going to be used, the generator manufacturer is to provide documentation showing the transient behaviour of the short circuit current upon a sudden short-circuit occurring when excited, and running at nominal speed. The influence of the automatic voltage regulator is to be taken into account, and the setting parameters for the voltage regulator are to be noted together with the decrement curve. Such a decrement curve is to be available when the setting of the distribution system's short-circuit protection is calculated. The decrement curve need not be based on physical testing. The manufacturer's simulation model for the generator and the voltage regulator may be used where this has been validated through the previous type test on the same model.

3.2.7 DC generators

3.2.7.1 All DC generators other than charging generators are, in general, to be of compound-wound or shunt-wound with automatic voltage regulator, or stabilized shunt-wound (shunt-wound with few turns of series windings).

3.2.7.2 Manual voltage regulators are to be provided at the control panel to enable the voltage of each DC generator to be adjusted separately. For each DC generator, at any temperature within the working range and at any load between no load and full load, and when the voltage varies from 80% to 105% of the rated value, the accuracy of voltage adjustment is to be as follows:
(1) 0.5% of rated voltage for generators of rating exceeding 100 kW;
(2) 1.0% of rated voltage for generators of rating not exceeding 100 kW.
The circuit of manual voltage regulators is in general to be capable of being opened and means are to be provided to protect against over-voltage when the circuit is opened. Non-opened circuit is permitted only in such a case where the manual voltage regulator could adjust the no-load voltage to a value approaching to the remanence voltage.
The handwheel of manual voltage regulators is to be so arranged that when it is turned clockwise, the generator voltage will rise and vice versa.

3.2.7.3 Equalizer leads are to have a cross-sectional area appropriate to the system but in no case less than 50% of that of the negative lead from the generator to the switchboard.

3.2.7.4 For compound-wound generators rated at 50 kW and over, at full load operating temperature and with due regard being paid to governing characteristics of the prime mover, the voltage regulation characteristics are to be such that voltage variations are within 1% of the rated voltage for 20% of the rated load, that voltage variations are within 2.5% of the rated voltage for the full rated load and that the average of the ascending and descending curves of voltage regulation characteristics between 20% load and full load does not vary more than 3% from the rated voltage.

3.2.7.5 All DC generating sets arranged to run in parallel are to be stable in operation. When the combined load on the sets is varied between 20% and 100% of the combined ratings, the individual load on each machine is not to differ from the theoretical load (proportional to rating) by an amount greater than:
(1) ±12% of the rated full load of the largest machine; or
(2) ±25% of the rating of the smallest machine when the rating of the smallest machine is less than 50% of that of the largest one.
Such a load sharing is not to result in overloading the smaller set.

3.2.8 AC generators

3.2.8.1 Each AC generator, unless of the self-regulated type, is to be provided with separate automatic and manual voltage regulators at the generator control panel.
3.2.8.2 Each AC generator driven by the prime mover having governing characteristics complying with Chapter 7, 8 or 9, PART THREE of the Rules together with its excitation system is to be capable of maintaining the voltage under steady conditions within ±2.5% of the rated voltage from zero to full load at rated power factor. These limits may be increased to ±3.5% for emergency generators.
3.2.8.3 When the generator is driven at rated speed and a voltage close to its rated voltage on no-load, and is subjected to a sudden change of symmetrical load within the limits of 60% of the rated current with a power factor not exceeding 0.4 (lagging), the transient voltage is not to fall below 85% nor exceed 120% of the rated voltage. The voltage of the generator is then to be restored to within plus or minus 3% of the rated voltage in not more than 1.5 s. For emergency generators, these values may be increased to plus or minus 4% of the rated voltage in not more than 5 s, respectively.
3.2.8.4 For AC generators, the sinusoidal distortion of the voltage waveform under no-load conditions is not to exceed 5%, except for small (e.g. less than 24 kW) generators.
3.2.8.5 All AC generating sets arranged to run in parallel are to be stable in operation. In the range between 20% and 100% of the combined rated load of all generators, the load sharing is to be as follows:
(1) The active load on any individual generator is not to differ from the proportionate share of the total active load by more than the lesser of the following:
① ±15% of the rated active output of the largest generator; or
② ±25% of the rated active output of the individual generator.
Facilities are to be provided to adjust the governor of the prime mover sufficiently fine to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.
(2) The reactive load on any individual generator is not to differ from the proportionate share of the total reactive load by more than the lesser of the following:
① ±10% of the rated reactive output of the largest generator;
② ±25% of the rated reactive output of the smallest generator.

3.2.9 Testing
3.2.9.1 All electrical machines are to be tested by the manufacturer according to IEC Publication 60092-301. Manufacturer's test records are to be provided for machines for essential services.
3.2.9.2 All machines of 50 kW and over, intended for essential services, are to be surveyed by CCS Surveyors during test and, if appropriate, during manufacturing. CCS and the manufacturer may agree on an alternative survey plan which makes Surveyor's attendance in accordance with the requirements above unnecessary.
3.2.9.3 Items for type and routine tests of the electrical machines are to be in compliance with Table 3.2.9.3. Test requirements may differ for shaft generators, special purpose machines and machines of novel construction.

Items for Type and Routine Tests of Electric Machines **Table 3.2.9.3**

No	Tests	AC Generators		Motors	
		Type test①	Routine test②	Type test①	Routine test②
1	Examination of the technical documentation, as appropriate and visual inspection	×	×	×	×
2	Insulation resistance measurement	×	×	×	×
3	Winding resistance measurement	×	×	×	×
4	Verification of the voltage regulation system	×	×③		
5	Rated load test and temperature rise measurements	×		×	
6	Overload/overcurrent test	×	×④	×	×④
7	Verification of steady short circuit conditions⑤	×			
8	Overspeed test	×	×	×⑥	×⑥
9	Dielectric strength test	×	×	×	×
10	No-load test	×	×	×	×
11	Verification of degree of protection	×		×	
12	Verification of bearings	×	×	×	×

Notes: ① Type tests on prototype machine or tests on at least the first batch of machines.
② The report of machines routine tested is to contain the manufacturer's serial number of the machine which has been type tested and the test result.
③ Only functional test of voltage regulator system.
④ Only applicable for machines of essential services rated above 100 kW.

⑤ Verification of steady short circuit condition applies to synchronous generators only.
⑥ Not applicable for squirrel cage motors.

3.2.9.4 The tests required in Table 3.2.9.3 are to be in accordance with the requirements in 3.2.9.5 to 3.2.9.15, in addition to complying with the relevant requirements of acceptable standards①.

3.2.9.5 Visual inspection

A visual examination is to be made of the machine to ensure, as far as is practicable, that it complies with submitted technical documentation.

3.2.9.6 Insulation resistance measurement

Immediately after the high voltage tests the insulation resistances are to be measured using a direct current insulation tester (DC megameter) between:

(1) all current carrying parts connected together and earth;

(2) all current carrying parts of different polarity or phase, where both ends of each polarity or phase are individually accessible.

The minimum values of test voltages and corresponding insulation resistances are given in Table 3.2.9.6. The insulation resistance is to be measured close to the operating temperature, or an appropriate method of calculation is to be used.

Minimum Test Voltage and Minimum Insulation Resistance Value Table 3.2.9.6

Related voltage U_n (V)	Minimum test voltage (V)	Minimum insulation resistance (MΩ)
$U_n \leq 250$	$2 \times U_n$	1
$250 < U_n \leq 1{,}000$	500	1
$1{,}000 < U_n \leq 7{,}200$	1,000	$(U_n/1{,}000) + 1$
$7{,}200 < U_n \leq 15{,}000$	5,000	$(U_n / 1{,}000) + 1$

3.2.9.7 Winding resistance measurement

The resistances of the machine windings are to be measured and recorded using an appropriate bridge method or voltage and current method.

3.2.9.8 Verification of voltage regulation system

Verification results are to meet the requirements in 3.2.8.2 and 3.2.8.3 of the Section. Subject to agreement of CCS, such voltage regulation during transient conditions may be calculated values based on the previous type test records, and need not be tested during factory testing of a generator, however the calculation report is to be submitted by the manufacturer to demonstrate that the requirements of 3.2.8.3 are met.

3.2.9.9 Rated load test and temperature rise measurements

The temperature rises are to be measured at the rated output, voltage, frequency and the duty for which the machine is rated and marked in accordance with the testing methods specified in IEC Publication 60034-1, or by means of a combination of other tests. Temperature rise is to be measured after the test and the limits of temperature rise are those specified in Table 3.2.3.1.

3.2.9.10 Overload/over-current tests

Electrical machines are to be able to withstand the overload/over-current tests as required in 3.2.5.1 of this Section after the rated load test. The overload test can be replaced at routine test by the over-current test.

3.2.9.11 Verification of steady short-circuit conditions

Verification of AC synchronous generators and their excitation systems is to be in accordance with the requirements in 3.2.6.1, 3.2.6.2 of this Section.

3.2.9.12 Overspeed test

Machines are to withstand the overspeed test as specified in IEC Publication 60034-1. This test is not applicable for squirrel cage motors.

3.2.9.13 Dielectric strength test

Machines are to withstand a dielectric test as specified in IEC Publication 60034-1. For high voltage machines an impulse test is to be carried out on the coils according to 2.14.3.3 of this PART.

3.2.9.14 No load test

Machines are to be operated at no load and rated speed whilst being supplied at rated voltage and frequency as a motor or if a generator it is to be driven by a suitable means and excited to give rated terminal voltage. During the running test, the vibration of the machine and operation of the bearing lubrication system, if appropriate, are to be checked.

3.2.9.15 Verification of degree of protection

---

① Refer to IEC Publication 60092-301: Electrical installations in ships – Part 301: Equipment – Generators and motors and IEC Publication 60034-1: Rotating electrical machines – Part 1: Rating and performance, or other equivalent standards.

As specified in the standards acceptable to CCS①.

3.2.9.16 Verification of bearings

Upon completion of the above tests, machines which have sleeve bearings are to be opened to establish that the shaft is correctly seated in the bearing shells.

Section 3 SWITCHGEAR ASSEMBLIES

3.3.1 Plans and documents

3.3.1.1 The following plans and documents are to be submitted for approval:

(1) General plan;

(2) Front panel arrangement;

(3) Technical specifications of the products;

(4) Electrical schematic diagram.

3.3.1.2 The following plans and documents are to be submitted for information:

(1) Specifications of associated electrical appliances;

(2) Operation instructions for the products (which may be omitted if they are covered in other plans and documents for switchgear assemblies);

(3) External wiring diagram.

3.3.2 Design and construction of switchgear assemblies

3.3.2.1 The construction of main and emergency switchboards is to satisfy the following requirements:

(1) The top of switchboards is to have a degree of protection of IP22, and where the switchboard is installed in the control room complying with the requirements of 2.1.4.2 of this PART, a protection of IP21 at the top may be accepted. The sides of switchboards are to have at least a degree of protection of IP2X. For switchboards having a rated voltage in excess of 500 V, a protection of at least IP2X at the rear is to be provided.

(2) For switchboards having a voltage to earth or a working voltage above 50 V, exposed live parts are not to be installed on the front.

(3) Insulated handrails are to be provided at the front of all main and emergency switchboards. Where access to the rear of above-mentioned switchboards is necessary for operational or maintenance purposes, an insulated handrail is to be fitted on the rear. And horizontal insulated handrails are to be fitted on a fixed part of the switchboard.

(4) Provision is to be made at the cable entry to switchboards so that there is no water leakage into the switchboard along the cables.

(5) The main bus-bar is to be subdivided in accordance with the requirements in 2.1.1.1(5) of this PART.

(6) Where the total capacity of the main generating sets exceeds 100 kVA, a separate cubicle is to be provided for each generator, and the cubicles are to be separated from each other by partitions of steel or flame-retardant material.

(7) Terminals for systems having a rated voltage above 500 V are to be separated from terminals for lower voltages and are to be clearly marked.

3.3.2.2 Section and distribution boards are to be enclosed according to Table 1.3.2.2 of this PART. All enclosures are to be constructed of flame-retardant and non-hygroscopic material, and are to be of robust construction.

3.3.2.3 The arrangement of protection of electrical installations and the choice of protective devices are to comply with the relevant requirements of Section 5 of Chapter 2 of this PART.

3.3.2.4 All instruments, switchgear, pilot lamps, push buttons, operating handles or handwheels fitted on switchboards are to be provided with durable labels indicating their purposes and operating positions.

3.3.2.5 A durable label indicating the purpose of each circuit and the rating or appropriate setting of its overload protective device is to be provided at the location of the protective device. For fuses above 500 V where the fuse holders permit the insertion of fuses for lower rated voltages, special warning labels are to be placed, for example, “CAUTION: 660 V FUSES ONLY!”.

3.3.2.6 Devices for monitoring the insulation level to earth, which are in compliance with the requirements of 2.4.2.2 of this PART, are to be provided on the main and emergency switchboards.

3.3.2.7 Pilot lamps are to be provided at the generator control panels to indicate whether the generator circuit breakers are at the on or off position. Where a space heater is provided for the generator, a pilot lamp

---

① Refer to IEC Publication 60034-5 Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification, or other equivalent standards.

indicating the operation of the space heater is to be provided at the control panel.
3.3.2.8 Means are to be provided at the control panel of DC generators to enable the voltage to be regulated in accordance with the requirements of 3.2.7.2 of this PART.
3.3.2.9 For each AC generator arranged to operate in parallel, a remote control device is to be provided at the control panel to enable the speed of the prime mover to be adjusted within 10% of its rated value.
3.3.2.10 Means are to be provided at the control panel for magnetization of the DC generator.
3.3.2.11 Shore connection boxes of shore supply or other external sources are to be provided with the following:
(1) suitable terminals for connecting the flexible cables;
(2) an earth terminal for connecting the hull to the shore;
(3) switches with necessary protection complying with the requirements of 2.5.9.5 of this PART;
(4) a lamp or voltmeter to indicate the terminal voltage;
(5) means for checking the polarity (for direct current) or the phase sequence (for three-phase AC) of the incoming supply in relation to the ship's system;
(6) means to prevent the imposing of excessive mechanical forces on cable terminals;
(7) a nameplate giving full information on the system of supply, the rated voltage and frequency (for AC) of the ship's system.
3.3.2.12 The charging facilities of battery charging and discharging boards for the emergency or transitional source of electrical power are to comply with the requirements of 2.11.3 of this PART.
3.3.2.13 A disconnect switch and a indicator light for power supply are to be provided on battery charging and discharging boards for the emergency or transitional source of electrical power.

3.3.3 Bus-bars

3.3.3.1 Bus-bars are to be made of conducting cathode copper or copper-sheeted aluminium alloy. The maximum permissible temperature rise for bus-bars is 45 K.
3.3.3.2 Bus-bars and their supports are to be designed to withstand the mechanical stresses which will arise during short-circuits.
3.3.3.3 Bare main bus-bars in main and emergency switchboards (excluding the conductors between the main bus-bar and the supply side of outgoing units) are to have the minimum clearances and creepage distances as given in Table 3.3.3.3.

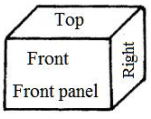
Minimum Clearances and Creepage Distances **Table 3.3.3.3**

Rated voltage (V)	Minimum clearance (mm)	Minimum creepage distance (mm)
$U_n \leq 250$	15	20
$250 < U_n \leq 690$	20	25
$U_n > 690$	25	35

Note: Values given in the Table apply to clearances and creepage distances between live parts as well as between live parts and exposed conductive parts.

3.3.3.4 The current rating of equalizer bus-bars is not to be less than 50% of the rated full load current of the largest generator in the generating plant.
3.3.3.5 The cross sectional area of neutral bus-bar in AC three-phase four-wire systems are not to be less than 50% of that of the bus-bar in the corresponding phase.
3.3.3.6 The arrangement of bus-bars in the switchboard as per the phase sequence (DC) or the polarity (AC) is to be arranged in accordance with Table 3.3.3.6 (as viewed from the front of the assembly).

Arrangement per Phase Sequence or Polarity **Table 3.3.3.6**

Bus bar	Phase sequence or polarity	Position of bus bars			Sketch
		Vertically	Horizontally	Outgoing	
AC	1st phase	Top	Front	Left	As viewed from the front of switchboard assembly 
	2nd phase	Middle	Middle	Middle	
	3rd phase	Bottom	Back	Right	
DC	Positive pole	Top	Front	Left	
	Equalizer pole	Middle	Middle	Middle	
	Negative pole	Bottom	Back	Right	

Note: AC neutral bus-bars may be located at suitable positions.

3.3.4 Measuring instruments

3.3.4.1 The precision grade of instruments is to be selected according to the service of the instruments, but in no case is the precision grade to be inferior to 1.5.
3.3.4.2 The range and scale of the measuring instruments are to comply with the following requirements:
(1) The upper limit of the scale of every voltmeter is to be approximately 120% of the normal voltage of the circuit.
(2) The upper limit of the scale of every ammeter is to be approximately 130% of the normal rating of the circuit in which it is installed.
(3) The upper limit of the scale of every wattmeter is to be approximately 120% of the normal rating of the circuit in which it is installed. Ammeters for use with direct current generators operating in parallel and wattmeters for use with alternating current generators operating in parallel are to be capable of indicating 15% reverse current or power respectively.
(4) The frequency meter is to have a scale range of approximately ±10% of the rated frequency.
(5) Ammeters, voltmeters and wattmeters are to be clearly marked on the scale to indicate their rated values.
3.3.4.3 Generator control panels are to be provided at least with the measuring instruments as required in Table 3.3.4.3.
3.3.4.4 The secondary windings of potential and current transformers are to be effectively earthed.
3.3.4.5 At least the following meters are to be provided for battery charging and discharging boards for emergency or transitional sources of power:
(1) voltmeter to measure the charging voltage;
(2) ammeter to measure the charging current.

Measuring Instruments of Generator Control Panel **Table 3.3.4.3**

Generator	Operating condition	Type of instrument	Quantity
DC	Not in parallel	Ammeter	1 for each generator (connected to positive pole)
		Voltmeter	1 for each generator
	In parallel	Ammeter	1 for each generator (connected to positive pole)
		Voltmeter	2 (1 for measuring the bus-bar voltage, 1 for measuring the voltage of each generator)
AC	Not in parallel	Ammeter	1 for each generator (to be capable of measuring the current in each phase or each line separately)
		Voltmeter	1 for each generator (to be capable of measuring the voltage in each phase or each line separately)
		Wattmeter	1 for each generator (excluding generators rated less than 50 kW (kVA))
		Frequency meter	1 for each generator
		Excitation ammeter	1 for each generator (to be fitted only when necessary)
	In parallel	Ammeter	1 for each generator (to be capable of measuring the current in each phase or each line separately)
		Voltmeter	2 (1 for measuring the voltage in each phase or each line of the generator separately, 1 for measuring the bus-bar voltage)
		Wattmeter	1 for each generator
		Frequency meter	2 (1 for measuring the bus-bar voltage, 1 for measuring the frequency of each generator)
		Synchronous meter	1 for all generators
		Excitation ammeter	1 for each generator (to be fitted only when necessary)

3.3.5 Circuit breakers and switches

3.3.5.1 Circuit breakers are to be designed, manufactured and tested in accordance with IEC Publication 60947-2 or other recognized standards. Circuit breakers are to be of the trip-free type.
3.3.5.2 Circuit breakers and switches are to be so arranged that when in the OFF position, they cannot accidentally move to close the circuit.
3.3.5.3 The protective performance of circuit breakers for generators is to comply with the requirements of 2.5.6 of this PART. The overcurrent trip setting of these circuit breakers is to be adjustable, or if not adjustable, the set values are to be readily replaceable by different ones.
3.3.5.4 Where circuit breakers are operated by a power operating device, a hand operated mechanism is to be provided to operate the circuit breaker in case of failure of the electrical driven gear. For AC main switchboard of less than 1 kV in rated voltage, the generator circuit breaker is to be operated at the front of panels without opening the panel.
3.3.5.5 The fused circuit breakers are to be so constructed that single phasing does not occur in the event

of blowing of fuses and that the fuses can be replaced easily without the risk of accidental touch to their live parts.
3.3.5.6 Durable labels are to be fitted on circuit breakers to indicate their rated voltage, and the rated current and setting of their overcurrent trip devices, etc.

3.3.6 Fuses
3.3.6.1 Fuses are to be designed, manufactured and tested in accordance with IEC Publication 60269 or other recognized standards.
3.3.6.2 Fuses are to be of enclosed type and the construction is to be such that the enclosure is not broken or burnt and the adjacent insulation is not deteriorated by melted metal or emitted gases, when the fuse element has blown out.
3.3.6.3 Fuses are to be easily replaceable for their spare parts without the risk of getting electrical shock or burn on removing and replacing of fuses.
3.3.6.4 When fuses are operating for long periods at rated current, the temperature rise at the terminals is to be such that the maximum permissible operating temperature of the connected cable is not exceeded.
3.3.6.5 Fuses are to be durably marked to indicate their rated voltage, rated current and rated breaking capacity.

3.3.7 Testing
3.3.7.1 Switchboards are to be tested at the manufacturer in accordance with the provisions of 3.3.7.2 to 3.3.7.5 of this Section. However, the test required in 3.3.7.2 may be omitted for batch products of the same type.
3.3.7.2 Switchboards are to be subjected to temperature rise test at the specified load current.
3.3.7.3 Switchboards are to be subjected to functional testing for verifying the function of instruments and switchgear.
3.3.7.4 Switchboards are to be subject to high voltage test as required in Table 3.3.7.4. The test voltage may be applied at any frequency between 25 and 100 Hz and is to be maintained for one minute without breakdown. Instruments and ancillary apparatus may be disconnected during the test.

Test Voltage **Table 3.3.7.4**

Rated voltage (V)	Test voltage a.c. r.m.s.(V)	Test voltage d.c.(V)
$U_n \leq 60$	1000	1415
$60 < U_n \leq 300$	1500	2120
$300 < U_n \leq 690$	1890	2670
$690 < U_n \leq 800$	2000	2830
$800 < U_n \leq 1{,}000$	2200	3110
$1{,}000 < U_n \leq 1{,}500$①	——	3820

Notes: ① For DC only.
② During testing all semi-conductor component parts are to be disconnected from the circuits to be tested and in the meantime, the measuring instruments, condensers, pilot lamps and other ancillary apparatus may also be disconnected.
③ The test voltage is to be applied between all current carrying parts and earthed enclosure, and between current carrying parts of different polarity or phase.

3.3.7.5 Insulation resistance measurement: Immediately after the high-voltage test, the insulation resistance between all current-carrying parts connected together and earth and between all current-carrying parts of different polarity or phase is not to be less than 1 MΩ, tested at least with a DC 500 V megameter.

Section 4 CONTROL GEAR

3.4.1 General requirements
3.4.1.1 The operating wheels or handles of the control gear are to comply with the following requirements:
(1) The temperature is not to exceed 55℃ for those made of metal , and not to exceed 65℃ for those made of insulating material.
(2) They are to be provided with mechanically locking devices so that their operating positions will not be changed due to shock or vibration.

(3) They are to be provided with durable labels to indicate their purposes, positions and effect of movement.

3.4.1.2 The hand wheels of the control gear are to be arranged to rotate clockwise to “raise”, “heave anchor”, “haul in rope”, and counterclockwise to “lower”, “drop anchor”, “pay out rope”, if position “0” is the starting point.

The handles of control gear are to be arranged to move forward to “lower”, “drop anchor”, “pay out rope”, and counterclockwise to “raise”, “heave anchor”, “haul in rope”, if position “0” is the starting point.

3.4.1.3 The control gear is to be provided with protective devices complying with the relevant requirements of Section 5, Chapter 2 of this PART.

3.4.1.4 Suitable means are to be provided for the control push buttons against wrong action due to inadvertent touching.

3.4.1.5 Parallel field windings which allow an open circuit are to be provided with discharge circuits to protect against induced overvoltage.

3.4.2 Plans and documents

3.4.2.1 The following plans and documents are to be submitted for approval:

(1) General plan;

(2) Detailed drawings of main parts;

(3) Technical specifications of the products;

(4) Electrical schematic diagram.

3.4.2.2 The Operation Instructions for the Products is to be submitted for information.

3.4.3 Motor control gear

3.4.3.1 The motor control gear is to be provided with an indicating device to show that the motor is running.

3.4.3.2 The control gear of motors used for various services is also to comply with the relevant requirements of Section 6, Chapter 2 of this PART. The control gear of the steering gear is also to comply with the relevant requirements of Chapter 13, PART THREE of the Rules.

3.4.3.3 The control gear of windlasses, warping winches, and cargo winches is to be provided with a device for emergency disconnection of the circuits.

3.4.3.4 Where windlass motors and warping winch motors have rating equal to or more than 10 kW, their control gears are to be provided with an ammeter to monitor the operating current of the motors, and this ammeter is to be properly illuminated or to be of fluorescent type.

3.4.4 Testing

3.4.4.1 Temperature rise test: Control gear is to be subjected to temperature rise test under normal working conditions. However, for the products of the same type and the same specification, only the first product is required to be tested.

3.4.4.2 Functional test: All control gears are to be subjected to functional testing.

3.4.4.3 High voltage test: The test is to be carried out according to Table 3.3.7.4. The test voltage may be applied at any frequency between 25 and 100 Hz and is to be maintained for one minute without breakdown. Instruments and ancillary apparatus may be disconnected during the test.

3.4.4.4 Insulation resistance test: Immediately after the high voltage test, the insulation resistance is not to be less than 1 MΩ, tested at least with a DC 500 V megameter.

Section 5 CABLES

3.5.1 General requirements

3.5.1.1 Cables are to comply with the requirements of this Section. Those not covered in this Section are to comply with the relevant requirements of acceptable standards[①]. Fire-resisting cables are to additionally comply with the relevant requirements for fire-resisting cables of acceptable standards[②].

---

① Refer to IEC publications 60092-350, 60092-352, 60092-353, 60092-354, 60092-360, 60092-370 and 60092-376.

② Refer to:

IEC publication 60331-1 for testing electric cables of greater than 20 mm overall diameter;

IEC publication 60331-21 or 60331-2 for testing electric cable of up to 20 mm overall diameter;

IEC publication 60331-23 for testing electric data cables;

IEC publication 60331-25 for testing optical fibre cables.

3.5.1.2 Cables manufactured and tested to standards other than those specified in 3.5.1.1 will be accepted provided they are in accordance with an acceptable and relevant international or national standard and are of an equivalent or higher safety level than those listed in 3.5.1.1. However, cables such as flexible cable, fibre-optic cable, etc., used for special purposes may be accepted provided they are manufactured and tested in accordance with the relevant standards accepted by CCS.
3.5.1.3 Structural drawings and technical specifications of cables are to be submitted for approval.

3.5.2 Conductors

3.5.2.1 Conductors are to be of annealed copper with or without metal coating. The component copper wires are to be metal-coated and the wire surface is to appear smooth, uniform and bright when used for conductors having a thermosetting insulation, unless a separator between the conductor and the insulation is provided. The same applies to thermosetting insulation provided suitable type tests demonstrate that no harmful effects occur.
3.5.2.2 Conductor composition and stranding is to be according to IEC 60028 class 2 or class 5 and that adequate flexibility of the finished cable is assured. Cores of multi-core cables are to be readily identifiable.

3.5.3 Insulating materials

3.5.3.1 Permitted insulating materials and maximum rated conductor temperatures are to comply with the requirements of 2.12.2.2 of this PART. Insulating materials are to comply with the provisions of IEC60092-360.

3.5.4 Sheaths

3.5.4.1 The sheath is to be selected from one of those listed in IEC 60092-360 as specified in Table 3.5.4.1.

Sheath Materials **Table 3.5.4.1**

Type of materials		Remarks
Cross-linked material	Polychloroprene rubber	Suitable for use on insulating materials other than cross-linked polyethylene (XLPE); harmful smoke is released in case of fire.
	Chlorosulphonated polyethylene or chlorinated polyethylene rubber	
	Halogen-free rubber	——
Thermoplastic material	Polyvinyl chloride thermoplastic compound	Harmful smoke is released in case of fire.
	Halogen-free thermoplastic compound	——

3.5.4.2 Metal braid armour is to be made of galvanized steel, copper or copper alloy wires. The coverage density of the braid is to be such that the weight of the braid is at least 90% of the weight of a tube of the same metal, having an internal diameter equal to the internal diameter under the braid and a thickness equal to the nominal diameter of the wires forming the braid.
3.5.4.3 A protective bedding is to be inserted beneath armour (of any type). This may be textile tape or braid, chloroprene rubber tape or other suitable material. Textile materials are to be treated against moisture. The bedding is to be compatible with the operating temperature of the cable. It is to be possible to remove the bedding without damaging the underlying part.

3.5.5 Testing

3.5.5.1 Tests in accordance with the relevant acceptable standards① are to be made at the manufacturer prior to delivery.

Section 6 POWER AND LIGHTING TRANSFORMERS

3.6.1 General requirements

3.6.1.1 The requirements of this Section apply to single phase transformers rated at 1 kVA or more and 3-phase transformers rated at 5 kVA or more.

---

① Refer to IEC Publication 60092 or relevant standards.

3.6.1.2 All transformers, except those used for motor starting, are to be double wound or multi wound, with no electrical connection between primary and secondary windings.
3.6.1.3 In general, transformers are to be of dry air-cooled type. The use of liquid-filled transformers is to comply with the following requirements:
(1) Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Such transformers are to have a pressure release device with an alarm and there is to be a suitable means provided to contain any liquid which may leak from the transformer due to the operation of the release device or damage to the tank.
(2) Where forced liquid cooling is used, there is to be temperature monitoring of the cooling medium and transformer windings with an alarm being given when the temperature exceeds a preset limit, and provision is to be made for reducing the load to a level commensurate with the cooling available.
3.6.1.4 Transformers rated at 50 kVA and over are to be inspected by CCS Surveyors during testing and where necessary, during manufacturing.

3.6.2 Plans and documents
3.6.2.1 The following plans and documents are to be submitted for approval:
(1) General plan;
(2) Detailed drawings of main parts including coils, magnetic cores and connection boxes;
(3) Technical specifications of the products.
3.6.2.2 The following plans and documents are to be submitted for information:
(1) Operation instructions for the products;
(2) External wiring diagram.

3.6.3 Voltage regulation
3.6.3.1 The voltage drop of transformers supplying secondary distribution systems from no load to rated load at resistive load is not to exceed the following:
(1) 2.5% for single phase transformers rated more than 5 kVA or 3-phase transformers rated more than 15 kVA;
(2) 5% for single phase transformers rated up to 5 kVA or 3-phase transformers rated up to 15 kVA.

3.6.4 Temperature rise
3.6.4.1 The temperature rise of transformers at any part is not to exceed the values given in Table 3.6.4.1 during continuous operation at rated output, where the ambient air temperature is based on 45℃.

Limit of Temperature Rise **Table 3.6.4.1**

Part of transformer		Limit of temperature rise (K)	Method of measurement
Windings	Class A insulation	55	Resistance method
	Class E insulation	70	
	Class B insulation	75	
	Class F insulation	95	
	Class H insulation	120	
External surface of the magnetic core and structural components		Not to exceed the permissible temperature rise of the insulating material in contact	Thermometer or thermocouple

3.6.5 Short-circuits
3.6.5.1 All transformers are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding for 2 s.

3.6.6 Tests
3.6.6.1 Performance tests (winding resistance measurement, voltage ratio measurement and check of phase displacement, short-circuit impedance and load loss measurement, no-load loss and no-load current measurement, etc.) are to to be carried out to all transformers at the manufacturer and in addition to the tests in 3.6.6.2 to 3.6.6.5 of this Section as a minimum, relevant tests are to be carried out in accordance with the requirements of IEC 60076 series publication and equivalent standards. However, the test required in 3.6.6.2 may only be carried out to the first product for batch products of the same type and specification.
3.6.6.2 Temperature rise test: Transformers are to be tested for temperature rise at rated output or in accordance with accepted standards[①]. The limits of temperature rise are not to exceed the values given in

① Refer to publications of IEC 60076 series or equivalent standards.

Table 3.6.4.1.

3.6.6.3 High voltage test[①②]: Transformers are to be subjected to high voltage test according to Table 3.6.6.3, applying a test voltage between primary and secondary windings and between windings and the earthed enclosure for 1 min without breakdown and flashover.

Voltage of High Voltage Test **Table 3.6.6.3**

Highest voltage (root-mean-square value) kV	Rated short duration power frequency withstand voltage (root-mean-square value) kV
≤ 1.1	3
3.6	10
7.2	20
12.0	28
17.5	38
24.0	50
36.0	70

3.6.6.4 Induced high voltage test: Transformers are to withstand an induced high voltage test with a voltage twice the rated voltage. The duration of the test is to be 1 min with a frequency less than or equal to twice the rated frequency. If the frequency is greater than twice the rated frequency, the duration of the test is to be obtained from the following formula with a minimum of 15 s:

$$t = \frac{60 \times 2 \times \text{rated frequency}}{\text{test frequency}} \quad \text{s}$$

For transformers subject to temperature rise test, the induced high voltage test is to be carried out immediately after the temperature rise test.

3.6.6.5 Insulation resistance test: The insulation resistance of each winding to earth is to be measured, with all other windings, magnetic core, frame and casing or enclosure connected together to earth, and recorded together with the temperature of the transformer at the test.

Section 7 STORAGE BATTERIES

3.7.1 General requirements

3.7.1.1 This Section is applicable to the permanently installed batteries.

3.7.2 Plans and documents

3.7.2.1 The following plans and documents are to be submitted for approval:

(1) General plan;

(2) Detailed drawings of main parts including enclosures and pole plates;

(3) Technical specifications of the products.

3.7.2.2 The Operation Instructions for the Products is to be submitted for information.

3.7.3 Type

3.7.3.1 Storage batteries used on board ships may be of lead-acid or nickel-alkaline type. Other types of batteries are not to be put on board ships without agreement of CCS.

3.7.4 Construction

3.7.4.1 All pole plates are to be of rigid construction, and are to be designed to reduce the shedding of active material to a minimum. The cells are to be so constructed as to prevent spilling of electrolyte due to an inclination of 40° from the normal, and to prevent emission of acid or alkaline spray.

3.7.4.2 The cells are to be grouped in crates or trays of rigid construction and suitable material and equipped with means to facilitate handling. The weight of the assembled batteries is preferably not to exceed 100 kg.

This requirement does not apply to the cells the assembly of which in the above-mentioned crates or trays is impossible due to their weight.

3.7.4.3 Emergency accumulator batteries are to be so designed and arranged as to ensure that they will

---

① For transformers subject to temperature rise test, the high voltage test is to be carried out immediately after the temperature rise test.

② The high voltage test is in general not to be repeated, but if it is necessary, one additional test is permitted to be carried out with a test voltage equal to 75% of the voltage at the first test.

function at full rated power when the ship is upright or when inclined at any angle of list up to 22.5° or when inclined up to 10° either way in the fore or aft direction, or is in any combination of angles within those limits.

3.7.5 Nameplate

3.7.5.1 Each crate or tray is to be provided with a durable nameplate securely attached, indicating the manufacturer's name, type designation, voltage and the ampere-hour rating at a specific rate of discharge (preferably that corresponding to the duty for the specific application 5 h, 10 h or 20 h rating).

Section 8 POWER SEMICONDUCTOR CONVERTORS

3.8.1 General requirements

3.8.1.1 This Section is applicable to power semiconductor convertors using semiconductor rectifying elements such as diodes, reverse blocking triode thyristors etc., and does not apply to convertors for communication and the ancillary apparatus for instrumentation. The conversion may be from AC to DC, from DC to AC, from DC to DC and from AC to AC.

3.8.1.2 Unless otherwise specified by the manufacturer, the maximum permissible junction temperature of the rectifier cells is not to exceed the following values:

Selenium diodes: 70℃;
Silicon diodes: 150℃;
Silicon thyristor: 100℃ (up to 50 A);
125℃ (more than 50 A).

3.8.1.3 Semiconductor convertors are preferably to be of the dry air-cooled type.

3.8.1.4 Liquid-filled semiconductor convertors are preferably to be hermetically sealed. If provision is made for breathing, suitable desiccants are to be provided.

3.8.1.5 Transformers used in combination with semiconductor convertors are to be of two-winding transformers and are to comply with the relevant requirements of Section 6 of this Chapter.

3.8.1.6 Semiconductor convertors or semiconductor components are to be mounted in such a manner that they may be removed from a unit without dismantling the complete unit.

3.8.1.7 Mercury-based fungicides are not to be used in the vicinity of the selenium rectifiers.

3.8.2 Plans and documents

3.8.2.1 The following plans and documents are to be submitted for approval:

(1) General plan;
(2) Electrical schematic diagram;
(3) Technical specifications of the products.

3.8.2.2 The following plans and documents are to be submitted for information:

(1) External wiring diagram;
(2) Specification list of associated electrical appliances;
(3) Operation instructions for the products.

3.8.3 Protection

3.8.3.1 Where forced cooling is provided, the circuit is to be so designed that the convertor cannot remain in operation unless effective cooling is maintained.

3.8.3.2 Semiconductor convertors are to be capable of withstanding the effects of transient over-voltage from the ship's network and the effects of DC voltage rise due to regenerated power.

3.8.3.3 Semiconductor convertors are to be protected against overload and short-circuit in accordance with the requirements of 2.5.14.1 of this PART.

3.8.3.4 For liquid-filled semiconductor convertors, consideration is to be given to the provision of an alarm for excessive liquid temperature and of pneumatic protection devices.

3.8.4 Testing

3.8.4.1 Semiconductor convertors are to be tested at the manufacturer in accordance with the requirements of 3.8.4.2 to 3.8.4.5 of this Section. However, the test required in 3.8.4.2 may be omitted for the products produced in series.

3.8.4.2 Semiconductor convertors are to be subjected to temperature rise test under normal working conditions.

3.8.4.3 Semiconductor convertors are to be subjected to functional test.

3.8.4.4 Semiconductor convertors are to withstand a high voltage test at the following testing voltage (with a minimum of 2,000 V):

$$U_p = 2 \times \frac{U_m}{\sqrt{2}} + 1000 \quad \text{V}$$

where: U_p — the effective value of testing voltage, in V;
U_m — the maximum no-load peak value between any pair of terminals of semiconductor convertors. If the voltage to earth is higher than the voltage between two terminals (e.g. the convertors are connected in series), the higher voltage, in V, is to be taken.

If $U_m/\sqrt{2}$ is less than 90 V, U_p is to be taken as 1,000 V.
This testing voltage is to be alternating at any frequency between 25 and 100 Hz and is to be applied between the live parts and any non-current carrying metal part which may be earthed for a period of 1 min without breakdown or flashover.
3.8.4.5 The insulation resistance between live parts of convertors or their accessories and earth is not to be less than 1 MΩ when tested with a DC 500 V megameter.

Section 9 UNINTERRUPTIBLE POWER SYSTEM

3.9.1 Application
3.9.1.1 The UPS① units specified in this Section apply to the following scenarios:
(1) when providing an alternative power supply or transitional power supply to emergency services as defined in 2.2.2 and 2.2.3, Chapter 2 of this PART;
(2) where required, constituting a means of continuous and uninterruptible power supply to essential services as defined in 1.1.2.1(1), Chapter 1 of this PART;
(3) when providing power supply in accordance with 2.9.6.4, Chapter 2 of this PART.
3.9.1.2 In addition to the scenarios specified in 3.9.1.1, the use of UPS units in other scenarios may refer to the requirements of this Section, subject to the agreement of CCS.

3.9.2 Plans and documents
3.9.2.1 The following plans and documents are to be submitted for approval:
(1) General plan;
(2) Electrical schematic diagram;
(3) Technical specifications of the products.
3.9.2.2 The following plans and documents are to be submitted for information:
(1) External wiring diagram;
(2) Specifications of associated electrical appliances;
(3) Operation instructions for the products.

3.9.3 Design and construction
3.9.3.1 UPS units are to be constructed in accordance with IEC 62040, or an acceptable a standard.
3.9.3.2 The operation of the UPS unit is not to depend upon external services.
3.9.3.3 The configuration and topology of UPS unit employed are to be appropriate to the power supply requirements of the connected load equipment.
3.9.3.4 When external bypass is provided, bypass transfer switch is to be arranged to protect the load against power disturbances or interruption arising from inrush or fault current.
3.9.3.5 The UPS unit is to be monitored and audible and visual alarm is to be given in continuously manned station(s) for:
(1) power supply failure (voltage and frequency) to the connected load;
(2) earth fault;
(3) operation of battery protective device;
(4) when the battery is being discharged;
(5) when the bypass is in operation in case an external bypass is provided;
(6) any other fault and abnormal conditions of UPS unit (as applicable).

3.9.4 Performance
3.9.4.1 The output power is to be maintained for the duration required for the connected equipment as

① Refer to IEC publication 62040-3.

stated in 2.2.2 and 2.2.3 of Chapter 2 of this PART.
3.9.4.2 No additional circuits are to be connected to the UPS unit without verification that the UPS unit has adequate capacity. The UPS unit battery capacity is, at all times, to be capable of supplying the designated loads for the time specified in Chapter 2 of this PART.
3.9.4.3 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

3.9.5 Testing and survey
3.9.5.1 UPS units of 50 kVA and over are to be surveyed by CCS Surveyors during manufacturing and testing. Testing specified in 3.9.5.2 is at least to be completed.
3.9.5.2 Appropriate testing is to be carried out to demonstrate that the UPS unit is suitable for its intended environment. This is expected to include as a minimum the following tests:
(1) Functionality, including operation of alarms specified in 3.9.3.5;
(2) Temperature rise;
(3) Ventilation rate;
(4) Battery capacity.
3.9.5.3 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical test.

Section 10 OTHER ELECTRICAL EQUIPMENT

3.10.1 Incandescent lighting
3.10.1.1 The voltage and load of tungsten filament lamps and lampholders are not to exceed the values specified in Table 3.10.1.1.

Voltage and Load of Tungsten Filament Lamps **Table 3.10.1.1**

Type of lampholders		Voltage (V)	Load
Bayonet cap	B22	250	200W/4A
	B15d	250	250W/4A
	B15s	55	15W/2A
Screw cap	E40	250	3,000W/16A
	E27	250	250W/4A
	E14	250	60W/2A

3.10.1.2 Lampholders are to be constructed of non-toxic, flame-retarding and non-hygroscopic material, and provided with means for locking the lamp in the holder.
3.10.1.3 The temperature rise of terminals for connection of supply cables is not to exceed 40℃. Insulation materials of internal parts are to have temperature class corresponding to the maximum temperature within the luminaires.

3.10.2 Tubular fluorescent lamp
3.10.2.1 The voltage and load of the fluorescent lamps and lampholders are not to exceed the values specified in Table 3.10.2.1.

Voltage and Load of Fluorescent Lamps **Table 3.10.2.1**

Type of lampholders	Voltage (V)	Load (W)
G13	250	115
G5	250	80

3.10.2.2 The construction of fluorescent lamp holders is to comply with the requirements of 3.10.1.2 and 3.10.1.3 of this Section.

3.10.3 Discharge lamps operating at voltages above 250 V
3.10.3.1 Discharge lamps must be securely fixed.
3.10.3.2 All independent ballasts, capacitors and other accessories mounted separately from the luminaires are to be enclosed in earthed metal casing.
3.10.3.3 Warning notices calling attention to “DANGER! HIGH VOLTAGE!” are to be provided in accordance with 2.7.1.3 of this PART.

3.10.4 Heating and cooking appliances

3.10.4.1 Heating elements are to be substantially guarded. The holes of the protective guard are to be sufficiently narrow to prevent foreign bodies from falling in.

3.10.4.2 Heating and cooking appliances are to be so constructed that the temperature of supply cable terminals will not exceed the maximum rated conductor temperature given in Table 2.12.2.2 of this PART.

3.10.4.3 Internal connection wires of heating and cooking appliances are to be continuously insulated with incombustible material. Connections between heating elements are not to be effected by soldering.

3.10.4.4 The insulation resistance of heating and cooking appliances in hot condition is not to be less than 0.5 MΩ.

3.10.4.5 Heating and cooking appliances are to be so constructed that the parts which must be hand-held in use cannot be heated to a temperature exceeding the values given in Table 3.10.4.5.

Maximum Temperature of Hand-Held Parts **Table 3.10.4.5**

Material of handles, grips and the like	Maximum temperature for normal hand-held operation (℃)	
	Long period	Short period
Metal	55	60
Porcelain, vitreous material, moulded material, rubber or wood	65	70

3.10.4.6 Heating and cooking appliances and their control gear fitted in galley spaces are to have a degree of protection of at least IP44. Their enclosures are to be corrosion-resistant and provided with one or more drainage holes.

3.10.4.7 Cooking appliances are to be so constructed that spilling or overflowing of liquid or food will not cause insulation failures or short-circuits.

3.10.4.8 Space heaters are to be so constructed, protected and installed that clothing, bedding or other combustible materials cannot come in contact with them in such a manner as to cause risk of fire. Furthermore, they are to be so constructed that combustible materials cannot be placed on the top of their enclosures.

3.10.4.9 Space heaters are to be equipped with means to interrupt the current when the temperature exceeds the permissible limit.

3.10.5 Accessories to luminaires

3.10.5.1 Accessories are to be so designed and constructed that the passages for the insulated conductors are of ample size and free from rough projections, sharp angles, and abrupt bends. All outlets for cables are to have well-rounded edges or be suitably bushed.

3.10.5.2 Accessories are to be so designed and insulated conductors so installed that stress cannot be applied by the conductors to any terminal to which the conductors may be connected.

3.10.5.3 Accessories are to be so designed and fixed that dust and moisture will not readily accumulate on live parts and their insulation.

3.10.5.4 Enclosures are to be made of metal or halogen-free flame-retardant insulating material.

3.10.5.5 When a socket has an earthing pin, the socket and plug are to have additional connections to earth the casing or frame of appliance. When inserting the plug, the earthing pin is to be connected before the live contact pins.

3.10.5.6 Socket outlets of current rating in excess of 16 A are to be interlocked with a switch such that the plug cannot be inserted or withdrawn when the switch is in the “on” position.

3.10.5.7 Socket outlets and plugs with protection degree of IP56 are to be provided with means to maintain the same degree of protection whether the plug is inserted or withdrawn.

3.10.6 LED luminaires for lighting purpose

3.10.6.1 LED luminaires described in this section are used for general lighting purpose only, excluding navigation lights, signal lights and colorful lights for decoration purpose.

3.10.6.2 LED luminaires are to comply with the provisions of IEC Publication 60598-1 Luminaires – Part 1: General requirements and tests and IEC 62722-2-1 Luminaire performance - Part 2-1: Particular requirements for LED luminaires.

CHAPTER 4 SUPPLEMENTARY REQUIREMENTS FOR CARGO SHIPS OF LESS THAN 500 GROSS TONNAGE

Section 1 CARGO SHIPS OF LESS THAN 500 GROSS TONNAGE

4.1.1 General requirements

4.1.1.1 The requirements of this Chapter apply to electrical installations on cargo ships of less than 500 gross tonnage, and may substitute for the related aforesaid requirements in this PART.

4.1.1.2 Except for tankers carrying dangerous liquid cargoes and ships carrying other dangerous goods, an earth indicator may be used instead of an alarm device for monitoring the insulation level to earth as required in 2.4.2.2 of this PART.

4.1.2 Distribution systems

4.1.2.1 In addition to the distribution systems as referred to in 2.4.1.1 of this PART, an AC three-phase four-wire insulated system may be used.

4.1.3 Main source of electrical power

4.1.3.1 The minimum comfortable conditions of habitability as required in 2.1.1.1(2) of this PART may not be complied with.

4.1.3.2 The requirements in 2.1.1.1(4) and (5) of this PART may not be complied with.

4.1.3.3 Distribution boards are not required to be positioned in accordance with 2.1.4.1 of this PART.

4.1.4 Reserve sources of electrical power

4.1.4.1 The emergency source of electrical power as required in Section 2, Chapter 2 of this PART may not be fitted provided that an independent reserve power source in compliance with the following requirements is fitted.

(1) The reserve power source is to be the accumulator battery in compliance with the following requirements:

① located not in the same space as the main source of electrical power and located above the uppermost continuous deck as far as practicable;

② complying with the requirements of 2.2.1.4(1), (2) and 1.2.1.1(2) of this PART;

③ capable of providing immediately power supply for any equipment as required in 4.4.4.1(2) of this Section.

(2) The capacity of the reserve power source is to be sufficient to supply the following equipment for at least 3 h:

① lighting at muster and embarkation stations, over the sides, in all alleyways, stairways and exits, in cabins accommodating more than 16 persons, and at the main switchboard, reserve power source and control stations;

② navigation lights and other signal lights as required in the International Regulations for Preventing Collisions at Sea;

③ internal communication equipment required in emergency;

④ fire detection and fire alarm system (if any);

⑤ daylight signalling lamp in intermittent operation, the ship's whistle, the manually operated call points (if any) and all internal signals that are required in an emergency (e.g. general emergency alarm system, etc.);

⑥ radio communications on board.

4.1.5 Control box for navigation lights

4.1.5.1 The control box of navigation lights may be supplied by the main switchboard and the reserve power source.

4.1.5.2 The alarms for failure required in 2.7.4.4 of this PART may not be satisfied.

4.1.6 Engineers' alarm system

4.1.6.1 Engineers' alarm system required in 2.8.4 of this PART may not be provided.

4.1.7 Lighting

4.1.7.1 Main engine rooms, large machinery spaces other than main engine rooms, large galleys, passageways (including accesses), stairways leading to boat decks, public spaces and berthing compartments accommodating more than 16 passengers specified in 2.7.2.2, Chapter 2 of this PART may be reduced to requirements only for main engine rooms and boiler rooms.

APPENDIX 1 SHORT-CIRCUIT CURRENTS CALCULATIONS WITH REGARD TO ELECTRICAL INSTALLATIONS

1.1 General Provisions

1.1.1 General requirements

1.1.1.1 This Appendix applies to the calculation of three-phase short-circuit currents that occur on a marine AC electrical installation and short-circuit power factors. The value of a two-phase short-circuit current may be taken as 0.866 times the corresponding value of a three-phase short-circuit current.

1.1.1.2 The calculation methods are for use on unmeshed low and high voltage three-phase alternating current systems operating at 50 Hz or 60 Hz, and having their neutral point connected to the ship's hull through an impedance, or having their neutral point isolated from the ship's hull.

1.1.1.3 The calculating methods described produce sufficiently accurate results to calculate the short-circuit current during the first 100 ms of a fault condition. The results of calculation may be used for:

(1) checking short-circuit making and breaking capacity of the protection devices selected;

(2) checking electrodynamic stability and thermal equilibrium of bus-bars etc.;

(3) providing the basis for design and setting of electrical system protection;

(4) providing the basis for the selection, if necessary, of suitable devices capable of limiting short-circuit currents within the capacity of protective devices.

1.1.1.4 When calculating the maximum short-circuit current, the following are to be considered in the most severe condition, i.e. the condition corresponding to the fully loaded generating plant of ships or offshore installations:

(1) All short-circuit currents fed through generators which may be connected in parallel to the main bus-bar (including the generators transferring load in short time).

(2) All short-circuit currents fed through motors which may be put into service.

1.1.1.5 In general, the short-circuit current is to be calculated at:

(1) output of generators;

(2) main bus-bars;

(3) bus-bars of emergency switchboards, sub-switchboards and distribution boards;

(4) secondary side of power and lighting transformers.

Sometimes, feeder terminal short-circuit currents are additionally to be calculated for design and setting of electrical system protection.

1.1.1.6 The manufacturers are to provide the characteristic parameters of generators, motors, transformers and cables as needed by the calculations and ensure that the parameters are within sufficiently accurate.

1.1.2 Definitions

1.1.2.1 Short-circuit

The accidental or intentional connection, by a relatively low resistance or impedance, of two or more points in a circuit, which are normally at different voltages.

1.1.2.2 Short-circuit current

An over-current resulting from a short circuit due to a fault or an incorrect connection in an electric circuit without any change of the supply.

1.1.2.3 Prospective short-circuit current (with respect to a switching device)

The short-circuit current that would flow in the circuit if each pole of the device were replaced by a conductor of negligible impedance.

1.1.2.4 Symmetrical short-circuit current

The r.m.s. value of the AC symmetrical component of a prospective (available) short-circuit current, the DC component, if any, being neglected.

1.1.2.5 DC component of the short-circuit current

The component of current in the circuit immediately after it has been suddenly short-circuited, all components of fundamentals and harmonics being excluded.

1.1.2.6 Peak short-circuit current

The maximum possible instantaneous value of the prospective (available) short-circuit current.

1.1.2.7 Equivalent generator

In order to calculate short-circuit currents, individual generators and motors in service are combined to form an equivalent generator, the short-circuit current fed through which is equivalent to the sum of the short-circuit currents fed through such generators and motors.

1.1.2.8 Equivalent motor

In order to simplify the calculation of short-circuit currents, individual motors in service, other than large

motors, are combined to form an equivalent motor, the short-circuit current fed through which is equivalent to the sum of the short-circuit currents fed through such motors.

1.1.2.9 Large motor

Any motor rated more than 100 kW or 25% of the rated power of the maximum generator in the system.

1.1.3 Symbols, Subscripts and superscripts

1.1.3.1 General requirements

(1) The symbols, subscripts and superscripts specified in 1.1.3.2 and 1.1.3.3 below are used and uniform units provided in this Appendix.

(2) In case of impedance, reactance, resistance and voltage drops, capital letters denote absolute values and lowercase letters denote relative values (per unit or per cent).

(3) For time-dependent values (current, voltage), capital letters denote r.m.s. values and lowercase letters denote momentary (instantaneous) values.

1.1.3.2 Symbols

(1) Voltage symbols are given in Table 1.1.3.2(1).

Voltage Symbols **Table 1.1.3.2(1)**

Symbol	Name	Unit
E''_{q0}	Subtransient q-axis voltage of a generator	V
E'_{q0}	Transient q-axis voltage of a generator	V
E''_M	Subtransient voltage of a motor	V
U_r	Rated voltage (line to line)	V
U_{rM}	Rated voltage of a motor	V
U_{rT2}	Rated line voltage at the secondary side of a transformer	V
u_K	Rated short circuit voltage of a transformer in %.	%
u_R	Rated ohmic voltage of a transformer in %	%
u_x	Rated ohmic voltage of a transformer in %	%

(2) Current symbols are given in Table 1.1.3.2(2).

Current Symbols **Table 1.1.3.2(2)**

Symbol	Name	Unit
I''_{Kd}, I'_{Kd}	Subtransient and transient short-circuit current of a synchronous generator (r.m.s.)	kA
I''_*, I'_*	Subtransient and transient short-circuit current of an equivalent generator (r.m.s.)	kA
I_*	Current of an equivalent generator (r.m.s.)	kA
I''_M, I''_{M*}	Subtransient short-circuit current of a asynchronous motor and an equivalent motor (r.m.s.)	kA
I_{ac}	Symmetrical short-circuit current at the fault point (r.m.s.)	kA
I_{acG}	Symmetrical short-circuit current of a synchronous generator (r.m.s.)	kA
I_{acM}	Symmetrical short-circuit current of a asynchronous motor (r.m.s)	kA
i_{dc}	DC component of the short-circuit current at the fault point	kA
i_{dcG}	DC component of the short-circuit current of a synchronous generator	kA
i_{dcM}	DC component of the short-circuit current of an asynchronous motor	kA
i_K	Upper envelope of the short-circuit current	kA
I_{K*}	Steady state short-circuit current of an equivalent generator (r.m.s.)	kA
I_{Kd}	Steady state short-circuit current of a synchronous machine (r.m.s.)	kA
i_M	Upper envelope of the short-circuit current of a asynchronous motor	kA
i_{pG}	Peak value of the short-circuit current of a synchronous machine	kA
i_{pM}	Peak value of the short-circuit current of an asynchronous motor	kA
i_p	Peak value of the short-circuit current at the fault point	kA
I_r	Rated current (r.m.s.)	kA
I_{ac2}	Symmetrical short-circuit current at the secondary side of a transformer (r.m.s.)	kA
i_{K2}	Upper envelope of the short-circuit current at the secondary side of a transformer	kA
i_{p2}	Peak value of the short-circuit current at the secondary side of a transformer	kA
I_{CR}	Rated short-circuit breaking capacity of a circuit breaker, as given	kA

Symbol	Name	Unit
I_{Cr}	Rated short-circuit breaking capacity of a circuit breaker, as converted	kA

(3) Symbols of reactance, resistance and impedance are given in Table 1.1.3.2(3).

Symbols of Reactance, Resistance and Impedance **Table 1.1.3.2(3)**

Symbol	Name	Unit
R	Resistance	mΩ
r	Cable resistance per unit length	mΩ/m
R_*	Stator resistance of an equivalent generator	mΩ
R_a	Stator resistance of a synchronous generator	mΩ
R_M	Resistance of an asynchronous motor	mΩ
R_R	Rotor resistance of an asynchronous motor as converted to the stator side	mΩ
R_{R*}	Rotor resistance of an equivalent asynchronous motor as converted to the stator side	mΩ
R_S	Stator resistance of an asynchronous motor	mΩ
R_{S*}	Stator resistance of an equivalent asynchronous motor	mΩ
R_T	Resistance of a transformer	mΩ
X	Reactance	mΩ
x	Cable reactance per unit length	mΩ/m
X''_*, X'_*	Subtransient and transient reactance of an equivalent generator	mΩ
X''_d, X'_d	Subtransient and transient reactance of a synchronous generator in the d-axis	mΩ
X''_M	Subtransient reactance of an asynchronous motor	mΩ
X''_{M*}	Subtransient reactance of an equivalent asynchronous motor	mΩ
X_R	Rotor reactance of an asynchronous motor as converted to the stator side	mΩ
X_S	Stator reactance of an asynchronous motor	mΩ
X_d	Reactance of a synchronous generator in the d-axis	mΩ
X_T	Reactance of a transformer	mΩ
Z	Impedance	mΩ
Z_*	Equivalent impedance	mΩ
Z''_d, Z'_d	Subtransient and transient impedance of a synchronous generator	mΩ
Z''_*, Z'_*	Subtransient and transient impedance of an equivalent generator (including circuit impedance)	mΩ
Z''_M	Subtransient impedance of an asynchronous motor	mΩ
Z''_{M*}	Subtransient impedance of an equivalent asynchronous motor	mΩ
Z_T	Impedance of a transformer	mΩ
R_{e1}	Primary cable resistance of a transformer	mΩ
R_{e2}	Cable resistance at the secondary side of a transformer as converted to the primary side	mΩ
X_{e1}	Primary cable reactance of a transformer	mΩ
X_{e2}	Cable reactance at the secondary side of a transformer as converted to the primary side	mΩ

(4) Symbols of time and time constants are given in Table 1.1.3.2(4).

Symbols of time and time constants **Table 1.1.3.2(4)**

Symbol	Name	Unit
t	Time duration from the beginning of a short circuit	ms
t_x	Defined time duration from the beginning of a short circuit	ms
T''_d, T'_d	Subtransient and transient time constant of a synchronous generator in the d-axis	ms
T''_{d*}, T'_{d*}	Subtransient and transient time constant of an equivalent generator in the d-axis	ms
T''_e, T'_e	Subtransient and transient time constant of a synchronous generator including non-active components	ms
T''_M, T''_{M*}	Subtransient time constant of an asynchronous motor and an equivalent asynchronous motor	ms
T''_{Me}	Subtransient time constant of an asynchronous motor including the connecting cables	ms
T_{dc}, T_{dc*}	DC time constant of a synchronous generator and an equivalent generator	ms

Symbol	Name	Unit
T_{dce}	DC time constant of a synchronous generator including non-active components	ms
T_{dcM} , T_{dcM*}	DC time constant of an asynchronous motor and an equivalent asynchronous motor	ms
T_{dcMe}	DC time constant of an asynchronous motor including the connecting cables	ms

(5) Power symbols are given in Table 1.1.3.2(5).

Power Symbols **Table 1.1.3.2(5)**

Symbol	Name	Unit
S_{rG}	Rated apparent power of a synchronous generator	kVA
P_{rG}	Rated power of a synchronous generator	kW
P_{rM}	Rated output power of an asynchronous motor	kW
P_{rM*}	Rated output power of an equivalent asynchronous motor	kW
S_{rT}	Rated apparent power of a transformer	kVA
P_K	Short circuit losses of a transformer	kW

(6) Other symbols are given in Table 1.1.3.2(6).

Other Symbols **Table 1.1.3.2(6)**

Symbol	Name	Unit
$\cos\varphi_K$	Power factor of a short circuit	
$\cos\varphi_r$	Rated power factor of a generator	
$\cos\varphi_M$	Rated power factor of an asynchronous motor	
η_M	Efficiency of an asynchronous motor	
a	Number of parallel cables	
A_i	Fault point at the power end of a generator breaker	
B_i	Fault point adjacent to the main bus-bar	
C_i	Fault point in the feeder circuit of primary distribution system outside the main bus-bar	
D_i	Fault point at the secondary side of a transformer	
e	Radix of exponential	
f	Frequency	Hz
l	Cable length	m
n	Coefficient of peak value	
S	Sectional area of cable	mm^2
T	Period	ms
CB	Circuit breaker	
FU	Fuse	

1.1.3.3 Subscripts and superscripts

(1) Symbols of subscripts are given in Table 1.1.3.3(1).

Symbols of Subscripts **Table 1.1.3.3(1)**

Symbol	Meaning
*	Equivalent generator and equivalent asynchronous motor
0	Prefault condition
a	**ARMATURE**
ac	**ALTERNATING CURRENT**
d	**DIRECT AXIS**
dc	Direct current
e	Value including non-active components (external)
E, I, U	phasor of E,I and U
G	Synchronous generator
i	Number of generators
j	Number of motors
K	Short circuit
M	Asynchronous motor or group of asynchronous motors
q	Quadrature-axis
R	Rotor of an asynchronous motor

Symbol	Meaning
S	Stator of an asynchronous motor
T	Transformer
$\underline{Z}$	Complex impedance

(2) Symbols of superscripts are given in Table 1.1.3.3(2).

Symbols of Superscripts **Table 1.1.3.3(2)**

Symbol	Meaning
”	Subtransient value
,	Transient value

1.2 Calculation of Short-circuit Currents

1.2.1 Basic assumptions

1.2.1.1 The formulae described herein, calculate the upper envelope of the maximum value of the time dependent short-circuit current (see Figure 1.2.2.2). The envelope is calculated using particular machine characteristic parameters obtainable from equipment manufacturers using recognized testing methods, and applying the following assumptions:

(1) all system capacitances are neglected;

(2) at the start of the short circuit, the instantaneous value of voltage in one phase at the fault point is zero;

(3) during the short circuit, there is no change in the short-circuit current path;

(4) the short-circuit arc impedance is neglected. The impedance of the bus-bar, potential transformer (PT) and the contact resistance of the connecting points between the conductors are also neglected;

(5) transformers are set at the main tap position;

(6) the short circuit occurs simultaneously in all three phases;

(7) in the prefault condition, the generator is operated at its rated values of load;

(8) for generators connected in parallel, all generators share their active and reactive load proportionally at the start of and during the short circuit;

(9) during each discrete time interval, all circuit components react linearly.

With the above assumptions, the calculation results are considered to be acceptable for the engineering objectives.

1.2.2 Calculation of the short-circuit current fed through a synchronous machine

1.2.2.1 General

(1) The synchronous machines used on marine/offshore electrical installations comprise synchronous generators, motors and condensers. The short-circuit currents produced by these machines are fundamental to the calculation of the short-circuit current of an electrical system.

During the first few cycles of a short circuit, all synchronous machines respond in a similar way and accordingly the short-circuit current produced has the same basic characteristics.

(2) Equivalent electrical circuit

When the three-phase terminal short-circuit current of a synchronous generator occurs, the equivalent electrical circuit under subtransient and transient conditions are as shown in Figure 1.2.2.1.

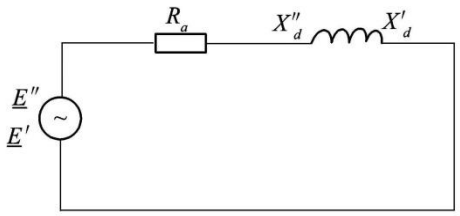
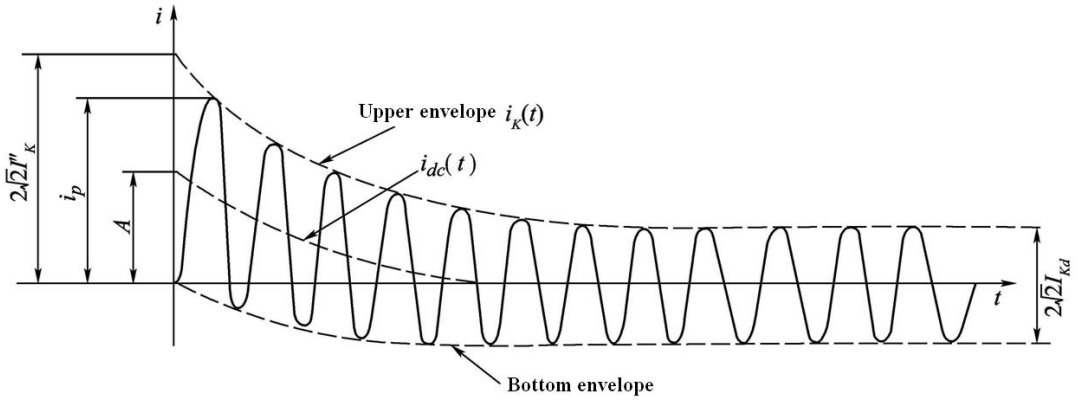


Figure 1.2.2.1 Equivalent Electrical Circuit of the Three-Phase Terminal Short-Circuit Current of a Synchronous Generator

1.2.2.2 Three-phase short-circuit current

(1) The three-phase short-circuit current condition occurs when all three phase are simultaneously shorted together. The resulting current is a complex time-dependent function occurring in each phase. The time-dependent oscillogram of the typical three-phase terminal short-circuit current of a synchronous generator is shown in Figure 1.2.2.2. The current consists of a synchronous short-circuit current (AC components) and DC components.



I''_K – Initial symmetrical short-circuit current; i_p – Peak short-circuit current; I_{Kd} – Steady-state short-circuit current;

i_{dc} – Decaying (aperiodic) component of short-circuit current; A – Initial value of the aperiodic component

Figure 1.2.2.2 Terminal Short-Circuit Current Time Function of a Typical Synchronous Generator on No-Load

1.2.2.3 Calculation of the shot-circuit current

(1) When calculating the short-circuit current, it is usual to consider only the highest values of the current, Figure 1.2.2.2 shows that the highest values vary as a function of time along the upper envelope of the complex time-dependent function. The current $i_K(t)$ defined by this upper envelope is calculated from formula (1):

$$i_K(t) = \sqrt{2} I_{ac}(t) + i_{dc}(t) \tag{1}$$

(2) The calculation of symmetrical short-circuit current $I_{ac}(t)$

$I_{ac}(t)$ may be calculated using the following formulae:

$$I_{ac}(t) = (I''_{Kd} - I'_{Kd}) \cdot e^{-t/T''_d} + (I'_{Kd} - I_{Kd}) \cdot e^{-t/T'_d} + I_{Kd} \tag{2}$$

$$I''_{Kd} = \frac{E''_{q0}}{Z''_d} = \frac{E''_{q0}}{\sqrt{R_a{}^2 + X''_d{}^2}} \tag{3}$$

$$I'_{Kd} = \frac{E'_{q0}}{Z'_d} = \frac{E'_{q0}}{\sqrt{R_a{}^2 + X'_d{}^2}} \tag{4}$$

$$E''_{q0} = \sqrt{(\frac{U_r}{\sqrt{3}}\cos\varphi_r + R_a \cdot I_r)^2 + (\frac{U_r}{\sqrt{3}}\sin\varphi_r + X''_d \cdot \mathrm{I}_r)^2} \tag{5}$$

$$E'_{q0} = \sqrt{(\frac{U_r}{\sqrt{3}}\cos\varphi_r + R_a \cdot I_r)^2 + (\frac{U_r}{\sqrt{3}}\sin\varphi_r + X'_d \cdot \mathrm{I}_r)^2} \tag{6}$$

(3) I_{Kd} is the steady-state short-circuit current and to be obtained from the manufacturer.

(4) The calculation of the DC component $i_{dc}(t)$

$i_{dc}(t)$ may be calculated from the following formula (7):

$$i_{dc}(t) = \sqrt{2}(I''_{Kd} - I_r \cdot \sin\varphi_r) \cdot e^{-t/T_{dc}} \tag{7}$$

(5) The calculation of the peak value i_p of the short-circuit current

The peak value of the short-circuit current occurs between time t = 0 and t = T/2 of the short-circuit condition. The exact time depends on the preload conditions, the generator impedance and time constants. In general, it is acceptable to calculate i_p at time T/2, i.e. at the first half cycle of the short-circuit condition, using formula (8):

$$i_p = \sqrt{2} I_{ac}(\frac{T}{2}) + i_{dc}(\frac{T}{2}) \tag{8}$$

1.2.3 Calculation of the short-circuit current fed through a asynchronous motor

1.2.3.1 General

(1) Quite a number of asynchronous motors are fitted on ships and offshore installations, which can be considered in two broad groups, i.e. large motors and small motors. The grouping depends upon both the system generator capacity and the actual motor rating.

(2) When a short circuit occurs on a system, all motors connected at instant of short circuit, contribute to the short-circuit current. In general large motors must be evaluated individually. Small motors may be grouped together and treated as an equivalent single source.

1.2.3.2 Equivalent electrical circuit

(1) Where the three-phase terminal short-circuit current of an asynchronous motor occurs, the equivalent electrical circuit is as shown in Figure 1.2.3.2.

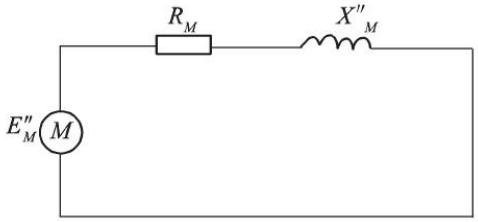


Figure 1.2.3.2 Equivalent Electrical Circuit of the Three-Phase Terminal Short-Circuit Current of an Asynchronous Motor

1.2.3.3 Basic calculation of three-phase short-circuit currents

(1) The upper envelope $i_M(t)$ of the maximum values of the three-phase short-circuit current of an asynchronous motor may be obtained from the following formula:

$$i_M(t) = \sqrt{2} I_{acM}(t) + i_{dcM}(t) \tag{9}$$

(2) The calculation of the symmetrical short-circuit current $I_{acM}(t)$

$I_{acM}(t)$ may be obtained from formula (10):

$$I_{acM}(t) = I''_M \cdot e^{-t/T''_M} \tag{10}$$

If the preload condition is ignored, I''_M may be obtained from the formula (11):

$$I''_M = \frac{U_{rM}}{\sqrt{3} \cdot \sqrt{(R_R + R_S)^2 + (X_R + X_S)^2}} = \frac{U_{rM}}{\sqrt{3} \cdot \sqrt{R_M{}^2 + X''_M{}^2}} \tag{11}$$

(3) Where the of preload condition is ignored, the DC component $i_{dcM}(t)$ and the peak value i_{pM} of the short-circuit may be obtained from formulae (12) and (13) respectively:

$$i_{dcM}(t) = \sqrt{2} I''_M \cdot e^{-t/T_{dcM}} \tag{12}$$

$$i_{pM} = \sqrt{2} I_{acM}(\frac{T}{2}) + i_{dcM}(\frac{T}{2}) \tag{13}$$

1.2.3.4 Calculation of the short-circuit current of large motors

(1) For large motors defined in 1.1.2.9, the terminal short-circuit current is to be calculated using respectively the calculation methods given in 1.2.3.3.

(2) If insufficient motor data are available, the following approximate values for the motor characteristic parameters may be used:

① Motor impedance (for both 50 Hz and 60 Hz installations)

$z''_M = 0.16$

$x''_M = 0.15$

$r_s = 0.034$

$r_R = 0.021$

② Time constants

At 50 Hz, T''_M = 22.4 ms, T_{dcM} = 14.08 ms

At 60 Hz, T''_M = 18.67 ms, T_{dcM} = 11.73 ms

1.2.3.5 Calculation of the short-circuit current of small motors

(1) Comparatively speaking, except large motors involved in 1.2.3.4(1), all other motors fitted on ships or offshore installations belong to small motors. The total motor group including their connecting cables may be considered as a single equivalent motor and if insufficient motor data are available, the following approximate values for the motor characteristic parameters may be used:

① Motor impedance (for both 50 Hz and 60 Hz installations)

$z''_M = 0.2$

$x''_M = 0.188$

$r_S = 0.043$

$r_R = 0.027$

② Time constants

At 50 Hz, T''_M = 22.4 ms, T_{dcM} = 14.08 ms

At 60 Hz, T''_M = 18.67 ms, T_{dcM} = 11.73 ms

(2) The rated output of the equivalent motor may be calculated in accordance with the Electrical Load Calculations or may be taken as 60% of the total rated active output of actually running generators (excluding those transferring loads in short time) minus the sum of the rated outputs of individual large motors.

1.2.4 Effects of non-active component impedances on short-circuit currents

1.2.4.1 General

(1) In actual electrical systems, the cables, transformers and reactors connected in series with synchronous motors and asynchronous motors are to be also taken into account. Although these components do not feed the short-circuit current, they have a significant impact on the value of the short-circuit current. In general, the net effect is a lower value of short-circuit current which decays more slowly.

1.2.4.2 Effects on short-circuit current of generators

(1) Non-active component impedances R_e and X_e are taken into account by increasing the impedance of the active components, and in formulae (3) and (4) Z''_d and Z'_d are to be replaced by Z''_e and Z'_e where

$$Z''_e = \sqrt{(R_a + R_e)^2 + (X''_d + X_e)^2} \tag{14}$$

$$Z'_e = \sqrt{(R_a + R_e)^2 + (X'_d + X_e)^2} \tag{15}$$

For steady-state short-circuit currents accordingly:

$$Z_e = \sqrt{(R_a + R_e)^2 + (X_d + X_e)^2} \tag{16}$$

However, the effects of the cable impedance on steady-state short-circuit currents between the generator and the main switchboard near the main bus-bar may be ignored.

(2) Time constants T''_d, T'_d and T_{dc} are also changed and become T''_e, T'_e and T_{dce}

$$T''_e = \frac{[(R_a + R_e)^2 + (X''_d + X_e)^2] \cdot X'_d \cdot T''_d}{[(R_a + R_e)^2 + (X''_d + X_e)(X'_d + X_e)] \cdot X''_d} \tag{17}$$

$$T'_e = \frac{[(R_a + R_e)^2 + (X'_d + X_e)^2] \cdot X_d \cdot T'_d}{[(R_a + R_e)^2 + (X'_d + X_e)(X_d + X_e)] \cdot X'_d} \tag{18}$$

$$T_{dce} = \frac{T_{dc} + 1000 X_e / (2\pi f R_a)}{1 + R_e / R_a} \tag{19}$$

1.2.4.3 Effects on short-circuit current of motors

(1) The impedance is increased and in formula (11) R_M and X''_M are to be replaced by R_{Me} and X''_{Me} where

$$R_{Me} = R_R + R_S + R_e \tag{20}$$

$$X''_{Me} = X_R + X_S + X_e \tag{21}$$

(2) Time constant changes

The subtransient time constant:

$$T''_{Me} = \frac{1000 X''_{Me}}{2\pi f R_R} \tag{22}$$

The DC time constant:

$$T''_{dcMe} = \frac{1000 X''_{Me}}{2\pi f (R_s + R_e)} \tag{23}$$

1.2.5 Calculation of short-circuit currents at the main bus-bar

1.2.5.1 General

(1) Owing to neglecting the contact resistance between bus-bars, mutual inductors and conductors, the short circuits within the main bus-bar in the main switchboard are regarded as the short circuit at the main bus-bar.

1.2.5.2 Calculation of the short-circuit current

(1) With the assumption that a ship's electrical system is provided with *i* generators and *j* motors connected in parallel to the main bus-bar, the maximum short-circuit current at the main bus-bar is to be calculated as follows:

① First, the short-circuit current fed through each individual generator and motor is to be calculated in accordance with the requirements of 1.2.2, 1.2.3 and 1.2.4 of this Appendix.

② The maximum short-circuit current at the main bus-bar is to be the algebraic sum of short-circuit currents of individual generators and motors, i.e.:

$$I_{ac}(t) = \sum_i I_{acG}(t)_i + \sum_j I_{acM}(t)_j \tag{24}$$

$$i_{dc}(t) = \sum_i i_{dcG}(t)_i + \sum_j i_{dcM}(t)_j \tag{25}$$

$$i_K(t) = \sum_i i_{KG}(t)_i + \sum_j i_{KM}(t)_j \tag{26}$$

1.2.6 Calculation of the short-circuit current at the feeder circuit outside the main bus-bar

1.2.6.1 Application of the equivalent generator

(1) In order to calculate the short-circuit current at the feeder outside the main bus-bar, all generators and motors, which feed the short-circuit current to fault points, are to be combined to form an equivalent generator at the point of common connection (at the main bus-bar). The short-circuit current fed through the equivalent generator is equal to the sum of the short-circuit currents fed through individual generators and motors.

1.2.6.2 Determination of the characteristic parameters of an equivalent generator

(1) As mentioned above, the short-circuit current fed through the equivalent generator at the main bus-bar is correspondingly equal to the sum of the short-circuit currents fed through individual generators and motors, i.e.:

$$I_{ac}(t)_* = \sum_i I_{acG}(t)_i + \sum_j I_{acM}(t)_j \tag{27}$$

$$i_{dc}(t)_* = \sum_i i_{dcG}(t)_i + \sum_j i_{dcM}(t)_j \tag{28}$$

$$I''_* = \sum_i I''_{Kdei} + \sum_j I''_{Mej} \tag{29}$$

$$I'_* = \sum_i I'_{Kdei} \tag{30}$$

$$I_{K*} = \sum_i I_{Kdei} \tag{31}$$

(2) As in the case of a single generator, the time function $I_{ac}(t)_*$ of the symmetric short-circuit current of the equivalent generator is corresponding to formula (2) as follows:

$$I_{ac}(t)_* = (I''_* - I'_*) \cdot e^{-t/T''_{d*}} + (I'_* - I_{K*}) \cdot e^{-t/T'_{d*}} + I_{K*} \tag{32}$$

Assuming $M_* = I''_* - I'_*$

$N_* = I'_* - I_{K*}$

formula (32) may be rewritten as:

$$I_{ac}(t)_* = M_* \cdot e^{-t/T''_{d*}} + N_* \cdot e^{-t/T'_{d*}} + I_{K*} \tag{33}$$

(3) Determination of equivalent generator subtransient time constant T''_{d*}

Ignoring the transient decay of the short circuit of the generator, the time-dependent function $K''(t)$ of the symmetric short-circuit current for each generator may be expressed as follows:

$$K''(t) = (I''_{Kd} - I'_{Kd}) \cdot e^{-t/T''_d} + I'_{Kd} \tag{34}$$

For the equivalent generator accordingly:

$$K''(t)_* = M_* \cdot e^{-t/T''_{d*}} + I'_* \tag{35}$$

The following is obtained from formulae (27) and (10):

$$K''(t)_* = \sum_i K''(t)_i + \sum_j I''_{Mj} \cdot e^{-t/T''_M} \tag{36}$$

$K''(t_x)_*$ may be obtained using formula (36) where $t = t_x$, then:

$$T''_{d*} = \frac{-t_x}{\ln\left[(K''(t_x)_* - I'_*)/M_*\right]} \tag{37}$$

(4) Determination of equivalent generator transient time constant T'_{d*}

The symmetric short-circuit current fed through the equivalent generator may be calculated using formula (33) where $t = t_x$:

$$I_{ac}(t_x)_* = M_* \cdot e^{-t_x/T''_{d*}} + N_* \cdot e^{-t_x/T'_{d*}} + I_{K*} \tag{38}$$

Similarly, $I_{ac}(t_x)_*$ may be obtained as follows:

$$I_{ac}(t_x)_* = \sum_i I_{acG}(t_x)_i + \sum_j I_{acM}(t_x)_j \tag{39}$$

Accordingly T'_{d*} may be obtained from:

$$T'_{d*} = \frac{-t_x}{\ln\{[I_{ac}(t_x)_* - (M_* \cdot e^{-t_x/T''_{d*}} + I_{K*})]/N_*\}} \tag{40}$$

(5) Determination of DC time constant T_{dc*}

The DC component of the short-circuit current fed through the equivalent generator for $t = t_x$ may be calculated as follows:

$$i_{dc}(t_x)_* = \sqrt{2} I''_* \cdot e^{-t_x/T_{dc*}} \tag{41}$$

and $i_{dc}(t_x)_*$ may be calculated also as follows:

$$i_{dc}(t_x)_* = \sum_i i_{dcG}(t_x)_i + \sum_j i_{dcM}(t_x)_j \tag{42}$$

Accordingly T_{dc*} may be calculated from:

$$T_{dc*} = \frac{-t_x}{\ln[i_{dc}(t_x)_*/(\sqrt{2} I''_*)]} \tag{43}$$

(6) Determination of impedances

Where the preload condition is ignored, the equivalent generator impedance may be obtained as follows:

$$R_* = \frac{1000 X''_*}{2\pi f T_{dc*}} \tag{44}$$

Assuming $C = \frac{1000}{2\pi f T_{dc*}}$,

Hence $R_* = C X''_*$

$$Z''_* = U_r/(\sqrt{3} I''_*) \tag{45}$$

$$Z'_* = U_r/(\sqrt{3} I'_*) \tag{46}$$

$$Z_* = U_r/(\sqrt{3} I_*) \tag{47}$$

Hence:

$$X''_* = \frac{Z''_*}{\sqrt{1 + C^2}} \tag{48}$$

$$X'_* = \sqrt{Z'^2_* - R_*^2} \tag{49}$$

$$X_* = \sqrt{Z_*^2 - R_*^2} \tag{50}$$

1.2.6.3 Calculation of the short-circuit current at the feeder outside the main bus-bar

(1) First, characteristic parameters of an equivalent generator at the main bus-bar are to be obtained in accordance with the above-mentioned requirements of 1.2.6.2. Then the short-circuit current at any point on the feeder outside the main bus-bar may be calculated in accordance with the requirements of 1.2.2 and 1.2.4.

(2) When the short-circuit current at the feeder of a large motor is calculated, the impact of the motor may not be taken into account.

1.2.6.4 Calculation of the short-circuit current at secondary side of transformers

(1) This belongs to one of the cases of the short circuit at the feeder outside the main bus-bar, only the transformer impedance is considered as one part of the circuit impedance (for impedance calculation see 1.4.2), and the changes of the transformer impedance are to be also considered.

1.2.7 Simplified calculation of short-circuit currents

1.2.7.1 Synchronous machines

(1) If the stator resistance is unavailable it may be ignored in formulae (3), (4), (5) and (6). For a short-circuit current calculated at the terminals of a machine, the result will be higher but well within

acceptable tolerances. For system calculations, the error is negligible.
(2) If the preload condition, I_0, is ignored, i.e. assuming a generator on no load in formulae (5), (6), (7) and (8), the values of E''_{q0} and E'_{q0} may be assumed to be equal to $U_r / \sqrt{3}$, and results in lower calculated value (generally less than 10%).
(3) If the transient AC component decay is ignored, formula (2) becomes:

$$I_{ac}(t) = (I''_{Kd} - I'_{Kd}) \cdot e^{-t/T''_d} + I'_{Kd} \tag{51}$$

Excessive inaccuracies occur in the peak short-circuit current for formula (51). Such inaccuracies will invalidate any results calculated beyond the first half-cycle of the fault condition, and accordingly this approximation is not recommended when time-dependent calculations are required.
(4) If the short-circuit current decay is ignored and stator resistance and preload current are ignored for the terminal short-circuit, the AC component of the short-circuit current may be assumed to be a ratio of a constant voltage divided by constant subtransient reactance and the DC component as a proportional constant, i.e.:

$$I_{ac} = U_r / \sqrt{3} X''_d \tag{52}$$

$$i_p = \sqrt{2} I_{ac} + i_{dc} = 1.8(\sqrt{2} I_{ac}) \tag{53}$$

These assumptions are only to be made when estimating approximate values, as the results will produce excessive positive errors for calculations required beyond the first 0.5 cycles.
1.2.7.2 Asynchronous motors
(1) As a first approximation, it may be assumed that all asynchronous motors connected at the time of the short-circuit, contribute an AC short-circuit current equal to their starting current (usually 4 to 7 times the machine's normal full load current).
It may also be assumed that the motor contribution is constant throughout the complete short-circuit fault period.
Such assumptions will give higher values of short-circuit currents than will occur on the actual installation. The error will depend upon the number and size of motors connected.
(2) As above mentioned in 1.2.3.3(2) of this Appendix, if the preload condition is ignored when the short-circuit current of motors is calculated, the preload motor condition can be neglected with negligible errors.
(3) On the basis of asynchronous motor characteristic parameters given in 1.2.3.4(2) and 1.2.3.5(1) of this Appendix, the short-circuit current fed through the motor, with a short circuit occurring near the main bus-bar, may be calculated as follows:

① Large motors:

$I''_M = 6.25 I_{rM}$

$I_{acM} = 4.00 I_{rM}$ (for $t = T/2$)

$i_{pM} = 10 I_{rM}$

② Small motors:

$I''_M = 5 I_{rM}$

$I_{acM} = 3.2 I_{rM}$ (for $t = T/2$)

$i_{pM} = 8 I_{rM}$

(4) If insufficient data is available, the motor rated current may be evaluated using the following formula:

$$I_{rM} = \frac{P_{rM}}{\sqrt{3} \cdot U_{rM} \cdot \eta_M \cdot \cos\varphi_M} \tag{54}$$

where $\eta_M \cdot \cos\varphi_M$ may be calculated from the following formula:

$$\eta_M \cdot \cos\varphi_M = 0.76$$

(5) The short-circuit current of asynchronous motor designed to work in limited service, whose parameters are not completely known, may be calculated assuming the motor is in continuous service and operating at reduced power.

1.3 Calculation of Circuit Power Factor

1.3.1 General

1.3.1.1 The rated short-circuit breaking capacity of the circuit breaker is related to the short-circuit power factor for the interruption of power in the circuit, and the power factor of a short circuit near the main bus-bar on marine and offshore AC electrical installations is generally less than those used for circuit breaker short-circuit tests. Therefore, the short-circuit power factor is to be calculated and if necessary, the short-circuit breaking capacity of the selected breaker is to be converted in accordance with the conversion

coefficient provided by the manufacturer. If insufficient data are available, the method given in Appendix B of this Appendix can be used for conversion (not applicable to the circuit breaker with time delay).

1.3.2 Calculation of short-circuit power factor

1.3.2.1 For the short-circuit at a certain point in way of the feeder outside the main bus-bar, the short-circuit power factor during subtransient periods may be calculated using formula (55):

$$\cos\varphi_K = \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}} \tag{55}$$

1.3.2.2 For the short-circuit near the main bus-bar, the short-circuit power factor during subtransient periods may be calculated in accordance with formula (55), but $R_e = 0$ and $X_e = 0$ are to be taken.

1.4 Calculation and Conversion for Reactance, Resistance and Impedance

1.4.1 Conversion for generator/motor reactance and resistance

1.4.1.1 Conversion for generator reactance and resistance

(1) Conversion for subtransient reactance acting in the direct axis is as follows:

$$X''_d = x''_d \frac{U_r}{\sqrt{3} I_{rG}} = x''_d \frac{U^2{}_r}{S_{rG}} \tag{56}$$

(2) Transient reactance acting in the direct axis:

$$X'_d = x'_d \frac{U_r}{\sqrt{3} I_{rG}} = x'_d \frac{U^2{}_r}{S_{rG}} \tag{57}$$

(3) Conversion for stator resistance:

$$R_a = r_a \frac{U_r}{\sqrt{3} I_{rG}} = r_a \frac{U^2{}_r}{S_{rG}} \tag{58}$$

1.4.1.2 Conversion for motor resistance and reactance

(1) Conversion for motor subtransient resistance and reactance:

$$X''_M = x''_M \frac{U_{rM}}{\sqrt{3} I_{rM}} = x''_M \frac{U^2{}_{rM} \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}} \tag{59}$$

$$R_s = r_s \frac{U_{rM}}{\sqrt{3} I_{rM}} = r_s \frac{U^2{}_{rM} \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}} \tag{60}$$

$$R_R = r_R \frac{U_{rM}}{\sqrt{3} I_{rM}} = r_R \frac{U^2{}_{rM} \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}} \tag{61}$$

1.4.2 Calculation and conversion for transformer reactance, resistance and impedance

1.4.2.1 Calculation and conversion for transformer reactance and resistance may be carried out using the following formulae:

$$Z_T = u_K \frac{U^2{}_r}{S_{rT}} \tag{62}$$

$$R_T = P_K \frac{U^2{}_r}{S^2{}_{rT}} \tag{63}$$

$$X_T = \sqrt{Z_T{}^2 - R_T{}^2} \tag{64}$$

$$R_T = r_T \frac{U^2{}_r}{S_{rT}} = u_R \frac{U_r{}^2}{S_{rT}} \tag{65}$$

$$X_T = x_T \frac{U^2{}_r}{S_{rT}} = u_X \frac{U_r{}^2}{S_{rT}} \tag{66}$$

1.4.3 Calculation for cable resistance and reactance

1.4.3.1 Cable reactance and resistance can be calculated using the following formulae:

$$R = rl / a \tag{67}$$

$$X = xl / a \tag{68}$$

Appendix A Examples of Calculation

A.1 The diagrammatic sketch of an electrical system

A.1.1 The diagrammatic sketch of an electrical system indicating the position of each fault point is as shown in Figure A.1.1

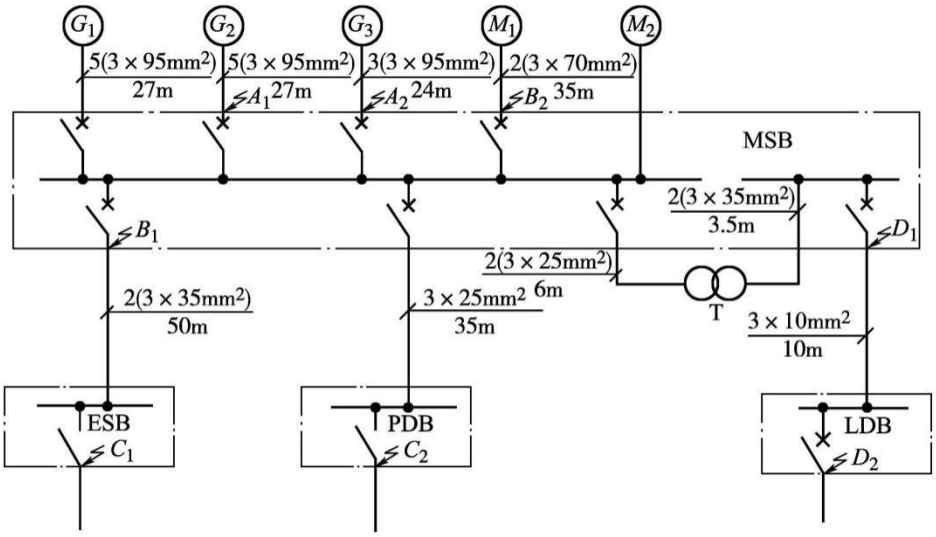


Figure A.1.1 Diagrammatic Sketch of Electrical System

A.2 Parameters for calculation

A.2.1 Generator parameters for calculation are given in Table A.2.1.

Generator Parameters **Table A.2.1**

Code	G_1, G_2	G_3
Type	IFC5502-8TA42	IFC5354-4
S_{rG} (kVA)	550	312.5
U_r (V)	400	400
I_{rG} (kA)	0.79	0.451
f (Hz)	50	50
x''_d	0.112	0.099
x'_d	0.193	0.17
x_d	2.19	3.16
r_a	0.0178	0.0174
T''_d (ms)	3	3
T'_d (ms)	80	49
T_{dc} (ms)	22	20
I_{Kd} (kA)	2.4	1.40

A.2.2 Transformer parameters for calculation are given in Table A.2.2.

Transformer Parameters **Table A.2.2**

Code	T
Type	CSGD-100
S_{rT} (kVA)	100
U_{rT2} (V)	230
u_K (%)	3.5
P_K (kW)	2.0

A.2.3 Motor parameters for calculation are given in Table A.2.3.

Motor Parameters **Table A.2.3**

Code	M_1	M_2 (Equivalent motor)
P_{rM} (kW)	120	408

Code	M_1	M_2 (Equivalent motor)
U_{rM} (V)	380	380
r_R	0.021	0.027
r_S	0.034	0.043
x''_M	0.15	0.188
T''_M (ms)	22.4	22.4
T_{dcM} (ms)	14.076	14.076

A.3 Calculation of the short-circuit current fed through the generator where the short-circuit occurs at the main bus-bar

A.3.1 Calculation of the impedance of cables connecting the generator to the main bus-bar

G_1, G_2:

$$R_e = rl/a = 0.215 \times 27 \div 5 = 1.161 \quad \text{m}\Omega$$

$$X_e = xl/a = 0.0809 \times 27 \div 5 = 0.437 \quad \text{m}\Omega$$

G_3:

$$R_e = rl/a = 0.215 \times 24 \div 3 = 1.72 \quad \text{m}\Omega$$

$$X_e = xl/a = 0.0809 \times 24 \div 3 = 0.647 \quad \text{m}\Omega$$

A.3.2 Calculation of generator reactance and resistance

G_1, G_2:

$$X''_d = x''_d \cdot \frac{U_{rG}^{\ 2}}{S_{rG}} = \frac{0.112 \times 160000}{550} = 32.582 \quad \text{m}\Omega$$

$$X'_d = x'_d \cdot \frac{U_{rG}^{\ 2}}{S_{rG}} = \frac{0.193 \times 160000}{550} = 56.145 \quad \text{m}\Omega$$

$$X_d = x_d \cdot \frac{U_{rG}^{\ 2}}{S_{rG}} = \frac{2.19 \times 160000}{550} = 637.09 \quad \text{m}\Omega$$

$$R_e = r_a \cdot \frac{U_{rG}^{\ 2}}{S_{rG}} = \frac{0.0178 \times 160000}{550} = 5.18 \quad \text{m}\Omega$$

G_3:

$$X''_d = x''_d \cdot \frac{U_{rG}^{\ 2}}{S_{rG}} = \frac{0.099 \times 160000}{312.5} = 50.688 \quad \text{m}\Omega$$

$$X'_d = x'_d \cdot \frac{U_{rG}^{\ 2}}{S_{rG}} = \frac{0.17 \times 160000}{312.5} = 87.04 \quad \text{m}\Omega$$

$$X_d = x_d \cdot \frac{U_{rG}^{\ 2}}{S_{rG}} = \frac{3.16 \times 160000}{312.5} = 1617.92 \quad \text{m}\Omega$$

$$R_a = r_a \cdot \frac{U_{rG}^{\ 2}}{S_{rG}} = \frac{0.0174 \times 160000}{312.5} = 8.909 \quad \text{m}\Omega$$

A.3.3 Calculation of generator phase electromotive forces E''_{q0} and E'_{q0}

G_1, G_2:

$$E''_{q0} = \sqrt{\left(\frac{U_r}{\sqrt{3}}\cos\varphi_r + R_a I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}}\sin\varphi_r + X''_d I_r\right)^2}$$

$$= \sqrt{\left(\frac{400 \times 0.8}{\sqrt{3}} + 5.18 \times 0.79\right)^2 + \left(\frac{400 \times 0.6}{\sqrt{3}} + 32.582 \times 0.79\right)^2}$$

$$= 250.314 \text{ V}$$

$$E'_{q0} = \sqrt{\left(\frac{U_r}{\sqrt{3}}\cos\varphi_r + R_a I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}}\sin\varphi_r + X'_d I_r\right)^2}$$

$$= \sqrt{\left(\frac{400 \times 0.8}{\sqrt{3}} + 5.18 \times 0.79\right)^2 + \left(\frac{400 \times 0.6}{\sqrt{3}} + 56.145 \times 0.79\right)^2}$$

$$= 262.908 \text{ V}$$

G_3:

$$E''_{q0}=\sqrt{(\frac{U_r}{\sqrt{3}}\cos\varphi_r+R_aI_r)^2+(\frac{U_r}{\sqrt{3}}\sin\varphi_r+X''_dI_r)^2}$$
$$=\sqrt{(\frac{400\times0.8}{\sqrt{3}}+8.909\times0.451)^2+(\frac{400\times0.6}{\sqrt{3}}+50.688\times0.451)^2}$$
$$=248.377\text{ V}$$
$$E'_{q0}=\sqrt{(\frac{U_r}{\sqrt{3}}\cos\varphi_r+R_aI_r)^2+(\frac{U_r}{\sqrt{3}}\sin\varphi_r+X'_dI_r)^2}$$
$$=\sqrt{(\frac{400\times0.8}{\sqrt{3}}+8.909\times0.451)^2+(\frac{400\times0.6}{\sqrt{3}}+87.04\times0.451)^2}$$
$$=259.332\text{ V}$$

A.3.4 Calculation of generator short-circuit currents

1 Calculations of $I''_{Kde}, I'_{Kde}, T''_e, T'_e$ and T_{dce}

(1) I''_{Kde} and I'_{Kde}

G_1, G_2:

$$I''_{Kde}=\frac{E''_{q0}}{\sqrt{(R_a+R_e)^2+(X''_d+X_e)^2}}$$
$$=\frac{250.314}{\sqrt{(5.18+1.161)^2+(32.582+0.437)^2}}$$
$$=7.445\text{ kA}$$
$$I'_{Kde}=\frac{E'_{q0}}{\sqrt{(R_a+R_e)^2+(X'_d+X_e)^2}}$$
$$=\frac{262.908}{\sqrt{(5.18+1.161)^2+(56.145+0.437)^2}}$$
$$=4.618\text{ kA}$$

G_3:

$$I''_{Kde}=\frac{E''_{q0}}{\sqrt{(R_a+R_e)^2+(X''_d+X_e)^2}}$$
$$=\frac{248.377}{\sqrt{(8.909+1.72)^2+(50.688+0.647)^2}}$$
$$=4.738\text{ kA}$$
$$I'_{Kde}=\frac{E'_{q0}}{\sqrt{(R_a+R_e)^2+(X'_d+X_e)^2}}$$
$$=\frac{259.332}{\sqrt{(8.909+1.72)^2+(87.04+0.647)^2}}$$
$$=2.936\text{ kA}$$

(2) T''_e, T'_e and T_{dce}

G_1, G_2:

$$T''_e=\frac{[(R_a+R_e)^2+(X''_d+X_e)^2]\cdot X'_d\cdot T''_d}{[(R_a+R_e)^2+(X''_d+X_e)(X'_d+X_e)]\cdot X''_d}$$
$$=\frac{(40.208+1090.254)\times56.145\times3}{(40.208+33.019\times56.582)\times32.582}$$
$$=3.062\quad\text{ms}$$
$$T'_e=\frac{[(R_a+R_e)^2+(X'_d+X_e)^2]\cdot X_d\cdot T'_d}{[(R_a+R_e)^2+(X'_d+X_e)(X_d+X_e)]\cdot X'_d}$$

$$= \frac{(40.208 + 3201.523) \times 637.09 \times 80}{(40.208 + 56.582 \times 637.527) \times 56.145}$$

$$= 81.49 \quad \text{ms}$$

$$T_{dce} = \frac{T_{dc} + 1000 X_e / (2\pi f R_a)}{1 + R_e / R_a}$$

$$= \frac{22 + 1000 \times 0.437 / (100\pi \times 5.18)}{1 + 1.161 / 5.18}$$

$$= 18.191 \quad \text{ms}$$

G_3:

$$T_e'' = \frac{[(R_a + R_e)^2 + (X_d'' + X_e)^2] \cdot X_d' \cdot T_d''}{[(R_a + R_e)^2 + (X_d'' + X_e)(X_d' + X_e)] \cdot X_d''}$$

$$= \frac{(112.9756 + 2635.282) \times 87.04 \times 3}{(112.9756 + 4501.412) \times 50.688}$$

$$= 3.068 \quad \text{ms}$$

$$T_e' = \frac{[(R_a + R_e)^2 + (X_d' + X_e)^2] \cdot X_d \cdot T_d'}{[(R_a + R_e)^2 + (X_d' + X_e)(X_d + X_e)] \cdot X_d'}$$

$$= \frac{(112.9756 + 7689.01) \times 1617.92 \times 49}{(112.9756 + 87.687 \times 1618.567) \times 87.04}$$

$$= 50.03 \quad \text{ms}$$

$$T_{dce} = \frac{T_{dc} + 1000 X_e / (2\pi f R_a)}{1 + R_e / R_a}$$

$$= \frac{20 + 1000 \times 0.647 / (100\pi \times 8.909)}{1 + 1.72 / 8.909}$$

$$= 16.957 \quad \text{ms}$$

2 Where t = 10 ms, the short-circuit current is to be calculated as follows:

G_1, G_2:

$$I_{acG} = (I_{Kde}'' - I_{Kde}') \cdot e^{-t/T_e''} + (I_{Kd}' - I_{Kd}) \cdot e^{-t/T_e'} + I_{Kd}$$

$$= (7.445 - 4.618) \cdot e^{-10/3.062} + (4.618 - 2.4) \cdot e^{-10/81.49} + 2.4$$

$$= 4.47 \text{ kA}$$

$$i_{dcG} = \sqrt{2}(I_{Kde}'' - I_r \cdot \sin\varphi_r) \cdot e^{-t/T_{dce}}$$

$$= \sqrt{2}(7.445 - 0.79 \times 0.6) \cdot e^{-10/18.191}$$

$$= 5.689 \text{ kA}$$

$$i_{pG} = \sqrt{2} I_{acG} + i_{dcG}$$

$$= \sqrt{2} \times 4.47 + 5.689$$

$$= 12.01 \text{ kA}$$

G_3:

$$I_{acG} = (I_{Kde}'' - I_{Kde}') \cdot e^{-t/T_e''} + (I_{Kde}' - I_{Kd}) \cdot e^{-t/T_e'} + I_{Kd}$$

$$= (4.738\text{-}2.936) \cdot e^{-10/3.068} + (2.936 - 1.4) \cdot e^{-10/50.03} + 1.4$$

$$= 2.727 \text{ kA}$$

$$i_{dcG} = \sqrt{2}(I_{Kde}'' - I_r \cdot \sin\varphi_r) \cdot e^{-t/T_{dce}}$$

$$= \sqrt{2}(4.738 - 0.451 \times 0.6) \cdot e^{-10/16.957}$$

$$= 3.503 \text{ kA}$$

$$i_{pG} = \sqrt{2} I_{acG} + i_{dcG}$$

$$= \sqrt{2} \times 2.727 + 3.503$$

$$= 7.36 \text{ kA}$$

A.4 Calculation of the short-circuit current fed through the motor where the short-circuit occurs at the main bus-bar

A.4.1 Calculation of impedance

A.4.1.1 The impedance of large motor M_1

1 Calculation of X''_M, R_S and R_R

$$X''_M = x''_M \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= \frac{0.15 \times 380^2 \times 0.76}{120}$$
$$= 137.18 \quad \text{m}\Omega$$
$$R_S = r_S \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= 0.034 \times 914.533$$
$$= 31.094 \quad \text{m}\Omega$$
$$R_R = r_R \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= 0.021 \times 914.533$$
$$= 19.205 \quad \text{m}\Omega$$

2 Cable impedance from the motor to the main bus-bar

$$R_e = rl / a$$
$$= 0.279 \times 35 \div 2$$
$$= 5.198 \quad \text{m}\Omega$$
$$X_e = xl / a$$
$$= 0.0821 \times 35 \div 2$$
$$= 1.437 \quad \text{m}\Omega$$

A.4.1.2 The impedance of equivalent motor M_2

$$X''_M = x''_M \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= 0.188 \times \frac{380^2 \times 0.76}{408}$$
$$= 50.568 \quad \text{m}\Omega$$
$$R_S = r_S \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= 0.043 \times 268.98$$
$$= 11.566 \quad \text{m}\Omega$$
$$R_R = r_R \frac{U_{rM}{}^2 \cdot \eta_M \cdot \cos\varphi_M}{P_{rM}}$$
$$= 0.027 \times 268.98$$
$$= 7.262 \quad \text{m}\Omega$$

A.4.2 Calculation of time constants for large motor M_1

$$T''_{Me} = \frac{1000 X''_{Me}}{2\pi f R_R}$$
$$= \frac{1000(X''_M + X_e)}{2\pi f R_R}$$
$$= \frac{1000 \times (137.18 + 1.437)}{100\pi \times 19.205}$$
$$= 22.975 \quad \text{ms}$$
$$T_{dcMe} = \frac{1000(X''_M + X_e)}{2\pi f (R_s + R_e)}$$
$$= \frac{10 \times 138.617}{\pi \times (31.094 + 5.198)}$$
$$= 12.158 \quad \text{ms}$$

A.4.3 Calculation of short-circuit currents

A.4.3.1 Where t = 10 ms, the short-circuit current of large motor M_1 is to be calculated as follows:

$$I''_{Me} = \frac{U_{rM}}{\sqrt{3}\sqrt{(R_R + R_S + R_e)^2 + (X''_M + X_e)^2}}$$
$$= \frac{380}{\sqrt{3} \times \sqrt{(19.205 + 31.094 + 5.198)^2 + (137.18 + 1.437)^2}}$$
$$= 1.469 \quad \text{kA}$$
$$I_{acM} = I''_{Me} \cdot e^{-t/T''_{Me}}$$
$$= 1.469 \times e^{-10/22.975}$$
$$= 0.951 \quad \text{kA}$$
$$i_{dcM} = \sqrt{2} I''_{Me} \cdot e^{-t/T''_{dcMe}}$$
$$= \sqrt{2} \times 1.469 \times e^{-10/12.158}$$
$$= 0.913 \quad \text{kA}$$
$$i_{pM} = \sqrt{2} I_{acM} + i_{dcM}$$
$$= \sqrt{2} \times 0.951 + 0.913$$
$$= 2.258 \quad \text{kA}$$

A.4.3.2 Where t = 10 ms, the short-circuit current of the equivalent motor (small motor group) M_2 is to be calculated as follows:

$$I''_{Me} = \frac{U_{rM}}{\sqrt{3}\sqrt{(R_S + R_R)^2 + X''^2_M}}$$
$$= \frac{380}{\sqrt{3} \times \sqrt{(11.566 + 7.262)^2 + 50.568^2}}$$
$$= 4.066 \quad \text{kA}$$
$$I_{acM} = I''_{Me} \cdot e^{-t/T''_{Me}}$$
$$= 4.066 \times e^{-10/22.4}$$
$$= 2.602 \quad \text{kA}$$
$$i_{dcM} = \sqrt{2} I''_{Me} \cdot e^{-t/T_{dcMe}}$$
$$= \sqrt{2} \times 4.066 \times e^{-10/14.076}$$
$$= 2.826 \quad \text{kA}$$
$$i_{pM} = \sqrt{2} I_{acM} + i_{dcM}$$
$$= \sqrt{2} \times 2.602 + 2.826$$
$$= 6.506 \quad \text{kA}$$

A.5 Calculation of short-circuit currents at points A_1, A_2, B_1 and B_2

A.5.1 Calculation of the short-circuit current at point A_1

A.5.1.1 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = I_{acG1} + I_{acG3} + I_{acM1} + I_{acM2}$$
$$= 4.47 + 2.727 + 0.951 + 2.602$$
$$= 10.75 \quad \text{kA}$$
$$i_p = i_{pG1} + i_{pG3} + i_{pM1} + i_{pM2}$$
$$= 12.01 + 7.36 + 2.258 + 6.506$$
$$= 28.134 \quad \text{kA}$$

A.5.2 Calculation of the short-circuit current at point A_2

A.5.2.1 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = I_{acG1} + I_{acG2} + I_{acM1} + I_{acM2}$$
$$= 2 \times 4.47 + 0.951 + 2.602$$
$$= 12.493 \quad \text{kA}$$
$$i_p = i_{pG1} + i_{pG2} + i_{pM1} + i_{pM2}$$

$= 2 \times 12.01 + 2.258 + 6.506$
$= 32.784$ kA

A.5.3 Calculation of the short-circuit current at point B_1

A.5.3.1 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = I_{acG1} + I_{acG2} + I_{acG3} + I_{acM1} + I_{acM2}$$
$= 2 \times 4.47 + 2.727 + 0.951 + 2.602$
$= 15.22$ kA
$$i_p = i_{pG1} + i_{pG2} + i_{pG3} + i_{pM1} + i_{pM2}$$
$= 2 \times 12.01 + 7.36 + 2.258 + 6.506$
$= 40.144$ kA

A.5.4 Calculation of the short-circuit current at point B_2

A.5.4.1 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = I_{acG1} + I_{acG2} + I_{acG3} + I_{acM2}$$
$= 2 \times 4.47 + 2.727 + 2.602$
$= 14.269$ kA
$$i_p = i_{pG1} + i_{pG2} + i_{pG3} + i_{pM2}$$
$= 2 \times 12.01 + 7.36 + 6.506$
$= 37.886$ kA

A.6 Calculation of short-circuit currents at points C_1, C_2, D_1 and D_2

A.6.1 Determination of parameters of the equivalent generator where t = 10 ms

A.6.1.1 The determination of subtransient time constant T''_{d*}

1 It may be calculated from formulae (29), (30) and (31):

$$I''_* = \sum_i I''_{Kdei} + \sum_j I''_{Mej}$$
$= 2 \times 7.445 + 4.738 + 1.469 + 4.066$
$= 25.163$ kA
$$I'_* = \sum_i I'_{Kdei}$$
$= 2 \times 4.618 + 2.936$
$=12.172$ kA
$$I_{K*} = \sum_i I_{Kdi}$$
$= 2 \times 2.4+ 1.4$
$= 6.2$ kA

Hence: $M_* = I''_* - I'_*$
$= 25.163 – 12.172$
$= 12.991$ kA
$N_* = I'_* - I_{K*}$
$= 12.172 – 6.2$
$= 5.972$ kA

2 Where t_x = 10 ms, $K''(t)$ and $K''(t)_*$ of G_1, G_2 and G_3 are to be calculated from formulae (34) and (36)

G_1, G_2:

$$K''(t_x) = (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T''_e} + I'_{Kde}$$
$= (7.445\text{-}4.618) \cdot e^{-10/3.062} + 4.618$
$= 4.726$ kA

G_3:

$$K''(t_x) = (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T''_e} + I'_{Kde}$$
$= (4.738\text{-}2.936) \cdot e^{-10/3.068} + 2.936$
$= 3.005$ kA

Hence: $K''(t_x)_* = \sum_i K''(t_x)_i + \sum_j I''_{Mj} \cdot e^{-t/T''_{Me}}$

$= 2 \times 4.726 + 3.005 + 0.951 + 2.602$

$= 16.01$ kA

3 Hence:

$$T''_{d*} = \frac{-t_x}{\ln\left[(K''(t_x)_* - I'_*)/M_*\right]}$$

$$= \frac{-10}{\ln\left[(16.01 - 12.172)/12.991\right]}$$

$= 8.20$ ms

A.6.1.2 The determination of transient time constant T'_{d*}

Where t_x = 10 ms, it is to be calculated from formula (39):

$$I_{ac*} = \sum_i I_{acGi} + \sum_j I_{acMj}$$

$= 15.22$ kA (i.e. the value of I_{ac} at point B_1)

Hence:

$$T'_{d*} = \frac{-t_x}{\ln\left[\frac{I_{ac}(t_x)_* - (M_* \cdot e^{-t_x/T''_{d*}} + I_{k*})}{N_*}\right]}$$

$$= \frac{-10}{\ln\left[\frac{15.22 - (12.991 \times e^{-10/8.20} + 6.2)}{5.972}\right]}$$

$= 70.553$ ms

A.6.1.3 The determination of DC time constant T_{dc*}

Where t_x = 10 ms, it is to be calculated from formula (42):

$$i_{dc}(t_x)_* = \sum_i i_{dcGi} + \sum_j i_{dcMj}$$

$= 2 \times 5.689 + 3.503 + 0.913 + 2.826$

$= 18.62$ kA

Hence:

$$T_{dc*} = \frac{-t_x}{\ln\left[\frac{i_{dc}(t_x)_*}{\sqrt{2}I''_*}\right]}$$

$$= \frac{-10}{\ln\left[\frac{18.62}{\sqrt{2} \times 25.163}\right]}$$

$= 15.439$ ms

A.6.1.4 The determination of impedance

It may be calculated from formulae (45), (46) and (47):

$$Z''_* = \frac{U_r}{\sqrt{3}I''_*} = \frac{400}{\sqrt{3} \times 25.163} = 9.178 \quad \text{m}\Omega$$

$$Z'_* = \frac{U_r}{\sqrt{3}I'_*} = \frac{400}{\sqrt{3} \times 12.172} = 18.973 \quad \text{m}\Omega$$

$$Z_* = \frac{U_r}{\sqrt{3}I_{K*}} = \frac{400}{\sqrt{3} \times 6.2} = 37.248 \quad \text{m}\Omega$$

and

$$C = \frac{1000}{2\pi f T_{dc*}} = \frac{10}{\pi \times 15.439} = 0.2062 \quad \text{m}\Omega$$

Hence:

$$X''_* = \frac{Z''_*}{\sqrt{1 + C^2}} = \frac{9.178}{\sqrt{1 + 0.2062^2}} = 8.99 \quad \text{m}\Omega$$

$$R_* = CX''_* = 0.2062 \times 8.99 = 1.854 \quad \text{m}\Omega$$

$$X'_* = \sqrt{Z'^2_* - R_*^2} = \sqrt{18.973^2 - 1.854^2} = 18.88 \quad \text{m}\Omega$$

$$X_* = \sqrt{Z_*^2 - R_*^{\ 2}} = \sqrt{37.248^2 - 1.854^2} = 37.202 \quad \text{m}\Omega$$

A.6.2 Calculation of the short-circuit current at point C_1

A.6.2.1 The calculation of the circuit impedance from the main bus-bar to fault points

$$R_e = rl/a = 0.582 \times 50/2 = 14.55 \quad \text{m}\Omega$$

$$X_e = xl/a = 0.0871 \times 50/2 = 2.178 \quad \text{m}\Omega$$

A.6.2.2 The calculation of $T_e^{''}$, T_e' and T_{dce}

$$T_e'' = \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2] \cdot X_*' \cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)] \cdot X_*''}$$

$$= \frac{[(1.854 + 14.55)^2 + (8.99 + 2.178)^2] \times 18.88 \times 8.20}{[(1.854 + 14.55)^2 + (8.99 + 2.178)(18.88 + 2.178)] \times 8.99}$$

$$= 13.449 \quad \text{ms}$$

$$T_e' = \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2] \cdot X_* \cdot T_{d*}'}{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)] \cdot X_*'}$$

$$= \frac{[(1.854 + 14.55)^2 + (18.88 + 2.178)^2] \times 37.202 \times 70.553}{[(1.854 + 14.55)^2 + (18.88 + 2.178)(37.202 + 2.178)] \times 18.88}$$

$$= 90.186 \quad \text{ms}$$

$$T_{dce} = \frac{T_{dc*} + 1000 X_e / (2\pi f R_*)}{1 + R_e / R_*}$$

$$= \frac{15.439 + 1000 \times 2.178 / (100\pi \times 1.854)}{1 + 14.55 / 1.854}$$

$$= 2.168 \quad \text{ms}$$

A.6.2.3 The calculation of I''_{Kde}, I'_{Kde} and I_{Kde}

$$I_{Kde}^{''} = \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*^{''} + X_e)^2}}$$

$$= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 14.55)^2 + (8.99 + 2.178)^2}}$$

$$= 11.637 \quad \text{kA}$$

$$I_{Kde}^{'} = \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*^{'} + X_e)^2}}$$

$$= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 14.55)^2 + (18.88 + 2.178)^2}}$$

$$= 8.652 \quad \text{kA}$$

$$I_{Kde} = \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}}$$

$$= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 14.55)^2 + (37.202 + 2.178)^2}}$$

$$= 5.413 \quad \text{kA}$$

A.6.2.4 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = (I_{Kde}^{''} - I_{Kde}^{'}) \cdot e^{-t/T_e^{''}} + (I_{Kde}^{'} - I_{Kde}) \cdot e^{-t/T_e^{'}} + I_{Kde}$$

$$= (11.637 - 8.652) \cdot e^{-10/13.449} + (8.652 - 5.413) \cdot e^{-10/90.186} + 5.413$$

$$= 9.731 \quad \text{kA}$$

$$i_{dc} = \sqrt{2} I_{Kde}^{''} \cdot e^{-t/T_{dce}}$$

$$= \sqrt{2} \times 11.637 \times e^{-10/2.168}$$

$$= 0.163 \quad \text{kA}$$

$$i_p = \sqrt{2} I_{ac} + i_{dc}$$
$$= \sqrt{2} \times 9.731 + 0.163$$
$$= 13.925 \quad \text{kA}$$

A.6.3 Calculation of the short-circuit current and power factor at point C_2

A.6.3.1 The calculation of the circuit impedance from the main bus-bar to fault points

$$R_e = rl / a = 0.807 \times 35 = 28.245 \quad \text{m}\Omega$$
$$X_e = xl / a = 0.0855 \times 35 = 3.098 \quad \text{m}\Omega$$

A.6.3.2 The calculation of T_e'', T_e' and T_{dce}

$$T_e'' = \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2] \cdot X_*' \cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)] \cdot X_*''}$$
$$= \frac{[(1.854 + 28.245)^2 + (8.99 + 3.098)^2] \times 18.88 \times 8.20}{[(1.854 + 28.245)^2 + (8.99 + 3.098)(18.88 + 3.098)] \times 8.99}$$
$$= 15.464 \quad \text{ms}$$
$$T_e' = \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2] \cdot X_* \cdot T_{d*}'}{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)] \cdot X_*'}$$
$$= \frac{[(1.854 + 28.245)^2 + (18.88 + 3.098)^2] \times 37.202 \times 70.553}{[(1.854 + 28.245)^2 + (18.88 + 3.098)(37.202 + 3.098)] \times 18.88}$$
$$= 107.775 \quad \text{ms}$$
$$T_{dce} = \frac{T_{dc*} + 1000 X_e / (2\pi f R_*)}{1 + R_e / R_*}$$
$$= \frac{15.439 + 1000 \times 3.098 / (100\pi \times 1.854)}{1 + 28.245 / 1.854}$$
$$= 1.28 \quad \text{ms}$$

A.6.3.3 The calculation of I_{Kde}'', I_{Kde}' and I_{Kde}

$$I_{Kde}'' = \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*'' + X_e)^2}}$$
$$= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 28.245)^2 + (8.99 + 3.098)^2}}$$
$$= 7.12 \quad \text{kA}$$
$$I_{Kde}' = \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*' + X_e)^2}}$$
$$= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 28.245)^2 + (18.88 + 3.098)^2}}$$
$$= 6.197 \quad \text{kA}$$
$$I_{Kde} = \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}}$$
$$= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 28.245)^2 + (37.202 + 3.098)^2}}$$
$$= 4.591 \quad \text{kA}$$

A.6.3.4 Where: t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = (I_{Kde}'' - I_{Kde}') \cdot e^{-t/T_e''} + (I_{Kde}' - I_{Kde}) \cdot e^{-t/T_e'} + I_{Kde}$$
$$= (7.12 - 6.197) \cdot e^{-10/15.464} + (6.197 - 4.591) \cdot e^{-10/107.775} + 4.591$$
$$= 6.538 \quad \text{kA}$$
$$i_{dc} = \sqrt{2} I_{Kde}'' \cdot e^{-t/T_{dce}}$$

$$= \sqrt{2} \times 7.12 \times e^{-10/1.28}$$
$$= 0.0041 \quad \text{kA}$$
$$i_p = \sqrt{2} I_{ac} + i_{dc}$$
$$= \sqrt{2} \times 6.538 + 0.0041$$
$$= 9.25 \quad \text{kA}$$

A.6.4 Calculation of the short-circuit current at point D_1

A.6.4.1 The calculation of the circuit impedance from the main bus-bar to fault points

1. The primary circuit impedance of a transformer

$$R_{e1} = rl / a = 0.807 \times 6 / 2 = 2.421 \quad \text{m}\Omega$$
$$X_{e1} = xl / a = 0.0885 \times 6 / 2 = 0.2655 \quad \text{m}\Omega$$

2. The calculation of the transformer impedance

$$Z_T = u_K \cdot \frac{U_r^{\ 2}}{S_{rT}}$$
$$= 3.5\% \times \frac{400^2}{100}$$
$$= 56 \quad \text{m}\Omega$$
$$R_T = P_K \cdot \frac{U_r^{\ 2}}{S_{rT}^{\ 2}}$$
$$= 2.0 \times \frac{400^2}{100^2}$$
$$= 32 \quad \text{m}\Omega$$
$$X_T = \sqrt{Z_T^{\ 2} - R_T^{\ 2}}$$
$$= \sqrt{56^2 - 32^2}$$
$$= 45.9565 \quad \text{m}\Omega$$

3. The circuit impedance at the secondary side of the transformer as converted to the primary side

$$R_{e2} = (rl / a) \cdot (U_r / U_{rT2})^2$$
$$= (0.582 \times 3.5 / 2) \times (400 / 230)^2$$
$$= 3.0805 \quad \text{m}\Omega$$
$$X_{e2} = (xl / a) \cdot (U_r / U_{rT2})^2$$
$$= (0.0871 \times 3.5/2) \times (400/230)^2$$
$$= 0.461 \quad \text{m}\Omega$$

4. The circuit impedance from the main bus-bar to fault points

$$R_e = R_{e1} + R_T + R_{e2}$$
$$= 2.421 + 32 + 3.0805$$
$$= 37.5015 \quad \text{m}\Omega$$
$$X_e = X_{e1} + X_T + X_{e2}$$
$$= 0.2655 + 45.9565 + 0.461$$
$$= 46.683 \quad \text{m}\Omega$$

A.6.4.2 The calculation of T_e'', T_e' and T_{dce}

$$T_e'' = \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2] \cdot X_*' \cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)] \cdot X_*''}$$
$$= \frac{[(1.854 + 37.5015)^2 + (8.99 + 46.683)^2] \times 18.88 \times 8.20}{[(1.854 + 37.5015)^2 + (8.99 + 46.683)(18.88 + 46.683)] \times 8.99}$$
$$= 15.397 \quad \text{ms}$$
$$T_e' = \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2] \cdot X_* \cdot T_{d*}'}{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)] \cdot X_*'}$$
$$= \frac{[(1.854 + 37.5015)^2 + (18.88 + 46.683)^2] \times 37.202 \times 70.553}{[(1.854 + 37.5015)^2 + (18.88 + 46.683)(37.202 + 46.683)] \times 18.88}$$

$$= 115.328 \quad \text{ms}$$

$$T_{dce} = \frac{T_{dc*} + 1000X_e/(2\pi f R_*)}{1 + R_e/R_*}$$

$$= \frac{15.439 + 1000 \times 46.683/(100\pi \times 1.854)}{1 + 37.5015/1.854}$$

$$= 4.503 \quad \text{ms}$$

A.6.4.3 The calculation of I''_{Kde}, I'_{Kde} and I_{Kde}

$$I''_{Kde} = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}}$$

$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 37.5015)^2 + (8.99 + 46.683)^2}}$$

$$= 3.387 \quad \text{kA}$$

$$I'_{Kde} = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X'_* + X_e)^2}}$$

$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 37.5015)^2 + (18.88 + 46.683)^2}}$$

$$= 3.02 \quad \text{kA}$$

$$I_{Kde} = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}}$$

$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 37.5015)^2 + (37.202 + 46.683)^2}}$$

$$= 2.492 \quad \text{kA}$$

A.6.4.4 Where t = 10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T''_e} + (I'_{Kde} - I_{Kde}) \cdot e^{-t/T'_e} + I_{Kde}$$

$$= (3.387 - 3.02) \cdot e^{-10/15.397} + (3.02 - 2.492) \cdot e^{-10/115.328} + 2.492$$

$$= 3.168 \quad \text{kA}$$

$$i_{dc} = \sqrt{2} I''_{Kde} \cdot e^{-t/T_{dce}}$$

$$= \sqrt{2} \times 3.387 \times e^{-10/4.503}$$

$$= 0.52 \quad \text{kA}$$

$$i_p = \sqrt{2} I_{ac} + i_{dc}$$

$$= \sqrt{2} \times 3.168 + 0.52$$

$$= 5.0 \quad \text{kA}$$

The short-circuit current at the secondary side of a transformer

$$I_{ac2} = I_{ac}(U_r/U_{rT2})$$

$$= 3.168 \times 400/230$$

$$= 5.51 \text{ kA}$$

$$i_{p2} = i_p(U_r/U_{rT2})$$

$$= 5.0 \times 400/230$$

$$= 8.696 \quad \text{kA}$$

A.6.5 Calculation of the short-circuit current at point D_2

A.6.5.1 The calculation of the circuit impedance from the main bus-bar to fault points

1 The circuit impedance from the main bus-bar to the lighting bus-bar (i.e. the impedance at point D_1)

$R_e = 37.5015$ mΩ

$X_e = 46.683$ mΩ

2 The circuit impedance from the lighting bus-bar to fault points as converted to the primary side of the transformer

$$R_{e2} = (rl/a)\cdot(U_r/U_{rT2})^2$$
$$= (2.02 \times 10/1)\times(400/230)^2$$
$$= 61.096 \quad \text{m}\Omega$$
$$X_{e2} = (xl/a)\cdot(U_r/U_{rT2})^2$$
$$= (0.0957\times 10/1)\times(400/230)^2$$
$$= 2.895 \quad \text{m}\Omega$$

3 The circuit impedance from the main bus-bar to fault points

$$R_e = R_{e(D1)} + R_{e2}$$
$$= 37.5015 + 61.096$$
$$= 98.598 \quad \text{m}\Omega$$
$$X_e = X_{e(D1)} + X_{e2}$$
$$= 46.683 + 2.895$$
$$= 49.578 \quad \text{m}\Omega$$

A.6.5.2 The calculation of T_e'', T_e' and T_{dce}

$$T_e'' = \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2]\cdot X_*' \cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)]\cdot X_*''}$$
$$= \frac{[(1.854 + 98.598)^2 + (8.99 + 49.578)^2]\times 18.88 \times 8.20}{[(1.854 + 98.598)^2 + (8.99 + 49.578)(18.88 + 49.578)]\times 8.99}$$
$$= 16.513 \quad \text{ms}$$
$$T_e' = \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2]\cdot X_* \cdot T_{d*}'}{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)]\cdot X_*'}$$
$$= \frac{[(1.854 + 98.598)^2 + (18.88 + 49.578)^2]\times 37.202 \times 70.553}{[(1.854 + 98.598)^2 + (18.88 + 49.578)(37.202 + 49.578)]\times 18.88}$$
$$= 128.144 \quad \text{ms}$$
$$T_{dce} = \frac{T_{dc*} + 1000X_e/(2\pi f R_*)}{1 + R_e/R_*}$$
$$= \frac{15.439 + 1000\times 49.578/(100\pi \times 1.854)}{1 + 98.598/1.854}$$
$$= 1.89 \quad \text{ms}$$

A.6.5.3 The calculation of I_{Kde}'', I_{Kde}' and I_{Kde}

$$I_{Kde}'' = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*'' + X_e)^2}}$$
$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 98.598)^2 + (8.99 + 49.578)^2}}$$
$$= 1.986 \quad \text{kA}$$
$$I_{Kde}' = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*' + X_e)^2}}$$
$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 98.598)^2 + (18.88 + 49.578)^2}}$$
$$= 1.899 \quad \text{kA}$$
$$I_{Kde} = \frac{U_r/\sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}}$$
$$= \frac{400/\sqrt{3}}{\sqrt{(1.854 + 98.598)^2 + (37.202 + 49.578)^2}}$$
$$= 1.74 \quad \text{kA}$$

A.6.5.4 Where t =10 ms, the short-circuit current is to be calculated as follows:

$$I_{ac} = (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T''_e} + (I'_{Kde} - I_{Kde}) \cdot e^{-t/T'_e} + I_{Kde}$$
$$= (1.986 - 1.899) \cdot e^{-10/16.513} + (1.899 - 1.74) \cdot e^{-10/128.144} + 1.74$$
$$= 1.931 \quad \text{kA}$$
$$i_{dc} = \sqrt{2} I''_{Kde} \cdot e^{-t/T_{dce}}$$
$$= \sqrt{2} \times 1.986 \times e^{-10/1.89}$$
$$= 0.0141 \quad \text{kA}$$
$$i_p = \sqrt{2} I_{ac} + i_{dc}$$
$$= \sqrt{2} \times 1.931 + 0.0141$$
$$= 2.745 \quad \text{kA}$$

The short-circuit current at the secondary side of a transformer

$$I_{ac2} = I_{ac}(U_r / U_{rT2})$$
$$= 1.931 \times 400/230$$
$$= 3.358 \quad \text{kA}$$
$$i_{p2} = i_p(U_r / U_{rT2})$$
$$= 2.745 \times 400/230$$
$$= 4.774 \quad \text{kA}$$

A.7 Calculation of short-circuit power factors

A.7.1 Calculation of short-circuit power factors at points A_1, A_2, B_1 and B_2.

$$\cos\varphi_K = \frac{R_*}{\sqrt{R_*^2 + X_*''^2}}$$
$$= \frac{1.854}{\sqrt{1.854^2 + 8.99^2}}$$
$$= 0.202$$

A.7.2 Calculation of short-circuit power factors at points C_1, C_2, D_1 and D_2

1 At point C_1:

$$\cos\varphi_K = \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}}$$
$$= \frac{1.854 + 14.55}{\sqrt{(1.854 + 14.55)^2 + (8.99 + 2.178)^2}}$$
$$= 0.827$$

2 At point C_2:

$$\cos\varphi_K = \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}}$$
$$= \frac{1.854 + 28.245}{\sqrt{(1.854 + 28.245)^2 + (8.99 + 3.098)^2}}$$
$$= 0.928$$

3 At point D_1:

$$\cos\varphi_K = \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}}$$
$$= \frac{1.854 + 37.5015}{\sqrt{(1.854 + 37.5015)^2 + (8.99 + 46.683)^2}}$$
$$= 0.577$$

4 At point D_2:

$$\cos\varphi_K = \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X''_* + X_e)^2}}$$

$$= \frac{1.854 + 98.598}{\sqrt{(1.854 + 98.598)^2 + (8.99 + 49.578)^2}}$$
$$= 0.864$$

A.8 A complete summary of results of short-circuit current calculation and data of selected protective devices

A.8.1 A complete summary of the results of the short-circuit current calculation and the data of the selected protective devices is given in Table A.8.1.

A Complete Summary of Results of Short-Circuit Current Calculation and Data of Selected Protective Devices **Table A.8.1**

Results of short-circuit current calculation					Selected protective devices								
Code of fault points	Time after occurrence of short-circuit	Symmetrical short-circuit current (kA)	Upper envelope of short-circuit current (kA)	Power factor of short-circuit current	Type	Rated current (A)	Rated voltage (V)	Rated short-circuit breaking capacity (kA)	Rated short-circuit making capacity (kA)	Rated short-time withstanding current (kA)	Power factor of short-circuit	$\cos\varphi_K$ conversion	
												Conversion coefficient	Short-circuit breaking capacity (kA)
A_1	T/2 Steady state	10.75 3.80	28.134	0.202	AH-10B	790	500	40	104	30 (1 s)			
A_2	T/2 Steady state	12.493 4.80	32.784	0.202	AH-6B	451	500	35	98.5	22 (1 s)			
B_1	T/2	15.22	40.144	0.202	TG-100B	50	500	42	95.5				
	T/2 Steady state	15.22 6.20	40.144	0.202	XH225NE①	150	415	25	50	5.0 (300 ms)			
	Steady state	6.20			XH600NE②	200	415			10.0 (300 ms)			
B_2	T/2	14.269	37.886	0.202	TO-225BA	225	500	22	44				
C_1	T/2	9.731	13.925	0.827	TO-100BA	15	500	18	38				
C_2	T/2	6.538	9.25	0.928	TO-100BA	15	500	18	38				
$D_1$③	T/2	5.51	8.696	0.577	TO-100BA	15	250	22	35				
D_2	T/2	3.358	4.774	0.864	TH-50B	10	250	5	8.6				

Notes:

① High-efficiency instantaneous trip breaker for the primary side of transformer T, with the transient current being 4 kA.

② Circuit breaker for feeders connecting main switchboard and emergency switch board.

③ Points D_1 and D_2 are short-circuit currents at the secondary side of the transformer.

Appendix B Conversion of Short-Circuit Breaking Capacity of Circuit Breaker

B.1 Foreword

The rated short-circuit breaking capacity of a circuit breaker is values provided by the manufacturer for the short-circuit breaking capacity corresponding to different rated operational voltages at the rated frequency and specified short-circuit power factor.

Because the sources of the short-circuit current in marine AC electrical systems are AC synchronous and asynchronous motors and the short-circuit power factor is small, the short-circuit power factors specified in standards for industrial circuit breakers cannot in general meet marine requirements.

This Appendix provides a method for conversion of the short-circuit breaking capacity where the given value of the test power factor of the selected breaker is not in compliance with the actual short-circuit power factor required for a marine electrical system.

B.2 Conversion method

The conversion is to be in accordance with the following steps:

a. The peak coefficient n corresponding to the given value of the test short-circuit power factor $\cos\varphi_{Kr}$ of the breaker may be obtained from Figure B.2.

Note: Where only the rated short-circuit making capacity and rated short-circuit breaking capacity of the breaker is given, the ratio of the rated short-circuit making capacity to the rated short-circuit breaking capacity is peak coefficient n.

b. The peak coefficient n' corresponding to the actually required short-circuit power factor $\cos\varphi_K$ may be obtained from Figure B.2.

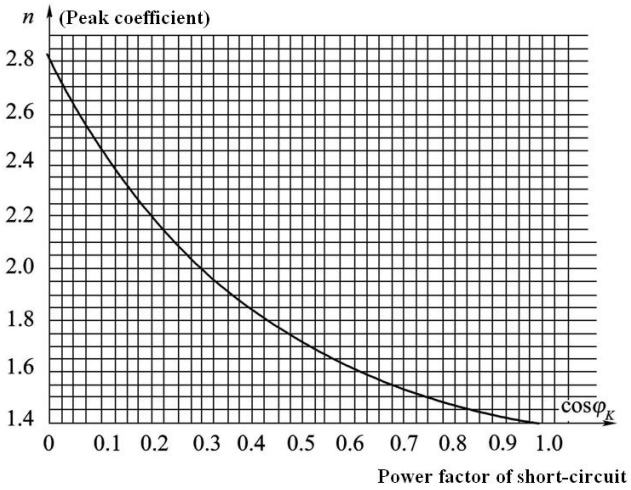


Figure B.2 Curve where Peak Value Coefficient $n = f(\cos\varphi_K)$

c. With the short-circuit power factor $\cos\varphi_K$, the short-circuit breaking capacity I_{Cr} of the breaker conversion is as follows:

$$I_{Cr} = \frac{n}{n'} I_{CR} = C I_{CR}$$

B.3 Example

It is assumed that the considered short-circuit power factor $\cos\varphi_K$ at the main bus-bar of a ship equals 0.16, and the known parameters of the selected TO-100BA circuit breaker are as follows:

Rated voltage: 500 V
Rated short-circuit breaking capacity: 18 kA
Rated short-circuit making capacity: 38 kA

Evaluation: The value of the short-circuit breaking capacity where the short-circuit power factor $\cos\varphi_K = 0.16$.

Solution:

(a) $n = \frac{38}{18} = 2.111$;

(b) $n' = 2.30$ where $\cos\varphi_K = 0.16$, as shown in Figure B.2;

(c) $I_{Cr} = \frac{n}{n'} I_{CR} = \frac{2.111}{2.30} \times 18 = 16.52$ kA.

APPENDIX 2 TYPE APPROVAL PROCEDURE FOR CABLE TRAYS/PROTECTIVE CASINGS MADE OF PLASTIC MATERIALS

2.1 General design requirements

2.1.1 Ambient temperatures

Cable trays/protective casings are to be designed to the following ambient temperatures:

–25℃ to 90℃ for outdoor use;

+ 5℃ to 90℃ for indoor use.

Consideration will be given to the use of plastic cable trays/protective casings in the cold environment where the ambient temperature is below –25℃ provided the mechanical properties of the plastics can be maintained for the intended purpose and the installation location. In this particular instance, the cold bend and cold impact properties of the material are also to be considered.

2.1.2 Safe Working Load

Cable trays/protective casings are to be assigned a Safe Working Load in accordance with 2.2.2 of this Appendix.

2.2 Mechanical requirements

2.2.1 Impact resistance test

The test is to be performed according to IEC 60068-2-75 using the pendulum hammer.

2.2.1.1 The test is to be carried out on samples of cable tray lengths or cable ladder lengths, of 250 mm ±5 mm long. Samples of ladder are to consist of two side-members with one rung positioned centrally. Samples of mesh trays are to be prepared in such a way that there will be a wire in the centre.

2.2.1.2 Before the test, plastic components are to be aged at a temperature of 90℃ ±2℃ for 240 h continuously.

2.2.1.3 The samples are to be mounted on wooden fibreboard of thickness 20 mm ±2 mm.

2.2.1.4 The samples to be tested are to be placed in a refrigerator, the temperature within which is maintained at the declared temperature according to 1.1 above with a tolerance of ±2℃.

2.2.1.5 After 2 h, the samples are, in turn, to be removed from the refrigerator and immediately placed in the test apparatus.

2.2.1.6 At 10 s ±1 s after removal of each sample from the refrigerator, the hammer complying with Table 2.2.1.6 is to be allowed to fall with impact energy.

Hammer Specification **Table 2.2.1.6**

Approximate energy (J)	Mass of hammer (kg)	Fall height (mm)
10	5.0	200 ±2

2.2.1.7 The impact is to be applied to the base, or the rung, in the first sample, to one of the side members in the second sample, and to the other side member in the third sample. In each case, the impact is to be applied to the centre of the face being tested.

2.2.1.8 After the test, the samples are to show no signs of disintegration and/or deformation that will impair the safety.

2.2.2 Safe Working Load (SWL) test

2.2.2.1 Cable trays/protective casings and joints are to be assigned a Safe Working Load (SWL) satisfying the following criteria, tested at the declared temperatures according to 2.1.1 above (see note):

- the maximum deflection is not to exceed $L/100$, where L is the distance between the supports,
- no mechanical defects or failure are observed when tested to 1.7 × SWL.

2.2.2.2 All loads are to be uniformly distributed (UDL) over the length and width of the samples as shown in Figure 2.2.2.2.

The loads are to be applied in such a way that a UDL is ensured even in the case of extreme deformation of the samples.

To allow for settlement of the samples, a preload of 10% of the test load unless otherwise specified, is to be applied and held for at least 5 min, after which the measurement apparatus is to be calibrated to zero.

2.2.2.3 The load is then to be gradually increased evenly longitudinally and transversely up to the test load continuously or when a continuous increase is impractical, the load may be increased by increments. These increments are not to exceed about a quarter of the safe working load. The load increments are to be distributed through the load plates longitudinally and transversely as evenly as is practical.

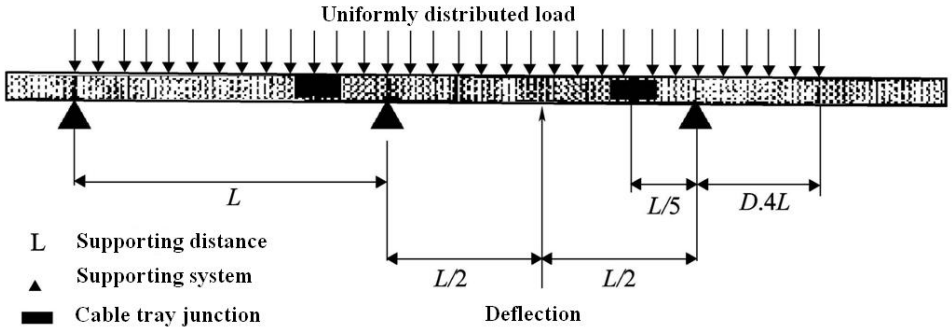


Figure 2.2.2.2 IEC 61537 Loading Test Procedure Summary

2.2.2.4 After loading, the deflection is to be measured at the points specified to give a practical mid-span deflection.

2.2.2.5 The samples are to be left and the deflections measured every 5 min until the difference between two consecutive sets of readings is less than 2 % with regard to the first set of the two consecutive sets of readings. The first set of readings measured at this point is the set of deflections measured at the test load.

2.2.2.6 When subject to the test load the samples, their joints and internal fixing devices, are to show no damage or crack visible to normal view or corrected vision without magnification.

2.2.2.7 The load is then to be increased to l.7 times the test load.

The samples are to be left and the deflections measured every 5 min until the difference between two consecutive sets of readings is less than 2% with regard to the first set of the two consecutive sets of readings. The samples are to sustain the increased loading without collapsing. Buckling and deformation of the samples is permissible at this loading.

Note: Alternatively, tests can be carried out:

- at any temperature within the declared range if documentation is available which states that the relevant structural properties of the materials as used within the system do not differ by more than 5% of the average between the maximum and minimum property values, or
- only at maximum temperature within the range, if documentation is available which states that the relevant structural properties of the materials as used within the system decrease when the temperature is increasing, or
- at maximum and minimum temperature only.

Tests are to be carried out for the smallest and largest sizes of cable tray lengths or cable ladder lengths, having the same material, joint and topological shape.

2.3 Fire properties

2.3.1 Flame retardant test

The cable trays/protective casings are to be at least flame retardant. They are to be tested in accordance with Table 2.3.1.

Flame Retardant Test **Table 2.3.1**

Procedure according to	Test parameters	Other information
IEC 60092-101, or	– Flame application: 5 times 15 s each – Interval between each application: 15 s or 1 time 30 s	− The burnt out or damaged part of the specimen by not more than 60 mm long − Equipment design and the choice of materials is to reduce the likelihood of fire ensuring where surfaces of the specimen can be exposed to external fire they do not contribute to the fire growth
IEC60695-11-5	Test criteria based upon application	

2.3.2 Smoke and toxicity test

The cable trays/protective casings are to be tested in accordance with Part 2 of 2010 FTP Code adopted by IMO Resolution MSC.307(88) as amended by IMO Resolution MSC.437(99), or any international or national standard.

2.4 Special requirements

2.4.1 Resistivity test

Cable trays/protective casings of plastic materials passing through a hazardous area are not to be electrically non-conductive and are to ensure satisfactory earthing between any point in these appliances and the ship's hull.

The volume resistivity level of the cable trays/protective casings and fittings is to be below 10^5 Ωm and the surface resistivity is to be below 10^8 Ω. The cable trays/protective casings are to be tested in accordance

with IEC62631-3-1 and IEC62631-3-2.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2025

PART FIVE REFRIGERATED CARGO INSTALLATIONS

CONTENTS

CHAPTER 1 GENERAL 5-1
Section 1 GENERAL PROVISIONS 5-1
Section 2 TESTS 5-2
CHAPTER 2 REFRIGERATING PLANT 5-4
Section 1 GENERAL PROVISIONS 5-4
Section 2 REFRIGERATING MACHINERY 5-5
Section 3 PRESSURE VESSELS, PIPING, FITTINGS AND ACCESSORIES 5-6
Section 4 CONTROL, ALARM AND SAFETY SYSTEMS 5-9
Section 5 LOCATION OF REFRIGERATING MACHINERY SPACE OR UNIT 5-10
Section 6 SAFETY DEVICES 5-12
CHAPTER 3 REFRIGERATED CARGO HOLDS/CHAMBERS 5-13
Section 1 DESIGN OF CARGO HOLDS/CHAMBERS 5-13
Section 2 ACCESSORIES 5-13
Section 3 INSULATION 5-15
CHAPTER 4 CARRIAGE OF REFRIGERATED CONTAINERS IN CARGO HOLDS 5-16
Section 1 GENERAL PROVISIONS 5-16
Section 2 ARRANGEMENT 5-16
Section 3 VENTILATION WITHIN HOLDS 5-17
Section 4 ELECTRICAL INSTALLATIONS 5-18

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 Ships with refrigerated cargo systems complying with the relevant requirements of Chapters 1 to 3 of this PART may be assigned the following class notations as appropriate:

CRS (× × Hold × ×℃, ××℃ Max. Sea Water)

— For ships fitted with refrigerated cargo installations, this notation is to be added after type notation, and minimum temperature(s) to be maintained by the installation at maximum sea water temperature stated and cargo area covered by the minimum temperature(s) are to be stated;

CF — For refrigerated installations for cargo fruits, this notation is to be added;

1.1.1.2 The certification requirements for and the products inspections related to refrigerated cargo systems are to comply with the relevant requirements of Chapter 3, PART ONE of the Rules.

1.1.2 Refrigerants

1.1.2.1 The provisions of this PART are applicable to the refrigerants listed in Table 1.1.2.1:

Refrigerants Table 1.1.2.1

Refrigerant No.	Chemical formula or composition	Blending Ratio
R717	NH_3	-
R134a	$CH_2F\text{-}CF_3$	-
R404A	CHF_2CF_3(R125)/CH_3CF_3(R143a)/CH_2FCF_3(R134a)	（44%/52%/4%）
R407C	CH_2F_2(R32)/CHF_2CF_3(R125)/CH_2FCF_3(R134a)	(23%/25%/52%)
R410A	CH_2F_2(R32)/CHF_2CF_3(R125)	(50%/50%)
R507A	CHF_2CF_3(R125)/CH_3CF_3(R143a)	(50%/50%)

1.1.2.2 Where other refrigerants are to be used, relevant information is to be submitted for approval.

1.1.2.3 In addition, consideration is to be given to the relevant provisions for the application scope of refrigerants specified by the flag State Administration.

1.1.3 Operating conditions

1.1.3.1 The refrigeration systems are to operate satisfactorily when the ship is under the following conditions:

(1) permanent list up to 15º, and permanent trim up to 5º;

(2) rolling: 22.5º, and pitching: 7.5º.

1.1.3.2 Where the refrigerating units are provided with centralized control or automatic controlling and monitoring systems, the equipment of such systems is to comply with the relevant requirements of Chapter 2, PART SEVEN of the Rules.

1.1.4 Special cases

1.1.4.1 Any proposed addition to or relaxation of the requirements of this PART in respect to ships engaged on voyages of short duration, to installations of small capacity, or to other special cases is subject to agreement of CCS. In such cases a service limitation may be made to the ship.

1.1.4.2 Cargo chambers are in general not to be refrigerated by the direct expansion pipe grid system when R717 is used as refrigerant. However, in the case of a ship engaged in restricted service where the total capacity of its refrigerated cargo chambers is less than 500 m^3, a direct expansion ammonia pipe grid system may be adopted.

1.1.5 Plans and documents

1.1.5.1 The following plans and documents are to be submitted for approval. Where necessary, additional plans and documents may be required:

(1) General arrangement of insulated chambers (including neighbouring tanks and holds);

(2) Detailed plans showing the construction of insulation within refrigerated chambers;

(3) Details of insulation of piping and supports;

(4) General arrangement of refrigerating machinery space;

(5) Ventilation details of refrigerating machinery space;

(6) Arrangement of air cooling system;

(7) Arrangements of air cooler defrosting and drainage;
(8) Arrangement of brine grids or refrigerant grids in refrigerated chambers and method of construction;
(9) Piping diagrams of refrigerant, brine and cooling water systems;
(10) Arrangements of drainage and ventilation in refrigerated chambers;
(11) Arrangement of temperature measuring system in refrigerated chambers;
(12) Sectional arrangement and performance data of refrigeration compressors, detailed dimensioned plans of reciprocating compressor crankshafts;
(13) Plans of condensers, air and brine coolers, oil separators, liquid receivers and other pressure vessels;
(14) Schematic diagrams of automatic control, safety and alarm systems (including the specifications, types and functions).

1.1.5.2 The following plans and documents are to be submitted for information:
(1) Specifications for refrigerating plant (including centralized control and monitoring) and for insulation of refrigerated chambers;
(2) Calculations for refrigerating capacity.

Note: Plans and documents of the products which have been approved by CCS need not be resubmitted for approval.

1.1.6 Novel arrangement and construction

1.1.6.1 Where the proposed construction of the refrigerating unit or refrigerated chambers is novel in design or involves the use of unusual material, details are to be submitted for approval, and special tests may be required when necessary.

Section 2 TESTS

1.2.1 Pressure tests

1.2.1.1 Pressure tests after completion of manufacturing
(1) On completion of manufacturing, components and parts exposed to the pressure of the refrigerants are to be subject to strength and leak tests as detailed in Table 1.2.1.1.

Test Pressure **Table 1.2.1.1**

Component or part	Strength test (hydraulic)	Leak test (pneumatic)
Pressure vessels	1.5*p*	1.0*p*
Compressors:		
Cylinders	1.5*p*	1.0*p*
Crankcase	1.5*p*	1.0*p*
Valves and fittings	2.0*p*	1.0*p*
Pressure piping, welded fabricated headers, air coolers, etc.	1.5*p*	1.0*p*

Notes: ① *p* is the design pressure, see Table 2.1.4.1.
② The leak test normally requires an air pressure to be applied to the component while submerged in water. Alternative methods for leak test may be considered if practicable.

(2) Components exposed to the pressure of brine or cooling water are to be hydraulically tested to 1.5*p*, but in no case less than 0.34 MPa.
(3) For components not suitable for hydraulic pressure test, the relevant test program is to be submitted to CCS for approval if air pressure test is adopted in lieu of hydraulic pressure test.

1.2.1.2 Pressure tests after installation on board ship
(1) For pressure piping welded in place, hydraulic tests of the welds are to be carried out at a test pressure of 1.5*p*.
(2) For pressure piping welded in place, the hydraulic tests required in 1.2.1.2(1) may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out with satisfactory results on the entire circumferential butt welds.
Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a test report confirming that ultrasonic examination has been carried out and that there were no indications of defects which could be expected to have a prejudicial effect on the service performance of the piping.
(3) After completion of the test required in 1.2.1.2(1) or (2), a leak test is to be carried out at a pressure given in Table 1.2.1.1, and to be witnessed by the Surveyor on site.

1.2.1.3 After tightness testing and before charging with refrigerant and oil, the complete plant is to be dried by a method of evacuation. The plant is to be evacuated until the minimum absolute pressure is reached as far as practicable, which is to be held constant until all water is evaporated. The plant is then to be refilled with air and the same procedure is to be repeated until no water is left in the plant.

1.2.2 Operation tests

1.2.2.1 Preparations for tests

(1) Before the operation test, all thermometers or temperature measuring equipment fitted in the refrigerated chambers or on the refrigerating machinery are to be checked for accuracy, and a statement is to be given to the Surveyor. The Surveyor may require a random test if deemed necessary.

(2) Pressure gauges and other measuring instruments are, before the operation test, also to be checked to the satisfaction of the Surveyor.

1.2.2.2 Air cooler fans are to be tested under working conditions after the air circulating system has been completed. During the test, the static pressure of air outlet, the volume of air circulated per minute, the fan speed and the power consumption are to be recorded. The air circulation arrangements in the chambers are to be checked.

A statement of the results for each chamber is to be handed to the Surveyor on completion of tests.

1.2.2.3 Refrigeration tests

(1) All refrigerating units of the refrigeration system are to be subject to refrigeration tests under working conditions. The refrigeration test is to be carried out for a period of at least 12 h after the chamber temperatures have been lowered to the minimum temperature as required. However, the total time is not to be less than 24 h throughout the test.

In general, the refrigeration test may be carried out with all chambers empty. The hatch covers, access plugs or doors and air refreshing arrangements are to be closed up and liquid sealed traps for scuppers are to be primed with brine.

(2) At the beginning of the refrigeration test, all refrigerating units are to be put into action. After the chamber has been cooled down to the design temperature, the test may be carried on with one of the units out of action in turn in accordance with the requirements of 2.1.3, Chapter 2 of this PART, provided that the minimum required temperature in the chamber is maintained constant throughout the test. During the test, each unit is to operate for about the same time.

(3) Refrigeration systems are to be tested during a period when a reasonable difference between the external and internal temperatures exists.

1.2.2.4 Thermal balance tests

(1) During the refrigeration test of newly designed refrigeration systems, a thermal balance test is to be carried out to the plant in combination with the insulated chambers, so as to determine the minimum chamber temperature as required in the design and the running conditions when the chamber temperature and the capacity of the plant are balanced. The thermal balance test is to be carried out in the presence of the Surveyor.

(2) When the chambers are cooled down to the minimum designed temperature, the thermal balance test is to be commenced after such a temperature has been maintained constant for a stabilizing period during which heat is removed from the insulation etc. The heat balance test is to last for 8 h. During the test, the temperature of the chambers is to be maintained at the minimum designed temperature and is not to be reduced by more than 1℃. The thermal test may be evaluated in accordance with the relevant programme or standard accepted by CCS.

On completion of the thermal balance test, a thermal balance calculation is to be carried out and the calculations are to be submitted.

1.2.2.5 Temperature rise test for the refrigerated cargo chambers

With the chambers at the minimum designed temperatures, a test for the capability of insulation is to be carried out. The temperature rises in the chambers are to be logged hourly for a period of 6 h.

The total temperature rise t_G (average value of all measuring points) after 6 h temperature rise test is not to be greater than that obtained from the following formula based on the initial temperature difference between the external and chamber temperatures at the beginning of the temperature rise test:

$$t_G = 0.24 t_F \quad ℃$$

where: t_F — initial temperature difference between the external and chamber temperatures, in ℃.

1.2.2.6 Other tests

(1) The air refreshing arrangements, if fitted, are to be tested under operating conditions.

(2) The automatic monitoring system is to be subjected to operation test. This test is, in general, to be carried out when the refrigerating machinery is in running condition, but the functions of alarm and safety devices may be tested under simulated fault conditions if necessary.

(3) Prior to, or on completion of the refrigeration test, the defrosting arrangements of the air coolers are to be tested as per different methods of defrosting. The drainage of bilge water in refrigerated chambers and defrosting water from air coolers may be carried out in conjunction with the refrigeration test.

CHAPTER 2 REFRIGERATING PLANT

Section 1 GENERAL PROVISIONS

2.1.1 Definition of a unit

2.1.1.1 A refrigerating unit comprises one (or a group of) independent refrigeration compressor(s), its driving motor and one gas condenser. Where a secondary refrigerant of brine is employed, the unit is also to include a brine cooler. It is usual for the compressor and the condenser of the refrigerating plant to be permanently connected to the installation with all necessary piping, fittings and electrical equipment.

Two or more refrigeration compressors driven by a single motor, or having only one condenser or brine cooler, are to be regarded as one unit. Where a refrigerating plant is provided for sub-cooling the liquid refrigerant of other units, but is not arranged for cooling the cargo chambers independently, it will not be regarded as a unit.

2.1.1.2 Refrigerating units for refrigerated cargo installations must be completely independent of any refrigerating machinery associated with air conditioning plant, or any domestic refrigerated installation, unless otherwise approved by CCS.

2.1.2 Number of units

2.1.2.1 In ships intended for the carriage of refrigerated cargo, at least two complete refrigerating units are to be provided.

2.1.2.2 In ships classed for restricted service where the total capacity of the refrigerated chambers is less than 1,500 m^3, only one complete refrigerating unit may be provided, but a standby compressor is to be fitted as an addition.

2.1.3 Refrigerating capacity

2.1.3.1 Where a ship is classed for unrestricted service and is intended to carry cargoes requiring different refrigerating temperatures, the refrigerating capacity of the units is to be calculated according to the minimum temperature required to be maintained by the various cargo chambers, with the outside seawater temperature being assumed not less than 32℃.

2.1.3.2 The refrigerating capacity of the refrigerating plant is to be sufficient to maintain the minimum design temperatures in the refrigerated cargo chambers when operating 24 h per day with any one of the refrigerating units out of operation.

2.1.3.3 In order to compensate for possible deterioration of the refrigerating capacity of compressors and the performance of insulation material over the life of the installation, the actual capacity of the refrigerating units is to have at least 5% excess capacity over that required for maximum design output.

2.1.3.4 Where the units are not connected in common to all refrigerated chambers, the refrigerating capacity of the unit serving each chamber (or a group of chambers) is to comply with 2.1.3.2 and 2.1.3.3 of this Section.

2.1.4 Design pressure of refrigerating plant

2.1.4.1 The design pressure of the high pressure side and the low pressure side of the refrigerating plant is to be not less than the values given in Table 2.1.4.1 respectively.

Design Pressure of Refrigerating Plant **Table 2.1.4.1**

Refrigerant	Design pressure of high pressure side① (MPa)	Design pressure of low pressure side② (MPa)
R717	2.2	1.7
R134a	1.4	1.1
R404A	2.5	2.0
R407C	2.4	1.9
R410A	3.3	2.6
R507A	2.5	2.0

Notes: ① High pressure side means the pressed parts of the compressor between its exhausting side and expansion valve.

② Low pressure side means the pressed parts from behind the expansion valve to suction valve of the compressor. Where the change-over of the plant (e.g. for defrosting) will put these parts under high pressure, they are to be designed and tested to the specified pressure of high pressure side.

2.1.4.2 Where any other refrigerant is used, the design pressure of high pressure side and low pressure side of the refrigerating plant is to be not less than the saturated vapour pressure at 56℃ and 46℃ respectively.

Section 2 REFRIGERATING MACHINERY

2.2.1 Reciprocating compressors

2.2.1.1 The diameter d of the crankshaft of a reciprocating compressor is not to be less than that determined by the following formula, when all cranks are located between two main bearings:

$$d = C\sqrt[3]{\frac{D^2P\left(\frac{S}{16}+\frac{ab}{a+b}\right)Z}{7.85}} \text{ mm}$$

where: C — constant, to be determined in accordance with the specific arrangement of cranks and cylinders as shown in Table 2.2.1.1.

D — diameter of compressor cylinder, in mm;

P — design pressure as defined in Table 2.1.4.1 of this Chapter, in MPa;

S — length of piston stroke, in mm;

a — distance between inner edge of one main bearing and the centreline of the crankpin nearest the center of the span, in mm;

$a + b$ — span between inner edges of two main bearings, in mm;

Z — strength coefficient of material, to be determined by the following formula:

For steel:

$$Z=\frac{560}{R_m+160}$$

For spheroidal or nodular graphite cast iron:

$$Z=\frac{700}{R_m+260-0.059d_p}$$

For grey cast iron:

$$Z=\frac{700}{R_m+260-0.069d_p}$$

where: R_m — specified minimum tensile strength of crankshaft material, in N/mm^2;

d_p — proposed minimum diameter of crankshaft, in mm;

Arrangement of Cranks and Cylinders **Table 2.2.1.1**

Number of crankpins	Number of cylinders per crank	Angle between adjacent cylinders (°)
1 or 2	2	45 60 90
3	2	45 60
4	2	45 60
1	3	45 60 90
2	3	45 60
3	3	45
1	4	45 60
2	4	45

For shafts having one cylinder per crank:

$C = 1.0$

For shafts having several cylinders, with 90° between adjacent cylinders on the same crankpin:

$C = 1.05$

For shafts having several cylinders, with 60° between adjacent cylinders on the same crankpin:

$C = 1.18$

For shafts having several cylinders, with 45° between adjacent cylinders on the same crankpin:

$C = 1.25$

2.2.1.2 Where the shaft is supported additionally by a centre bearing, the diameter is to be evaluated from the half shaft between the inner edges of the centre and outer main bearings. The diameter so found for the half shaft is to be increased by 6% for the full length shaft diameter.
2.2.1.3 The dimensions of crankwebs are to be such that bt^2 is to be not less than given by the following formulae:
For the web adjacent to the main bearing:

$$bt^2 = 0.4d^3$$

For intermediate webs:

$$bt^2 = 0.75d^3$$

where: b — breadth of web, in mm;
t — axial thickness of web which is to be not less than $0.45d$ for the web adjacent to the main bearing, or $0.60d$ for intermediate webs, in mm;
d — minimum diameter of crankshaft as required in 2.2.1.1 of this Section, in mm.
2.2.1.4 Fillets at the junction of crankwebs with crankpins or journals are to be machined to a radius r not less than $0.05d$. Smaller fillets, but of a radius not less than $0.025d$, may be used provided the diameter of the shaft is not less than the product of c and d, where: $c = 1.1 - 2r/d$, but not to be taken as less than 1.0.
2.2.1.5 Fillets and oil holes on the crankshafts are to be rounded to an even contour and smooth finish.
2.2.1.6 The crankcase of a trunk piston type compressor is to be designed to withstand an internal pressure at least equal to the maximum working pressure of the refrigerating system.

2.2.2 Strength of materials for the compressor crankshafts

2.2.2.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following limits:
(1) carbon and carbon-manganese steel forgings (normalized and tempered): 400 to 600 N/mm^2;
(2) carbon and carbon-manganese steel forgings (quenched and tempered): not exceeding 700 N/mm^2;
(3) carbon and carbon-manganese steel castings: 400 to 550 N/mm^2;
(4) spheroidal or nodular graphite iron castings: 370 to 800 N/mm^2;
(5) grey iron castings: not less than 300 N/mm^2.
Where it is proposed to use materials other than those listed above, details are to be submitted to for approval.

Section 3 PRESSURE VESSELS, PIPING, FITTINGS AND ACCESSORIES

2.3.1 Pressure vessels

2.3.1.1 Among refrigerants specified in 1.1.2.1 of Chapter 1 of this PART, pressure vessels for refrigerants R717 are to be constructed in accordance with the relevant provisions for Class I pressure vessels specified in Chapter 6, PART THREE of the Rules, and in CCS Rules for Materials and Welding. Other pressure vessels for refrigerants are to comply with the relevant requirements for Class II pressure vessels. The design pressure of pressure vessels for refrigerants is to comply with the requirements of Table 2.1.4.1 of this Chapter.
2.3.1.2 Where pressure vessel cylinders are made of steel tubes, these are to be seamless, electrical resistance welded or longitudinally submerged arc welded. Forge butt welded and spirally welded tubes are not to be used.
2.3.1.3 All pressure vessels with a design temperature below -40℃ and also vessels with a design temperature below 0℃ where the pressure/saturation temperature relationship does not apply, are to be manufactured from steels with mechanical properties, including notch toughness, suitable for the thickness and the lowest design temperature, and relevant information is to be submitted.

2.3.2 Pressure piping

2.3.2.1 All steel pressure pipes for the refrigerating plant are to comply with the relevant provisions specified in Chapter 2, PART THREE of the Rules. Among refrigerants specified in 1.1.2.1 of Chapter 1 of this PART, piping for refrigerants R717 is to be considered as Class I piping and class of pipings for other refrigerants is to comply with the relevant requirements of 2.1.5 of Chapter 2 of PART THREE of the Rules.

2.3.2.2 Pipes for the condensers are to be made of corrosion-resistant material. Pipes for condensers suitable for refrigerants R134a are to be made of corrosion-resistant copper.
Condenser tube plates are to be made of corrosion-resistant material on the seawater side, or alternatively, means capable of efficiently protecting against corrosion may be used.
2.3.2.3 Materials used for refrigerant, brine or seawater cooling piping and accessories are to be suitable for use with the liquids flowing within the pipes. Copper, brass, bronze and other copper alloy are not to be used for ammonia refrigerant. Magnesium alloy is not to be used for fluorine-substituted hydrocarbon refrigerant, and zinc is not to be used for ammonia and fluorine-substituted hydrocarbon refrigerants.
2.3.2.4 Refrigerant and brine pipes are to be seamless, of which the ammonia and brine pipes are to be of seamless steel.
Pipe fittings for the ammonia unit are to be made of steel, but malleable cast iron may be accepted. Pipe fittings for the fluorine-substituted hydrocarbon unit are to be made of steel or bronze.
2.3.2.5 The joints of steel refrigerant pipes are to be butt welded. Where the piping is galvanized in lengths and then joined by welding, the galvanizing is to be removed in way of the pipe ends before welding. Butt joints of copper pipes are to be brazed. If necessary, a particular length of piping may be connected by means of welded-on flanges having grooves in a raised face and with gaskets fitted between them, or by means of screw joint sleeves.
The gaskets for the pipe joints are to be approved by CCS.
2.3.2.6 The stop valves in the refrigerant piping are to be so constructed and arranged as to ensure safe renewal of the packings in the valve stuffing boxes without removing the refrigerant. The stop valves in the R134a refrigerant piping are to be constructed without stuffing boxes. If safety valves with soft stuffing boxes are adopted, they are to be provided with sealing glands.

2.3.3 Oil separators
2.3.3.1 Suitable oil separators with drains are to be provided in the refrigerant lines. If wire gauze is used in the separator, it is to be sufficiently robust and supported to prevent disintegration.

2.3.4 Filters
2.3.4.1 Suitable filters are to be provided in the refrigerant gas lines in the following positions:
(1) suction lines to compressors;
(2) liquid lines before expansion valves.
Wire gauze in filters is to be sufficiently robust and well supported to prevent disintegration. The material of wire gauzes is to be corrosion-resistant to refrigerants. The refrigerant piping is to be designed according to the characteristics of refrigerants, and pipelines are to be fitted with suitable means for separating, storing and purifying refrigerants.
2.3.4.2 The filters are to be so installed and arranged that the filters may be repaired and maintained without interrupting the supply of refrigerants.

2.3.5 Driers
2.3.5.1 Driers are to be fitted in R134a refrigerant systems and the arrangement is to be such that a drier can be by-passed, isolated and opened up without interrupting plant operations.

2.3.6 Thermometers
2.3.6.1 Thermometers are to be provided in systems of the refrigerating plant in the following positions:
(1) suction and delivery lines to compressors;
(2) inlet and outlet cooling water lines to condensers;
(3) brine inlet and outlet lines;
(4) refrigerant return pipes to air coolers of direct expansion type.

2.3.7 Pressure gauges
2.3.7.1 Pressure gauges are to be provided in systems of the refrigerating plant in the following positions:
(1) suction and delivery lines to compressors;
(2) delivery lines to brine pumps;
(3) all refrigerant return pipes to air coolers;
(4) lubricating oil inlets to compressors with pressure lubrication.

2.3.8 Liquid receiver and liquid level indication
2.3.8.1 Refrigeration system is to be provided with necessary liquid receivers, the capacity of which is to be such that all refrigerants filled in the refrigerating unit may be received during the maintenance and

repairing. If independent liquid receiver is provided for each refrigerating unit, the capacity of receiver is to be capable of receiving the refrigerant filled in the refrigerating unit.
2.3.8.2 Refrigerant liquid receivers are to be provided with liquid level indicators. If the level indicator constructed of glass is used, it is to be of the flat glass type. The indicators are to be provided with self closing valves in lower and upper connections so as to prevent the loss of refrigerant in the event of breakage of the indicator. All liquid level indications are to be capable of withstanding the maximum working pressure.

2.3.9 Cooling appliances
2.3.9.1 Chambers may be refrigerated by pipe grids on the ceiling, bulkheads and sides or by the circulation of air over air coolers.
2.3.9.2 Except in the case of chambers employing direct expansion pipe grids as specified in 1.1.4.2 of this PART, refrigeration in the chambers is to be effected by the circulation of brine. The brine pipe grids in each chamber are to be arranged in not less than two sections, each section is to be provided with valve(s) or cock(s) for closing. For a refrigerated chamber with a capacity of less than 300 m^3, one section may be permitted.
2.3.9.3 Steel piping used to convey brine or primary refrigerants within the refrigerated cargo chambers, or where embedded in insulation, is to be galvanized externally. Alternative equivalent methods of protecting the piping against corrosion may be accepted.
Brine piping and tanks are not to be galvanized on the brine side. However, if any parts of the brine system have been galvanized, the brine cooling and return tanks, if closed, are to be provided with a ventilating pipe or pipes led to the atmosphere in a location where no damage will arise from the gas discharged, and the ventilating pipes are to be fitted with wire gauze diaphragms which can readily be renewed.
Where the brine tanks are not closed, the compartments in which they are situated are to be efficiently ventilated.
2.3.9.4 Where the steel pipes used to convey primary or secondary refrigerants are connected by butt welds or by screwed couplings, the ungalvanized portion of the joints is to be suitably coated and taped after hydraulic testing to reduce the incidence of corrosion. The locations of the joints are to be marked on the outside of the insulation.
2.3.9.5 Where cooling pipes pass through watertight bulkheads or decks, the construction of penetrations and packings are to comply with the requirements of 3.1.1.5 of this PART.
2.3.9.6 Either brine or direct expansion of the refrigerant may be employed in the coils of air coolers for each of the chambers. The coils are to be arranged in not less than two sections, each of which is to be fitted with a valve capable of being readily isolated when necessary. The chamber is to be provided with at least one air pipe length and two grids in a certain distance. If the coils are not arranged in sections, at least two independent air coolers of single coil are to be fitted.
A single coil cooler may be provided for a chamber with a net capacity of less than 300 m^3.
2.3.9.7 Means are to be provided for effectively defrosting air coolers. Air coolers are to be provided with trays arranged to collect all condensate. The trays are to be provided with drains at their lowest points to enable the condensate to be drained away when the chambers are in service. The inside diameter of drains is not to be less than 40 mm.
2.3.9.8 Air coolers including fans and motors are to be, as far as practicable, separated from the refrigerated spaces loaded with cargo, and adequate space is to be provided such that both the fan and the motor may be readily removed for repair or renewal. Access for servicing only is required where several fans and motors are installed in a chamber.
2.3.9.9 In order to minimize the dehydration of the cargo and the frosting of the cooling appliances in the refrigerated cargo chambers, the plant is to be designed to maintain the required minimum temperature with a minimum of difference between the cooling medium and chamber temperatures.

2.3.10 Heating arrangements
2.3.10.1 Where it is intended to carry fruit cargoes which may be adversely affected by ambient temperatures which may be below the carrying temperatures, facilities for heating the cargo chambers are to be provided.

2.3.11 Air refreshing arrangements in cargo chambers
2.3.11.1 Where chambers are intended for the carriage of refrigerated cargoes requiring controlled ventilation, air refreshing means are to be provided. The positions of the air inlets are to be carefully selected to minimize the possibility of contaminated air entering the chambers. A distance of at least 3 m is to be maintained between inlet and exhaust vents so as to prevent them from being choked.

Chambers or spaces are to be provided with separate inlet and discharge vents. Each vent is to have a positive airtight valve capable of closing onto a seat.

2.3.12 Pumps

2.3.12.1 The refrigerating units are to be provided with at least two separate cooling water pumps, one of which may be a standby pump. This pump may be used for other purposes provided that it is of adequate capacity and its use on other services does not interfere with the supply of cooling water to the units.

2.3.12.2 Where the primary and/or secondary refrigerants are circulated in the system by pumps, a standby pump, which is not to be used for other purposes and capable of operating on all cargo chambers, is to be provided.

2.3.13 Sea connections

2.3.13.1 The refrigerant gas condenser cooling pump is to be supplied by two sea valves, one of which is provided on the port and the other on the starboard side.

2.3.14 Motive power

2.3.14.1 Where the refrigerating plant is electrically driven, the electrical power is to be supplied by at least two generators. Where any one of the generators is out of operation, the ratings of remaining generators are to be sufficient to maintain, at the seawater temperature specified in 2.1.3.1 of this Chapter, the required minimum temperatures specified in 2.1.3.2 or 2.1.3.3 of this Chapter for the refrigerated cargo chambers, and to ensure the simultaneous operation of other services essential for the propulsion and safety of the ship.

Section 4 CONTROL, ALARM AND SAFETY SYSTEMS

2.4.1 Automatic control for refrigerating plant

2.4.1.1 Where refrigerating plants are operated automatically, efficient manual controls are also to be provided so that manual control can be effected in the event of failure of the automatic control. The automatic control for the plant is to comply with the provisions set forth in 2.4.1.2 to 2.4.1.4 below.

2.4.1.2 The basic performances of all equipment in the refrigerating plant automatic control systems are to comply with the relevant requirements of Chapter 2, PART SEVEN of the Rules.

2.4.1.3 The refrigerating plant automatic control system is to cover the following:

(1) the control of the temperature in the refrigerated cargo chambers within the predetermined temperature limits;

(2) the control of the temperature of cooling air at the outlet not less than the minimum permissible temperatures when the chamber is air-cooled.

2.4.1.4 When the automatic thermostatic control mentioned in 2.4.1.3(1) above is changed over to manual control, the arrangement is to be such that thermostatic controls can be bypassed and isolated. As an alternative, duplicate thermostatically operated refrigerant control valves may be fitted, each valve is to be capable of the required duty and operable with the other out of action.

2.4.2 Alarm

2.4.2.1 The items of monitoring and alarms are not to be less than hose given in Table 2.4.2.1. Audible and visual fault alarms for the refrigerating plant are to be given at the appropriate control station or room.

Items of Monitoring and Alarms for the Refrigerating Plant① Table 2.4.2.1

No.	Item	Display	Alarm
1	Air temperature in the refrigerated cargo chambers	Temperature	High and low
2	Failure of air cooler fans	−	Failure
3	Bilge water level in the refrigerated cargo chambers	−	High
4	Condenser cooling water outlet temperature	Temperature	High
5	Compressor shutdown in the event of failure	−	Shutdown
6	Lubricating oil pressure of compressors	Pressure	Low
7	Suction pressure of compressors	Pressure	Low
8	Exhaust pressure of compressors	Pressure	High
9	Failure of seawater circulating pumps	−	Failure

No.	Item	Display	Alarm
10	Ammonia leakage in refrigerating machinery spaces	−	Leakage②
11	Brine cooler inlet and outlet	Temperature	High (outlet)
12	Failure of brine circulating pumps	−	Failure
13	Brine return tank level	−	Low

Note: ① Where the refrigerating machinery space is unattended, the fault alarms are to be relayed to the engineers' accommodation or other location where an engineer on duty stays.

② For setting of concentration for ammonia leakage alarm in refrigerating machinery space, see 2.5.5.3 of this Chapter.

2.4.3 Safety

2.4.3.1 The refrigerating plant is to be provided with safety systems to automatically shut down the compressors in the following events:

(1) excessively low pressure at the suction side of compressors;

(2) excessively high pressure at the delivery side of compressors;

(3) excessively low lubricating oil pressure in compressors;

(4) requirements specified in 2.5.5.3 of this Chapter for safety protection after ammonia leakage in the refrigerating machinery space;

(5) failure of seawater circulating pumps.

Section 5 LOCATION OF REFRIGERATING MACHINERY SPACE OR UNIT

2.5.1 Refrigerating machinery spaces

2.5.1.1 Where R717 is used as the refrigerant, the machinery compartment is to be isolated by gastight bulkheads and decks from any adjacent accommodation or working spaces.

2.5.1.2 Machinery using refrigerants other than R717 will not, in general, be subject to restriction on location. Where relatively large plants are adopted, they are to be installed in a separate compartment.

2.5.1.3 R717 is to be installed in dedicated gastight compartments. Except for small compartments, at least two access doors as apart from each other as possible, which are capable of being opened outwards and self-closed, are to be provided for R717 refrigerating machinery space.

2.5.1.4 In each R717 refrigerating machinery space at least two gas masks with canisters are to be provided near the entrance to that space and are to be kept in a box with glass window for immediate use when necessary.

2.5.1.5 The arrangements of the refrigerating machinery are to be such that all components are to be easily accessible for inspection or overhaul. Sufficient space is to be provided for cleaning and renewal of the tubes in brine coolers and condensers.

2.5.2 Ventilation and lighting

2.5.2.1 Any refrigerating machinery space is to be provided with an efficient mechanical ventilation system. The ventilation is to provide at least 30 air changes per hour in the refrigerating machinery space.

2.5.2.2 The suction ducts of the ventilation systems are to be constructed of steel or other equivalent material, and the exhaust ports of the ventilation systems are to be located in positions where no danger will arise. In the case of refrigerating machinery spaces other than R717, power exhaust ventilation systems are to be fitted with the suction inlets located at the lowest part of such spaces. Ventilation in R717 refrigerating machinery space is to comply with the relevant requirements in 2.5.3.1.

2.5.2.3 The mechanical ventilation for the refrigerating machinery space is to be capable of being controlled from two positions, and one of which is to be situated in a suitable position outside such space.

2.5.2.4 The fans in R717 refrigerating machinery space are to be of non-sparking type and the material and design of the fan are to comply with the requirements of 3.3.5 of Chapter 3, PART SIX of the Rules. Where the ventilation of R717 refrigerating machinery space is located within the ventilation corridor, the electrical motors are to be of certified safe type, and the explosion groups and temperature classes are not to be lower than IIA T1.

2.5.2.5 Sufficient lighting is to be provided in refrigerating machinery space. Lighting fittings required to be operating after the emergency shut-off of R717 refrigerating machinery space due to leakage of ammonia are to be of certified safe type, and the explosion groups and temperature classes are not to be lower than IIA T1 in accordance with 2.5.5.3(3) of this Chapter.

2.5.3 Use of R717 as a refrigerant

2.5.3.1 Compartments containing R717 machinery (including process vessels) are to be fitted with:

(1) a negative ventilation system independent of ventilation systems serving other ship spaces and the capacity of the refrigerating machinery space is to meet the requirements of 2.5.2.1; other suitable arrangements may be considered; Suction inlets of R717 refrigerating machinery space is to be located on the upper part of the compartment. The ventilation inlets of R717 refrigerating machinery space is to be from the safe area and the exhaust ports are to be lead to the safe location on the open deck;

(2) an emergency ventilation system independent of ventilation systems serving other ship spaces and the capacity of which is to provide at least 40 air changes per hour. If the capacity of the normal ventilation system in the refrigerating machinery space is increased to an amount of not less than 40 air changes per hour for that space, the emergency ventilation system may be dispensed with;

(3) if emergency water-spraying system is accepted in lieu of emergency ventilation system as equivalent, the emergency water-spraying system is to meet the requirements of 2.5.4 of this section; the emergency water-spraying system is to be capable of being operated from a position outside the refrigerating machinery space;

(4) a fixed R717 vapor detector system with alarms inside and outside the compartment;

(5) water screens above all access doors, operable manually from outside the compartment;

(6) an independent bilge system.

2.5.3.2 At least the following safety and protective equipment are to be provided outside of the R717 refrigerating machinery space and the storage location is to be marked for identification and restoration in the event of a refrigerant leak:

(1) two sets of protective clothing (helmet, face masks, boots, gloves etc.);

(2) two sets of independent respirators (at least for 30 min use);

(3) two goggles;

(4) two 30 kg bottles of boric acid;

(5) two emergency electric torches (to be certified safe type and the explosion groups and temperature classes are not to be lower than IIA T1);

(6) one electrical insulation resistance meter.

2.5.3.3 R717 piping is not to pass through accommodation spaces.

2.5.3.4 In case of R717 plants with a quantity of ammonia not greater than 25 kg, the plants are permitted to be located in the machinery space, provided that:

(1) the area where the R717 machinery is installed is served by a hood with a negative ventilation system, so as not to permit any leakage of ammonia from dissipating into other areas in the space;

(2) a water spray system is provided for the said area;

(3) the requirements in 2.5.3.1(2), 2.5.3.2(1) and 2.5.3.3 above are met.

2.5.4 Water-spraying system for R717 refrigerating machinery space

2.5.4.1 The system is to be independent and contains only fresh water, but may also be used for supply to the water screens.

2.5.4.2 The discharge nozzles in the space(s) protected are to be positioned such that the spray is directed over the entire area containing the ammonia refrigeration machinery. The spray volume of the water-spraying system is to be capable of absorbing the leaked ammonia.

2.5.4.3 The supply water of water-spraying system is to be pressurized. The pressurized system is to consist of two pumps and a tank which is to be fitted with adequate safety relief arrangements, pressure gauge(s), level control and level gauge.

2.5.4.4 Means are to be provided to automatically maintain the required pressure and the water level in the tank. In the event of low pressure or the low level, an audible alarm is to sound in the refrigeration machinery room and control room.

2.5.4.5 The water-spraying system is to be arranged to automatically start when the concentration of ammonia in the space exceeds 300 ppm.

2.5.4.6 If water-spraying system is fitted in the refrigerating machinery space, all electrical equipment in the space is to be to IP44 enclosure.

2.5.5 R717 vapor detection and alarm system

2.5.5.1 The detector is to be of a certified safe type, and the explosion groups and temperature classes are not to be lower than IIA T1 and to be suitable for the low temperature working environment.

2.5.5.2 The arrangement of R717 vapor detector is to meet the following requirements:

(1) The refrigerating machinery spaces; one detector per 36 m^2 of the space floor area.

(2) One detector in the exhaust duct of the refrigerating machinery space ventilation system.
(3) One detector in the access corridors leading to the ammonia refrigerating machinery spaces.
(4) One detector in the ammonia storage space.
2.5.5.3 The alarming and safety protection after detection of ammonia leak are to meet the following requirements:
(1) When the concentration of ammonia exceeds 25 ppm, the detectors are to activate alarms.
(2) When the concentration of ammonia exceeds 300 ppm, the detectors in the refrigerating machinery space are to automatically stop the refrigerating plant and automatically activate the emergency ventilation system.
(3) When the ammonia concentration exceeds 5000 ppm, all non-explosion proof electrical equipment in the refrigerating machinery space is to be cut off.

Section 6 SAFETY DEVICES

2.6.1 Relief valves and safety valves

2.6.1.1 A pressure relief valve and/or safety disc is to be fitted between each compressor and its gas delivery stop valve. The safety devices are to come into action in case of excessive refrigerant pressure, the discharge being led to the suction side of the compressor. No closing appliances are to be permitted in the backflow pipes.
2.6.1.2 The opening pressure or bursting pressure of relief valves and/or safety discs at the delivery side of compressors is to be not greater than the design pressure of high pressure side given in Table 2.1.4.1, according to different refrigerants.
2.6.1.3 Where the power of the compressor prime mover does not exceed 10 kW, the relief valves and/or safety discs at the delivery side of the compressors may be omitted.
2.6.1.4 All pressure vessels or other components of refrigerant systems which could become filled with liquid refrigerant and isolated are to be provided with safety discs and/or relief valves, the discharge being led to a safe place above deck. When the safety disc is fitted in front of the relief valve, the back of the safety disc is to be provided with a bulwark to ensure the function of the relief valve. When the safety disc is fitted behind the relief valve, a pressure gauge indicating the intermediate pressure is to be fitted between the relief valve and the safety disc.
2.6.1.5 In the fluorine-substituted hydrocarbon systems, the safety valves and safety discs may be substituted by fusible plugs having a fusion point of 65℃, provided that the individual capacity of the above-mentioned pressure vessels is less than 100 *l*.
2.6.1.6 The opening pressure or bursting pressure of relief valves and/or safety discs as required in 2.6.1.4 is to be not greater than the design pressure of the system or components given in Table 2.1.4.1.
2.6.1.7 Suitable safety valves are to be provided to the cooling water side of condensers and the brine side of evaporators where the discharge pressure from any cooling water pump or brine circulating pump in the circuit could exceed the design pressure of the piping or any component forming part of the cooling system.

2.6.2 Emergency drainage

2.6.2.1 The R717 systems are to be provided with emergency drain pipes so as to immediately drain off the ammonia overboard in case of accident. Stop valves fitted in such pipes are to be situated outside the refrigerating machinery spaces and to be placed in a sealed box with glass window. The outlets of the drain pipes at the ship's side are to be placed below the light ballast waterline, and are to be provided with non-return valves.

2.6.3 Emergency stopping devices

2.6.3.1 For a refrigerating plant using R717 refrigerant, the prime mover of the compressors is to be provided with an emergency stopping device which is to be situated outside the refrigerating machinery space, and provision is to be made for preventing the inadvertent touching by unauthorized persons.

2.6.4 Alarm buttons in the refrigerated cargo chambers

2.6.4.1 Alarm buttons are to be fitted in the refrigerated cargo holds/chambers for giving alarms to the refrigerating machinery space, engine room and navigation bridge in case of emergency.

CHAPTER 3 REFRIGERATED CARGO HOLDS/CHAMBERS

Section 1 DESIGN OF CARGO HOLDS/CHAMBERS

3.1.1 Airtightness of holds/chambers

3.1.1.1 Each individual hold/chamber is to be of steel construction throughout and hose-tested for tightness, or alternatively, air pressure test may be accepted.

Special consideration will be given to the construction of divisional bulkheads of materials other than steel, between refrigerated cargo holds/chambers, where the holds/chambers concerned are intended for cargo which will not taint or otherwise adversely affect the cargo in any other hold/chamber.

3.1.1.2 Hatch closing appliances, access doors, bilge and manhole plugs are to be made airtight. Where hatch covers or plugs are exposed to ambient conditions, they are to be provided with a double seal.

3.1.1.3 Air ducts and insulation linings are to be so constructed and fitted that moving air is prevented from entering the insulation. Special care is to be taken where cooling pipes, air refreshing ducts, fan supports, etc. protrude through the lining.

3.1.1.4 Refrigeration pipes passing through bulkheads or decks of refrigerated cargo holds/chambers are not to be in direct contact with the steelwork, and the holes through which they pass are to be true and of suitable finish for effectively sealing by the method intended so as to maintain the airtightness of the bulkheads or decks.

The temperature of ship's steelwork close to low temperature refrigeration piping is not to be lower than that acceptable for the steel grade.

3.1.1.5 Where cooling pipes pass through watertight deck plating and bulkheads, the fittings are to be both fire resisting and watertight. Refrigerating pipelines are to be effectively insulated outside the chambers they serve, except within insulated brine coolers and control rooms.

3.1.2 Air circulation

3.1.2.1 When frozen cargo is carried, provision is to be made for adequate circulation of air between the frozen cargo and all the insulation lining surfaces. When cooled cargo of a type which may generate heat or emit gas is carried, provision is to be made for the adequate circulation of air through all the stacks.

3.1.2.2 For the purpose of providing air passage in the refrigerated cargo holds/chambers, cargo battens fastened to or temporary dunnage added during cargo loading to the exposed vertical or near vertical surfaces of the insulation linings may be used. They are to be arranged to suit the air flow.

3.1.2.3 Adequate air flow is to be maintained between cargo and cooling grids, where fitted.

3.1.3 Galvanizing of fixtures

3.1.3.1 All steel bolts, nuts, hangers, brackets and fixtures which support or secure cooling appliances, insulation, meat rail, etc., are to be galvanized.

3.1.4 Oil-impervious coatings of oil tank tops and bulkheads

3.1.4.1 Before insulating the oil tank tops and bulkheads, successive coatings impervious to oil are to be applied. The total thickness of the coating required is to depend on the construction of the tank and the composition of the coating used.

3.1.5 Liquid-tightness

3.1.5.1 Tank top insulation in way of manholes and bilge hats is to be provided with a liquid-tight steel coaming to prevent seepage into the insulation.

Section 2 ACCESSORIES

3.2.1 Temperature measurement instruments in cargo holds/chambers

3.2.1.1 Each refrigerated cargo hold/chamber is to be provided with a suitable number of thermometers, and the exact number and positions of which are subject to approval.

The inside diameter of thermometer tubes is not to be less than 50 mm, and the tubes are not to be in contact with cold decks. Thermometer tubes with their flanges and covers are to be insulated from the deck plating.

Thermometer tubes are to be so arranged on weather decks that water will not run down the tubes when temperatures are being taken.
Where thermometer tubes pass through compartments other than those which they serve, they are to be efficiently insulated.
3.2.1.2 Where electrical remote reading thermometers are adopted for the refrigerated cargo chambers, they are to be fitted in accordance with the relevant requirements in 3.2.2 of this PART. Such thermometers are also to comply with the relevant requirements specified in Chapters 1 and 2, PART SEVEN of the Rules.
3.2.1.3 Where the hold/chamber is intended for the carriage of frozen cargo only, the temperature readings are to be accurate to within ±0.5℃ of the true temperature. Where the hold/chamber is intended for the carriage of fruit, the readings are to be accurate to within +0.2℃ to -0.1℃ of the true temperature in the range -3℃ to +3℃, and to +0.3℃ to -0.2℃ in other parts of the range.
For scale instruments, the scale deflection is to be not less than 5 mm/℃ with division markings enabling the indication to be estimated within 0.1 of a degree.

3.2.2 Installation requirements for remote reading temperature instruments

3.2.2.1 At least two instruments are to be provided for each refrigerating system, with the sensing elements so connected that in the event of a failure of any one instrument, it is to be ensured that other temperature instruments are capable of testing the temperature of each hold/chamber.
Where a data logger is installed and all the sensing elements are connected to this single instrument, at least one sensing element in each hold/chamber or in its circulating air system is to be connected to a separate instrument.
The display of data loggers is to be in digital form or other equally effective visual indication, registering to 0.1 of a degree.
Where the equipment controlling the temperature of the air delivered from the cooler is equipped with a temperature indicator, this indicator will be given consideration as a standby instrument provided that the readings are accurate to within ±0.5℃ of the true temperature.
3.2.2.2 Where galvanometers are fitted, two are to be provided for each indicating instrument and a checking resistance is to be fitted.
3.2.2.3 Where the instruments have individual power supply units, a spare power unit (e.g. transformer and rectifier or battery) is to be provided for each instrument.

3.2.3 CO_2 indication equipment

3.2.3.1 All holds/chambers designed for carriage of fruit in general are to be fitted with permanently installed equipment for indication of CO_2 content.

3.2.4 Sounding, air and drain pipes

3.2.4.1 All sounding pipes, whether for compartments or tanks, which pass through refrigerated spaces or the insulation thereof, in which the temperatures contemplated are 0℃ or below, are to be not less than 65 mm bore.
3.2.4.2 Sounding pipes to oil compartments are not to terminate within refrigerated cargo holds/chambers or in the fan and cooler rooms for these holds/chambers, nor are these pipes to terminate in enclosed spaces from which access is provided to refrigerated cargo holds/chambers or their fan and cooler rooms.

3.2.5 Drainage from refrigerated cargo spaces

3.2.5.1 Provision is to be made for the continuous drainage of the inside of all insulated holds/chambers and cooler trays.
3.2.5.2 Drains which are led from cooler trays situated in the hold/chamber are to be fitted with liquid sealed traps. The inside diameter of drains is not to be less than 38 mm.
3.2.5.3 Where drains from separate holds/chambers join a common main, the branch pipes are each to be provided with a liquid sealed trap.
3.2.5.4 The liquid sealed traps are to be of adequate depth, and arrangements are to be made for ready access to the traps for cleaning and refilling with brine.
3.2.5.5 Screwed plugs or other means for blanking off scuppers draining insulated holds/chambers and cooler trays are not to be fitted. If, however, it is specially desired to provide means for temporarily closing these scuppers, they may be fitted with shut-off valves controlled from readily accessible positions on a deck above the load waterline.
3.2.5.6 Drainage from compartments outside the insulated holds/chambers is not permitted to be led into the bilge of the latter.

Section 3 INSULATION

3.3.1 General requirements

3.3.1.1 All steel bulkheads and shell plating inside the refrigerated cargo holds/chambers are to be covered with insulation material. Metallic lining or other equivalents are to be fitted for the protection of the outer surface of the insulants. Such linings are to be constructed and fitted in accordance with 3.1.1.3 of this Chapter.

3.3.1.2 Insulation linings and air screens, together with supports, are to be strong enough to withstand the loads imposed by either refrigerated or general cargo.

3.3.2 Insulation material

3.3.2.1 The insulants, linings, sealants and paints are not to emit odours which may taint subsequent cargo.

3.3.2.2 The insulants used for the refrigerated cargo holds/chambers are to be suitably resistant to fire and resistant to flame spread. The materials used and their adhesives are to be subject to approval by CCS. If chemical foam type of insulation is proposed, the process is to be subject to approval by CCS and the insulants are to be tested according to the recognized standards (e.g.: GB8624-2012 class B2 and other equivalent standards).

3.3.2.3 The covering on the surface of insulant is to be with the same performance to resist fire and flame spread as that of insulants.

3.3.3 Fitting of insulation material

3.3.3.1 Steelwork is to be thoroughly cleaned and dried, and suitably coated against corrosion before insulation is applied.

3.3.3.2 The insulation is to be efficiently packed and, where it is of slab form, the joints are to be butted closely together and staggered. Unavoidable crevices are to be filled with insulating material, but bitumen is not to be used for filling crevices.

3.3.3.3 If the cargo to be loaded on to tank top insulation could cause damage to the lining, then additional protection is to be provided in way of the hatch and 0.6 m beyond. The protection may either be of a permanent or temporary nature.

3.3.4 Insulated plugs and panels

3.3.4.1 Insulated removable plugs are to be provided in the insulation where required for easy access to the bilge, bilge suction wells, cooler and chamber drains and tank manhole lids.

Insulated removable panels are to be provided for access to tank air and sounding pipes and drains. If necessary corrosion protection has been considered for the material of air, sounding and drains pipes, insulated removable panels may be dispensed with.

3.3.4.2 Insulation linings, bilge limbers and plugs, hatch covers and plugs and chamber access doors are to be made of water-vapour resisting material, or covered with such material and, where exposed to bilge or external conditions, they are to be sealed.

3.3.5 Insulation of pipes

3.3.5.1 Where the pipes, including scupper pipes, air pipes and sounding pipes, pass through refrigerated holds/chambers intended for temperatures of 0℃ or below, they are to be insulated from the steel structure, except in positions where the temperature of the structure is mainly controlled by the external temperature and will normally be above freezing point. Pipes passing through a deck plate within the ship side insulation, where the deck is fully insulated below and has an insulation ribband on top, are to be attached to the steel deck plating. In the case of pipes adjacent to the shell plating, metallic contact between the pipes and the shell plating or frames is to be avoided in so far as practicable.

The air refreshing pipes described in 2.3.11.1 need not, however, be insulated from the steelwork.

3.3.5.2 All pipes passing through the refrigerated cargo chambers mentioned in 3.3.5.1 above are to be well insulated.

CHAPTER 4 CARRIAGE OF REFRIGERATED CONTAINERS IN CARGO HOLDS

Section 1 GENERAL PROVISIONS

4.1.1 Class notation

4.1.1.1 The ships carrying refrigerated containers in cargo holds and complying with the requirements of this Chapter may be assigned the following class notation:

CRC (×× holds), AC f/WC

where: AC — air-cooled refrigerated containers;

f — the simultaneity factor for the refrigerating plant, refer to 4.3.2.3 of this Chapter;

WC — water-cooled refrigerated containers.

4.1.2 Plans and documents

4.1.2.1 The following plans and documents are to be submitted for approval:

(1) Calculations of hold ventilation;

(2) Arrangement of hold ventilation system;

(3) Arrangement of power sockets of refrigerated containers;

(4) Arrangement of hold temperature measuring and monitoring system (where fitted);

(5) Arrangement of refrigerated containers;

(6) Arrangement of safety passageway for personnel.

Section 2 ARRANGEMENT

4.2.1 General requirements

4.2.1.1 A passageway or platform for operators with a width of not less than 2 frames or 1 m, whichever is less, is to be provided on transverse bulkheads at a position corresponding to the height of each tier of containers. Handrail or portable rail is to be fitted at the outside of the passageway for the safety of operators.

4.2.1.2 Where torsion boxes are used as ventilation duct, the size of openings on longitudinal bulkheads is to be minimized as possible so as not to affect the overall longitudinal strength.

4.2.1.3 The deck of the passageway or platform for operators is to be of coarse lattice construction as possible to facilitate air flow.

4.2.2 Arrangement of ventilating equipment

4.2.2.1 In general, the supply fan and air inlet are to be arranged at the fore end of holds and the discharge fan and air outlet at the aft end.

4.2.2.2 The air inlet and outlet on deck are to be located as far apart from each other as is practicable. The height of ventilator coaming above deck is to comply with the relevant requirements of Load Line Convention. Where the ventilator is fitted in the masthouse, openings of a size sufficient for ventilation on both fore and aft end bulkheads are to be considered. Roller blinds are to be fitted on the openings to protect the masthouse from flooding. Suitable drainage means in the masthouse are to be considered for preventing water accumulation.

4.2.2.3 Supply fans or discharge fans may be arranged in holds if necessary.

4.2.2.4 Ventilation ducts are to be arranged as reasonably and uniformly as possible. Air supply ducts are to be extended to the refrigerating units of containers of the lowest tier or the bottom of hold as possible, and air vents are to be provided at each tier of stowed containers as possible. The air vents are to be directly facing the discharge fans of container condensers. The upper and lower air vents are to be spaced according to the general container size. Where stowage of superhigh containers is not specified, the spacing is to be determined according to the standard container size, i.e. approximately 2.5 m.

4.2.2.5 The ventilation duct and air inlet and outlet within a hold are to be evenly arranged as possible so that all spaces of the hold are well ventilated.

4.2.2.6 The ventilating equipment is to be capable of being switched on or off remotely from the bridge where it is to be clearly indicated whether the equipment is switched on or off.

4.2.3 Arrangement of refrigerated containers in hold

4.2.3.1 The distance between the containers and the longitudinal bulkhead is in general not to be less than 250 mm.

4.2.3.2 In case of mixed stacks of refrigerated and non-refrigerated containers, the refrigerated containers are to be stowed at the lower tiers and at both ends of the transverse bulkhead as possible. The refrigerating units of containers are to face the transverse bulkhead.

Section 3 VENTILATION WITHIN HOLDS

4.3.1 General requirements

4.3.1.1 This Section applies to cargo holds carrying refrigerated containers. In addition to the requirements of this Section, the corresponding requirements in this PART are to be complied with.

4.3.1.2 The ventilation of holds carrying refrigerated containers is to be determined mainly according to size, type, number of containers, type of refrigerated cargo to be carried and service area of the ship.

4.3.1.3 The design of ventilation is to comply with the following criteria:

External environment: Air temperature 35℃, relative humidity 70%, seawater temperature 32℃

Temperature in hold: Maximum permissible temperature 45℃.

4.3.2 Air supply required for holds carrying air-cooled refrigerated containers

4.3.2.1 Heat balance calculations are to comply with the following:

(1) The minimum power required for cooling of each refrigerated container:

20 ft 7.5 kW

40 ft 11.0 kW

(2) The effective power loss of supply fan is also to be taken into account.

4.3.2.2 For air supply required in each refrigerated container, the following values are applicable:

20 ft 3,100 m^3/h

40 ft 4,500 m^3/h

4.3.2.3 In general, the simultaneity factor for the refrigerating plant is to be taken as 1. Where the ventilation system of the hold is specially designed for refrigerated containers carrying sharp frozen products, the simultaneity factor may be taken as 0.7 ~ 0.8.

4.3.3 Air supply required for holds carrying water-cooled refrigerated containers

4.3.3.1 Heat balance calculations are to comply with the following:

(1) The minimum power required for cooling of each refrigerated container:

20 ft 1.5 kW

40 ft 2.1 kW

(2) The effective power loss of supply fan is also to be taken into account.

4.3.3.2 For air supply required in each refrigerated container, the following values are applicable:

20 ft 460 m^3/h

40 ft 700 m^3/h

4.3.4 Air inlet and distribution

4.3.4.1 The design of air inlet and distribution is to ensure that refrigerated containers will be effectively cooled under circumstances not related to loading conditions and the occurrence of hot spots is to be avoided. For the design conditions stated in 4.3.2 of this Section, it is recommended that air supply inlets be so arranged and distributed that air flow will directly face the refrigerating units of containers; for the design conditions stated in 4.3.3 of this Section, air supply is to be led into the lowest area in the hold.

4.3.5 Air inlets and outlets on deck

4.3.5.1 The air inlets and outlets of hold ventilation system are to be so arranged as to ensure air supply to refrigerated containers in holds under all weather conditions, and choking of air flow of inlets and outlets is to be avoided.

4.3.6 Bilge arrangement

4.3.6.1 Where the length of the hold carrying refrigerated containers is over 12 m, bilge drainage means are to be arranged both at the fore and aft parts of the hold.

4.3.7 Temperature measuring in holds

4.3.7.1 Temperature measuring devices are to be provided in the holds carrying refrigerated containers, and generally one measuring point each before, after, left of and right of containers above the second tier in each hold.

Section 4 ELECTRICAL INSTALLATIONS

4.4.1 General requirements

4.4.1.1 This Section applies to ships carrying refrigerated box containers in holds and on deck. In addition to the requirements of this Section, the corresponding requirements in PART FOUR of the Rules are to be complied with.

4.4.2 Capacity of power plant

4.4.2.1 Where refrigerated containers are supplied by the main power plant of the ship, the number and capacity of the main generating sets are to be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide normal operational condition of propulsion and safety as well as refrigerated containers.

4.4.2.2 For ships adapted to carry refrigerated containers, the containers may be supplied by a leased temporary power plant on deck. If impracticable, standby generating sets are not necessary for power supply of the containers subject to agreement of CCS.

4.4.2.3 For calculation of the capacity of generating sets, see 2.1.1.4 of Chapter 2, PART FOUR of the Rules.

4.4.3 Power distribution for refrigerated containers

4.4.3.1 The sockets of refrigerated containers are to be supplied by special distribution panel which is to be capable of indicating whether the sockets are live and which feeders are electrically connected.

4.4.3.2 The sockets of several containers may be combined to be supplied by one cable, but the connection line of each socket is to be provided with individual short-circuit and overload protection. The common power cable is to be determined according to the total capacity required and the diversity factor specified in 4.4.3.3 of this Section may be used if necessary.

4.4.3.3 Where no exact data are available, the following values may be used as diversity factor for the circuit of container sockets:

20 and less sockets: 0.8;
20 and more sockets: 0.65.

4.4.3.4 The sockets of refrigerated containers are to comply with the standard acceptable to CCS (see ISO 1496-2), and they are to be so fitted as to enable easy use and maintenance.

4.4.3.5 All socket outlets of refrigerated containers are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the ‘on’ position.

4.4.4 Monitoring of refrigerated containers

4.4.4.1 In general, the following conditions of refrigerated containers are to be monitored:
FULL COLD, LOW COLD, NULL, DEFROST, HEAT and NO UNIT, actual temperature of air supply and return, set values, etc. The codes of containers for which alarms are initiated may also be monitored.

4.4.4.2 The information on monitoring is generally to be transmitted to the bridge or management center.

4.4.4.3 The automatic monitoring of refrigerated containers may be replaced by manual inspection where practicable.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2025

PART SIX FIRE PROTECTION, DETECTION AND EXTINCTION

CONTENTS

CHAPTER 1 GENERAL 6-1
Section 1 GENERAL PROVISIONS 6-1
CHAPTER 2 FIRE EXTINCTION SYSTEMS 6-3
Section 1 WATER FIRE-EXTINGUISHING SYSTEMS 6-3
Section 2 FIXED GAS FIRE-EXTINGUISHING SYSTEMS 6-3
CHAPTER 3 FIRE SAFETY MEASURES 6-7
Section 1 SAFETY MEASURES FOR DUCT KEELS IN DOUBLE BOTTOM UNDER CARGO OIL TANKS 6-7
Section 2 FIRE PROTECTION OF MACHINERY SPACES 6-7
Section 3 PROTECTION OF CARGO PUMP ROOMS ON OIL TANKERS 6-8
Section 4 MISCELLANEOUS 6-9
CHAPTER 4 INERT GAS SYSTEMS 6-14
Section 1 GENERAL PROVISIONS 6-14
Section 2 INERT GAS SYSTEMS AND NITROGEN GENERATOR SYSTEMS OF DIFFERENT TYPES 6-14
Section 3 EXAMINATION AND TESTING 6-15
CHAPTER 5 HELICOPTER FACILITIES 6-16
Section 1 GENERAL PROVISIONS 6-16

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 For passenger ships and cargo ships of 500 gross tonnage and upwards engaged on international voyages, the fire detection, fire protection and fire extinction (hereinafter referred to as fire safety) are to comply with the relevant provisions of the International Convention for the Safety of Life at Sea, 1974 (hereinafter referred to as SOLAS Convention) and its amendments, taking into account the requirements of the flag Administration (if any), other than those for personnel qualification, management, operation and maintenance. Ships of less than 500 gross tonnage are to comply with the fire protection requirements of CCS Guidelines for Surveys of Non-convention Ships.

1.1.1.2 The performance standards and test methods for related systems and equipment are to comply with the relevant provisions of the International Code for Fire Safety Systems (hereinafter referred to as FSS Code) and the International Code for Application of Fire Test Procedures (hereinafter referred to as FTP Code).

1.1.1.3 In addition to the above-mentioned requirements, the fire safety of ships engaged on international voyages is to comply with the requirements of this PART.

1.1.1.4 The fire safety of ships engaged on international voyages is also to comply with the requirements, as appropriate, in PART ONE of the Rules.

1.1.1.5 Where necessary, the ship's operator/owner is to pay attention to the standards of other industries and organizations in respect to fire safety of ships. However, such requirements are not conditions for classification with CCS.

1.1.2 Plans and documents

1.1.2.1 The following plans and documents are to be submitted for approval:

(1) Details of fire division plan and fire protection typical nodes;

(2) Arrangement of fire insulation, arrangement of deck covering and arrangement of fire doors;

(3) Arrangement of ventilation system (including fire dampers and smoke dampers, if applicable);

(4) Arrangement of fixed fire extinguishing systems (including the fire extinguishing system for scavenge spaces of crosshead type diesel engines) together with extinguishing medium calculations;

(5) Arrangement of water fire-extinguishing systems;

(6) Arrangement of local water-based fixed fire-extinguishing systems and calculations (if applicable);

(7) Arrangement of fixed fire detection and fire alarm systems;

(8) Diagram of control system of quick-closing valve of fuel and lub. oil tanks;

(9) Fire control plan;

(10) Arrangement of inert gas systems (if applicable);

(11) Arrangement of oxygen and acetylene bottle including pipes (if applicable);

(12) Arrangement of liquefied petroleum gas cooking ranges and gas bottles including pipes (if applicable);

(13) Arrangement of oil-fired cooking ranges including pipes (if applicable);

(14) Arrangement of fire-extinguishing means for paint lockers and store rooms containing flammable liquids (if applicable);

(15) Arrangement of fire-extinguishing system of deep-fat cooking equipment (if applicable);

(16) Other plans and documents as deemed necessary by CCS.

1.1.2.2 The following plans and documents are to be submitted for information:

(1) Instruction manual or operating manual of the inert gas systems required by Chapter 15 of FSS Code.

1.1.3 Products certificate

1.1.3.1 The principal materials, equipment and installations used for the fire safety of ships are all to be provided with CCS appropriate products certificate, as detailed in Appendix 1B — List of Certification Requirements for Statutory Marine Products of Chapter 3, PART ONE of the Rules.

1.1.4 Basic requirements for arrangement of fire stations and systems

1.1.4.1 Any fixed fire-extinguishing systems and their stations, fire pumps, fire-extinguishing medium containers as well as other arrangements on board passenger ships are not to be arranged forward of the collision bulkhead.

1.1.4.2 Stations or centralized distribution manifolds for all fixed fire-extinguishing systems and their power sources are to be located in easily accessible positions and are not likely to be cut off by a fire in the spaces protected.
1.1.4.3 All fixed fire-extinguishing systems and their stations are to be clearly marked and the walkways leading to the stations are to be kept clear.
1.1.4.4 The fixed fire-extinguishing system for the protection of machinery spaces where main propulsion engine and main generator set are located is to be designed such that any action other than the release of fire extinguishing media are not to lead to automatic shutdown of ventilation fans and oil pumps in these machinery spaces, such as opening the release box (cabinet) door during fire drills.

1.1.5 Fire safety measures for ships

1.1.5.1 The fire safety measures for tugs are to be dealt with as those for cargo ships of equivalent tonnage; the fire safety measures for ice-breakers, salvage ships and self-propelled working ships (such as dredges, floating cranes and other working ships etc.) are to be dealt with in accordance with the relevant requirements of the Code of Safety for Special Purpose Ships (resolution MSC.266(84)).
1.1.5.2 The fire safety of special purpose ships are to comply with the requirements in the Code of Safety for Special Purpose Ships, 2008, adopted by the International Maritime Organization by resolution MSC.266(84).
1.1.5.3 For non-propelled ships, the fire safety measures are to be provided by making reference to the relevant provisions in this PART according to the ship types and purposes.
1.1.5.4 Tankers carrying products having a flash point exceeding 60℃ (closed-cup test) are to be dealt with as cargo ships of equivalent tonnage, in addition to complying with the following requirements:
(1) Isolation valves are to be fitted in the fire main of the water fire-extinguishing system at the poop front in a protected position and on the tank deck at intervals of not more than 40 m to preserve the integrity of the fire main system in case of fire or explosion.
(2) Four fire-fighter's outfits are to be provided.
(3) In lieu of the fixed fire-extinguishing system for tanks, they are to be fitted with a fixed deck foam system complying with requirements.
1.1.5.5 Unless expressly provided otherwise, for the purpose of this PART, oil tankers mean tankers carrying crude oil or petroleum products having a flash point not exceeding 60℃ (closed-cup test), as determined by an approved flash point apparatus, and a Reid vapour pressure which is below the atmospheric pressure. Other tankers carrying liquids having the same fire hazard, e.g. liquefied gas carriers and chemical tankers, are also to comply with the requirements of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, as appropriate.

1.1.6 Acceptance of substitutes

1.1.6.1 Where in this PART any particular type of appliances, apparatus, extinguishing media or arrangements is specified for any ship, any other type of appliance etc., not less effective may be allowed, provided the relevant calculations and test or application information are provided.

1.1.7 Miscellaneous

1.1.7.1 The arrangement of fuel oil, lubricating oil and other flammable oils is to be in compliance with the relevant requirements of Chapter 4, PART THREE of the Rules.
1.1.7.2 Unless expressly specified in this PART, the machinery, piping and pressure vessels used in fire safety systems are also to be in compliance with the relevant requirements of PART THREE of the Rules.
1.1.7.3 In addition to complying with the requirements of this PART, the electrical equipment and electronic devices in fire detection systems and other detection and alarm systems used for periodically unattended machinery spaces are to be in compliance with the relevant requirements of PART SEVEN of the Rules.
1.1.7.4 In addition to complying with the requirements of this PART, the electrical equipment and electronic devices used in fire safety systems are to be in compliance with the relevant requirements of PART FOUR of the Rules.
1.1.7.5 Fire extinguishing appliances are to be kept in good order and available for immediate use at all times.

CHAPTER 2 FIRE EXTINCTION SYSTEMS

Section 1 WATER FIRE-EXTINGUISHING SYSTEMS

2.1.1 Capacity of fire pumps

2.1.1.1 Where the water fire-extinguishing system is used for a deck foam system in tankers, the capacity of the fire pumps is to be sufficient to satisfy the requirements for operation of the deck foam system at its required output and the simultaneous use of two water jets with a throw of 12 m at the required pressure from the fire main.

2.1.2 Number and arrangement of fire pumps

2.1.2.1 Cargo ships are to be provided with fire pumps according to the following:

(1) in cargo ships of 500 gross tonnage and upwards but less than 1,000 gross tonnage, at least two power pumps are to be provided, one of which is to be an independent pump;

(2) in cargo ships of less than 500 gross tonnage, at least one independently driven fire pump is to be provided.

2.1.2.2 The arrangement of emergency fire pump is to comply with the requirements of Chapter 12 of the International Code for Fire Safety Systems (FSS Code).

2.1.3 Internal diameter and pressure of fire main

2.1.3.1 In general, the internal diameter of the fire main is not to be less than that required in the following formula:

$$d = \frac{L}{1.2} + 25 \quad \text{mm}$$

where: d — internal diameter of the fire main, in mm, but need not exceed 125 mm for cargo ships (except for ships designed to carry five and more tiers of containers on or above the weather deck) and 180 mm for passenger ships and in no case to be less than 50 mm;

L — length of ship measured between perpendiculars, in m.

2.1.3.2 In cargo ships of less than 1,000 gross tonnage, with the two pumps simultaneously delivering water through the specified nozzles, through any adjacent hydrants, a minimum pressure of 0.25 N/mm^2 is to be maintained at all hydrants.

Section 2 FIXED GAS FIRE-EXTINGUISHING SYSTEMS

2.2.1 General requirements

2.2.1.1 Means are to be provided for automatically giving audible warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The alarm is to operate for not less than 20 s before the medium is released.

Where automatic audible alarms are fitted to warn of the release of fire-extinguishing medium into cargo pump rooms onboard tankers carrying crude oil or petroleum products having a flash point not exceeding 60°C (closed-cup test), they may be of the pneumatic type or electric type:

(1) if pneumatically operated, in cases where the periodic testing of such alarms is required, CO_2-operated alarms should not be used owing to the possibility of the generation of static electricity in the CO_2 cloud; air operated alarms may be used provided the air supply is clean and dry.

(2) if electrically operated, the alarms are to satisfy the requirements of Section 16, Chapter 2, PART FOUR of the Rules and the arrangements are to be such that the electrical actuating mechanism is located outside the cargo pump room, except where the alarms are certified intrinsically safe.

2.2.1.2 At each location of the means of control of any fixed gas fire-extinguishing system, there is to be sufficient illumination including emergency lights in addition to the main lights.

2.2.1.3 Storage rooms of extinguishing medium used for all fixed gas fire-extinguishing systems are to comply with the following requirements:

(1) Storage rooms of extinguishing medium are to be used only for the storage of containers and other components and parts of the systems.

(2) Storage rooms of extinguishing medium are to be provided with direct communications to the bridge or control station.

(3) The key to the storage rooms of extinguishing medium is to be stowed in a box with glass cover which is to be situated in an easily accessible and conspicuous position near the door.
(4) In each storage room of extinguishing medium there is to be displayed a clear and permanent schematic diagram showing the arrangement of the containers, manifold, piping and fittings relating to the release of extinguishing medium, together with the concise instructions for the operation of the system.
2.2.1.4 The release and alarm of the fixed gas fire-extinguishing system for the protection of machinery spaces, including the opening of the release box door for the purpose of test, is not to have automatic linkage with the system that shuts down the ventilation fans and oil pumps in machinery spaces.

2.2.2 High-pressure carbon dioxide systems

2.2.2.1 For cargo spaces the quantity of carbon dioxide available is, unless otherwise provided, to be sufficient to give a minimum volume of free gas equal to 30% of the gross volume of the largest cargo space so protected in the ship.
2.2.2.2 For machinery spaces the quantity of carbon dioxide carried is to be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either:
(1) 40% of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40% per cent or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or
(2) 35% of the gross volume of the largest machinery space protected, including the casing.
Provided that the above-mentioned percentages may be reduced to 35% and 30% respectively for cargo ships of less than 2,000 gross tonnage; provided also that if two or more machinery spaces are not entirely separate they are to be considered as forming one space.
2.2.2.3 Where the volume of free air contained in air receivers in any space is such that, if released in such space in the event of fire, such release of air within that space would seriously affect the efficiency of the fixed fire-extinguishing system, an additional quantity of fire-extinguishing medium is to be provided.
In general, for the space (e.g. engine room) fitted with starting air receivers, the effect upon free air volume in the air receivers is to be taken into account, when calculating CO_2. Or, if compressed air in the air receivers can be discharged into open space located outside the engine room through safe valves and its conducting pipes, the effect upon air receivers is not to be taken into account, when calculating CO_2.
2.2.2.4 When carbon dioxide is used as an extinguishing medium for the cargo pump room in tankers carrying cargo oil having a flash point not exceeding 60℃, the quantity of carbon dioxide is to be sufficient to give a minimum volume of free gas equal to 45% of the gross volume of the cargo pump room including the casing. For tankers carrying cargo oil having a flash point exceeding 60℃, if the cargo pump room is located in a separate space, it is to be treated as a machinery space.
2.2.2.5 For ro-ro spaces and vehicle spaces, other than special category spaces, which are capable of being sealed from a location outside the spaces, if a carbon dioxide system is fitted, the quantity of gas available is to be at least sufficient to give a minimum volume of free gas equal to 45% of the gross volume of the largest such cargo space which is capable of being sealed.
2.2.2.6 For the purpose of this paragraph the volume of free carbon dioxide is to be calculated at 0.56 m^3/kg.
2.2.2.7 Piping of carbon dioxide is to comply with the following requirements:
(1) Each connecting pipe led from each bottle head valve to the collecting pipe is to be provided with a non-return valve.
(2) The manifold connecting the collecting pipes and distribution manifold is to be provided with a pressure gauge having a maximum range of 1.5 times the working pressure.
(3) For machinery spaces of Category A or cargo pump rooms, the piping is to be provided with sufficient number and adequate size of nozzles so that 85% of carbon dioxide can be discharged into the space within 2 min. Approximately 10% of the total quantity of CO_2 is to be discharged to the protected space below the floor in engine room. For vehicle spaces and ro-ro spaces which are not special category spaces, the arrangements are to be such as to ensure that at least two thirds of the gas required for the relevant space are introduced within 10 min. For container and general cargo spaces (primarily intended to carry a variety of cargoes separately secured or packed) the fixed piping system is to be such that at least two thirds of the gas can be discharged into the space within 10 min. For solid bulk cargo spaces the fixed piping system is to be such that at least two thirds of the gas can be discharged into the space within 20 min. The system controls are to be arranged to allow one third, two thirds and the entire quantity of gas to be discharged based on the loading condition of the hold.
(4) The diameter of carbon dioxide piping leading to the spaces as stated in 2.2.2.7(3) above is to be determined by calculation in accordance with the expected quantity to be conveyed through the piping

based on the recognized standard①.The diameter of carbon dioxide piping in machinery spaces of category A and cargo pump rooms may also be determined from Table 2.2.2.7(4). The maximum quantities of carbon dioxide conveyed by the corresponding pipe diameters are given in Table 2.2.2.7(4).

Internal Diameter of Pipes and Conveyed Quantity Table 2.2.2.7(4)

Maximum quantity of carbon dioxide conveyed by the pipe (kg)	Internal diameter of pipe (mm)
60	15
100	20
135	25
275	32
500	40
1100	50
1600	65
2400	80
3300	90
4750	100
6800	114
9500	127
15250	152

(5) The minimum wall thickness of CO_2 pipes is given in Table 2.2.2.7(5). Slight difference from the thickness listed in the Table will be accepted for the purpose of selecting standard pipes.

Minimum Wall Thickness of CO_2 Pipes Table 2.2.2.7(5)

External diameter of pipe (mm)	Wall thickness (mm)	
	Piping forward of distribution manifold	Piping from distribution manifold to protected space (nozzles)
21.3 ~ 26.9	3.2	2.6
30.0 ~ 48.3	4.0	3.2
51.0 ~ 60.3	4.5	3.6
63.5 ~ 76.1	5.0	3.6
82.5 ~ 88.9	5.6	4.0
101.6	6.3	4.0
108.0 ~ 114.3	7.1	4.5
127.0	8.0	4.5
133.0 ~ 139.7	8.0	5.0
152.4 ~ 168.3	8.8	5.6

Notes:
1. Pipes are to be galvanized at least inside, except those fitted in the engine room where galvanizing may not be required.
2. For threaded pipes, where allowed, the minimum wall thickness is to be measured at the bottom of the thread.
3. The external diameters and thicknesses have been selected from ISO Recommendations R336 for smooth welded and seamless steel pipes. Diameter and thickness according to other national or international standards may be accepted.
4. For larger diameters the minimum wall thickness will be subject to special consideration.
5. In general the minimum thickness is the nominal wall thickness and no allowance need be made for negative tolerance or reduction in thickness due to bending.

(6) Distribution piping leading to cargo spaces is to have a bore of not less than 20 mm, and those leading to the nozzles are to have a bore of not less than 15 mm.
(7) CO_2 piping is to be provided with compressed air cleaning connections at its manifold or distribution manifold.
(8) CO_2 pipes are to be of seamless steel, except that flexible metallic pipes can be used as the connecting pipe led from each bottle head valve to the collecting pipe in accordance with recognized standards.
(9) For closed ro-ro cargo spaces, the piping arrangements are to be such that 2/3 of the gas required for a particular space can be discharged into the space within 10 min.
2.2.2.8 Carbon dioxide bottles are to comply with the following requirements:
(1) CO_2 bottles are to be of seamless steel. Each bottle is to be furnished with a certificate and to have on its body clear and permanent identification of weight, capacity, hydraulic test pressure, date of test, manufacturer' serial number and also inspection stamp.
(2) The bottles are to be wholly painted in bright colour but white in way of the markings, and with letters of "carbon dioxide (or CO_2)".
(3) The charging ratio for CO_2 bottles is to be suitable for the strength of the bottles and generally not to be more than 0.67 kg/L.

①E.g. Code of Design for Carbon Dioxide Fire Extinguishing System (GB50193-93(2010 edition)) or Fire Protection Equipment – Carbon Dioxide Extinguishing Systems for Use on Premises – Design and Installation (ISO 6183-2022), etc.

(4) Bottle head valves are to be associated with a steel or copper seamless tube having a diameter of 10 to 12 mm snipped off at its lower end and terminated near the bottom of the bottle.
(5) Bottle head valves are to be provided with safety diaphragms or other approved safety devices. The bursting pressure of the safety diaphragms is to be 18.6 ±1 MPa. For other approved safety devices, the relevant technical and test data are to be provided with, to demonstrate that the escape gas is ensured to be capable of being released when the bursting pressure reaches the same as above.
After bursting of safety diaphragms, the escape gas from bottle head valves is to be led to the open atmosphere through suitable piping. However, where the storage room for CO_2 cylinders is fitted with a dedicated mechanical ventilation system capable of providing at least 6 air changes per hour and keeping temperature in the room below 45℃ and provided with a temperature alarm, such piping may be dispensed with.
(6) Bottles head valves are to be made of forged bronze or other suitable materials.
(7) CO_2 bottles are to be divided into groups according to the required quantity for different spaces to be protected. If releasing of the carbon dioxide is hand-operated directly by mechanical means, the number of bottles in each group is not to exceed 12.
2.2.2.9 Testing of carbon dioxide systems
(1) CO_2 bottles and bottle head valves are to be subjected to a hydraulic test of 24.5 MPa. Safety diaphragms are to be burst-tested in accordance with 2.2.2.8(5) by selecting 10% at random.
(2) On completion of fitting the bottle head valves, CO_2 bottles are to be subjected to an air-tightness test in the workshop to a pressure equal to the design pressure of the bottle.
(3) The pipes and valves of CO_2 piping systems are to be subjected to a hydraulic test with a pressure of at least 11.8 MPa for the distribution manifold and control valves and for pipe lengths between bottle head valves and the distribution manifold, and 1.0 MPa for pipe lengths between the distribution manifold and nozzles. The above tests may be carried out in workshop. On completion of the hydraulic test, CO_2 piping is to be subjected to an airtightness test using compressed air on board the ship to at least 0.69 MPa with the ends closed for checking the tightness of each connection.
(4) On completion of installation on board, the CO_2 piping system is to be function-tested with a pneumatic pressure not less than 2.47 MPa for checking the operation of releasing mechanism.

2.2.3 Low-pressure carbon dioxide systems

2.2.3.1 Where a low-pressure CO_2 system is fitted, the piping system is to be designed in such a way that the CO_2 pressure at the nozzles should not be less than $1N/mm^2$.

CHAPTER 3 FIRE SAFETY MEASURES

Section 1 SAFETY MEASURES FOR DUCT KEELS IN DOUBLE BOTTOM UNDER CARGO OIL TANKS

3.1.1 Safety aspects of double bottoms and duct keels under cargo oil tanks (corresponding to SOLAS regulation II-2/4.5.2.4)

3.1.1.1 Pipe ducts in the double bottom are to comply with the following requirements:

(1) They are not to communicate with the engine room.

(2) Provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. One of these exits fitted with a watertight closure may lead to the cargo pump room.

(3) In the duct, provision is to be made for adequate mechanical ventilation.

Section 2 FIRE PROTECTION OF MACHINERY SPACES

3.2.1 Measures to prevent the spills of oil fuel, lubricating oil, hydraulic oil, thermal oil and other combustible liquids

3.2.1.1 Tanks (corresponding to SOLAS regulation II-2/4.2.2.4)

(1) Air pipes from fuel oil tanks are to be led to a safe position on the open deck.

Air pipes from lubricating oil storage tanks may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

(2) Any overflow pipe is to have a sectional area of at least 1.25 times that of the filling pipe and is to be led to an overflow tank of adequate capacity or to a storage tank having space reserved for overflow purposes.

An alarm device is to be provided to give warning when the oil reaches a predetermined level in the tank, or alternatively, a sight glass with good illumination is to be provided in the overflow pipe to indicate when any tank is overflowing. Such sight glasses are to be placed on vertical pipes only and in readily visible positions.

3.2.1.2 Oil fuel gauge (corresponding to SOLAS regulation II-2/4.2.2.3.5.1 and 4.2.2.3)

(1) Short sounding pipes may be used for tanks other than double bottom tanks without the additional closed level gauge, provided an overflow system is fitted.

(2) Level switches may be used below the tank top provided they are contained in a steel enclosure or other enclosures not capable of being destroyed by fire.

3.2.1.3 Pump control (corresponding to SOLAS regulation II-2/5.2.2.3)

Controls of the oil pumps (e.g. oil transfer pumps, oil fuel unit pumps, lubricating oil service pumps, thermal oil circulating pumps and oil separators) required by Regulation II-2/5.2.2.3 of SOLAS are also to be provided from the compartment itself.

3.2.1.4 Oil fuel pipelines (corresponding to SOLAS regulation II-2/4.2.2.5.1)

Hose clamps and similar types of attachments for flexible pipes are not to be permitted.

3.2.1.5 Arrangements of oil fuel (corresponding to SOLAS regulation II-2/4.2.2 and 4.2.5.2)

Oil fuel in storage tanks is not to be heated to temperature within 10℃ below the flash point of the oil fuel, except that where oil fuel in service tanks, settling tanks and any other tanks in supply system is heated the following arrangements are to be provided:

(1) the length of the vent pipes from such tanks and/or a cooling device is sufficient for cooling the vapours to below 60℃, or the outlet of the vent pipes is located 3 m away from a source of ignition;

(2) the vent pipes are fitted with flame screens;

(3) there are no openings from the vapour space of the fuel tanks into machinery spaces (bolted manholes are acceptable);

(4) enclosed spaces are not located directly over such fuel tanks, except for vented cofferdams;

(5) electrical equipment is not fitted in the vapour space of the tanks, unless it is certified to be intrinsically safe.

Section 3 PROTECTION OF CARGO PUMP ROOMS ON OIL TANKERS

3.3.1 Measures to prevent explosions in cargo pump rooms on oil tankers

3.3.1.1 The requirements of 3.3.1.2 to 3.3.1.5 below apply to the cargo pump rooms of oil tankers where pumps for cargo, such as cargo pumps, stripping pumps, pumps for slop tanks, pumps for COW or similar pumps are provided. Pump rooms intended solely for ballast or oil fuel transfer, however, need not comply with these requirements.

3.3.1.2 Cargo pumps, ballast pumps and stripping pumps, installed in cargo pump rooms and driven by shafts passing through cargo pump room bulkheads are to be fitted with temperature sensing devices for bulkhead shaft glands, bearings and pump casings. These devices are to be capable of automatically effecting a continuous audible and visual alarm in the cargo control room or the pump control station.

3.3.1.3 Lighting in cargo pump rooms, except emergency lighting, is to be interlocked with ventilation such that the ventilation has been in operation for at least 5 min before switching on the lighting. Failure of the ventilation system is not to cause the lighting to go out.

3.3.1.4 A system for continuously monitoring the concentration of hydrocarbon gases is to be fitted. Sampling points or detector heads are to be located in suitable positions in order that potentially dangerous leakages are readily detected. When the hydrocarbon gas concentration reaches a preset level, which is not to be higher than 10% of the lower flammable limit, a continuous audible and visual alarm signal is to be automatically effected in the cargo pump room, engine control room, cargo control room and navigation bridge to alert personnel to the potential hazard.

(1) Where a system for sequential sampling is used for sampling of cargo pump rooms including exhaust ducts, the time between two samplings of a same position is to be reasonably short.

(2) For the number and arrangement of sampling points, appropriate consideration is to be given to the vapour density of carried cargo and the ventilation condition of tanks.

3.3.1.5 All cargo pump rooms are to be provided with bilge level monitoring devices together with appropriately located alarms. Bilge high-level alarms are acceptable as an alternative means for the level monitoring devices.

3.3.2 Gland seals in cargo pump room bulkheads

3.3.2.1 Where drive shafts pass through cargo pump room bulkhead or deck plating, gastight glands are to be fitted. The glands are to be efficiently lubricated from outside the cargo pump room.

3.3.2.2 The seal parts of the glands are to be of material that will not initiate sparks. The glands are to be constructed and fitted in accordance with the relevant requirements for fittings attached to watertight bulkheads, and if a bellows piece is incorporated in the design, it is to be pressure tested before fitting.

3.3.3 Cargo pump room ventilation

3.3.3.1 With the following arrangement of exhaust trunking there are to be 20 air changes per hour on the total volume of the cargo pump room:

(1) In the cargo pump room bilges just above the transverse floor plates on bottom longitudinals, so that air can flow over the top from adjacent spaces.

(2) The ventilator inlet of the cargo pump room is to be close to the bottom so far as practicable and above floors or bottom longitudinals. An emergency intake is to be fitted about 2 m above the cargo pump room lower grating (This emergency intake would be used when the lower intakes are sealed off due to flooding in the bilges.). The emergency intake is to have a damper fitted which is capable of being opened or closed from the exposed main deck and cargo pump room lower grating level.

(3) The foregoing exhaust system is in association with open grating floor plates to allow the free flow of air.

(4) A grating damper may be used between upper emergency and lower main ventilator openings, which can be shown to result in at least the required 20 air changes per hour through the lower inlets, can be adopted without the use of dampers. When the lower access inlets are closed, then at least 15 air changes per hour are to be obtained through the upper inlets.

3.3.4 Temperature of steam and heating media within the cargo area

3.3.4.1 On oil tankers, the steam and heating media temperature within the cargo area is not to exceed 220℃.

3.3.4.2 On gas carriers and chemical tankers, the maximum temperature is to be adjusted to take into account the temperature class of the cargoes.

3.3.5 Non-sparking fans

3.3.5.1 A fan is considered as non-sparking if in either normal or abnormal conditions it is unlikely to produce sparks.

3.3.5.2 Design criteria

(1) The air gap between the impeller and the casing is not to be less than 0.1 times the shaft diameter in way of the impeller bearing but not less than 2 mm. It need not be more than 13 mm.

(2) Protection screens of not more than 13 mm square mesh are to be fitted in the inlet and outlet of ventilation openings on the open deck to prevent the entrance of objects into the fan housing.

3.3.5.3 Materials

(1) The impeller and the housing in way of the impeller are to be made of alloys which are recognized as being spark-proof by appropriate test.

(2) Electrostatic charges both in the rotating body and the casing are to be prevented by the use of anti-static materials. Furthermore, the installation on board of the ventilation units is to be such as to ensure the safe bonding to the hull of the units themselves.

(3) Tests may not be required for fans having the following combinations:

① impellers and/or housings of nonmetallic material, due regard being paid to the elimination of static electricity;

② impellers and housings of non-ferrous materials;

③ impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller;

④ any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

(4) The following impellers and housings are considered as sparking and are not permitted:

① impellers of an aluminium alloy or magnesium alloy and a ferrous housing, regardless of tip clearance;

② housing made of an aluminium alloy or a magnesium alloy and a ferrous impeller, regardless of tip clearance;

③ any combination of ferrous impellers and housings with less than 13 mm design tip clearance.

(5) Type tests on the finished product are to be carried out in accordance with the requirements of CCS or an equivalent national or international standard acceptable to CCS.

Section 4 MISCELLANEOUS

3.4.1 Aluminium coatings on board oil tankers and chemical tankers

3.4.1.1 The use of aluminium coatings containing greater than 10 percent aluminium by weight in the dry film is prohibited in cargo tanks, cargo tank deck area, cargo pump rooms, cofferdams or any other area where cargo vapour may accumulate.

3.4.1.2 Aluminized pipes may be permitted in ballast tanks, in inerted cargo tanks and, provided the pipes are protected from accidental impact, in hazardous areas on open deck.

3.4.2 Tank cleaning openings

3.4.2.1 Ullage plugs, sighting ports and tank cleaning openings are not to be arranged in enclosed spaces.

3.4.3 Portable instruments for measuring oxygen and flammable vapour concentrations

3.4.3.1 Every oil tanker is to be provided with at least two portable gas detectors capable of measuring flammable vapour concentrations in air (%LEL) and at least two portable O_2 analysers. Alternatively, at least two gas detectors, each capable of measuring both oxygen and flammable vapour concentrations in air (%LEL), are to be provided.

3.4.3.2 In addition to the requirement in 3.4.3.1, for tankers fitted with inert gas systems, at least two portable gas detectors are to be capable of measuring concentrations of flammable vapours in inerted atmosphere (% gas by volume).

3.4.4 Pressurization of cargo tanks

3.4.4.1 PV valves to oil tanks are not to be set at pressures in excess of 0.021 MPa unless the tank scantlings have been specially considered.

3.4.5 Reinforced thickness of ballast and cargo oil piping

3.4.5.1 Ballast piping passing through cargo tanks and cargo oil pipes passing through segregated ballast tanks, as defined by regulation 19.3.6 of MARPOL Annex I, are to comply with the following requirements:

(1) The pipes are to be of heavy gauge steel of minimum wall thickness according to Table 3.4.5.1 hereunder with welded or heavy flanged joints① the number of which is to be kept to a minimum.

(2) Expansion bends② only are permitted in these lines within cargo tanks for serving the ballast tanks and within the ballast tanks for serving the cargo tanks.

Minimum Wall Thickness of Pipes **Table 3.4.5.1**

Nominal diameter (mm)	Minimum wall thickness (mm)
50	6.3
100	8.6
125	9.5
150	11.0
200 and above	12.5

3.4.5.2 The thicknesses shown in Table 3.4.5.1 refer to carbon steel pipes.

3.4.5.3 Connection between cargo piping and ballast piping referred to above is not permitted except for emergency discharge as specified in the Unified Interpretation to regulation 1.18 of MARPOL Annex I.

Nevertheless, provision may be made for emergency discharge of the segregated ballast by means of a connection to a cargo pump through a portable spool piece. In this case non-return valves are to be fitted on the segregated ballast connections to prevent the passage of oil to the ballast tanks. The portable spool piece is to be mounted in a conspicuous position in the cargo pump room and a permanent notice restricting its use is to be prominently displayed adjacent to it.

Shut-off valves are to be provided to shut off the cargo and ballast lines before the spool piece is removed.

3.4.5.4 The ballast pump is to be located in the cargo pump room, or a similar space within the cargo area not containing any source of ignition.

3.4.6 Bow and stern loading and unloading arrangements on oil tankers

3.4.6.1 Where a cargo hose connection is arranged outside the cargo tank area, the pipe leading to such connections is to be provided with means of segregation such as a spectacle flange, removable spool piece or equivalent③ located within the cargo area. The space within 3 m of the manifold is to be considered as a dangerous area with regard to electrical or incendive equipment.

3.4.7 Direct loading pipes to oil tanker cargo tanks

3.4.7.1 In order to avoid the generation of static electricity when cargo is loaded direct into tanks, the loading pipes are to be led as low as practicable in the tank.

3.4.8 Cargo openings in the bottoms of topside tanks of ships carrying alternatively oil and grain

3.4.8.1 This requirement applies to ships carrying alternatively oil having a flash point not exceeding 60℃ or other cargoes.

When ships are designed to transport alternatively oil or dry cargoes, openings which may be used for cargo operations are not permitted in bulkheads and decks separating oil cargo spaces from other spaces not designed and equipped for the carriage of oil cargoes unless alternative approved means are provided to ensure equivalent integrity.

3.4.9 Emergency fire pumps in cargo ships④

3.4.9.1 In cargo ships, the room(s) where the pump and prime mover are installed is/are to have adequate space for maintenance work and inspections.

---

① Heavy flanges joints means welded flange joints rated at least PN10 or one pressure rating higher than required design pressure, whichever is greater.

② Expansion bends means expansion loops such as an omega bend ('Ω') in piping system to counteract excessive stresses or displacement caused by thermal expansion or hull deformation which could be fabricated from straight lengths of pipe.

③ Refer to IMO MSC/Circ.474.

④ Emergency fire pumps in cargo ships are to additionally comply with the requirements of SOLAS regulation II-2/10 and Chapter 12 of FSS Code, as appropriate.

3.4.10 Prohibition of carriage in fore peak tanks of oil or other liquid substances which are flammable

3.4.10.1 In ships of 400 gross tonnage and above, compartments forward of the collision bulkhead are not to be arranged for the carriage of oil or other liquid substances which are flammable.

3.4.11 Sea intakes for fire pump on ships with ICE Class

3.4.11.1 On ships with ICE Class at least one of the fire pumps is to be connected to a sea chest which is provided with de-icing arrangements.

3.4.12 Installation requirements for analysing units for continuous monitoring of flammable vapours

3.4.12.1 This requirement applies to gas analysing units of the sampling type located outside gas dangerous zones and fitted on board gas carriers or on board oil/chemical tankers.

3.4.12.2 Gas analysing units with non-explosion proof measuring equipment may be located in areas outside cargo areas, e.g. in cargo control room, navigation bridge or engine room when mounted on the forward bulkhead provided the following requirements are observed:

(1) Sampling lines are not to run through gas safe spaces, except where permitted under (5).

(2) The gas sampling pipes are to be equipped with flame arresters. Sample gas is to be led to the atmosphere with outlets arranged in a safe location.

(3) Bulkhead penetrations of sample pipes between safe and dangerous areas are to be of approved type and have same fire integrity as the division penetrated. A manual isolating valve is to be fitted in each of the sampling lines at the bulkhead on the gas safe side.

(4) The gas detection equipment including sample piping, sample pumps, solenoids, analysing units etc. is to be located in a reasonably gastight enclosure (e.g. a fully enclosed steel cabinet with a gasketed door) which is to be monitored by its own sampling point. At gas concentrations above 30% LFL inside the enclosure the entire gas analysing unit is to be automatically shut down.

(5) Where the enclosure cannot be arranged directly on the bulkhead, sample pipes are to be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and analysing units, and are to be routed on their shortest ways.

3.4.13 Fore peak ballast system on oil tankers

3.4.13.1 The fore peak tank can be ballasted with the system serving other ballast tanks within the cargo area, provided:

(1) the fore peak tank is considered as hazardous;

(2) the vent pipe openings are located on open deck at an appropriate distance from sources of ignition. In this respect, the hazardous zones distances are to be determined according to the hazardous zones defined in paragraphs 4.2.2.9 and 4.2.3.1 of IEC 60092-502: Electrical installations in ships - Tankers - Special features;

(3) means are provided, on the open deck, to allow measurement of flammable gas concentrations within the fore peak tank by a suitable portable instrument;

(4) the sounding arrangement to the fore peak tank is direct from open deck;

(5) the access to the fore peak tank is direct from open deck. Alternatively, indirect access from the open deck to the fore peak tank through an enclosed space may be accepted provided that:

① in case the enclosed space is separated from the cargo tanks by cofferdams, the access is through a gas tight bolted manhole located in the enclosed space and a warning sign is to be provided at the manhole stating that the fore peak tank may only be opened after it has been proven to be gas free; or any electrical equipment which is not certified safe in the enclosed space is isolated;

② in case the enclosed space has a common boundary with the cargo tanks and is therefore hazardous, the enclosed space can be well ventilated.

3.4.14 Arrangement of oxygen, acetylene cylinders

3.4.14.1 Storage of oxygen, acetylene cylinders is to meet the following requirements:

(1) The design, construction and approval of gas cylinders are to comply with the applicable requirements of PART THREE of the Rules or requirements of the recognized standards. Oxygen cylinders are to be provided with proper pressure relief device such as a fusible plug or a rupture disc.

(2) Pipes, pipe fittings, pipe joints and valves are to comply with the requirements of Class I piping systems. Materials for acetylene on the high-pressure side between the cylinders and the regulator are to be steel.

Copper or copper alloys containing more than 65% copper are not to be used in the whole fixed acetylene piping. Materials for oxygen piping are to be of steel or copper. Materials for both oxygen and acetylene systems are to be corrosion resistant, all the pipes of the fixed piping are to be seamless drawn.
(3) The connections between fixed pipe sections are to be carried out by means of butt welding. Other types of connections including threaded connections and flange connections are not permitted.
(4) Where there are two or more cylinders of each gas, separate dedicated storage rooms are to be provided for each gas.
(5) Storage rooms are to be constructed of steel, not located below the open deck, and be well ventilated and accessible from the open deck. The ventilation arrangement is to be separate from the ship's ventilation systems.
(6) Possible sources of ignition are not to be fitted in acetylene storage room and any electrical installation, if fitted, is to be of a certified explosion-proof type.
(7) Securing arrangements of gas cylinders are to be released easily and quickly for the expeditious removal of cylinders in the event of fire.
(8) Prominent and permanent "NO SMOKING" signs are to be displayed at the gas cylinder storage room.
(9) Where cylinders are stowed in open locations means are to be provided to:
① protect cylinders and associated piping from physical damage;
② minimize the likelihood of exposure to hydrocarbons;
③ ensure suitable drainage.
(10) If the pipes connecting the work station for oxyacetylene welding and gas storage room need to pass through deck or bulkhead, fixed pipes are to be provided between gas cylinder and work station for welding and they are not to pass through accommodation spaces, service spaces and control stations. Suitable protection is to be provided at the position passing through deck or bulkhead. Outlet stations of fixed pipes are to be fitted with shut-off valves.

3.4.15 Arrangement of liquefied-gas-fired ranges

3.4.15.1 If liquefied-gas-fired ranges are fitted in a galley, the following requirements are to be met:
(1) Ranges, gas cylinders, angle valves and pressure reduction valves, etc. are to be designed, manufactured and tested in accordance with applicable standards and codes.
(2) Unless separated from adjacent spaces by suitable fire division, the galley is to be situated above the main deck. Inside the galley no opening or stairway leading to the spaces below is allowed; or where an opening is arranged, a positive means of closing is to be provided.
(3) Liquefied gas ranges are to be fitted securely at predetermined positions. Means are to be provided to prevent shifting of ranges.
(4) Liquefied gas cylinders are to be positioned vertically and fixed securely. Fixed hoops are to be capable of being released easily and quickly. Cylinders are to be provided with wood blocks under the bottom to avoid impact.
(5) Steel liquefied gas pipe lengths are to be connected by welding. Threaded joints may be adopted for connecting ranges, valves, instrumentation etc. with pipes and valves. The joints are to be fitted with oil-resistant sealing washers or coated with binder to ensure gastightness.
The joints between rubber hoses and pressure reduction valves, ranges or steel pipes are to be cramped by metal clamps. The clamps are to be connected securely. They are to be capable of being easily fitted or removed and to ensure gastightness.
(6) For the pressure of strength test and tightness test on liquefied gas piping system, the requirements given in Table 3.4.15.1 are to be complied with.

Test Pressure of Piping **Table 3.4.15.1**

Liquefied gas piping	Test pressure	
	Strength test (in workshop) (MPa)	Tightness test (after installation on board) (MPa)
Piping from cylinder to pressure reduction valve	2.4	2.0
Piping from pressure reduction valve to range	0.2	0.1

(7) Storage spaces containing liquefied gas cylinders are to comply with the requirements of 3.4.14 of this Section and the fire safety requirements of 3.4.17 of this Section.
3.4.15.2 For galleys where oil or flammable gas is in use, their structure and arrangement are to comply with the following requirements:

(1) The oil fuel tank is to be located outside the galley and is to be fitted with approved means of filling and venting.
(2) The oil fuel or flammable gas supply to the burners is to be capable of being cut off from a readily accessible position outside the galley in the event of a fire occurring in the galley.
(3) Naked fire is not to be in use for ignition of oil fuel or flammable gas, except for galley stoves or water heaters. All pipelines for delivering oil fuel or flammable gas from containers to the stoves or water heaters are to be of steel or other approved materials. And safety appliances for automatic shutoff are to be provided so that they will automatically shut off oil fuel and flammable gas supply when the flame in the stoves goes out.
(4) Naked fire is not to be in use for warming oneself. Galley stoves and similar appliances are to be firmly fixed at their design positions, and means are to be provided to prevent them from shifting. Sufficient fire protection and insulation layers are to be provided under, around and over. The possibility of blocking up by combustion remains is to be kept to a minimum and cleaning tools are to be provided. Where the damper for limitation of the exhaust in the uptake is in a closed position, sufficient flow area is to be kept. The ventilator in way of the stove space is to be of sufficient cross-sectional area so as to supply the stoves with enough air for full combustion.
(5) Galleys are to be provided with ventilation appliances of sufficient capacity so as to purge the smoke and the gas liable to escape to a safe place.

3.4.16 Provision of fire extinguishers

3.4.16.1 In passenger ships, at least two portable fire extinguishers for each main vertical zone or enclosed space divided by watertight bulkheads, and for each floor of passenger spaces above the bulkhead deck are to be provided; and at least one for each galley and for store room is to be provided.
3.4.16.2 In cargo ships and tankers, at least two portable fire extinguishers for each deck and at least one for each galley are to be provided.

3.4.17 Fire-extinguishing arrangements for paint lockers and flammable liquid lockers

3.4.17.1 Paint lockers and flammable liquid lockers are to be provided with a fire-extinguishing arrangement enabling the crew to extinguish a fire without entering the space.
3.4.17.2 For paint lockers and flammable liquid lockers of a deck area of 4 m^2 and more, one of the fixed arrangements as specified below are to be provided:
(1) a CO_2 system, designed for 40% of the gross volume of the space;
(2) a dry powder system, designed for at least 0.5 kg powder/m^3;
(3) a pressure water-spraying or an automatic sprinkler system, designed for 5 $l/m^2 \cdot min$.
3.4.17.3 The pressure water-spraying system may be connected to the ship's fire main.
3.4.17.4 Systems or arrangements other than those mentioned in 3.4.17.2(1), (2), (3) may be accepted by CCS provided that relevant technical and test data are provided.
3.4.17.5 For paint lockers and flammable liquid lockers of a deck area of less than 4 m^2, which do not give access to accommodation spaces, a CO_2 portable fire extinguisher sized to provide a minimum volume of free gas equal to 40% of the gross volume of the space may be accepted in lieu of a fixed system as specified in 3.4.17.2. The extinguisher may be discharged through a port on the wall of the locker. The required portable fire extinguisher is to be stowed adjacent to the port. Alternatively, a port or hose connection may be provided to facilitate the use of fire main water.

CHAPTER 4 INERT GAS SYSTEMS

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.1 This Chapter applies to ships fitted with the inert gas systems and nitrogen generator systems.

4.1.1.2 All types of inert gas systems are to comply with the following:

(1) An automatic control capable of producing suitable inert gas under all service conditions is to be fitted.

(2) Surveys are to be carried out at the intervals as required by PART ONE of the Rules.

4.1.2 Class notation

4.1.2.1 Inert gas systems complying with the requirements of this Chapter may be assigned the following class notation:

IGS

4.1.3 Plans and documents

4.1.3.1 In addition to the plans and documents required by relevant PARTs of the Rules, the following ones are to be submitted for approval:

(1) Details and arrangement of the inert gas generating plant including all control and monitoring devices;

(2) Arrangement of the piping system for distribution of the inert gas.

Section 2 INERT GAS SYSTEMS AND NITROGEN GENERATOR SYSTEMS OF DIFFERENT TYPES

4.2.1 Requirements for all inert gas systems on tankers, including chemical tankers, to which SOLAS regulation II-2/4.5.5.1 applies

4.2.1.1 An inert gas system complying with the applicable requirements of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93), is to be fitted on tankers to which SOLAS regulation II-2/4.5.5.1 applies. In applying the applicable requirements of Chapter 15 of the FSS Code, any use of the word "Administration" therein is to be considered as meaning CCS. The inert gas system is to be operated in accordance with SOLAS regulation II-2/16.3.3, as amended by resolution MSC.365(93). In applying SOLAS regulation II-2/16.3.3.2, paragraph 2.2.1.2.4 of Chapter 15 of the FSS Code is to be complied with.

4.2.2 Additional requirements for nitrogen generator systems on tankers, including chemical tankers, to which SOLAS regulation II-2/4.5.5.1 applies

4.2.2.1 Where a nitrogen generator system is fitted on board as required by SOLAS regulation II-2/4.5.5.1, the inert gas is to be produced by separating air into its component gases by passing compressed air through a bundle of hollow fibres, semi-permeable membranes or adsorber materials. The following requirements are to be complied with.

4.2.2.2 In addition to the applicable requirements of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93), the nitrogen generator system is to comply with SOLAS regulations II-2/4.5.3.4.2, 4.5.6.3 and 11.6.3.4.

4.2.2.3 A nitrogen generator is to consist of a feed air treatment system and any number of membrane or adsorber modules in parallel necessary to meet paragraph 2.2.1.2.4 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93).

4.2.2.4 The nitrogen generator is to be capable of delivering high purity nitrogen in accordance with paragraph 2.2.1.2.5 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93). In addition to paragraph 2.2.2.4 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93), the system is to be fitted with automatic means to discharge "off-spec" gas to the atmosphere during start-up and abnormal operation.

4.2.2.5 The system is to be provided with one or more compressors to generate enough positive pressure to be capable of delivering the total volume of gas as required by 2.2.1.2 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93). Where two compressors are provided, the total required capacity of the system is preferably to be divided equally between the two compressors, and in no case is one compressor to have a capacity less than 1/3 of the total capacity required.

4.2.2.6 The feed air treatment system fitted to remove free water, particles and traces of oil from the compressed air as required by 2.4.1.2 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93), is also to preserve the specification temperature.
4.2.2.7 The oxygen-enriched air from the nitrogen generator and the nitrogen-product enriched gas from the protective devices of the nitrogen receiver are to be discharged to a safe location on the open deck.
"Safe location" needs to address the two types of discharges separately:
(1) Oxygen-enriched air from the nitrogen generator - safe locations on the open deck are:
① outside of hazardous area;
② not within 3 m of areas traversed by personnel;
③ not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.
(2) Nitrogen-product enriched gas from the protective devices of the nitrogen receiver - safe locations on the open deck are:
① not within 3 m of areas traversed by personnel;
② not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.
4.2.2.8 In order to permit maintenance, means of isolation are to be fitted between the generator and the receiver.

4.2.3 Nitrogen / inert gas systems fitted for purposes other than inerting required by SOLAS regulations II-2/4.5.5.1 and 4.5.5.2

4.2.3.1 This paragraph applies to systems fitted on oil tankers, gas tankers or chemical tankers to which SOLAS regulations II-2/4.5.5.1 and 4.5.5.2 do not apply.
4.2.3.2 The systems are to comply with the requirements of 2.2.2.2, 2.2.2.4, 2.2.4.2, 2.2.4.3, 2.2.4.5.1.1, 2.2.4.5.1.2, 2.2.4.5.4, 2.4.1.1, 2.4.1.2, 2.4.1.3, 2.4.1.4, 2.4.2.1 and 2.4.2.2 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93).
4.2.3.3 The requirements of 4.2.2 of this Chapter apply to the systems except 4.2.2.1, 4.2.2.2, 4.2.2.3 and 4.2.2.5.
4.2.3.4 Materials used in inert gas systems are to be suitable for their intended purpose in accordance with the relevant requirements of CCS Rules for Materials and Welding.
4.2.3.5 All the equipment is to be installed on board and then tested under working conditions to meet the functional requirements and to be satisfactorily inspected by the Surveyor.
4.2.3.6 Two non-return devices as required by paragraph 2.2.3.1.1 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93) are to be fitted in the inert gas main. The non-return devices are to comply with the requirements of 2.2.3.1.2 and 2.2.3.1.3 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93); however, where the connections to the cargo tanks, to the hold spaces or to cargo piping are not permanent, the non-return devices required by paragraph 2.2.3.1.1 of Chapter 15 of the FSS Code, as amended by resolution MSC.367(93), may be substituted by two non-return valves.

Section 3 EXAMINATION AND TESTING

4.3.1 General requirements

4.3.1.1 The devices and equipment required by this Chapter are, after having been installed on board, to be tested under working conditions to confirm their performance.

CHAPTER 5 HELICOPTER FACILITIES

Section 1 GENERAL PROVISIONS

5.1.1 Application

5.1.1.1 This Chapter applies to all ships requesting the class notation specified in 5.1.2 below and fitted with areas and facilities for normal takeoff and landing of helicopters.

5.1.1.2 Helicopter deck facilities covered by this Chapter mean all deck structure, fire-fighting appliances and other equipment necessary for the safe operation of helicopters as well as any refueling and hangar facilities.

5.1.1.3 Helicopter deck structure, strength and arrangement, and related plans and documents to be submitted for approval are to comply with the requirements of Section 18, Chapter 2, PART TWO of the Rules.

5.1.2 Class notation

5.1.2.1 Ships complying with the requirements of this Chapter may be assigned the following class notation:

Helicopter Facilities

5.1.3 Plans and documents

5.1.3.1 The following plans and documents are to be submitted for approval:

(1) Arrangement of structural fire protection of helicopter deck, including fire division, means of escape, openings, drainage facilities;

(2) Arrangement of fire-fighting appliances provided for helicopter deck, including calculations of quantity of extinguishing agents to be used;

(3) Arrangement of helicopter refueling facilities and systems, where fitted.

5.1.4 Fire safety of helicopter deck

5.1.4.1 The fire prevention and fire extinction of helicopter deck is to comply with the requirements of SOLAS regulation II-2/18, other than those for personnel qualification, management, operation and maintenance.

5.1.4.2 Where the helicopter deck forms a part of the strength deck or a hatch cover, aluminum or other low melting point metal construction is not to be used.

5.1.4.3 The means of escape required for the helicopter deck may be used as working access for crew, provided the access is maintained clear.

5.1.4.4 Where the helicopter deck is of aluminum alloy that is made equivalent to steel, the drainage facilities thereof may also be made of aluminum alloy.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2025

PART SEVEN AUTOMATION SYSTEMS

CONTENTS

CHAPTER 1 GENERAL 7-1
Section 1 GENERAL PROVISIONS 7-1
CHAPTER 2 BASIC REQUIREMENTS 7-3
Section 1 GENERAL PROVISIONS 7-3
Section 2 CONTROL SYSTEMS 7-4
Section 3 SAFETY SYSTEMS 7-5
Section 4 ALARM SYSTEMS (INCLUDING DISPLAYS) 7-5
Section 5 CONTROL STATIONS (ROOMS) 7-6
Section 6 COMPUTER BASED SYSTEMS 7-7
Section 7 SENSORS 7-16
Section 8 MAIN PROPULSION MACHINERY REMOTELY CONTROLLED FROM NAVIGATION BRIDGE 7-16
CHAPTER 3 REQUIREMENTS FOR CLASS NOTATION AUT-0 OF PERIODICALLY UNATTENDED MACHINERY SPACES 7-18
Section 1 GENERAL PROVISIONS 7-18
Section 2 MAIN PROPULSION MACHINERY 7-18
Section 3 BOILERS 7-20
Section 4 ELECTRIC GENERATING PLANT 7-22
Section 5 AUXILIARY MACHINERY 7-22
Section 6 OTHER EQUIPMENT 7-23
Section 7 ADDITIONAL REQUIREMENTS FOR CONTROL STATIONS (ROOMS) 7-23
Section 8 ADDITIONAL REQUIREMENTS FOR CONTROL AND MONITORING SYSTEMS 7-24
Section 9 FIRE PRECAUTIONS AND PROTECTION AGAINST FLOODING 7-25
Section 10 AUTOMATIC CONTROL AND MONITORING ITEMS 7-27
CHAPTER 4 REQUIREMENTS FOR MACHINERY NOTATIONS OF CONSTANTLY ATTENDED MACHINERY SPACES 7-38
Section 1 GENERAL PROVISIONS 7-38
Section 2 REQUIREMENTS FOR AUTOMATION OF SHIPS WITH CLASS NOTATION MCC 38
Section 3 REQUIREMENTS FOR AUTOMATION OF SHIPS WITH CLASS NOTATION BRC 7-48

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 This PART applies to automated systems for machinery and electrical installations installed on sea-going ships.

1.1.1.2 The automated system in this PART covers control, safety and alarm systems (including displays).

1.1.1.3 Ships with different levels of automation complying with the requirements of this PART may be assigned the following class notations:

(1) AUT−0 — indicating that the ship's propulsion plant can be remotely controlled from the bridge control station with the machinery spaces (including engine room centralized control station or room) periodically unattended;

(2) MCC — indicating that the machinery and electrical installations are capable of being operated with continuous supervision by watch-keepers from a centralized control station or room in the engine room;

(3) BRC — indicating that the ship's propulsion plant can be remotely controlled from the bridge control station with the engine room attended by watch-keepers.

1.1.1.4 Ships with automated systems complying with the requirements of this PART are to be adaptable to all sailing conditions, including maneuvering.

1.1.1.5 The safety of the ships with automated systems complying with the requirements of this PART is to be same as that of the ships with machinery spaces being attended. Means are to be provided to ensure that the machinery and electrical equipment can be manually and effectively operated from a local position in case of failure of the automated systems.

1.1.2 Definitions

1.1.2.1 For the purpose of this PART:

(1) *Automatic control* means self-regulating control carrying out predetermined orders to operate the machinery without action by an operator.

(2) *Remote control* means control of a device by an operator from a distance through mechanical, electrical, electronic, pneumatic, hydraulic, electromagnetic (radio) or optical means or combination thereof.

(3) *Local control* means direct manual control by an operator of machinery through a device located on or adjacent to the controlled machinery.

(4) *Control stations* (*rooms*) means spaces fitted with monitoring means capable of controlling the machinery and electrical installations. They are mainly divided into four categories as follows in this PART:

① *centralized control station* (*room*) *of engine room* (abbreviated to CCS) means a control station (room) in which all monitoring means for automated equipment in engine room are concentrated;

② *bridge control station* (abbreviated to BCS) means a control station monitoring the propelling plant and other equipment in bridge;

③ *local control station* (abbreviated to LCS) means a control station where machinery and electrical installations are locally controlled;

④ *other control stations* mean control stations except the above-mentioned three ones.

(5) *Safety systems* mean systems which will operate automatically for safeguarding the machinery or electrical equipment in question in the following three modes of operation in case of serious faults endangering the main propulsion machinery, boilers, electric generating plants and other essential machinery or electrical equipment:

Mode a: immediate shutdown, e.g. emergency stop of main engines, emergency cutoff of boiler fuel oil supply and emergency cutoff of electric power supply to consumers. And such machinery or equipment is not to be put into operation again if without the manual resetting;

Mode b: the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g., by reducing the output or rotation speed of the machinery;

Mode c: the normal operating conditions are restored by starting of standby machinery.

(6) *Alarm* means a visual and audible signal of a predetermined out-of-limits parameter for the monitored machinery or system, which can identify the particular fault condition and its location within the machinery spaces, which can identify the particular fault condition and its location within the machinery spaces.

(7) *Group alarm* means a common alarm activated by any abnormal conditions of the monitored machinery or system.

(8) *Fail-safe principle* means that upon failure or malfunction of a component or system, the output automatically reverts to a predetermined design state of least critical consequence.
(9) *Override* means the special control measures for the skipping of a certain procedure or a certain safeguard action so as to effect compulsory operation to the machinery or electrical equipment for a short period to ensure the safety of the ship.
(10) *Emergency shutdown device* means a device independent of any control system and intended for manual activation in an emergency to stop the operation of machinery and electrical installations, e.g. emergency stop button of main engines, emergency cutoff button of boiler fuel oil supply and emergency cutoff button of electric power supply to consumers.
(11) *Redundancy design* means standby technical means to be used in case of system or equipment fault, by which a corresponding function can be taken over to continue an action or an original function is restored to continue the operation condition.
(12) *Node* means a point of interconnection to a data communication link.
(13) *Network* means a communication net for data transfer and exchange between computers.
(14) *Major modification* means one of the following cases or a combination thereof which will cause a substantial change to functions or safety features of an onboard computer system (excluding peripherals):

① change of hardware configuration;

② update of software;

③ alteration of network (including topology structure).

1.1.3 Plans and documents

1.1.3.1 Where a ship is intended to be assigned a machinery notation, the following plans and documents associated with control, alarm (display) and safety systems covered by this PART are to be submitted for approval:
(1) List of monitored and display points;
(2) List of alarm points (including display position and mode of alarms in the control station/room);
(3) Items of safety systems;
(4) Schematic diagrams of (electric, pneumatic, hydraulic) power supply to automated systems.
1.1.3.2 Additional plans and documents are to be submitted for approval as deemed necessary by CCS.

1.1.4 Certification of products

1.1.4.1 For certification requirements for the equipment and installations used in automated systems of a ship, see for details in Appendix 1A — List of Certification Requirements for Classed Marine Products of Chapter 3, PART ONE of the Rules.

1.1.5 Trials

1.1.5.1 The automated systems together with the associated machinery and electrical equipment are to be subject to mooring and sea trails in accordance with a test program approved by CCS for ascertaining the normal working of the whole system.
1.1.5.2 The setting of alarm points of automated systems and the preset parameters of safety systems which are determined in compliance with the requirements of the Rules as shown by the trials are to be recorded and maintained onboard for information.

CHAPTER 2 BASIC REQUIREMENTS

Section 1 GENERAL PROVISIONS

2.1.1 Environmental conditions

2.1.1.1 The automated systems are to operate satisfactorily within the ambient air temperatures as specified in 1.2.1.1(1) of Chapter 1, PART FOUR of the Rules.

2.1.1.2 The automated systems are to operate satisfactorily under the following conditions of relative humidity:

95% ± 3% at temperatures up to +45℃;

70% ± 3% at temperatures higher than +45℃.

2.1.1.3 The automated systems are to operate satisfactorily under the vibration conditions listed in Table 2.1.1.3. Where resonance occurs in the following frequency ranges and exceeds the required values, suitable means are to be provided for vibration damping.

Vibration **Table 2.1.1.3**

Location of installation	Parameters of vibration	
General space	2.0 ~ 13.2 Hz Amplitude ±1 mm	13.2 ~ 100 Hz Acceleration ±0.7 g
On reciprocating engines (e.g. diesel engines, air compressors) and other similar spaces	2.0 ~ 25 Hz Amplitude ±1.6 mm	25 ~ 100 Hz Acceleration ±4.0 g
Other special locations, e.g. exhaust pipes for (particularly medium or high speed) diesel engines	40 ~ 2,000 Hz Acceleration ±10.0 g (temperature 600℃)	

2.1.1.4 The automated systems are to operate satisfactorily under inclination and rolling conditions in all directions from the mounting position up to 22.5° (period 10 s) and under linear vertical acceleration of ±9.8 m/s^2.

2.1.1.5 The automated systems are to be suitable for the normal conditions encountered on board ships, e.g. salt air, oil-laden atmosphere, mould and dust.

2.1.2 Other working conditions

2.1.2.1 The automated system is to comply with the requirements of paragraphs 1.2.2 and 1.2.3 of Section 2, Chapter 1, PART FOUR of the Rules.

2.1.2.2 The automated system is to have necessary electromagnetic compatibility.

2.1.2.3 The hydraulic and pneumatic equipment of automated systems is to operate satisfactorily under pressure variations in the system by ±20% of the rated values and is not to be damaged by transient pressure rise up to 1.5 times the rated pressure.

2.1.3 Fail-safe

2.1.3.1 Control systems, alarm systems and safety systems are to be designed on the fail-safe principle. The fail-safe principle is to be applied on the basis not only of the automated system itself and its associated machinery, but also of the whole machinery installation and the safety of the ship and personnel.

2.1.3.2 The design of the control system, alarm system and safety system is to be such that a failure in the operation will not cause other failures and will, so far as possible, lead to the least dangerous condition of the controlled process.

2.1.3.3 The automatic control and remote control systems are to ensure continuous, effective and reliable operation.

2.1.4 Independence

2.1.4.1 Control, safety and alarm systems are to be designed or rendered to function independently of each other so that a failure or malfunction in one or two of these systems will not prevent the other system(s) from operating.

2.1.4.2 In any case, a safety system of mode a is to function independently of control and alarm systems so that a failure or malfunction in these systems will not prevent the safety system from operating. For the safety systems of modes b and c, complete independence of other control and alarm systems is not required.

2.1.4.3 Safety systems of different units of the machinery plant are to be independent. Failure in the safety system of one part of the plant is not to interfere with the operation of the safety system in another part of the plant.

2.1.5 Examination and lock-in

2.1.5.1 The functions of control, safety and alarm systems are to be capable of being examined. Where the settings, e.g. sensitivity and limiting values of the control, safety and alarm equipment may be regulated, these regulated values are to be such that they may be easily examined, identified and locked-in.

2.1.6 Power supply

2.1.6.1 The safety and alarm systems and control systems (e.g. automated systems of an electric generating plant) requiring continuous use in the event of a failure of normal power supply are to be capable of being automatically changed over to an independent standby power supply. The standby power supply may be an accumulator battery, with a capacity at least sufficient for a period of supply of 30 min. Where such systems could be adversely affected by an interruption in power supply, change-over to the standby power supply is to be achieved without a break.

2.1.6.2 A visual and audible alarm is to be given in the event of a failure of power supply① for safety system, alarm system and control system.

2.1.6.3 Control system, safety system and alarm system are to be supplied by independent final sub circuit and protected against short circuit and overload.

Section 2 CONTROL SYSTEMS

2.2.1 General requirements

2.2.1.1 Control systems include automatic and remote control systems.

2.2.1.2 Control systems are to have good control properties. Control systems for the operation of machinery and electrical equipment are to have satisfactory characteristics, i.e., to be stable throughout their operating range so that the operation of the controls will not induce detrimental mechanical or thermal loads. Control systems are also to have necessary accuracy of control.

2.2.1.3 The design of the control system is to be such that a failure in the control system will lead to the least dangerous condition of the controlled process and furthermore, such failure is not to render any reserved automatic or manual control, or both, inoperative.

2.2.1.4 All machinery and electrical installations essential for the safe operation of the ship are, in the case of failure in or out-of-action of any part of automatic or remote control system including failure of power supply, to be capable of:

(1) sending out alarm signals;

(2) replacing immediately faulty component(s) or putting the back-up arrangements into service in time for recovering normal operation (if applicable);

(3) transferring to local manual control, and the transfer of control is not to seriously affect the operating conditions of the machinery and electrical equipment.

2.2.1.5 Control systems for the main propulsion machinery (including main engine and controllable pitch propeller), boilers and electric generating plant are to be independent of each other unless necessary for operation. The control system for each independent propulsion engine is to be provided separately.

2.2.1.6 Where necessary measures are taken to ensure effective monitoring of the partly common equipment in the systems mentioned in 2.1.4.1 above and an alarm is given in case of any failure in such equipment, a partly common use of the equipment may be permitted (see also 2.7.1.4 of this Chapter).

2.2.2 Hydraulic and pneumatic power sources

2.2.2.1 The hydraulic power source and piping of control systems are to comply with the relevant requirements of Chapter 2 and Section 7 of Chapter 4, PART THREE of the Rules, and the following requirements:

(1) The standby hydraulic pump is to start and operate automatically when the discharge pressure from the working pumps falls below a predetermined value and an alarm is to be given.

(2) Where the hydraulic pressure is lower than the required normal working pressure, an alarm is to be given.

2.2.2.2 The pneumatic power source and piping of control systems are to comply with the relevant requirements of Chapter 2, PART THREE of the Rules and the following requirements:

---

① A visual and audible alarm is to be given in the event of a failure of power supply for engine room centralized monitoring and alarm system. For alarms of safety system, alarm system and control system of other equipment in the event of a failure of power supply, refer to Table 3.10.1.1 of Chapter 3 of this PART.

(1) Air vessels for pneumatic controls may be supplied from the main engine starting air vessels or from exclusive air compressors.
(2) Where air vessels are supplied from the exclusive air compressors, at least two compressors are to be provided, one of which is standby, or from one exclusive air compressor and the main air vessel. The air compressors are to start and operate automatically when the air pressure falls below a predetermined value.
(3) Relief valves are to be fitted in the pneumatic control piping, which are to be set to open at a pressure not greater than 1.1 times the normal working pressure.
(4) Reducing valves, filters, oil separators and driers are to be provided in the pneumatic control piping so as to ensure dry, clean and oil-free air to the pneumatic controls. The reducing valves, filters and driers are to be, in general, fitted each in duplicate and in parallel. The provision of a single filter and a single drier may be permitted, provided that means are provided to ensure quick maintenance and renewal of the above-mentioned devices without interrupting the normal operation of the pneumatic control system.

Section 3 SAFETY SYSTEMS

2.3.1 General requirements

2.3.1.1 In case of serious faults endangering the main propulsion engines, boilers, electric generating plants and other essential machinery and electrical equipment, the safety systems are to operate automatically for safeguarding the machinery or electrical equipment in question in the three modes of operation required in 1.1.2.1(5) of this PART and alarms are to be given.
2.3.1.2 When the system has stopped a unit, the unit is not to be restarted automatically before a manual reset has been made.
2.3.1.3 In order to avoid undesirable interruption in the operation of machinery, the system is to intervene sequentially after the operation of alarm system by:
(1) starting of standby units;
(2) load reduction or shutdown, such that the least drastic action is taken first.
2.3.1.4 When the system has been activated, audible and visual alarms are to be given in control station to trace the cause of the safety action.

2.3.2 Means of overriding

2.3.2.1 For the purpose of ensuring the safety of ships, main propulsion machinery systems, such as main diesel engines, steam turbines, gas turbines and electric propulsion systems, are in general to be provided with arrangements for overriding.
2.3.2.2 An indication is to be given and a suitable alarm is to be activated when an overriding action is operated.
2.3.2.3 Means are to be provided to preclude inadvertent operation of the overriding function.

2.3.3 Pneumatic power source and piping

2.3.3.1 The pneumatic power source and piping of safety systems are to be in compliance with the requirements of 2.2.2 of this Chapter, and the pneumatic pipelines are to be as far as practicable separated from the control systems.

Section 4 ALARM SYSTEMS (INCLUDING DISPLAYS)

2.4.1 General requirements

2.4.1.1 All faults of the controlled and monitored machinery or electrical equipment and their control and monitoring systems are to be indicated with alarm signals at the relevant control stations (rooms) so that the engineering personnel on duty are made aware that a machinery fault has occurred.
2.4.1.2 All alarms are to be both audible and visual. According to the nature of faults, the colors used for visual signals are to be, in general, red for vital faults and yellow for general ones. Audible signal is to be of an adequate sound level and to be clearly distinguishable from the fire alarms, telephones and other sound signals (e.g. CO_2 flooding).
2.4.1.3 The alarm system is to be capable of indicating all faults occurred at the same time, and the operation and/or acknowledgement of any alarm is not to inhibit the operation and/or acknowledgement of other alarms occurred at the same time.

2.4.1.4 Arrangements may be fitted to extinguish (silence) audible alarm signals. When alarms are acknowledged and the silencing button is pressed, visual alarm signals are not to be extinguished, but may be altered, for example, from flashing to a steady light, and remain clearly visible. The local silencing of bridge or accommodation alarms is not to stop the audible machinery space alarm. The silencing button for the audible alarms in machinery spaces is permitted to be arranged only in the machinery space or at the engine room centralized control station and the visual alarm signals are to be retained until the fault has been rectified. When the fault has been rectified, the alarm system is to be automatically reset to its normal operating condition.
2.4.1.5 Where a single alarm has been shown in the local control station of engine room, the alarm signal is also to be shown in other relevant remote control stations and may be displayed by means of group alarm.

2.4.2 Inspection and self-monitoring of alarm systems

2.4.2.1 The alarm system is to be designed with self-monitoring properties, i.e., any fault in the alarm system should cause it to detect itself automatically and fall into the alarm (or indication) condition. The extent and depth of self-monitoring is to be determined in connection with the measures taken for maintenance and renewal.
2.4.2.2 The alarm system is to be capable of blockading meaningless signals during certain processes. Manual blockading is to be indicated.

2.4.3 Displays

2.4.3.1 Parameters may be clearly displayed by instrumentation or display units. Parameter displays may be performed separately or selectively, and may be alphanumeric or in the form of graphics or diagrams. But all displays or indications are to be clearly distinguishable. The color of indicating lamps is normally to be green or white. For display units incorporating with computers and the specific requirements for display, IEC 60092-504 Electrical installations in ships - Part 504: Automation, control and instrumentation is to be complied.

Section 5 CONTROL STATIONS (ROOMS)

2.5.1 Arrangement of control stations (rooms)

2.5.1.1 The engine room centralized control station (room) (abbreviated to CCS) is generally to be located within the machinery spaces.
2.5.1.2 The CCS is to be located as far as possible in a position of least vibrations and of low noise level while the ship operates at sea.
2.5.1.3 The CCS within the machinery spaces is to be of the sound-proof construction, with the window glass of the shatter-resistant type. The CCS is to have two means of access located as far remote from each other as practicable, and one of which is to be as far as possible situated near the escape trunk of the machinery spaces or the special purpose escape trunk.
2.5.1.4 The control and monitoring equipment, signal displays, control levers, switches and push buttons within the control stations (rooms) are to be arranged with due attention to thorough ergonomics for the convenience of operation, surveillance, maintenance and the safety of the operators.
2.5.1.5 The local control stations are to comply with the relevant requirements of 1.1.1.5 and 2.5.2 of this PART. It is to be possible for the propulsion machinery to be controlled from a local position even in the case of failure or malfunction in any part of the automatic or remote control systems of any other control station or the propulsion machinery.

2.5.2 Transfer of control

2.5.2.1 Transfer of control between control stations is to be possible to the machinery and electrical equipment under common control from such stations, either when these machinery and electrical equipment are in normal operation or in case of their failures. Such changeover is not to seriously affect the operating conditions of the machinery and electrical equipment.
2.5.2.2 The transfer of control between the CCS and BCS is to be possible only at the CCS, and the transfer of control between the LCS and CCS or BCS is to be possible only at the LCS.
2.5.2.3 Changeover between control stations is to be so arranged that it may be effected only with the acceptance of the station taking control.
2.5.2.4 Provision is to be made at all control stations (rooms) to indicate which station is in control.

2.5.2.5 Where machinery and electrical equipment may be controlled from two or more control stations (rooms), control is to be possible only from one control station at one time. At all control stations, interconnected control positions for the controllers for main propulsion machinery are permitted.
2.5.2.6 Propulsion machinery orders from the navigating bridge are to be indicated at all control positions for the machinery.
2.5.2.7 Where the manual control gear of the main engine or other machinery and electrical equipment is extended directly to the CCS by means of mechanical linkage, the provision of corresponding LCS may be exempted.

2.5.3 Other control stations

2.5.3.1 For the arrangement of other control stations which are in close relation to the safety of machinery and electrical equipment or the safety of the ship, relevant technical information (e.g. arrangement plan, specification of monitoring properties) are to be provided and the relevant requirements of this PART are to be complied with.

Section 6 COMPUTER BASED SYSTEMS

2.6.1 General requirements

2.6.1.1 This Section applies to design, construction, commissioning and maintenance of computer-based systems where they depend on software for the proper achievement of their functions. This Section applies to systems which provide control, alarm, monitoring, safety, or internal vessel communication functions that are subject to classification requirements. This Section does not apply to computer-based systems that are covered by statutory regulations, e.g. loading instruments/ stability computer① and radio communication and navigation equipment covered by SOLAS chapters IV and V.
2.6.1.2 Computer based systems are, in addition to satisfying the requirements of this Section, to satisfy relevant requirements in the Guidelines for Type Approval Test of Electric and Electronic Products. Computer based systems installed on all passenger ships and cargo ships of 500 GT and over which are engaged on international voyages are at least to satisfy the relevant requirements for Cyber Security (P[SL0]) in the Guidelines for Ship Cyber Security.
2.6.1.3 The following standards may be used for the development of hardware/software of computer based systems:
(1) IEC 61508 Functional safety of electrical/electronic/programmable electronic safety-related systems;
(2) ISO/IEC/IEEE 12207 Systems and software engineering – Software life cycle processes;
(3) ISO 9001 Quality Management Systems – Requirements;
(4) ISO/IEC/IEEE 90003 Software engineering - Guidelines for the application of ISO 9001:2015 to computer software;
(5) IEC 60092-504 Electrical installations in ships - Part 504: Special features - Control and instrumentation;
(6) ISO/IEC 25000 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE;
(7) ISO/IEC 25041 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Evaluation guide for developers, acquirers and independent evaluators;
(8) IEC 61511 Functional safety - Safety instrumented systems for the process industry sector;
(9) ISO/IEC/IEEE 15288 Systems and software engineering - System life cycle process;
(10) ISO 10007 Quality management – Guidelines for configuration management;
(11) ISO 24060 Ships and marine technology - Ship software logging system for operational technology.
Other standards accepted by CCS may also be considered.

2.6.2 Definitions

2.6.2.1 For the purpose of this Section:
(1) Black-box description: A description of a system's functionality and behaviour and performance as observed from outside the system in question.
(2) Black-box test methods: Verification of the functionality, performance, and robustness of a system, sub-system or component by only manipulating the inputs and observing the outputs. This does not require any knowledge of the system's inner workings and focuses only on the observable behaviour of the

① Refer to the requirements of Appendix 1 and Appendix 2 of Chapter 2, PART TWO of the Rules.

system/component under test in order to achieve the desired level of verification.
(3) Computer-based system(CBS): A programmable electronic device, or interoperable set of programmable electronic devices, organized to achieve one or more specified purposes such as collection, processing, maintenance, use, sharing, dissemination, or disposition of information. CBSs onboard include IT and OT systems. A CBS may be a combination of subsystems connected via network. Onboard CBSs may be connected directly or via public means of communications (e.g. Internet) to ashore CBSs, other vessels' CBSs and/or other facilities.
(4) Failure mode description: A document describing the effects due to failures in the system, not failures in the equipment supported by the system. The following aspects shall be covered:

① list of failures which are subject to assessment, with
② description of the system response to each of the above failures
③ comments to the consequence of each of these failures.

(5) Parameterization: To configure and tune system and software functionality by changing parameters. It does not usually require-computer programming and is normally done by the system supplier or a service provider, not the operator or end-user.
(6) Programmable device: Physical component where software is installed.
(7) Robustness:The ability to respond to abnormal inputs and conditions.
(8) Simulation test: Monitoring, control, or safety system testing where the equipment under control is partly or fully replaced with simulation tools, or where parts of the communication network and lines are replaced with simulation tools.
(9) Software component: A standalone piece of code that provides specific and closely coupled functionality.
(10) Software master files: The computer-files that constitutes the original source of the software. For custom made software this may be readable source- code files, and for COTS software it may be different forms of binary files.
(11) Software-structure: Overview of how the different software components interact and is commonly referred to as the Software Architecture, or Software Hierarchy.
(12) Sub-system: Identifiable part of a system, which may perform a specific function or set of functions.
(13) System: A combination of components, equipment and logic which has a defined purpose, functionality, and performance. In the context of this Section, a specific system is delivered by one system supplier.
(14) System of systems: A system which is made up of several systems In the context of this Section, the system of systems encompasses all monitoring, control and safety systems delivered from the Shipyard as a part of a vessel.
(15) Owner:The organization or person which orders the vessel in the construction phase or the organization which owns or manages the vessel in service. In the context of this Section this is a defined role with specific responsibilities.
(16) Supplier: A generic term used for any organisation or person that is a contracted or a subcontracted provider of services, system components, or software.
(17) Service supplier: A person or company, not employed by an IACS Member, who at the request of an equipment manufacturer, shipyard, vessel's owner or other client acts in connection with inspection work and provides services for a ship or a mobile offshore unit such as measurements, tests or maintenance of safety systems and equipment, the results of which are used by surveyors in making decisions affecting classification or statutory certification and services.
(18) System supplier: An organisation or person that is contracted or a subcontracted provider of system components or software under the coordination of the Systems integrator. In the context of this Section this is a defined role with specific responsibilities.
(19) Systems integrator: Single organization or a person coordinating interaction between suppliers of systems and sub-systems on all stages of life cycle of computer-based systems in order to integrate them into a verified vessel-wide system of systems and to provide proper operation and maintenance of the computer based systems. In the context of this Section this is a defined role with specific responsibilities. During the design and delivery phase the Shipyard is the default Systems integrator, during operations phase the Owner is the default.
(20) Vessel: Ship or offshore unit where the computer-based system is to be installed.

2.6.3 Approval of system and components

2.6.3.1 Computer-based systems that are necessary to accomplish vessel-functions of category II or category III shall be delivered with a vessel-specific Society certificate. The objective of the vessel-specific system certification is to confirm that design and manufacturing of the system has been completed and that

the system complies with applicable rules of the classification Society. Vessel-specific system certification consist of two main verification activities:
(1) Assessment of vessel-specific documentation (see documents listed in Table 2.6.4.1(1));
(2) Survey and testing of the system to be delivered to the vessel.
CCS may accept Alternative Certification Scheme (ACS) provided that the requirements are met, and that the system is provided with a vessel-specific certificate.
2.6.3.2 Computer-based systems that are routinely manufactured and include standardized software functions may be type approved in accordance with specified rules of CCS. The type approval consist of two main verification activities:
(1) Assessment of type-specific documentation, including documents listed in Table 2.6.4.1(1) and other documents required to apply for CCS type approval;
(2) Survey and testing of the standardized functions.
Type approval will normally not yield exemption from vessel-specific system certification since vessel-specific functions, parameter configurations and installation elements demand vessel specific verification.

2.6.4 Plans and documents

2.6.4.1 Plans and documents are to be submitted to CCS in accordance with the requirements of Tables 2.6.4.1(1) and 2.6.4.1(2) for computer based systems. Items in Table 2.6.4.1(3) are to be witnessed and surveyed by CCS surveyors.

Plans and documents to be submitted by system supplier **Table 2.6.4.1(1)**

No.	Name of plan	System category		
		Category I	Category II	Category III
1	Quality plan	—	Ⓘ	Ⓘ
2	System description	Ⓘ(if necessary)	Ⓐ	Ⓐ
3	Environmental compliance testing report	Ⓘ(if necessary)	Ⓘ	Ⓘ
4	Software testing report	—	Ⓘ(if necessary)	Ⓘ(if necessary)
5	System testing report	—	Ⓘ(if necessary)	Ⓘ(if necessary)
6	FAT program	—	Ⓐ	Ⓐ
7	FAT report	—	Ⓘ	Ⓘ
8	Additional FAT documents (e.g. user manuals)	—	Ⓘ(if necessary)	Ⓘ(if necessary)
9	Change management procedure	—	Ⓘ	Ⓘ

Plans and documents to be submitted by system integrator **Table 2.6.4.1(2)**

No.	Name of plan	System category		
		Category I	Category II	Category III
1	Quality plan	—	Ⓘ	Ⓘ
2	List of system category	Ⓐ	Ⓐ	Ⓐ
3	Risk assessment report	Ⓐ(if necessary)	Ⓐ(if necessary)	Ⓐ(if necessary)
4	Vessel's system-architecture description	Ⓘ	Ⓘ	Ⓘ
5	SAT program	—	Ⓐ	Ⓐ
6	SAT report	—	Ⓘ	Ⓘ
7	SOST program	—	Ⓐ	Ⓐ
8	SOST report	—	Ⓘ	Ⓘ
9	Software change management procedure	—	Ⓘ	Ⓘ

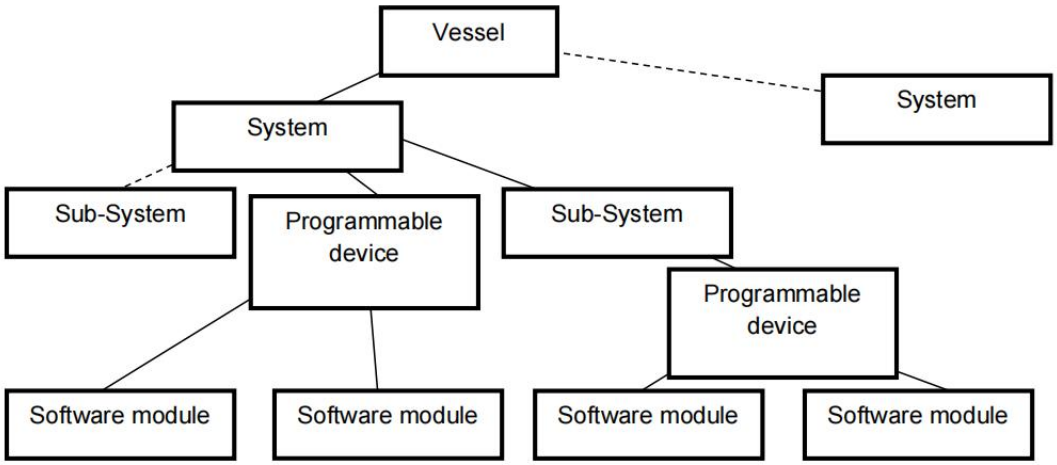
Items to be witnessed or surveyed by surveyors **Table 2.6.4.1(3)**

No.	Item	Responsible	System category		
			Category I	Category II	Category III
1	FAT	System supplier	—	Ⓦ	Ⓦ
2	SAT	System integrator	—	Ⓦ	Ⓦ
3	SOST	System integrator	—	Ⓦ	Ⓦ
4	Verification of Changes	System integrator	—	Ⓦ	Ⓦ

Note: The meanings of symbols used in the Table are as follows:
Ⓐ Submitted to CCS for approval; ① Provided to CCS for information; Ⓦ To be witnessed or surveyed by CCS surveyors.

2.6.5 Structure and category of computer based system

2.6.5.1 The hierarchy and relationships of a typical computer based system are as shown in Figure 2.6.5.1.



Note: Dashed lines show non-developed branches of diagram

Figure 2.6.5.1 Illustrative System Hierarchy

2.6.5.2 The categorization of a system is based on the potential severity of the consequences if the system serving the function fails. Table 2.6.5.2 provides the definitions of the categories.

System categories **Table 2.6.5.2**

Category	Failure effects	Typical System functionality
I	Those systems, failure of which will not lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Monitoring, informational and administrative functions
II	Those systems, failure of which could eventually lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Vessel alarm, monitoring and control functions which are necessary to maintain the vessel in its normal operational and habitable conditions
III	Those systems, failure of which could immediately lead to dangerous or catastrophic situations for human safety, safety of the vessel and/or threat to the environment.	- Control functions for maintaining the vessel's propulsion and steering - Vessel safety functions

2.6.5.3 Category I systems are normally not subject to verification by CCS, as failure of these systems shall not lead to dangerous situations. However, information pertinent to category I systems shall be required upon request to determine the correct category or ensure that they do not influence the operation of systems in category II and category III. The category of a system shall always be evaluated in the context of the specific vessel in question; thus, the categorization of a system may vary from one vessel to the next. This means that the examples of categories below are given as guidance only, the systems are not exhaustive.

(1) Category I systems:

① Fuel monitoring system;
② Maintenance support system;
③ Diagnostics and troubleshooting system;
④ Closed circuit television;
⑤ Cabin security, entertainment system;
⑥ Fish detection system.

(2) Category II systems:
① Fuel oil treatment system;
② Alarm monitoring and safety systems for propulsion and auxiliary machinery;
③ Inert gas system;
④ Control, monitoring and safety system for cargo containment system;
⑤ Monitoring and safety system.

(3) Category III systems:
① Propulsion control system;
② Steering gear control system;
③ Electric power system (including power management system);
④ Dynamic positioning system (DP 2 and DP 3).

2.6.6 Requirements on development and certification of computer-based system

2.6.6.1 A global top-down approach shall be undertaken in the design and development of both hardware and software and the integration in sub-systems, systems, and system of systems, spanning the complete system lifecycle. This approach shall be based on the standards as listed herein or other standards recognized by CCS.

2.6.6.2 Systems integrators and system suppliers shall, in the development of computer-based systems for category II and category III, comply to a recognised quality standard such as ISO 9001; also incorporating principles of IEC/ISO 90003. The quality system is certified as compliant to a recognized standard by an organisation with accreditation under a national accreditation scheme or CCS confirms compliance to a standard through a specific assessment of the quality system. The quality system shall as a minimum include the following topics in Table 2.6.6.2:

Quality system **Table 2.6.6.2**

Area		Role	
No.	Topic	System supplier	System integrator
1	Responsibilities and competency of the staff	x	x
2	The complete lifecycle of delivered software and of associated hardware	x	x
3	Specific procedure for unique identification of a computer-based system, its components and versions	x	
4	Creation and update of the vessel's system architecture		x
5	Organization set in place for acquisition of software and related hardware from suppliers	x	x
6	Organization set in place for software code writing and verification	x	
7	Organization set in place for system validation before integration in the vessel	x	
8	Specific procedure for conducting and approving of systems at FAT and SAT	x	x
9	Creation and update of system documentation	x	
10	Specific procedure for software modification and installation on board the vessel, including interactions with shipyard and owner	x	x
11	Specific procedures for verification of software code	x	
12	Procedures for integrating systems with other systems and testing of the system of systems for the vessel	x	x
13	Procedures for managing changes to software and configurations before FAT	x	
14	Procedures for managing and documenting changes to software and configurations after FAT	x	x
15	Checkpoints for the organization's own follow-up of adherence	x	x

	to the quality system		

2.6.7 Requirements on the system supplier

2.6.7.1 The system supplier shall define a quality plan (No.1 in Table 2.6.4.1(1)) and document that the quality management system is applied for the design, construction, delivery, and maintenance of the specific system to be delivered. All applicable items described in Table 2.6.6.2 (for the system supplier role) shall be demonstrated to exist and being followed, as relevant.

2.6.7.2 A method for unique identification of a system, its different software components and different revisions of the same software component shall be applied. The method shall be applied throughout the lifecycle of the system and the software. The documentation of the method is typically a part of the quality management system. Technical requirements for unique identification of systems and software are given in 2.6.11.1 of this Section.

2.6.7.3 The system's specification and design shall be determined and documented in a system description (No.2 in Table 2.6.4.1(1)). In addition to serve as a specification for the detailed design and implementation, the purpose of the system description is to document that the entire system-delivery is according to the specifications and in compliance with applicable rules and regulations. The system description shall contain information of the following:

(1) Purpose and main functions, including any safety aspects;
(2) System category as defined;
(3) Key performance characteristics;
(4) Compliance with the technical requirements and CCS rules;
(5) User interfaces/mimics;
(6) Communication and Interface aspects: Identification and description of interfaces to other vessel systems;
(7) Hardware-arrangement related aspects:

① Network-architecture/topology, including all network components like switches, routers, gateways, firewalls etc.;
② Internal structure with regards to all interfaces and hardware nodes in the system (e.g. operator stations, displays, computers, programmable devices, sensors, actuators, I/O modules etc.);
③ I/O allocation (mapping of field devices to channel, communication link, hardware unit, logic function);
④ Power supply arrangement;
⑤ Failure mode description.

2.6.7.4 Evidence of environmental type testing (No.3 in Table 2.6.4.1(1)) according to CCS Guidelines for Type Approval Test of Electric and Electronic Products regarding hardware elements included in the system and sub-systems shall be submitted to CCS.

2.6.7.5 The software created, changed, or configured for the delivery project shall be developed and have the quality assurance activities assessed according to the selected standard(s) as described in the quality plan. The quality assurance activities may be performed on several levels of the software -structure and shall include both custom-made software and configured components (e.g. software libraries) as appropriate. For components in systems of Category II and III, the scope, purpose, and results of all performed reviews, analyses, tests, and other verification activities shall be documented in test reports (No.4 in Table 2.6.4.1(1)).

The verification of the software shall as a minimum verify the following aspects based on black-box methods[①]:

(1) Correctness, completeness and consistency of any parameterization and configuration of software components;
(2) Intended functionality;
(3) Intended robustness.

2.6.7.6 The system shall as far as practicable be tested before the FAT. The main purpose of the system test is for the system supplier to verify that the entire system delivery is according to the specifications, approved documentation and in compliance with applicable rules and regulations; and further, that the system is completed and ready for the FAT. Faults are to be simulated as realistically as possible to demonstrate appropriate system fault detection and system response. Some of the testing may be performed by utilizing simulators and replica hardware. The test-environment shall be documented, including a

① Some of the methods utilized in this activity are sometimes referred to as "software unit test" or "developer test" and may also include verification methods like code-reviews and static- or dynamic code analysis.

description of any simulators, emulators, test-stubs, test-management tools, or other tools affecting the test environment and its limitations. Test cases and test results shall be documented in test programs and test reports (No.5 in Table 2.6.4.1(1)) respectively. The testing shall at least verify the following aspects of the system:
(1) Functionality;
(2) Effect of faults and failures (including diagnostic functions, detection, alerts response);
(3) Performance;
(4) Integration between software and hardware components;
(5) Human-machine interfaces;
(6) Interfaces to other systems.
2.6.7.7 A factory acceptance test (FAT) shall be arranged for the system in question. The main purpose of the FAT is to demonstrate to CCS that the system is completed and compliant with applicable classification rules, thus enabling issuance of a Society Certificate for the system. The FAT test program (No.6 in Table 2.6.4.1(1)) shall cover a representative selection of the test items from the internal system test (described in 2.6.7.6 of this Section), including normal system functionality and response to failures. For category II and III systems, network testing to verify the network resilience requirements in 2.6.11.2 of this Section shall be performed. If agreed by all parties, the network testing may be performed as a part of the system test onboard the vessel. The FAT shall as a rule be performed with the project specific software operating on the actual hardware components to be installed on board, with necessary means for simulation of functions and failure responses, however other solutions such as replica hardware or simulated hardware (emulators) may be agreed with CCS. For each test-case it shall be noted if the test passed or failed, and the test-results shall be documented in a test report (No.7 in Table 2.6.4.1(1)). The test report shall also contain a list of the software (including software versions) that were installed in the system when the test was executed[①].
2.6.7.8 The initial installation and subsequent updates of the software components of the system shall be done according to a management of change procedure which has been agreed between the system supplier and the systems integrator. The management of change procedure shall comply with the requirements in 2.6.10 of this Section. Cyber security measures shall be observed as described in CCS Guidelines for Ship Cyber Security.

2.6.8 Requirements on the systems integrator
2.6.8.1 For the purposes of this Section, the Shipyard is considered as the systems integrator in the development and delivery phase unless another organization or person is explicitly appointed by the Shipyard.
2.6.8.2 The systems integrator shall define a quality plan (No.1 in Table 2.6.4.2(1)) and document that the quality management system is applied for the installation, integration, completion, and maintenance of the systems to be installed on board. All applicable items described in Table 2.6.6.2 (for the systems integrator role) shall be demonstrated to exist and being followed, as relevant.
2.6.8.3 For each system delivery to a particular vessel, it shall be decided which category the system falls under based on the failure effects of the system (as defined in 2.6.5.2 of this Section). The category for a specific system must be conveyed to the relevant system supplier. CCS may decide that a risk-assessment[②] (No.3 in Table 2.6.4.1(2)) is needed to verify the proper system category.
2.6.8.4 The system of systems (SoS) shall be specified and documented (No.4 in Table 2.6.4.1(2)). This architecture specification provides the basis for category determination and development of the different integrated systems by allocating functionality to individual systems and by identifying the main interfaces between the systems[③]. It shall also serve as a basis for the testing of the integrated systems on the vessel level (see 2.6.8.6 of this Section).
The vessel's system architecture shall at least contain description of:
(1)Overview of the total systems architecture (the system of systems);
(2)Each system's purpose and main functionality;
(3)Communication and interface aspects between different systems.
2.6.8.5 A system acceptance test shall be arranged onboard the vessel. The main purpose of the system acceptance test (SAT) is to verify the system functionality, after installation and integration with the

---

① For complex systems there may be a large difference in scope between the "Internal system testing before FAT" activity and the FAT, while for some systems the scope may be identical.

② IEC/ISO31010 "Risk management - Risk assessment techniques" may be used as guidance in order to determine method of risk assessment.

③ See network topology in CCS Guidelines for Ship Cyber Security.

applicable machinery/electrical/process systems on board including possible interfaces with other control and monitoring systems. For each test-case it shall be noted if the test passed or failed, and the test-results shall be documented in a test report (No.6 in Table 2.6.4.1(2)). The test report shall also contain a list of the software (including software versions) that were installed in the system when the test was executed.

2.6.8.6 Integration tests shall be conducted after installation and integration of the different systems in its final environment on board①. The purpose of the tests is to verify the functionality of the complete installation (system of systems) including all interfaces and inter-dependencies in compliance with requirements and specifications. The testing shall at least verify the following aspects of the system of systems:

(1) The overall functionality of the interacting systems as a whole;

(2) Failure response between systems;

(3) Performance;

(4) Human-machine interfaces;

(5) Interfaces between the different systems.

2.6.8.7 The systems integrator shall follow procedures for management of change (No.9 in Table 2.6.4.1(2)) to the system as described in 2.6.10 of this Section.

2.6.9 Requirements on maintenance of computer-based systems

2.6.9.1 For the purposes of this Section, the vessel owner is considered to be the systems integrator in the operations phase unless another organization or person is explicitly appointed by the owner. Accordingly, CCS shall in a timely manner be informed by the owner about the appointed systems integrator which is responsible for implementing any changes to the systems in conjunction with system supplier(s).

2.6.9.2 The systems integrator shall ensure that necessary procedures for software and hardware change management exist on board, and that any software modification/upgrade are performed according to the procedure(s). For details about change management please see paragraph 2.6.10 of this Section.

2.6.9.3 Changes to computer-based systems in the operational phase shall be recorded. The records shall contain information about the relevant software versions and other relevant information as described in 2.6.10.9 of this Section.

2.6.9.4 The system supplier shall follow procedures for maintenance of the system including procedures for management of change as described in 2.6.10 of this Section.

2.6.9.5 The system supplier shall make sure that the planned changes to a system have passed relevant in-house tests before the change is made to systems on board.

2.6.10 Management of change

2.6.10.1 The management of change process shall be coordinated and agreed between the relevant stakeholders along the different stages of the lifecycle of the computer-based system②. If changes are required to a system after it has been approved by applicable stakeholders (typically the systems integrator and CCS at FAT) the modifications shall follow defined change management procedures.

2.6.10.2 The change management procedures cover both hardware and software. After FAT, the system supplier shall manage all changes to the system in accordance with the procedure. Examples could be qualification of new versions of acquired software, new hardware, modified control logic, changes to configurable parameters. The procedure(s) shall at least describe the activities listed in 2.6.10.3 to 2.6.10.10 of this Section.

2.6.10.3 The system supplier shall make sure that each system and software version is uniquely identifiable, see 2.6.7.2 of this Section.

2.6.10.4 There shall be defined mechanisms for handling of the files that constitutes the master-files for a software component. Personnel authorities shall be clearly defined along with the tools and mechanisms used to ensure the integrity of the master files.

2.6.10.5 It shall be clearly defined how to perform backup and restoration of the software components of a computer-based system onboard the vessel.

2.6.10.6 Before a change to the system is made, an impact analysis shall be performed in order to

---

① For complex systems there may be a large difference in scope between the "System acceptance test (SAT) onboard the vessel" activity and the SOST, while for some systems the scope may be overlapping or identical. It is possible to combine the two activities into one when the test scope is similar.

② Typically, the management of change address at least three different stages: Development and internal verification before FAT, involving the system supplier and sub-suppliers; From FAT to handover of the vessel to the owner, involving the system supplier, the systems integrator, CCS, and the owner; In operation, involving the system supplier, service suppliers, the owner, and CCS.

determine to what extent the change activities shall be performed. The analysis shall:
(1) Determine the criticality of the change.
(2) Determine the impact on existing documentation.
(3) Determine the needed verification and test activities.
(4) Determine the need to inform other stakeholders about the change.
(5) Determine the need to obtain approval from other stakeholders (e.g. CCS and or Owner) before the change is made.
2.6.10.7 When maintenance includes installation of new versions of the software in the system, it shall be possible to perform a rollback of the software to the previous installed version with the purpose of returning the system to a known, stable state. Roll-backs shall be documented and analysed to find and eliminate the root cause.
2.6.10.8 To the largest degree practically possible, modifications shall be verified before being installed onboard. After installation, the modification(s) shall be verified onboard according to a documented verification program containing:
(1) Verification that the new functionalities and/or improvements have had the intended effect.
(2) Regression test to verify that the modification has not had any negative effects on functionality or capabilities that was not expected to be affected.
2.6.10.9 Changes to systems and software shall be documented in change records to allow for visibility and traceability of the changes. The change records shall contain at least the following items:
(1) The purpose for a change;
(2) A description of the changes and modifications;
(3) The main conclusions from the impact analysis (see 2.6.10.6 of this Section);
(4) The identity and version of any new system or software version(s) (see 2.6.10.3 of this Section);
(5) Test reports or tests summaries (see 2.6.10.8 of this Section).
2.6.10.10 Documentation of the changes to software may be recorded in the planned maintenance system (PMS), in a software registry or equivalent.
2.6.10.11 During in operation (vessel in service) phase, the verification by CCS regarding the management of change in operation is generally performed during the annual survey of the vessel. Procedures for management of change and relevant change records shall be made available at the time of survey. In the cases where the change requires approval from CCS up front, the relevant procedures and documentation for the change in question may be verified at that time. During newbuilding, the verification of management of change in the newbuilding phase is divided into two:
(1) Procedures are verified as a part of the verification of the quality management system (Table 2.6.6.2);
(2) Project specific implementation of the procedures are verified during FAT and after FAT.

2.6.11 Technical requirements on computer-based systems

2.6.11.1 The system shall provide means to identify its name, version, identifier, and manufacturer. It is recommended that the system can automatically report the status of its software to a ship software logging system (SSLS) as specified in the international standard ISO 24060.
2.6.11.2 Loss of a data link shall be specifically addressed in risk assessment analysis/FMEA, including:
(1) A single failure in data link shall not cause loss of vessel- functions of category III. Any effect of such failures shall meet the principle of fail-to-safe for the vesselfunction(s) being served.
(2) For vessel-functions of category II and III, any loss of functionality in the remote control system shall be compensated for by local/manual means.
(3) The data link shall have means to prevent or cope with excessive communication rates.
(4) Data links shall be self-checking, detecting failures or performance issues on the link itself and data communication failures on nodes connected to the link.
(5) Detected failures shall initiate an alarm.
2.6.11.3 Category III systems shall not use wireless data links unless specifically considered by CCS on the basis of an engineering analysis carried out in accordance with an International or National Standard acceptable to CCS.
2.6.11.4 Other categories of systems may use wireless data links with the following requirements:
(1) Recognised international wireless communication system protocols shall be employed, incorporating:
① Message integrity. Fault prevention, detection, diagnosis, and correction so that the received message is not corrupted or altered when compared to the transmitted message.
② Configuration and device authentication. Shall only permit connection of devices that are included in the system design.
③ Message encryption. Protection of the confidentiality and or criticality of the data content.

④ Security management. Protection of network assets, prevention of unauthorized access to network assets.

(2) The internal wireless system within the vessel shall comply with the radio frequency and power level requirements of International Telecommunication Union and flag state requirements.

(3) Consideration should be given to system operation in the event of port state and local regulations that pertain to the use of radio-frequency transmission prohibiting the operation of a wireless data communication link due to frequency and power level restrictions.

(4) For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not self-fail as a result of electromagnetic interference during expected operating conditions.

2.6.11.5 The implementation of the technical requirements provided in 2.6.11 of this Section is verified as part of the system description, FAT and SAT described above.

Section 7 SENSORS

2.7.1 General requirements

2.7.1.1 The sensors are to give stable and normal operational performance over a long period of time. The measuring range and frequency characteristics (if applicable) of sensors are to be consistent with the expected maximum variation range and variation of velocity of the parameters being detected. The sensors are to possess suitable accuracy and sensitivity.

2.7.1.2 The sensors are to have good compatibility with the environmental conditions at their positions. The sensors are to be mechanically robust and durable, having good mechanical protection, reliable electrical connections and good insulated property.

2.7.1.3 The sensors are to be so sited that they can properly reflect the monitored parameters and are readily accessible for testing and renewal. In order that maintenance and renewal can be carried out easily, a protective cover is to be fitted for sensors. Where the sensors are sited in positions inaccessible for renewal, a standby sensor is to be fitted.

2.7.1.4 An independent sensor is to be provided for Mode a protective action; if not specially required, for Mode b protective action, the use of a common sensor with display and alarm is permitted; for Mode c protective action, the use of a common sensor with alarm is permitted.

Section 8 MAIN PROPULSION MACHINERY REMOTELY CONTROLLED FROM NAVIGATION BRIDGE

2.8.1 General requirements

2.8.1.1 If main propulsion machinery is remotely controlled from navigation bridge, the requirements of 2.8.1.2 to 2.8.1.12 of this Chapter are to be complied with.

2.8.1.2 Under all sailing conditions, including manoeuvring, the speed and direction of main propulsion machinery and, if applicable, pitch of the propeller are to be fully controllable from the navigating bridge.

2.8.1.3 The remote control of main propulsion machinery from navigation bridge is to be performed by a single control device for each independent propeller, with automatic performance of all associated services including, where necessary, means of preventing overload and prolonged running in critical speed ranges of the propelling machinery. Where multiple propellers are designed to operate simultaneously, they may be controlled by one control device.

2.8.1.4 The bridge control system is to be independent from the other transmission system, however, one control lever for both system may be accepted.

2.8.1.5 Operations following any setting of the bridge control device including reversing from the maximum ahead service speed in case of emergency are to take place in an automatic sequence and with time intervals acceptable to the machinery.

2.8.1.6 The main propulsion machinery is to be provided with an emergency stopping device on the navigating bridge and independent from the bridge control system, but its actuating unit may not be independent and the arrangement of which is to be such as to preclude inadvertent operation.

2.8.1.7 Main propulsion machinery orders from the navigation bridge are to be indicated in the engine room centralized control station (if fitted) or at the main propulsion machinery local control station.

2.8.1.8 Remote starting of the propulsion machinery is to be automatically inhibited if conditions exist which may hazard the machinery, e.g. shaft turning gear engaged, drop of lubricating oil pressure.

2.8.1.9 The design of the bridge control system is to be such that in case of its failure, an alarm is given. In this case, the speed and direction of the propeller thrust is to be maintained until local control is in operation, unless this is considered impracticable. In particular, lack of power (electric, pneumatic, hydraulic) is not to lead to major and sudden change in propulsion power or direction of propeller rotation.

2.8.1.10 An alarm is to be provided on the navigation bridge and in the machinery space to indicate low starting air pressure which is to be set at a level to permit further main propulsion machinery starting operations. If the remote control system of the main propulsion machinery is designed for automatic starting, the number of automatic consecutive is to be limited to not more than 3. Visual and audible alarms are to be given on the navigation bridge at the third failure.

2.8.1.11 Bridge control station is to indicate:

(1) main engine speed or propeller speed;

(2) the direction of rotation of fixed pitch propellers or the blade angle (or the pitch) for controllable pitch propellers;

(3) clutch position and shaft brake position (where applicable);

(4) the control station in control;

(5) the power supply to control and monitoring systems relating to the bridge control station.

2.8.1.12 If main propulsion machinery is remotely controlled from navigation bridge, automation systems are to be designed in a manner which ensures that threshold warning of impending or imminent shutdown or shutdown of the main propulsion machinery is given to the officer in charge of the navigational watch in time to assess navigational circumstances in an emergency. In particular, the systems are to control, monitor, report, alert and take safety action to slow down or stop propulsion while providing the officer in charge of the navigational watch an opportunity to manually intervene (such as overriding), except for those cases where manual intervention will result in total failure of the engine and/or main propulsion machinery within a short time, for example in the case of overspeed.

2.8.1.13 The bridge control of main steam turbines is to comply with the requirements in 3.2.3.2(1) of this PART. For attended machinery spaces, the slow turning device may be arranged to be operated manually.

CHAPTER 3 REQUIREMENTS FOR CLASS NOTATION AUT-0 OF PERIODICALLY UNATTENDED MACHINERY SPACES

Section 1 GENERAL PROVISIONS

3.1.1 Application

3.1.1.1 This Chapter applies to ships of which the main propulsion machinery is remotely controlled from the BCS and the machinery space including CCS is periodically unattended. In this connection, the class notation is AUT-0.

3.1.1.2 Ships with the class notation AUT-0 are, in addition to complying with the requirements of this Chapter, to be in compliance with the requirements of Chapters 1 and 2 of this PART.

3.1.1.3 For passenger ships with the class notation AUT-0, attention is to be paid to the requirements of the flag Administration, if any.

3.1.1.4 In the unattended period, automated systems are to ensure the normal continuous operation of the following machinery and electrical equipment:

(1) main propulsion machinery, including main engines (such as main diesel engine, main steam turbine, main gas turbine and electric propulsion installations), gearing (including clutches and reduction gearboxes) and propellers (including controllable pitch propellers);

(2) essential auxiliary machinery serving the main propulsion machinery;

(3) main and auxiliary boilers;

(4) electric generating plant;

(5) other machinery and electrical equipment, such as air compressors, bilge systems (including oily water separators), valves associated with remote control, fuel oil systems as well as others of which automated control and monitoring is deemed necessary by CCS.

Section 2 MAIN PROPULSION MACHINERY

3.2.1 General requirements

3.2.1.1 The starting, speed regulating, reversing (including shaft reversing) and stopping of the main propulsion machinery are to be capable of being remotely controlled or automatically, sequentially controlled from the CCS. In the case of failure of any part of the control systems, it is to be possible for the main propulsion machinery to be manually controlled from the LCS with regard to the above-mentioned operations.

3.2.2 Main diesel engines

3.2.2.1 The main diesel engines are to comply with the relevant requirements of Chapter 9, PART THREE of the Rules.

3.2.2.2 The control systems of main diesel engines are to comply with the following requirements:

(1) The control system is to ensure that under all operational conditions the engines and shafting will not be subjected to detrimental mechanical and thermal overloads.

(2) The automatic sequential control of main diesel engines is to be provided with necessary interlocks so as to prevent any mechanical damage.

(3) The number of unsuccessful automatic consecutive starts of main diesel engines is not to be more than 3. The main engine is to stop starting at the third failure, and an audible and visual alarm is to be given and the single alarm is to be extended to the BCS.

(4) The control system of main diesel engines is to be so designed that a critical speed range will be automatically crossed over promptly.

(5) Where the main diesel engine is used for main propulsion, means are to be provided to keep the starting air pressure within the required pressure range.

3.2.2.3 The safety system of main diesel engines is to comply with the following:

(1) Safeguards

① A suitable alarm is to be activated at the starting of standby pumps for which the automatic starting is required.

② If an overriding function of the required automatic reduction of power is provided, means are to be provided to preclude inadvertent operation of the overriding function, and a suitable alarm is to be

activated by the operation.

③ If an overriding function of the required automatic stops is provided (with the exception of overspeed), means are to be provided to preclude inadvertent operation of the overriding function, and a suitable alarm is to be activated by the operation. When the main engine is stopped automatically, restarting after restoration of normal operating conditions is to be possible only after manual reset, e.g. by-passing the control lever through the 'stop' position. Otherwise, automatic restarting is not permissible.

(2) For the requirements for the safety system of main diesel engines, refer to column 4 of Table 3.10.1.1 of this Chapter.

(3) In addition, emergency shutdown devices are to be provided at the BCS and CCS (see also 2.8.1.6 of this PART and 3.7.3.5 of this Chapter).

3.2.2.4 The alarm system (including displays) of main diesel engines is to satisfy the following requirements:

(1) Remote indications required in Table 3.10.1.1 of this Chapter are only for items to be displayed and alarmed at the CCS, see columns 2 and 3 of that Table.

(2) For items to be alarmed and the mode of alarms at the BCS, refer to column 5 of Table 3.10.1.1 of this Chapter. The items to be displayed are specified in 2.8.1.11, Chapter 2 of this PART.

3.2.2.5 Where vibration dampers are fitted for main engines:

For torsional or axial vibration dampers oiled by circulating lubrication from main engines and based on amortization thereof, the requirements for the items to be automatically controlled and monitored are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.2.3 Main steam turbines

3.2.3.1 The main steam turbines are to comply with the relevant requirements of Chapter 7, PART THREE of the Rules.

3.2.3.2 The control system of main steam turbines is to comply with the following requirements.

(1) Means are to be provided, by automatic steam spinning, to prevent the risk of thermal distortion of the main steam turbine, when the shaft has been stopped for a period exceeding the predetermined time in the maneuvering mode. However, device capable of stopping such automatic spinning is to be provided in the bridge.

(2) The control system is to be so designed that a critical speed range will be automatically crossed over promptly. Or alternatively, audible and visual alarms are to be given automatically when the turbine is running in the critical speed range, so as to warn the man-on-watch to cross over the critical speed range by manual control.

3.2.3.3 For the requirements for the safety system of main steam turbines, refer to column 4 of Table 3.10.1.1 of this Chapter.

3.2.3.4 The alarm system (including displays) of main steam turbines is to comply with the following requirements.

(1) For items to be displayed and alarmed at the CCS, refer to columns 2 and 3 of Table 3.10.1.1 of this Chapter.

(2) For items to be alarmed and the mode of alarms at the BCS, refer to column 5 of Table 3.10.1.1 of this Chapter. The items to be displayed are specified in 2.8.1.11, Chapter 2 of this PART.

3.2.4 Main gas turbines

3.2.4.1 The main gas turbines are to comply with the relevant requirements of Chapter 8, PART THREE of the Rules.

3.2.4.2 The control system of main gas turbines is to comply with the following requirements.

(1) When the gas turbine increases power from starting to rated condition or decreases power from rated condition to stop running, provision is to be made so that dangerous thermal and/or mechanical stresses will not occur in any part of the turbine due to the control of oil fuel supply, except in case of emergency control. Gas turbine remote control systems are to be so designed that the turbine exhaust gas temperature and the rotor speed can be maintained within a predetermined range and that the combustion in combustion chamber can be maintained in a steady state under normal operations.

(2) The remote control system of gas turbines is to be so designed that the lubricating oil system, oil fuel system and cooling system are interlocked as appropriate in order that the starting and stop of gas turbine operation can be carried out according to the predetermined procedure with sequential control complying with the following requirements:

① the lubricating oil pumps are to be kept in operation both before starting and after stopping the gas turbine. However, special consideration may be given to gas turbines fitted with roller bearings and attached lubricating oil pumps;
② the combustion chambers are to be sufficiently purged with air before ignition;
③ main oil fuel valves are not to open prior to ignition spark;
④ the ignition of each burner is not to exceed the predetermined duration. And if the gas turbine cannot achieve starting within the predetermined period, it is not to repeat the starting;
⑤ no excessive fuel is to be supplied into the combustion chamber during ignition.

(3) The remote control system for single-screw multi-turbine unit is to be so designed that the load on each turbine will not be abnormally distributed.

3.2.4.3 For the requirements for the safety system of main gas turbines, refer to column 4 of Table 3.10.1.1 of this Chapter.

3.2.4.4 The alarm system (including displays) of main gas turbines is to comply with the following requirements:

(1) For items to be displayed and alarmed at the CCS, refer to columns 2 and 3 of Table 3.10.1.1 of this Chapter.

(2) For items to be alarmed and the mode of alarms at the BCS, refer to column 5 of Table 3.10.1.1 of this Chapter. The items to be displayed are specified in 2.8.1.11, Chapter 2 of this PART.

3.2.5 Controllable pitch propellers

3.2.5.1 Controllable pitch propellers are to comply with the relevant requirements in Section 3, Chapter 11, PART THREE of the Rules.

3.2.5.2 Blade angle (or pitch) is to be capable of being remotely controlled or automatically, sequentially controlled from the BCS.

3.2.5.3 The remote control is to be performed by a single control device for each independent propeller, with automatic performance of all associated services. The control of a multi-propeller system where the propellers will possibly be in operation simultaneously may be performed by one device.

3.2.5.4 The combined control system of main engines and controllable pitch propeller for main propulsion is to be capable of preventing the engines and shafting from being overloaded and stopped due to overloading or overspeed.

3.2.5.5 For the hydraulic remote control system of controllable pitch propellers for main propulsion, a standby power source is to be provided. The standby pump supplying hydraulic power for pitch control is to be capable of automatically starting when the pressure of the hydraulic system is below the predetermined value.

3.2.5.6 The blade angle (or pitch) and shaft speed of controllable pitch propellers is to be indicated at each control station from which it is possible to control the propeller pitch (see 2.8.1.11, Chapter 2 and Table 3.10.1.1 of this PART).

3.2.5.7 For the items to be alarmed with regard to controllable pitch propellers, refer to Table 3.10.1.1 of this Chapter.

3.2.6 Electric propulsion installations

3.2.6.1 The function of control and monitoring of the electric propulsion installations is to comply with the requirements in Section 2, Chapter 15, PART EIGHT of the Rules.

3.2.6.2 The electric propulsion installations are to be capable of being controlled at the BCS, and there are to be provided with instruments for indicating the direction of rotation and speed of the propeller shaft, as well as those for indicating other necessary operational parameters.

3.2.7 Clutches

3.2.7.1 The requirements for the items to be automatically controlled and monitored for clutches are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.2.8 Gearboxes

3.2.8.1 The requirements for items to be automatically controlled and monitored for gearboxes are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

Section 3 BOILERS

3.3.1 Main boilers

3.3.1.1 The main boilers are to comply with the relevant requirements of Chapter 6, PART THREE of the Rules.

3.3.1.2 The control system of main boilers is to comply with the following requirements.

(1) Water level control

① The automatic control system is to ensure that the boiler water level is maintained within the predetermined range under all working conditions.

② Each boiler is to be provided with two independent low-water-level sensors (one of which is used in the safety system to detect the limited low water level) and one high-water-level sensor. Water level sensors are to be so located as to prevent the release of malfunction signals due to the rolling and pitching of the ship.

(2) Combustion control

① The automatic combustion control system is to be capable of maintaining the predetermined amount of steam generation, steam pressure, steam temperature and a stable combustion of the main steam turbine under all working conditions.

② The sequentially controlled boilers with an automatic ignition system are to satisfy the following requirements:

(a) prior to the initial ignition of the burner, the combustion chamber and flue passes are to be prepurged. The purging time is to be appropriate to a minimum of four air changes in the combustion chamber and flue passes. During boiler purge, the air registers and dampers are to be kept widely open;

(b) ignition can only be initiated after the air entry into and on completion of prepurging of the combustion chamber. The burner fuel valves are not to open prior to ignition spark. In the event of ignition failure, the ignition devices and burner fuel supply valves are to be automatically shut off. The time from fuel supply valve opening to closing is not to be greater than 15 s;

(c) each burner is to be fitted with a flame scanner designed to automatically shut off the fuel oil supply valve in the event of flame failure, and the action of shutoff is to be capable of closing the valve within 6 s following the flameout.

3.3.1.3 The safety system of main boilers:

(1) Where any one of the following faults takes place, the boiler fuel oil supply is to be automatically shut off, or alternatively, equivalent means are to be adopted for the emergency shutdown of the boiler:

① flame failure (i.e. flameout on all burners) in the combustion chamber or ignition failure;

② the water level in the boiler is below the limited low water level (the limited low water level is not to be lower than the lowest permissible water level or the level visible in the gauge glass);

③ loss of the pressure of combustion air in the forced draft to boiler.

(2) In addition to those mentioned in (1) above, separate emergency manual shutoff devices for each boiler fuel oil supply are to be provided at CCS (see also 3.7.3.5 of this Chapter).

(3) The standby pumps for boiler fuel oil are to start automatically when the discharge pressure from the working pumps falls below a predetermined value.

(4) The standby pumps for boiler feed water are to start automatically when the pressure or flow rate from the working pumps falls below a predetermined value.

3.3.1.4 The alarm system of main boilers (including displays)

(1) The items to be displayed and alarmed at the CCS are indicated in columns 2 and 3 of Table 3.10.1.1 of this Chapter.

(2) The items to be alarmed and the mode of alarms at the BCS are indicated in column 5 of Table 3.10.1.1 of this Chapter.

3.3.2 Auxiliary boilers

3.3.2.1 Auxiliary boilers are to comply with the relevant requirements of Chapter 6, PART THREE of the Rules.

3.3.2.2 The combustion control of auxiliary boilers is in general to comply with the requirements of 3.3.1.2(2) of this Section.

3.3.2.3 The safety system of auxiliary boilers is to comply with the requirements of 3.3.1.3(1), 3.3.1.3(2) and 3.3.1.3(3) of this Section. And the standby pumps for boiler feed water are to be started and put into service automatically in case the water level in the boiler is lower than the predetermined value.

3.3.2.4 The items to be automatically controlled and monitored for auxiliary boilers are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.3.3 Exhaust gas boilers

3.3.3.1 Exhaust gas boilers are to comply with the relevant requirements of Chapter 6, PART THREE of the Rules.
3.3.3.2 The items to be automatically controlled and monitored for exhaust gas boilers are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.
3.3.3.3 Indicating lights for the operation of boiler water pumps are to be provided at the CCS.
3.3.3.4 It is to be ensured that the safety system of exhaust gas boilers is capable of starting the action of by-pass of exhaust gas or the mechanism of vapour release in case steam drum outlet pressure/temperature of steam boilers is excessively high.

3.3.4 Thermal oil heaters

3.3.4.1 The thermal oil heaters are to comply with the relevant requirements in Section 8, Chapter 4, PART THREE of the Rules.
3.3.4.2 The items to be automatically controlled and monitored for thermal oil heaters are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.
3.3.4.3 The standby pumps are to be started automatically when outlet pressure of circulating pumps for transfer of fuel oil is lower than the predetermined value.
3.3.4.4 For ensuring stable working conditions throughout the operating range of the heater, automatic control is to be provided for the following:
(1) combustion system;
(2) temperature or viscosity of fuel oil (only for heavy oil);
(3) temperature of thermal oil.

Section 4 ELECTRIC GENERATING PLANT

3.4.1 General requirements

3.4.1.1 In addition to complying with the requirements of this Section, the electric generating plant is to be in compliance with the relevant requirements of Chapter 2, PART FOUR of the Rules.
3.4.1.2 The items to be automatically controlled and monitored for electric generating plant are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.4.2 Continuity of power supply

3.4.2.1 Where electrical power is normally supplied by one generating set, arrangements, such as load shedding referred to in 3.4.2.6 of this Section or automatic starting of a standby generating set, etc. are to be provided to ensure that the safety of the ship under all sailing conditions, including maneuvering, is at least equivalent to that of a ship having the machinery space manned.
3.4.2.2 If the electrical power is normally supplied by more than one generator operating in parallel, provision is to be made by means such as load shedding referred to in 3.4.2.6 of this Section, or by appropriate separation of the switchboard bus-bars to ensure that, in the event of loss of one of the generating sets, the remaining set(s) are kept in operation without overload to permit propulsion and steering, and to ensure the safety of the ship.
3.4.2.3 In the event of a failure of the generating set in service, a standby generating set is to be capable of automatically starting and connecting to the main switchboard, with a sufficient capacity to supply those services necessary to ensure that the safety of the ship under all sailing conditions, including maneuvering, is at least equivalent to that of a ship having the machinery spaces manned.
3.4.2.4 All motor-driven essential auxiliaries serving the main propulsion machinery are to be capable of automatically re-starting in a sequence upon restoration of power after interruption.
3.4.2.5 The automatic starting system and characteristics of the standby generating set are to be such as to permit the standby generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum period of 45 s.
3.4.2.6 For the safety of power supply to essential services, suitable load shedding devices are to be provided to automatically cut off the non-essential loads:
(1) when the total load exceeds the rated output power of generator caused by automatic switch-on of additional loads;
(2) when the total load exceeds the sum of rated powers of other generating sets which are still in service in case of the failure of one of generators as more than one generating sets are operating in parallel.

Section 5 AUXILIARY MACHINERY

3.5.1 General requirements

3.5.1.1 The auxiliary machinery referred to in this Section means the prime mover of electric generators, all kinds of pumps and air compressors serving the main propulsion machinery, etc.

3.5.1.2 During the unattended period of machinery spaces, all the auxiliary machinery are to be capable of being normally operated automatically.

3.5.2 Auxiliary diesel engines

3.5.2.1 The items to be automatically controlled and monitored for the auxiliary diesel engines are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.5.3 Pumps

3.5.3.1 The motor-driven pumps serving the main propulsion machinery are to be capable of being automatically started in sequence upon restoration of power after interruption. For the requirements for automatic changeover of standby pumps, see items marked with “c” in column 4 of Table 3.10.1.1 of this Chapter.

3.5.4 Air compressors

3.5.4.1 The items to be automatically controlled and monitored for air compressors are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

Section 6 OTHER EQUIPMENT

3.6.1 Bearings of tail pipes

3.6.1.1 The items to be automatically controlled and monitored for bearings of tail pipes are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.6.2 Valves

3.6.2.1 The valves covered by this Section mean the valves used in bilge and sea water systems (including ballast water system).

3.6.2.2 Failure of actuator power is not to put the valve and the whole ship to an unsafe condition.

3.6.2.3 Positive indication is to be provided at the station for valve control to show the actual valve position or alternatively, whether the valve is fully open or closed.

3.6.2.4 Operating equipment located in places which may be flooded is to be capable of normal operation when submerged.

3.6.2.5 In the event of a failure of the remote or automatic control the valves are to be capable of being operated manually.

3.6.3 Oil purifiers, etc.

3.6.3.1 The items to be automatically controlled and monitored for oil purifiers, oil return tanks of main and auxiliary engines and incinerators are to be in compliance with Table 3.10.1.1 of this Chapter as appropriate.

3.6.4 Oil tanks

3.6.4.1 The capacities of fuel oil daily service and settling tanks are to be appropriate to the consumption necessary for the unattended period (such as 8 h, 16 h, 24 h) plus 10% at least. A low level alarm is to be provided for the daily service fuel oil tanks (see Table 3.10.1.1 of this Chapter) and high and low level alarms are to be provided for the settling tanks.

3.6.4.2 Where the daily service fuel oil tanks are replenished automatically or remotely, means are to be provided to eliminate the possibility of overflow, and high and low level alarms are to be provided and extended to the BCS. In this case, the tanks may be exempted from the requirements for capacity as specified in 3.6.4.1 above.

Section 7 ADDITIONAL REQUIREMENTS FOR CONTROL STATIONS (ROOMS)

3.7.1 Provision of control stations (rooms)

3.7.1.1 Bridge control station (BCS), engine room centralized control station (CCS) and local control stations (LCS) are in general to be provided on ships with machinery spaces periodically unattended.

3.7.2 Functions of bridge control stations (BCS)

3.7.2.1 Under all sailing conditions including maneuvering, the speed and direction of thrust of main propulsion machinery as well as other associated installations (if fitted) are to be effectively controlled from the BCS. When necessary, the control is to be capable of being changed over to other control stations at any time and the changeover is to comply with the relevant requirements of 2.5.2 of this PART. The design and arrangement of bridge control station are to comply with the requirements in Section 8, Chapter 2 of this PART.

3.7.2.2 Alarms at the BCS

(1) For the items to be alarmed at the BCS and the mode of alarms, see column 5 of Table 3.10.1.1 of this Chapter. Alarms indicating the faults in the machinery and electrical equipment as well as the automated control and monitoring systems are, in general, to be relayed to the BCS in the following modes: group alarms for the protective actions of safety systems; separate alarms; group alarms for serious faults and group alarms for general faults.

(2) The audible alarms at the BCS are permitted to be silenced after acknowledgment, but the visual alarms are to be extinguished only after the rectification of faults, and furthermore, the visual signals are to be capable of being clearly distinguishable before and after acknowledgment.

3.7.2.3 If the main engine is remotely started from the bridge control station, the indicator is to be fitted on the bridge control station for the starting air pressure or voltage of starting storage batteries of main engines.

3.7.3 Functions of centralized control stations (rooms) of engine room (CCS)

3.7.3.1 The CCS is to be capable of performing functions of control and changeover of the main propulsion machinery as specified in 3.7.2.1 of this Section, and besides, it is also to be capable of controlling and monitoring the other equipment as specified in 3.1.1.4 of this Chapter.

3.7.3.2 Instruments or display units are to be provided at the CCS to indicate the essential parameters for ensuring the safe and reliable operation of the machinery and electrical equipment. The items to be displayed are given in column 2 of Table 3.10.1.1of this Chapter.

3.7.3.3 All faults including several faults occurred at the same time in the machinery and electrical equipment and in the control and monitoring systems are to be capable of being alarmed at the CCS. The items to be alarmed are given in column 3 of Table 3.10.1.1of this Chapter.

3.7.3.4 Audible alarms at the CCS are to be capable of being silenced only after being acknowledged at the station.

3.7.3.5 The emergency button for stopping main propulsion machinery and the emergency buttons for cutting off oil supply to boilers and incinerators provided at the CCS are to be independent of the automated systems of the station, but their actuating units may not be required to be independent and are to be arranged so as to preclude inadvertent operation.

3.7.3.6 Where overriding function as prescribed in 1.1.2.1(9) of this PART is provided for main engines, the overriding function is also to be provided at the CCS, and is to be so arranged as to preclude inadvertent operation.

3.7.4 Functions of local control stations (LCS)

3.7.4.1 The LCS is to comply with the requirements of 2.5.1.5 of this PART.

3.7.5 Communication

3.7.5.1 In addition to complying with the relevant requirements of PARTs THREE and FOUR of the Rules, reliable means of vocal communication are to be provided between the CCS or the LCS (if applicable), the BCS and the engineers' accommodation.

Section 8 ADDITIONAL REQUIREMENTS FOR CONTROL AND MONITORING SYSTEMS

3.8.1 Safety systems

3.8.1.1 The safety systems in all controlled and monitored machinery and electrical equipment are to be in compliance with the requirements of Section 3, Chapter 2 of this PART.

3.8.2 Alarm systems

3.8.2.1 The arrangement of the alarm display is to assist in identifying the particular fault condition and its location within the machinery space.

3.8.2.2 If the bridge navigating officer of the watch is the sole watch-keeper then, in the event of a machinery fault being monitored at the control location for machinery, the alarm system is to be such that this watch-keeper is made aware when:

(1) a machinery fault has occurred;

(2) the machinery fault is being attended to (e.g. acknowledging, silencing);

(3) the machinery fault has been rectified. Alternative means of communication between the bridge area, the accommodation for engineering personnel and the machinery spaces (CCS or local control stations) may be used for this function.

3.8.2.3 Group alarms may be arranged on the bridge to indicate machinery faults. Alarms associated with faults requiring speed reduction or automatic shutdown of propulsion machinery are to be separately identified (see column 5 in Table 3.10.1.1 of this Chapter).

3.8.2.4 The alarm system is to be capable of being tested during normal machinery operation. Where practicable, means are to be provided at convenient and accessible positions to permit the sensors to be tested without affecting the operation of the machinery.

3.8.2.5 If an alarm has been acknowledged and a second fault occurs before the first is rectified, then audible and visual alarms are to operate again. Alarms due to temporary failures are to remain activated until acknowledged.

3.8.2.6 Automatic recording devices are to be provided at the CCS for recording the important parameters and faults. Where a computer system is used, its recording device may be adopted instead.

3.8.2.7 A changeover switch is to be provided to relay all the fault alarms to the engineers' accommodation and each engineer's cabin by group alarms so as to ensure that the alarm signal is relayed at least to one cabin of the engineer on watch.

Acknowledgment of alarms at positions outside a machinery space (including the CCS) is not to silence the audible alarm or extinguish the visual alarm in that machinery space (including the CCS).

Where an alarm has not been acknowledged in a certain time (not more than 5 min) in the machinery space (including the CCS), the alarm system referred to in 2.8.4 of Chapter 2, PART FOUR of the Rules is to be activated automatically, and the alarm is to be clearly audible within the engineers' accommodation and related public spaces.

Section 9 FIRE PRECAUTIONS AND PROTECTION AGAINST FLOODING

3.9.1 Fire precautions

3.9.1.1 The fire precautions for periodically unattended machinery spaces (including the CCS) are to comply with the relevant requirements of PART SIX of the Rules, inter alia, the requirements for the special arrangements in machinery spaces, fire detection and alarm systems, and water fire-extinguishing systems. There is to be immediate water delivery from the fire main system at a suitable pressure, either by remote starting of one of the main fire pumps with remote starting from the navigating bridge or fire control station, if any, or permanent pressurization of the fire main system by one of the main fire pumps, except that this requirement need not be complied with for cargo ships of less than 1,600 gross tonnage if the fire pump starting arrangement in the machinery space is in an easily accessible position.

3.9.1.2 In addition to complying with the requirements for engine rooms given in PART THREE of the Rules, the fire precautions for periodically unattended machinery spaces are to comply with the following.

(1) Fuel oil, lubricating oil and hydraulic oil pipelines are to be so constructed and arranged as to avoid excessive stresses due to vibration and expansion. Flange joints are to be minimized as far as practicable in the above pipelines.

(2) Equipment for the automatic treatment of flammable oils, such as oil purifiers, oil heaters, oil filters, oil pumps, etc., are to be provided with means to prevent oil spillage, for instance, drip trays fitted below the equipment for collecting oil leakage and draining it to a sludge tank. The above-mentioned equipment is to be centralized as far as practicable in a special space.
(3) The high pressure fuel oil pipelines are to be screened or otherwise suitably protected to prevent leaks from dripping or spraying onto hot surfaces or into machinery air intakes, for instance, the fitting of metal sheathing to the high pressure fuel injection pipes of diesel engines.
(4) Leakage from high pressure fuel pipes are to be, as far as practicable, collected and led to a collector tank(s) fitted in a safe position and arrangements are to be provided for an alarm to be given in the event of leakage, see Table 3.10.1.1 of this Chapter.
(5) Fuel oil or lubricating oil heaters are to comply with the following:

① high temperature alarm or low flow alarm is to be provided unless it is impossible to reach the ignition temperature of medium;

② in addition to the temperature control, an independent safeguard is to be fitted which will automatically cut off the heating supply in the event of excessively high temperatures or loss of flow, except where the maximum temperature of the heating media remains limited to a value below 220℃;

③ where electric heaters are adopted, an independent safeguard is to be fitted which will automatically cut off the heating supply in the event of excessively high temperatures, except that all live heating components are soaked in oil and the surface temperature of the heating components remains below 220℃.

3.9.1.3 Special requirements for fire detection systems
(1) An automatic fire detection system is to be fitted in the machinery spaces.
(2) The system is to be designed with self-monitoring properties. Power or system failures are to initiate an audible alarm distinguishable from the fire alarm.
(3) The fire detection indicating panel is to be located on the navigation bridge, fire control station, or other accessible place where a fire in the machinery space will not render it inoperative.
(4) The fire detection indicating panel is to indicate the place of the detected fire in accordance with the arranged fire zones by means of a visual signal. Audible signals clearly distinguishable in character from any other audible signals are to be audible throughout the navigation bridge and the accommodation area of the personnel responsible for the operation of the machinery space.
(5) Fire detectors are to be of such types, and so located, that they will rapidly detect the onset of fire in conditions normally present in the machinery space. Consideration is to be given to avoiding false alarms. The type and location of detectors are to comply with the relevant requirements of the SOLAS Convention and the International Code for Fire Safety Systems (hereinafter referred to as FSS Code) as well as CCS rules, and a combination of detector types is recommended in order to enable the system to react to more than one type of fire symptom.
(6) Fire detector zones are to be arranged in a manner that will enable the operating staff to locate the seat of the fire. The arrangement of the fire detection system, the number of loops and the location of detector heads are to be approved in each case and comply with the relevant requirements of SOLAS Convention and FSS Code. Air currents created by the machinery are not to render the detection system ineffective.
(7) When fire detectors are provided with the means to adjust their sensitivity, necessary arrangements are to be ensured to fix and identify the set point.
(8) When it is intended that a particular loop or detector is to be temporarily switched off, this state is to be clearly indicated. Reactivation of the loop or detector is to be performed automatically after a preset time.
(9) The fire detection indicating panel is to be provided with facilities for functional testing.
(10) The fire detection system is to be fed automatically from the emergency source of power by separate feeder if the main source of power fails, and to comply with the requirements of 2.9.6, PART FOUR of the Rules.
(11) Facilities are to be provided in the fire detection system to release manually the fire alarm from the passageways having entrances to engine and boiler rooms, navigation bridge and control station in engine room.
(12) The fire detection system is to be tested upon installation on board to confirm compliance with the rule requirements for function.

3.9.2 Protection against flooding

3.9.2.1 An alarm system is to be provided to warn high bilge water level in machinery spaces. The alarm level is to be sufficiently low to prevent liquid overflowing from the bilge onto the tank top of double bottom tanks.

3.9.2.2 The number and location of bilge water level detectors are to be such as to prevent false alarms at normal angles of trim and heel.
3.9.2.3 The location of the controls of any valve serving a sea inlet, a discharge below the waterline or a bilge injection system, for controlling flooding upon damage, is to be such as to allow adequate time for operation in case of influx of water to the space, having regard to at least 10 min which could be required to reach and close the valve. Arrangements are to be made to operate the controls from a position above the level to which the space could become flooded due to any broken pipe with the ship being in the fully loaded condition.
3.9.2.4 Bilge wells are to be large enough to accommodate normal drainage during the unattended period. Where the bilge pumps are arranged to start automatically, smaller bilge wells may be permitted to accommodate the normal drainage for a suitable time, provided that an alarm is provided to indicate if the influx of liquid is greater than the pump capacity or if the pump is operating more frequently than would normally be expected and that the discharge complies with the relevant requirements for pollution prevention. The items to be controlled and monitored are indicated in Table 3.10.1.1 of this Chapter as appropriate.
3.9.2.5 Alarms required by 3.9.2.1 and 3.9.2.4 above are to be given at the CCS, BCS and engineers' accommodation area.

Section 10 AUTOMATIC CONTROL AND MONITORING ITEMS

3.10.1 Table of automatic control and monitoring items

3.10.1.1 The automatic control and monitoring items (if fitted) for all ships with the class notation AUT-0 are to comply with Table 3.10.1.1.
3.10.1.2 The designations used in Table 3.10.1.1 of this Section are defined as follows:

–: not required;
*: only required for trunk piston diesel engines;
a: Mode a protective action, such as emergency shutdown of the engine, fuel oil cutoff of boiler and cutoff of electric power supply, etc.;
b: Mode b protective action, such as reducing the speed of rotation or the output of machinery;
c: Mode c protective action, such as starting and putting into operation of standby pump or standby unit;
S: single alarm;
G_a: group alarm activated by Mode a protective action;
G_b: group alarm activated by Mode b protective action;
R: group alarm for serious faults;
Y: group alarm for general faults.

3.10.1.3 Where “per cylinder” appears in the column “Remark” of Table 3.10.1.1 of this Section, it applies only to crosshead diesel engines, and for trunk piston diesel engines, “fitted on manifold outlet” may be used to replace the “per cylinder”.
3.10.1.4 For the equipment marked with “▲” in Table 3.10.1.1 of this Section, if all of the single alarms and display items provided locally or in the vicinity of the engine are confirmed by CCS, the engine room central control station and the BCS may be exempted from the single alarms and display items as required in Table 3.10.1.1. Only one group alarm for general faults and one fault display are to be provided in this case.

Automatic Control and Monitoring Items for Ships with Class Notation AUT-0

Table 3.10.1.1

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
1. Main diesel engine **1.1 Fuel oil system**					
Fuel oil inlet pressure	Pressure	Low	c	*R*	Fitted after filter
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low and high	–	*Y*	Only for heavy oil
Leakage from high pressure fuel pipes	–	Leakage	–	*Y*	

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Level of fuel oil in daily service tanks	–	Low	–	*Y*	High-level alarm also required, if no suitable overflow arrangement provided
Common rail fuel oil pressure	–	Low	–	*Y*	
1.2 Lubricating oil system					
Lub-oil inlet pressure to main bearing & thrust bearing	Pressure	Low	c	*R*	
			b	G_b	Necessary for crosshead diesel engines
		Excessively low	a	G_a	
Lub-oil inlet pressure to crosshead bearing	Pressure	Low	c	*R*	Required if separate lub-oil system installed for crosshead diesel engines
			b	G_b	
		Excessively low	a	G_a	
Lub-oil inlet pressure to camshaft	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature to camshaft	Temp.	High	–	*Y*	
*Lub-oil filter differential pressure	Pressure	Great	–	*Y*	
Lub-oil inlet temperature	Temp.	High	–	*Y*	
Thrust bearing pad temperature or bearing temperature	Temp.	High	b	G_b	Necessary for crosshead diesel engines
		Excessively high	a	G_a	
Oil mist concentration in crankcase (or main, crank, crosshead bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	b	G_b	Applicable to low speed crosshead diesel engines specified in 9.7.6, Ch.9, Pt.3
*Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	G_a	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator (each apparatus)	–	Small	b	G_b	Required for trunk piston diesel engines if necessary for safe operation of the engines
Oil level in lub-oil circulating tank	–	Low	–	*Y*	Necessary for crosshead diesel engines; individual level alarms required for the tanks if separate lub-oil systems installed (e.g. camshaft, rocker arms, etc.) for crosshead diesel engines
Common rail servo oil pressure	–	Low	–	*Y*	
1.3 Turbocharger system					
Turbocharger lub-oil inlet pressure	Pressure	Low	–	*Y*	Unless provided with a self-contained lubricating oil system integrated with the turbocharger
Turbocharger lub-oil outlet temp each bearing	Temp	High	–	*Y*	Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design, alternative arrangements may be accepted. Continuous

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
					monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative.
Speed of turbocharger	Speed	High	–	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
1.4 Piston cooling system (Necessary for crosshead diesel engines)					
Piston coolant inlet pressure	Pressure	Low	c	*Y*	The slowdown is not required if the coolant oil taken from the main cooling system of the engine
		Excessively low	b	G_b	
Piston coolant outlet flow	–	Low	b	G_b	Per cylinder; where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted
Piston coolant outlet temperature	Temp.	High	b	G_b	Per cylinder
Level of piston coolant in expansion tank	–	Low	–	*Y*	
1.5 Seawater cooling system					
Pressure of cooling seawater	Pressure	Low	c	*Y*	
1.6 Cylinder fresh cooling water system					
Cylinder water inlet pressure or flow	Pressure or flow	Low	c	*Y*	Only cylinder coolant inlet pressure required for crosshead diesel engines
		Excessively low	b	G_b	
Cylinder water outlet temperature (from each cylinder) Cylinder water outlet temperature (general)	Temp.	High	b	G_b	Required for crosshead diesel engines where one common cooling space without individual stop valves is employed for all cylinder jackets. For trunk piston diesel engines, alarm and slowdown only for cylinder water outlet temperature (general) and two separate sensors required
Oily contamination of main engine cooling water system	–	Contaminated	–	–	Necessary for crosshead diesel engines; required where main engine cooling water is used in fuel and lubricating oil heat exchangers
Level of cylinder cooling water in expansion tank	–	Low	–	*Y*	
1.7 Starting and control air systems					
Starting air pressure before main shut-off valve	Pressure	Low	–	*S*	
Control air pressure	Pressure	Low	–	*S*	
Safety air pressure	Pressure	Low	–	*S*	Necessary for crosshead diesel engines
1.8 Scavenge air system					
Scavenge air receiver pressure	Pressure	–	–	–	Necessary for crosshead diesel engines
Scavenge air box temperature (fire)	Temp.	High	b	G_b	
Scavenge air receiver water level	–	High	–	*Y*	
*Scavenge air receiver temperature	Temp.	High	–	*Y*	
1.9 Exhaust gas system					
Exhaust gas temp. after each	Temp.	High	b	G_b	For trunk piston diesel engines

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
cylinder					having a power of more than 500 kW per cylinder only
Exhaust gas temperature after each cylinder. Deviation from average	–	Great	–	*R*	
Exhaust gas temperature before each turbocharger	Temp.	High	–	*R*	Necessary for crosshead diesel engines
Exhaust gas temperature after each turbocharger	Temp.	High	–	*R*	
1.10 Fuel valve coolant					
Pressure of fuel valve coolant	Pressure	Low	c	*R*	The requirement is to be complied with if the crosshead diesel engine is fitted with a separate fuel valve cooling system
Temperature of fuel valve coolant	Temp.	High	–	*Y*	
Level of fuel valve coolant in expansion tank	–	Low	–	*Y*	
1.11 Engine speed/direction of rotation					
Speed	Speed	Overspeed	a	G_a	See 9.7.9.1 of Pt.3
Direction of rotation	Direction of rotation	Wrong way	–	*S*	Necessary for crosshead diesel engines
1.12 Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
2 Auxiliary diesel engines▲					
Lub-oil inlet pressure	Pressure	Low	–	*Y*	
		Excessively low	a		
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Exhaust gas temp. after each cylinder	Temp.	High	–	*Y*	For engine power > 500 kW per cylinder only
Lub-oil inlet temperature	–	High	–	*Y*	
Temperature of cooling water or cooling air outlet	Temp.	High	–	*Y*	
Pressure or flow of cooling water	–	Low	–	*Y*	
Speed	–	Overspeed	a	*Y*	See 9.7.10.3 of Pt.3
Starting air pressure	Pressure	Low	–	*Y*	
Fuel oil leakage from pressure pipes	–	Leakage	–	*Y*	
Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	*Y*	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Level in fuel oil daily service tank	–	Low	–	*Y*	
Level in cooling water expansion tank	–	Low	–	*Y*	If not connected to main system
Common rail fuel oil pressure	–	Low	–	*Y*	
Common rail servo oil pressure	–	Low	–	*Y*	
Speed of turbocharger	Speed	High	–	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
3 Electric generating plant▲					
Bus bar voltage	Voltage	High and low	–	*Y*	
Bus bar frequency	Frequency	High and low	–	*Y*	
Load shedding	–	When in operation	–	*Y*	
Automatic switch-on of circuit breaker	–	Failure	–	*Y*	
Tripping of automatic circuit breaker	–	When in operation	–	*Y*	
Failure of load distribution	–	Failure		*Y*	Fitted if automatic load distribution is adopted
4 Main gas turbines					
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature to gas turbine and gearing	Temp.	High	–	*Y*	
Lub-oil filter differential pressure	–	Great	c	*Y*	
Oil level in lub-oil circulating tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Turbine main bearing temperature	Temp.	High	–	*Y*	
Coolant pressure or flow	–	Low	–	*Y*	
Coolant temperature	Temp.	High	–	*Y*	
Fuel oil temperature or viscosity	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Fuel oil pressure or flow	Pressure or flow	Low	c	*Y*	
Level in fuel oil daily service tank	–	Low	–	*Y*	When it is replenished automatically, high and low level alarms are to be fitted
Gas inlet or outlet temperature of turbine	Temp.	High	–	*Y*	
		Excessively high	a	G_a	
Deviation of exhaust gas temperature from average	–	High	–	*Y*	
Gas turbine combustion chamber flame and ignition	–	Failure	a	G_a	
Gas turbine vibration	–	High	–	*Y*	
		Excessively high	a	G_a	
Axial displacement of turbine rotor	–	Great	–	*R*	
Turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
5 Auxiliary gas turbines▲					
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	–	*Y*	
		Excessively low	a		
Exhaust gas temperature	Temp.	High	a	*Y*	
Combustion chamber flame	–	Extinguished	a	*Y*	
Gas turbine vibration	–	Excessive	a	*Y*	
Gas turbine speed	–	Overspeed	a	*Y*	
Power supply for	Electrical,	Loss	–	*Y*	Indication of voltage may be

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	pneumatic and hydraulic pressure				replaced by indicating lamp
6 Main steam turbines					
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature for turbine and gearing	Temp.	High	–	*Y*	
Lub-oil filter differential pressure	–	Great	–	*Y*	
Level of lub-oil tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Bearing temperature or bearing lub-oil outlet temperature of turbine and gearing	Temp.	High	–	*Y*	
Thrust bearing temperature or lub-oil outlet temperature	–	High	–	*Y*	
Astern turbine exhaust steam temperature	Temp.	High	–	*Y*	
Gland steam pressure	Pressure	High and low	–	*Y*	
Circulating seawater pressure or flow	Pressure or flow	Low	c	*Y*	
Main condenser vacuum	Vacuum	Low	b	G_b	
Main condenser condensate level	–	High and low	b	G_b	
Condensate pump	–	Stop/failure	–	*Y*	
Condensate salinity	–	High	–	*Y*	
Steam turbine vibration	–	Excessive	b	G_b	
Axial displacement of turbine rotor	–	Excessive	a	G_a	
Turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
7 Auxiliary steam turbines▲					
Lub-oil inlet temperature for turbine and gearing	–	High	–	*Y*	
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	–	*Y*	
		Excessively low	a		
Condenser vacuum	–	Low	a	*Y*	
Axial displacement of turbine rotor	–	Excessive	a	*Y*	
Turbine speed	–	Overspeed	a	*Y*	
Power supply for control-safety-alarm systems (electric, pneumatic, hydraulic)	Electric, pneumatic and hydraulic pressure	Loss	—	*Y*	Indication of voltage may be replaced by indicating lamp
8 Main steam boilers					
Steam drum or superheater outlet pressure	Pressure	High and low	–	*R*	
Superheated steam outlet temperature	Temp.	High	–	*R*	
De-superheated steam outlet temperature	Temp.	High	–	*R*	
Boiler feed water level	Level	High	–	*R*	At least 3 sensors fitted. See

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
		Low	c	*R*	3.3.1.2(1)② and 3.3.1.3(1)② of this Chapter
		Excessively low	a	G_a	
Temperature or viscosity of oil fuel to burners	Temp. or viscosity	Low and high	–	*Y*	Only for heavy oil Protective action with cutoff of boiler fuel oil supply in case of excessively high temperature or excessively low viscosity may be carried out by cutoff of fuel oil heating supply
		Excessively low and high	a	G_a	
Fuel oil pressure to burners	Pressure	Low	c	*Y*	See 3.3.1.3(3) of this Chapter
Forced draft pressure	Pressure	Loss	a	G_a	2 sensors fitted
Burner flame and ignition	–	Extinguished / ignition failure	a	G_a	Each burner is to be monitored
Fuel oil atomizing steam (air) pressure	Pressure	Low	–	*Y*	
Feed pump discharge pressure or flow	Pressure or flow	Low	c	*R*	See 3.3.1.3(4) of this Chapter
Feed water forced circulation flow	Flow	Low	a	G_a	Required for forced circulating boilers only
Level of feed water tank	–	Low	–	*Y*	Required for daily feed water tanks only
Feed water salinity	–	High	–	*Y*	
Water level of deaerator	–	High and low	–	*Y*	
Boiler air supply casing and exhaust pipe (smoke uptake)	–	Fire	–	*Y*	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
9 Auxiliary steam boilers▲					
Steam drum or superheater outlet pressure	Pressure	Low	–	*Y*	
Boiler feed water level	–	High	–	*Y*	See 3.3.2.3, 3.3.1.2(1)② and 3.3.1.3(1)② of this Chapter
		Low	c	*Y*	
		Excessively low	a	*Y*	
Temperature or viscosity of oil fuel to burners	Temp. or viscosity	Low and high	–	*Y*	Only for heavy oil Protective action with cutoff of boiler fuel oil supply in case of excessively high temperature or excessively low viscosity may be carried out by cutoff of fuel oil heating supply
		Excessively low and high	a	*Y*	
Fuel oil pressure to burners	Pressure	Low	c	*Y*	See 3.3.1.3(3) of this Chapter
Forced draft pressure	–	Loss	a	*Y*	
Burner flame and ignition	–	Extinguished / ignition failure	a	*Y*	
Feed water salinity	–	High	–	*Y*	Only applicable to auxiliary steam boiler for driving turbine-generator set
Boiler air supply casing and exhaust pipe (smoke uptake)	–	Fire	–	*Y*	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic	Electrical, pneumatic and	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
pressure)	hydraulic pressure				
10 Controllable pitch propeller					
Pitch or blade angle of controllable pitch propeller	Pitch or blade angle	—	—	—	See 2.8.1.11 of this PART
Propeller shaft speed	Speed	—	—	—	See 2.8.1.11 of this PART
Hydraulic system pressure for controlling propeller pitch	Pressure	Low	c	*S*	
Hydraulic oil tank level	–	Low	–	*Y*	
Hydraulic oil temp. (if oil cooler is fitted)	–	High	–	*Y*	
Electric power supply for electrohydraulic control system	Voltage	Loss	–	*Y*	
11 Vibration damper					
Oil inlet pressure or amplitude for vibration damper	Pressure or amplitude	Low or great	–	*Y*	See 3.2.2.5 of this Chapter and 12.1.4.3, Ch.12, Pt.3
12 Gearbox (for main propulsion machinery)					
Lub-oil inlet pressure of gearbox	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature of gearbox	Temp.	High	–	*Y*	
Gear oil pressure	Pressure	Low	–	*Y*	
13 Clutches					
Clutch position	Position	–	–	–	
Power supply for control of clutches (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	See 2.8.1.11 of this PART
14 Stern tube bearing					
Oil lubricated stern tube bearing temp.	–	High	–	*Y*	
Level of stern tube lubricating oil tank	–	Low	–	*Y*	
15 Exhaust gas boilers					
Circulating feed pump outlet pressure or flow	Pressure or flow	Low	c	*Y*	Only applicable to water tube exhaust gas boiler with forced circulation
Fire in exhaust gas pipelines	–	Fire	–	*Y*	
Steam pressure	Pressure	High	–	*Y*	
16 Air compressors▲					
Air compressor lubricating oil pressure	–	Low	a	*Y*	Except for splash lubrication
17 Thermal oil heaters▲					
(1) Oil-fired					
Thermal oil expansion tank level	–	Low	a	*Y*	
Thermal oil flow or pressure	–	Low	a	*Y*	
Thermal oil outlet temperature	–	High	a	*Y*	
Combustion air pressure or forced ventilation	–	Low or shutoff	a	*Y*	
Fuel oil pressure	—	Excessively low	c	*Y*	
Fuel oil temperature or viscosity	—	Low and high	—	*Y*	Only for heavy oil
Uptake temperature	–	High	a	*Y*	
Burner flame and ignition	–	Extinguished / ignition	a	*Y*	Each burner is to be monitored

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
		failure			
(2) Exhaust-fired					
Thermal oil expansion tank level	–	Low	a	*Y*	
Thermal oil flow or pressure	–	Low	a	*Y*	
Thermal oil outlet temperature	–	High	a	*Y*	
Exhaust temperature	–	High	–	*Y*	
18 Computer systems					
Computers under operating status	–	Failure	c	*R*	
Computer systems	–	Failure	–	*R*	Including ineffectiveness of local area network control, overload of local area network, running stop due to overflow, etc.
Electrical power of computer systems	Voltage	Failure	–	*Y*	Indication of voltage may be replaced by indicating lamp
19 Oil purifier▲					
Purifier oil outlet pressure	Pressure	Low	–	*Y*	
Purifier oil inlet temperature	–	High	–	*Y*	
20 Sludge tank					
Level of sludge tank	–	High	–	*Y*	
21 Bilge					
Bilge level	–	High	–	*S*	See 3.9.2.1 of this Chapter
Bilge pumps	Indication for operation time	Too long or more frequently	–	*Y*	For automatically controlled bilge pumps only, see 3.9.2.4 of this Chapter
22 Incinerator▲ (only for unattended operation during incinerating)					
Fuel oil viscosity or temperature	–	Low or high	–	*Y*	Only for heavy oil
Fuel oil pressure	–	Low	–	*Y*	
Combustion air pressure	–	Low	a	*Y*	
Burner flame and ignition	–	Extinguished / ignition failure	a	*Y*	
Furnace temperature	–	High	a	*Y*	
Exhaust gas temperature	–	High	–	*Y*	
23 Diesel engines driving propulsion generators					
Fuel oil inlet pressure	Pressure	Low	c	*R*	Fitted after filter
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
High pressure fuel pipes	–	Leakage	–	*Y*	
Level of fuel oil in daily service tank	–	Low	–	*Y*	
Common rail fuel oil pressure	–	Low	–	*Y*	
Common rail servo oil pressure	–	Low	–	*Y*	
Lub-oil inlet pressure	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil filter differential pressure	Pressure	Great	–	*Y*	
Lub-oil inlet temperature	–	High	–	*Y*	
Speed of turbocharger	Speed	High	–	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	*S*	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
					initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator. Each apparatus	–	Small	–	*Y*	Required if necessary for safe operation of the engines
Pressure of cooling seawater	Pressure	Low	c	*R*	
Cylinder cooling water pressure or flow	Pressure or flow	Low	c	*R*	
Cylinder cooling water outlet temperature	Temp.	High	–	*Y*	
Level of cylinder cooling water in expansion tank	–	Low	–	*Y*	
Starting air pressure	Pressure	Low	–	*S*	
Control air pressure	Pressure	Low	–	*S*	
Exhaust gas temp. after each cylinder	Temp.	High	–	*Y*	For diesel engines having a power of more than 500 kW per cylinder only
Speed	–	Overspeed	a	G_a	See 9.7.10.3 of Pt.3
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
24 Gas turbines driving propulsion generators					
Fuel oil pressure or flow	Pressure or flow	Low	c	*R*	
Fuel oil temperature or viscosity	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature to gas turbine and gearing	Temp.	High	–	*Y*	
Turbine main bearing temperature	Temp.	High	–	*Y*	
Lub-oil filter differential pressure	–	Great	–	*Y*	
Level in lub-oil circulating tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Coolant pressure or flow	–	Low	–	*Y*	
Coolant temperature	Temp.	High	–	*Y*	
Level in fuel oil tank for ignition and starting	–	Low	–	*S*	When it is replenished automatically, high and low level alarms are to be fitted
Gas turbine ignition	–	Failure	a	G_a	
Combustion chamber flame	–	Extinguished	a	G_a	
Exhaust gas temperature	Temp.	High	a	G_a	
Gas turbine vibration	–	Excessive	a	G_a	
Axial displacement of turbine rotor	–	Great	a	G_a	Automatic shutdown not required if fitted with roller bearings
Gas turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
25 Low sulphur distillate fuels					

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Temperature or viscosity of fuel oil	Temperature or viscosity	High or low	–	*Y*	
Temperature of fuel oil	Temperature	Low	–	*Y*	When a refrigerating system for low sulphur distillate fuels is provided
Level in cooling water expansion tank (if provided) of the fuel oil cooling system	–	Low	–	*Y*	
26 Miscellaneous					
Overriding function	–	When overriding is initiated	–	*S*	
Controlled environmental conditions	–	Abnormal	–	*Y*	Where controlled environment is required for equipment, this requirement is to be complied with
Automatic systems	–	Failure	–	*Y*	Including electric power fault

CHAPTER 4 REQUIREMENTS FOR MACHINERY NOTATIONS OF CONSTANTLY ATTENDED MACHINERY SPACES

Section 1 GENERAL PROVISIONS

4.1.1 Application

4.1.1.1 This Chapter applies to ships with machinery spaces (including the CCS) constantly attended by watch-keepers, and intended to be assigned machinery notations MCC and/or BRC.

4.1.1.2 In addition to this Chapter, ships intended to be assigned the above-mentioned machinery notations are to comply with the applicable requirements of Chapters 1 and 2 of this PART.

Section 2 REQUIREMENTS FOR AUTOMATION OF SHIPS WITH CLASS NOTATION MCC

4.2.1 Provision of control stations (rooms)

4.2.1.1 Ships with the class notation MCC are to be provided with the CCS and the LCS. When the machinery and electrical equipment are in normal operation, the CCS is to be constantly attended by watch-keepers.

4.2.2 Functions of the CCS

4.2.2.1 The control and monitoring functions of the CCS is to be in compliance with the following requirements:

(1) The starting, speed regulating, reversing (including shaft reversing) and stopping as well as blade angle (or pitches) of the main propulsion machinery are to be capable of being remotely controlled or automatically, sequentially controlled from the CCS. When necessary, the control is to be capable of being changed over to other control stations (rooms) at any time and the changeover is to comply with the relevant requirements of 2.5.2 in this PART. In addition, the other machinery and electrical equipment mentioned in 3.1.1.4 of this PART are to be controlled and monitored automatically.

(2) The design and arrangement of centralized control station of engine room are to comply with the following requirements:

① in principle, the remote control from the CCS to main propulsion machinery is to be performed by a single control device for each independent propeller, with automatic performance of all associated services including, where necessary, means of preventing overload and prolonged running in critical speed ranges of the propelling machinery;

② the control system of the CCS is to be independent from the other communication system, however, one control lever for both systems may be accepted;

③ operations following any setting of the CCS including reversing from the maximum ahead service speed in case of emergency are to take place in an automatic sequence and within time intervals acceptable to the machinery;

④ remote starting of the propulsion machinery in the CCS is to be automatically inhibited if conditions exist which may hazard the machinery, e.g., shaft turning gear engaged, drop of lubricating oil pressure;

⑤ the design of the control system in the CCS is to be such that in case of its failure an alarm is given. In this case, the speed and direction of the propeller are to be maintained until local control is in operation, unless this is considered impracticable. In particular, lack of power (electric, pneumatic, hydraulic) or changeover of control is not to lead to major and sudden change in propulsion power or propulsion direction.

(3) Instruments and display units are to be provided at the CCS to indicate the essential parameters for ensuring the safe and reliable operation of the machinery and electrical equipment. The items to be displayed are given in column 2 of Table 4.2.6.1 of this Chapter.

(4) All faults, including several faults occurred at the same time in the machinery and electrical equipment and in the control and monitoring systems are to be capable of being alarmed at the CCS. The items to be alarmed are given in column 3 of Table 4.2.6.1 of this Chapter.

(5) Audible alarms at the CCS are to be capable of being silenced only after being acknowledged at the station.
(6) The emergency button for stopping the main propulsion machinery and the emergency button for cutting off oil supply to boilers are to be provided at the CCS and independent of the control system, but their actuating units may not be independent, and are to be so arranged as to preclude inadvertent touching.
(7) Where overriding function is provided for the main engine, such function is also to be provided at the CCS, and is to be so arranged as to preclude inadvertent touching.
4.2.2.2 The functions of automatic and remote control of all the machinery and electrical equipment specified in 3.1.1.4 of this PART are to be, in general, in compliance with the requirements of Sections 2, 3, 5 and 6 of Chapter 3 of this PART. However, the intervention of some control processes by the attendant in the CCS is permitted, provided that the attendant is competent to perform such control, such as the employment of remote control to substitute some items in the automatic control.
4.2.2.3 For the safety system, Mode a protective action is to be carried out automatically, Modes b and c protective actions may be carried out automatically or by manual operation in the CCS.

4.2.3 Functions of the local control station (LCS)
4.2.3.1 The LCS is to comply with the requirements of 2.5.1.5 of this PART.

4.2.4 Fire precautions
4.2.4.1 The fire precautions are in general to comply with the requirements for fire detection and fire alarm systems in 3.9.1.3 of this PART (the areas of an engine room which can be seen from the CCS may be exempted from the required sensors) and the requirements in 3.9.1.2 (except (4)) of this PART.

4.2.5 Protection against flooding
4.2.5.1 A bilge high level alarm system is to be provided.
4.2.5.2 The overboard discharge of bilge is to comply with the relevant requirements for pollution prevention.

4.2.6 Table of automatic control and monitoring items
4.2.6.1 The automatic control and monitoring items (if fitted) for all ships with the class notation MCC are to comply with Table 4.2.6.1.
4.2.6.2 The designations used in Table 4.2.6.1 of this Section are defined as follows:
−: not required;
*: only required for trunk piston diesel engines;
a: Mode a protective action, such as emergency shutdown of the engine, fuel oil cutoff of boiler and cutoff of electric power supply, etc.;
b: Mode b protective action, such as reducing the speed of rotation or the output of machinery;
c: Mode c protective action, such as starting and putting into operation of standby pump or standby unit.
4.2.6.3 Where “per cylinder” appears in the column “Remark” of Table 4.2.6.1 of this Section, it applies only to crosshead diesel engines, and for trunk piston diesel engines, “fitted on manifold outlet” may be used to replace “per cylinder”.
4.2.6.4 For the equipment marked with “▲” in Table 4.2.6.1 of this Section, if all of the single alarms and display items provided locally or in the vicinity of the engine are confirmed by CCS, the engine room central control station may be exempted from the single alarms and display items as required in Table 4.2.6.1. Only one group alarm for general faults and one fault display are to be provided in this case.

Automatic Control and Monitoring Items for Ships with Class Notation MCC

Table 4.2.6.1

Item	CCS		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
1 Main diesel engine **1.1 Fuel oil system**				
Fuel oil inlet pressure	Pressure	Low	c	Fitted after filter
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	Only for heavy oil
Leakage from high pressure fuel pipes	–	Leakage	–	

Item	CCS		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Level of fuel oil in daily service tanks	–	Low	–	High-level alarm also required, if no suitable overflow arrangement provided
Common rail fuel oil pressure	–	Low	–	
1.2 Lubricating oil system				
Lub-oil inlet pressure to main bearing & thrust bearing	Pressure	Low	c	
			b	Necessary for crosshead diesel engines
		Excessively low	a	
Lub-oil inlet pressure to crosshead bearing	Pressure	Low	c	Required if separate lub-oil system installed for crosshead diesel engines
			b	
		Excessively low	a	
Lub-oil inlet pressure to camshaft	Pressure	Low	c	
		Excessively low	a	
Lub-oil inlet temperature to camshaft	Temperature	High	–	
*Lub-oil filter differential pressure	Pressure	Great	–	
Lub-oil inlet temperature	Temperature	High	–	
Thrust bearing pad temperature or bearing temperature	Temperature	High	b	Necessary for crosshead diesel engines
		Excessively high	a	
Oil mist concentration in crankcase (or main, crank, crosshead bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	b	Applicable to low speed crosshead diesel engines specified in 9.7.6, Ch.9, Pt.3
*Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator. Each apparatus	–	Small	b	Required for trunk piston diesel engines if necessary for safe operation of the engines
Oil level in lub-oil circulating tank	–	Low	–	Necessary for crosshead diesel engines; individual level alarms required for the tanks if separate lub-oil systems installed (e.g. camshaft, rocker arms, etc.) for crosshead diesel engines
Common rail servo oil pressure	–	Low	–	
1.3 Turbocharger system				
Turbocharger lub-oil inlet pressure	Pressure	Low	–	Unless provided with a self-contained lubricating oil system integrated with the turbocharger
Turbocharger lub-oil outlet temp each bearing	Temp	High	–	Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design, alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination

Item	CCS		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
				with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative
Speed of turbocharger	Speed	High	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
1.4 Piston cooling system (Necessary for crosshead diesel engines)				
Piston coolant inlet pressure	Pressure	Low	c	The slowdown is not required if the coolant oil taken from the main cooling system of the engine
		Excessively low	b	
Piston coolant outlet flow	–	Low	b	Per cylinder; where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted
Piston coolant outlet temperature	Temp.	High	b	Per cylinder
Level of piston coolant in expansion tank	–	Low	–	
1.5 Seawater cooling system				
Pressure of cooling seawater	Pressure	Low	c	
1.6 Cylinder fresh cooling water system				
Cylinder water inlet pressure or flow	Pressure or flow	Low	c	Only cylinder coolant inlet pressure required for crosshead diesel engines
		Excessively low	b	
Cylinder water outlet temperature (from each cylinder) Cylinder water outlet temperature (general)	Temperature	High	b	Required for crosshead diesel engines where one common cooling space without individual stop valves is employed for all cylinder jackets. For trunk piston diesel engines, alarm and slowdown only for cylinder water outlet temperature (general) and two separate sensors required
Oily contamination of main engine cooling water system	–	Contaminated	–	Necessary for crosshead diesel engines; required where main engine cooling water is used in fuel and lubricating oil heat exchangers
Level of cylinder cooling water in expansion tank	–	Low	–	
1.7 Starting and control air systems				
Starting air pressure before main shut-off valve	Pressure	Low	–	
Control air pressure	Pressure	Low	–	
Safety air pressure	Pressure	Low	–	Necessary for crosshead diesel engines
1.8 Scavenge air system				
Scavenge air receiver pressure	Pressure	–	–	Necessary for crosshead diesel engines
Scavenge air box temperature (fire)	Temperature	High	b	
Scavenge air receiver water level	–	High	–	
*Scavenge air receiver temperature	Temperature	High	–	
1.9 Exhaust gas system				
Exhaust gas temp. after each cylinder	Temperature	High	b	For trunk piston diesel engines having a power of more than 500 kW per cylinder only
Exhaust gas temperature after each cylinder. Deviation from average	–	Great	–	
Exhaust gas temperature before each turbocharger	Temperature	High	–	Necessary for crosshead diesel engines

Item	CCS		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Exhaust gas temperature after each turbocharger	Temperature	High	–	
1.10 Fuel valve coolant				
Pressure of fuel valve coolant	Pressure	Low	c	The requirement is to be complied with if the crosshead diesel engine is fitted with a separate fuel valve cooling system
Temperature of fuel valve coolant	Temperature	High	–	
Level of fuel valve coolant in expansion tank	–	Low	–	
1.11 Engine speed/direction of rotation				
Speed	Speed	Overspeed	a	See 9.7.9.1 of Pt.3
Direction of rotation	Direction of rotation	Wrong way	–	Necessary for crosshead diesel engines
1.12 Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
2 Auxiliary diesel engines▲				
Lub-oil inlet pressure	Pressure	Low	–	
		Excessively low	a	
Fuel oil temperature or viscosity (before injection pumps)	Temperature or viscosity	Low or high	–	Only for heavy oil
Exhaust gas temp. after each cylinder	Temperature	High	–	For engine power > 500 kW per cylinder only
Lub-oil inlet temperature	–	High	–	
Temperature of cooling water or cooling air outlet	Temperature	High	–	
Pressure or flow of cooling water	–	Low	–	
Speed	–	Overspeed	a	See 9.7.10.3 of Pt.3
Starting air pressure	Pressure	Low	–	
Fuel oil leakage from pressure pipes	–	Leakage	–	
Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Level in fuel oil daily service tank	–	Low	–	
Level in cooling water expansion tank	–	Low	–	If not connected to main system
Common rail fuel oil pressure	–	Low	–	
Common rail servo oil pressure	–	Low	–	
Speed of turbocharger	Speed	High	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
3 Main gas turbines				
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	c	
		Excessively low	a	
Lub-oil inlet temperature to gas turbine and gearing	Temperature	High	–	

Item	CCS		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Lub-oil filter differential pressure	–	Great	c	
Oil level in lub-oil circulating tank	–	Low	–	For gravity and circulating oil tanks
Turbine main bearing temperature	Temperature	High	–	
Coolant pressure or flow	–	Low	–	
Coolant temperature	Temperature	High	–	
Fuel oil temperature or viscosity	Temperature or viscosity	Low or high	–	Only for heavy oil
Fuel oil pressure or flow	Pressure or flow	Low	c	
Level in fuel oil daily service tank	–	Low	–	When it is replenished automatically, high and low level alarms are to be fitted
Gas inlet or outlet temperature of turbine	Temperature	High	–	
		Excessively high	a	
Deviation of exhaust gas temperature from average	–	High	–	
Gas turbine combustion chamber flame and ignition	–	Failure	a	
Gas turbine vibration	–	High	–	
		Excessively high	a	
Axial displacement of turbine rotor	–	Great	–	
Turbine speed	–	Overspeed	a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
4 Auxiliary steam turbines▲				
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	–	
		Excessively low	a	
Exhaust gas temperature	Temperature	High	a	
Combustion chamber flame	–	Extinguished	a	
Gas turbine vibration	–	Excessive	a	
Gas turbine speed	–	Overspeed	a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
5 Main steam turbines				
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	c	
		Excessively low	a	
Lub-oil inlet temperature for turbine and gearing	Temperature	High	–	
Lub-oil filter differential pressure	–	Great	–	
Level of lub-oil tank	–	Low	–	For gravity and circulating oil tanks
Bearing temperature or bearing lub-oil outlet temperature of turbine and gearing	Temperature	High	–	
Thrust bearing temperature or lub-oil outlet temperature	–	High	–	
Astern turbine exhaust steam temperature	Temperature	High	–	

Item	CCS		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Gland steam pressure	Pressure	High and low	–	
Circulating seawater pressure or flow	Pressure or flow	Low	c	
Condenser vacuum	Vacuum	Low	b	
Condenser condensate level	–	High and low	b	
Condensate pump	–	Stop/failure	–	
Condensate salinity	–	High	–	
Steam turbine vibration	–	Excessive	b	
Axial displacement of turbine rotor	–	Excessive	a	
Turbine speed	–	Overspeed	a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
6 Auxiliary steam turbines▲				
Lub-oil inlet temperature for turbine and gearing	–	High	–	
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	–	
		Excessively low	a	
Condenser vacuum	–	Low	a	
Axial displacement of turbine rotor	–	Excessive	a	
Turbine speed	–	Overspeed	a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
7 Main steam boilers				
Steam drum or superheater outlet pressure	Pressure	High and low	–	
Superheated steam outlet temperature	Temperature	High	–	
De-superheated steam outlet temperature	Temperature	High	–	
Boiler feed water level	Level	High	–	At least 3 sensors fitted. See 3.3.1.2(1)② and 3.3.1.3(1)② of this PART
		Low	c	
		Excessively low	a	
Temperature or viscosity of oil fuel to burners	Temperature or viscosity	Low and high	–	Only for heavy oil. Protective action with cutoff of boiler fuel oil supply in case of excessively high temperature or excessively low viscosity may be carried out by cutoff of fuel oil heating supply
		Excessively low and high	a	
Fuel oil pressure to burners	Pressure	Low	c	See 3.3.1.3(3) of this PART
Forced draft pressure	Pressure	Loss	a	2 sensors fitted
Burner flame and ignition	–	Extinguished/ ignition failure	a	Each burner is to be monitored
Fuel oil atomizing steam (air) pressure	Pressure	Low	–	
Feed pump discharge pressure or flow	Pressure or flow	Low	c	See 3.3.1.3(4) of this PART
Feed water forced circulation flow	Flow	Low	a	Required for forced circulating boilers only
Level of feed water tank	–	Low	–	Required for daily feed water tanks only

Item	CCS		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Feed water salinity	–	High	–	
Water level of deaerator	–	High and low	–	
Boiler air supply casing and exhaust pipe (smoke uptake)	–	Fire	–	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
8 Auxiliary steam boilers▲				
Steam drum or superheater outlet pressure	Pressure	Low	–	
Boiler feed water level	–	High	–	See 3.3.1.2(1)② and 3.3.1.3(1)② of this PART
		Low	c	
		Excessively low	a	
Temperature or viscosity of oil fuel to burners	–	Low and high	–	Only for heavy oil. Protective action with cutoff of boiler fuel oil supply in case of excessively high temperature or excessively low viscosity may be carried out by cutoff of fuel oil heating supply
		Excessively low and high	a	
Fuel oil pressure to burners	Pressure	Low	c	See 3.3.1.3(3) of this PART
Forced draft pressure	–	Loss	a	
Burner flame and ignition	–	Extinguished/ ignition failure	a	
Feed water salinity	–	High	–	Only applicable to auxiliary steam boiler for driving turbine-generator set
Boiler air supply casing and exhaust pipe (smoke uptake)	–	Fire	–	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
9 Controllable pitch propeller				
Pitch or blade angle of controllable pitch propeller	Pitch or blade angle	–	–	See 2.8.1.11 of this PART
Propeller shaft speed	Speed	–	–	See 2.8.1.11 of this PART
Hydraulic system pressure for controlling propeller pitch	Pressure	Low	c	
Hydraulic oil tank level	–	Low	–	
Hydraulic oil temp. (if oil cooler is fitted)	–	High	–	
Electric power supply for electrohydraulic control system	Voltage	Loss	–	
10 Vibration damper				
Oil inlet pressure or amplitude for vibration damper	Pressure or amplitude	Low or great	–	See 3.2.2.5 of this PART and 12.1.4.3 of Pt.3
11 Gearbox (for main propulsion machinery)				
Lub-oil inlet pressure of gearbox	Pressure	Low	c	
		Excessively low	a	
Lub-oil inlet temperature of gearbox	Temperature	High	–	

Item	CCS		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
Gear oil pressure	Pressure	Low	–	
12 Clutches				
Clutch position	Position	–	–	
Power supply for control of clutches (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	See 2.8.1.11 of this PART
13 Stern tube bearing				
Oil lubricated stern tube bearing temp.	–	High	–	
Level of stern tube lubricating oil tank	–	Low	–	
14 Air compressors▲				
Air compressor lubricating oil pressure	–	Low	a	Except for splash lubrication
15 Thermal oil heaters▲				
(1) Oil-fired				
Thermal oil expansion tank level	–	Low	a	
Thermal oil flow or pressure	–	Low	a	
Thermal oil outlet temperature	–	High	a	
Combustion air pressure or forced ventilation	–	Low or shutoff	a	
Fuel oil pressure	–	Excessively low	c	
Fuel oil temperature or viscosity	–	Low or great	–	Only for heavy oil
Uptake temperature	–	High	a	
Burner flame and ignition	–	Extinguished/ ignition failure	a	Each burner is to be monitored
(2) Exhaust-fired				
Thermal oil expansion tank level	–	Low	a	
Thermal oil flow or pressure	–	Low	a	
Thermal oil outlet temperature	–	High	a	
Exhaust temperature	–	High	–	
16 Oil purifier▲				
Purifier oil outlet pressure	Pressure	Low	–	
Purifier oil inlet temperature	–	High	–	
17 Sludge tank				
Level of sludge tank	–	High	–	
18 Bilge				
Bilge level	–	High	–	See 3.9.2.1 of this PART
Bilge pumps	Indication for operation time	Too long or more frequently	–	For automatically controlled bilge pumps only, see 3.9.2.4 of this PART
19 Diesel engines driving propulsion generators				
Fuel oil inlet pressure	Pressure	Low	–	Fitted after filter
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	Only for heavy oil
High pressure fuel pipes	–	Leakage	–	
Level of fuel oil in daily service tank	–	Low	–	
Common rail fuel oil pressure	–	Low	–	
Common rail servo oil pressure	–	Low	–	
Lub-oil inlet pressure	Pressure	Low	–	
		Excessively low	a	
Lub-oil filter differential pressure	Pressure	Great	–	
Lub-oil inlet temperature	–	High	–	
Speed of turbocharger	Speed	High	–	Applicable to Class B and C

Item	CCS		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
				turbochargers (refer to 9.6.2, Ch.9, Pt.3)
Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator. Each apparatus	–	Small	–	Required if necessary for safe operation of the engines
Pressure of cooling seawater	Pressure	Low	–	
Cylinder cooling water pressure or flow	Pressure or flow	Low	–	
Cylinder cooling water outlet temperature	Temp.	High	–	
Level of cylinder cooling water in expansion tank	–	Low	–	
Starting air pressure	Pressure	Low	–	
Control air pressure	Pressure	Low	–	
Exhaust gas temp. after each cylinder	Temp.	High	–	For diesel engines having a power of more than 500 kW per cylinder only
Speed	–	Overspeed	a	See 9.7.10.3 of Pt.3
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	Indication of voltage may be replaced by indicating lamp
20 Gas turbines driving propulsion generators				
Fuel oil pressure or flow	Pressure or flow	Low	–	
Fuel oil temperature or viscosity	Temp. or viscosity	Low or high	–	Only for heavy oil
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	–	
		Excessively low	a	
Lub-oil inlet temperature to gas turbine and gearing	Temp.	High	–	
Turbine main bearing temperature	Temp.	High	–	
Lub-oil filter differential pressure	–	Great	–	
Level in lub-oil circulating tank	–	Low	–	For gravity and circulating oil tanks
Coolant pressure or flow	–	Low	–	
Coolant temperature	Temp.	High	–	
Level in fuel oil tank for ignition and starting	–	Low	–	When it is replenished automatically, high and low level alarms are to be fitted
Gas turbine ignition	–	Failure	a	
Combustion chamber flame	–	Extinguished	a	
Exhaust gas temperature	Temp.	High	a	
Gas turbine vibration	–	Excessive	a	
Axial displacement of turbine rotor	–	Great	a	Automatic shutdown not required if fitted with roller bearings
Gas turbine speed	–	Overspeed	a	
Power supply for control-safety-alarm systems (electrical, pneumatic and	Electrical, pneumatic	Loss	–	Indication of voltage may be replaced by indicating lamp

Item	CCS		Mode of protective control action	Remark
	Display	Limit alarm		
1	2	3	4	5
hydraulic pressure)	and Hydraulic pressure			
21 Low sulphur distillate fuels				
Temperature or viscosity of fuel oil	Temperature or viscosity	High or low	–	
Temperature of fuel oil	Temperature	Low	–	When a refrigerating system for low sulphur distillate fuels is provided
Level in cooling water expansion tank (if provided) of the fuel oil cooling system	–	Low	–	
22 Miscellaneous				
Overriding function	–	When overriding is initiated	–	
Automatic systems	–	Failure	–	Including electric power fault

Section 3 REQUIREMENTS FOR AUTOMATION OF SHIPS WITH CLASS NOTATION BRC

4.3.1 General requirements

4.3.1.1 Ships with the class notation BRC are to be provided with the remote control of the main propulsion machinery and other related installations from the BCS. The machinery spaces are to be constantly attended by watch-keepers to look after the machinery and electrical equipment as described in 3.1.1.4 of this PART.

4.3.2 Functions of the BCS

4.3.2.1 Under all sailing conditions including maneuvering, the speed and direction of thrust of main propulsion machinery as well as other installations (if fitted) are to be effectively controlled from the BCS. The design and arrangement of BCS are to comply with the requirements of Section 8, Chapter 2 of this PART.

4.3.2.2 Where necessary, the control of propulsion machinery from the BCS is to be capable of being changed over to the local control station at any time and the changeover of the control is to comply with the relevant requirements of 2.5.2 of this PART.

4.3.2.3 The automatic and remote control of main engines, clutches, controllable pitch propeller, etc. is to be, in general, in compliance with the relevant requirements of Section 2, Chapter 3 of this PART.

4.3.2.4 The Mode a protective action of main engines is to be capable of being carried out automatically, the other actions (Mode b and Mode c) may be carried out by manual operation.

4.3.2.5 Alarms at the BCS:

(1) For the items to be alarmed at the BCS and the mode of alarms, see column 5 of Table 4.3.4.1 of this Section. Alarms indicating the faults in the machinery and electrical equipment as well as the automated control and monitoring systems are, in general, to be relayed to the BCS in the following modes: group alarms for the protective actions of safety systems; separate alarms; group alarms for serious faults and group alarms for general faults.

(2) The audible alarms at the BCS are permitted to be silenced after acknowledgment, but the visual alarms are to be extinguished only after the rectification of faults, and furthermore, the visual signals are to be capable of being clearly distinguishable before and after acknowledgment.

4.3.2.6 If the main engine is remotely started from the bridge control station, the indicator is to be fitted on the bridge control station for the starting air pressure or voltage of starting storage batteries of main engines.

4.3.3 Functions of the LCS

4.3.3.1 The LCS is to comply with the requirements in 2.5.1.5 of this PART.

4.3.3.2 The items to be displayed and alarmed, as required in columns 2 and 3 of Table 4.3.4.1 of this Section for the propulsion machinery (such as main engines, clutches, controllable pitch propeller, etc.), are to be provided at the LCS.

4.3.4 Table of automatic control and monitoring items

4.3.4.1 The automatic control and monitoring items (if fitted) for all ships with the class notation BRC are to comply with Table 4.3.4.1.

4.3.4.2 The designations used in Table 4.3.4.1 of this Section are defined as follows:

−: not required;
*: only required for trunk piston diesel engines;
S: single alarm;
G_a: group alarm activated by Mode a protective action;
G_b: group alarm activated by Mode b protective action;
R: group alarm for serious faults;
Y: group alarm for general faults.

4.3.4.3 Where "per cylinder" appears in the column "Remark" of Table 4.3.4.1 of this Section, it applies only to crosshead diesel engines, and for trunk piston diesel engines, "fitted on manifold outlet" may be used to replace "per cylinder".

Automatic Control and Monitoring Items for Ships with Class Notation BRC

Table 4.3.4.1

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
1 Main diesel engine **1.1 Fuel oil system**					
Fuel oil inlet pressure	Pressure	Low	c	*Y*	Fitted after filter
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Leakage from high pressure fuel pipes	–	Leakage	–	*Y*	
Level of fuel oil in daily service tanks	–	Low	–	*Y*	High-level alarm also required, if no suitable overflow arrangement provided
Common rail fuel oil pressure	–	Low	–	*Y*	
1.2 Lubricating oil system					
Lub-oil inlet pressure to main bearing & thrust bearing	Pressure	Low	c	*Y*	
			b	G_b	Necessary for crosshead diesel engines
		Excessively low	a	G_a	
Lub-oil inlet pressure to crosshead bearing	Pressure	Low	c	*Y*	Required if separate lub-oil system installed for crosshead diesel engines
			b	G_b	
		Excessively low	a	G_a	
Lub-oil inlet pressure to camshaft	Pressure	Low	c	*Y*	
		Excessively low	a	G_a	
Lub-oil inlet temperature to camshaft	Temp.	High	–	*Y*	
*Lub-oil filter differential pressure	Pressure	Great	–	*Y*	
Lub-oil inlet temperature	Temp.	High	–	*Y*	
Thrust bearing pad temperature or bearing temperature	Temp.	High	b	G_b	Necessary for crosshead diesel engines
		Excessively high	a	G_a	
Oil mist concentration in crankcase (or main, crank, crosshead bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	b	G_b	Applicable to low speed crosshead diesel engines specified in 9.7.6, Ch.9, Pt.3

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
*Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature of the above bearing or other equivalent devices)	–	High	a	G_a	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator. Each apparatus	–	Small	b	G_b	Required for trunk piston diesel engines if necessary for safe operation of the engines
Oil level in lub-oil circulating tank	–	Low	–	*Y*	Necessary for crosshead diesel engines; individual level alarms required for the tanks if separate lub-oil systems installed (e.g. camshaft, rocker arms, etc.) for crosshead diesel engines
Common rail servo oil pressure	–	Low	–	*Y*	
1.3 Turbocharger system					
Turbocharger lub-oil inlet pressure	Pressure	Low	–	*Y*	Unless provided with a self-contained lubricating oil system integrated with the turbocharger
Turbocharger lub-oil outlet temp each bearing	Temp.	High	–	*Y*	Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative
Speed of turbocharger	Speed	High	–	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
1.4 Piston cooling system (Necessary for crosshead diesel engines)					
Piston coolant inlet pressure	Pressure	Low	c	*Y*	The slowdown is not required if the coolant oil taken from the main cooling system of the engine
		Excessively low	b	G_b	
Piston coolant outlet flow	–	Low	b	G_b	Per cylinder; where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted
Piston coolant outlet temperature	Temp.	High	b	G_b	Per cylinder
Level of piston coolant in expansion tank	–	Low	–	*Y*	
1.5 Seawater cooling system					
Pressure of cooling seawater	Pressure	Low	c	*Y*	
1.6 Cylinder fresh cooling water system					
Cylinder water inlet pressure or flow	Pressure or flow	Low	c	*Y*	Only cylinder coolant inlet pressure required for crosshead diesel engines
		Excessively low	b	G_b	

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Cylinder water outlet temperature (from each cylinder) Cylinder water outlet temperature (general)	Temp.	High	b	G_b	Required for crosshead diesel engines where one common cooling space without individual stop valves is employed for all cylinder jackets. For trunk piston diesel engines, alarm and slowdown only for cylinder water outlet temperature (general) and two separate sensors required
Oily contamination of main engine cooling water system	–	Contaminated	–	–	Necessary for crosshead diesel engines; required where main engine cooling water is used in fuel and lubricating oil heat exchangers
Level of cylinder cooling water in expansion tank	–	Low	–	*Y*	
1.7 Starting and control air systems					
Starting air pressure before main shut-off valve	Pressure	Low	–	*Y*	
Control air pressure	Pressure	Low	–	*Y*	
Safety air pressure	Pressure	Low	–	*Y*	Necessary for crosshead diesel engines
1.8 Scavenge air system					
Scavenge air receiver pressure	Pressure	–	–	–	Necessary for crosshead diesel engines
Scavenge air box temperature (fire)	Temp.	High	b	G_b	
Scavenge air receiver water level	–	High	–	*Y*	
*Scavenge air receiver temperature	Temp.	High	–	*Y*	
1.9 Exhaust gas system					
Exhaust gas temp. after each cylinder	Temp.	High	b	G_b	For trunk piston diesel engines having a power of more than 500 kW per cylinder only
Exhaust gas temperature after each cylinder. Deviation from average	–	Great	–	*Y*	
Exhaust gas temperature before each turbocharger	Temp.	High	–	*Y*	Necessary for crosshead diesel engines
Exhaust gas temperature after each turbocharger	Temp.	High	–	*Y*	
1.10 Fuel valve coolant					
Pressure of fuel valve coolant	Pressure	Low	c	*Y*	The requirement is to be complied with if the crosshead diesel engine is fitted with a separate fuel valve cooling system
Temperature of fuel valve coolant	Temp.	High	–	*Y*	
Level of fuel valve coolant in expansion tank	–	Low	–	*Y*	
1.11 Engine speed/direction of rotation					
Speed	Speed	Overspeed	a	G_a	See 9.7.9.1 of Pt.3
Direction of rotation	Direction of rotation	Wrong way	–	*Y*	Necessary for crosshead diesel engines
1.12 Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
2 Main gas turbines					
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature to gas turbine and gearing	Temp.	High	–	*Y*	

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Lub-oil filter differential pressure	–	Great	c	*Y*	
Oil level in lub-oil circulating tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Turbine main bearing temperature	Temp.	High	–	*Y*	
Coolant pressure or flow	–	Low	–	*Y*	
Coolant temperature	Temp.	High	–	*Y*	
Fuel oil temperature or viscosity	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Fuel oil pressure or flow	Pressure or flow	Low	c	*Y*	
Level in fuel oil daily service tank	–	Low	–	*Y*	When it is replenished automatically, high and low level alarms are to be fitted
Gas inlet or outlet temperature of turbine	Temp.	High	–	*Y*	
		Excessively high	a	G_a	
Deviation of exhaust gas temperature from average	–	High	–	*Y*	
Gas turbine combustion chamber flame and ignition	–	Failure	a	G_a	
Gas turbine vibration	–	High	–	*Y*	
		Excessively high	a	G_a	
Axial displacement of turbine rotor	–	Great	–	*R*	
Turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
3 Main steam turbines					
Lub-oil inlet pressure for turbine and gearing	Pressure	Low	c	*R*	
		Excessively low	a	G_a	
Lub-oil inlet temperature for turbine and gearing	Temp.	High	–	*Y*	
Lub-oil filter differential pressure	–	Great	–	*Y*	
Level of lub-oil tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Bearing temperature or bearing lub-oil outlet temperature of turbine and gearing	Temp.	High	–	*Y*	
Thrust bearing temperature or lub-oil outlet temperature	–	High	–	*Y*	
Astern turbine exhaust steam temperature	Temp.	High	–	*Y*	
Gland steam pressure	Pressure	High and low	–	*Y*	
Circulating seawater pressure or flow	Pressure or flow	Low	c	*Y*	
Condenser vacuum	Vacuum	Low	b	G_b	
Condenser condensate level	–	High and low	b	G_b	
Condensate pump	–	Stop/ failure	–	*Y*	
Condensate salinity	–	High	–	*Y*	
Steam turbine vibration	–	Excessive	b	G_b	
Axial displacement of turbine rotor	–	Excessive	a	G_a	

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
4 Controllable pitch propeller					
Blade angle (or pitch) of controllable pitch propeller	Blade angle or pitch	–	–	–	See 2.8.1.11 of this PART
Propeller shaft speed	Speed	–	–	–	See 2.8.1.11 of this PART
Hydraulic system pressure for controlling propeller pitch	Pressure	Low	c	*Y*	
Hydraulic oil tank level	–	Low	–	*Y*	
Hydraulic oil temp. (if oil cooler is fitted)	–	High	–	*Y*	
Electric power supply for electrohydraulic control system	Voltage	Loss	–	*Y*	
5 Vibration damper					
Oil inlet pressure or amplitude for vibration damper	Pressure or amplitude	Low or great	–	*Y*	See 3.2.2.5 of this PART and 12.1.4.3 of Pt.3
6 Gearbox (for main propulsion machinery)					
Lub-oil inlet pressure of gearbox	Pressure	Low	c	*Y*	
		Excessively low	a	G_a	
Lub-oil inlet temperature of gearbox	Temp.	High	–	*Y*	
Gear oil pressure	Pressure	Low	–	*Y*	
7 Clutches					
Clutch position	Position	–	–	–	
Power supply for control of clutches (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	See 2.8.1.11 of this PART
8 Stern tube bearing					
Oil lubricated stern tube bearing temp.	–	High	–	*Y*	
Level of stern tube lubricating oil tank	–	Low	–	*Y*	
9 Diesel engines driving propulsion generators					
Fuel oil inlet pressure	Pressure	Low	–	*Y*	Fitted after filter
Fuel oil temperature or viscosity (before injection pumps)	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
High pressure fuel pipes	–	Leakage	–	*Y*	
Level of fuel oil in daily service tank	–	Low	–	*Y*	
Common rail fuel oil pressure	–	Low	–		
Common rail servo oil pressure	–	Low	–		
Lub-oil inlet pressure	Pressure	Low	–	*Y*	
		Excessively low	a	G_a	
Lub-oil filter differential pressure	Pressure	Great	–	*Y*	
Lub-oil inlet temperature	–	High	–	*Y*	
Speed of turbocharger	Speed	High	–	–	Applicable to Class B and C turbochargers (refer to 9.6.2, Ch.9, Pt.3)
Oil mist concentration in crankcase (or main, crank bearing temperature or lubricating oil outlet temperature	–	High	a	G_a	Applicable to diesel engines specified in 9.7.6, Ch.9, Pt.3; one oil mist detector for each

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
of the above bearing or other equivalent devices)					engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown systems
Flow rate of cylinder lubricator. Each apparatus	–	Small	–	*Y*	Required if necessary for safe operation of the engines
Pressure of cooling seawater	Pressure	Low	–	*Y*	
Cylinder cooling water pressure or flow	Pressure or flow	Low	–	*Y*	
Cylinder cooling water outlet temperature	Temp.	High	–	*Y*	
Level of cylinder cooling water in expansion tank	–	Low	–	*Y*	
Starting air pressure	Pressure	Low	–	*Y*	
Control air pressure	Pressure	Low	–	*Y*	
Exhaust gas temp. after each cylinder	Temp.	High	–	*Y*	For diesel engines having a power of more than 500 kW per cylinder only
Speed	–	Overspeed	a	G_a	See 9.7.10.3 of Pt.3
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
10 Gas turbines driving propulsion generators					
Fuel oil pressure or flow	Pressure or flow	Low	–	*Y*	
Fuel oil temperature or viscosity	Temp. or viscosity	Low or high	–	*Y*	Only for heavy oil
Lub-oil inlet pressure to gas turbine and gearing	Pressure	Low	–	*Y*	
		Excessively low	a	G_a	
Lub-oil inlet temperature to gas turbine and gearing	Temp.	High	–	*Y*	
Turbine main bearing temperature	Temp.	High	–	*Y*	
Lub-oil filter differential pressure	–	Great	–	*Y*	
Level in lub-oil circulating tank	–	Low	–	*Y*	For gravity and circulating oil tanks
Coolant pressure or flow	–	Low	–	*Y*	
Coolant temperature	Temp.	High	–	*Y*	
Level in fuel oil tank for ignition and starting	–	Low	–	*Y*	When it is replenished automatically, high and low level alarms are to be fitted
Gas turbine ignition	–	Failure	a	G_a	
Combustion chamber flame	–	Extinguished	a	G_a	
Exhaust gas temperature	Temp.	High	a	G_a	
Gas turbine vibration	–	Excessive	a	G_a	
Axial displacement of turbine rotor	–	Great	a	G_a	Automatic shutdown not required if fitted with roller bearings
Gas turbine speed	–	Overspeed	a	G_a	
Power supply for control-safety-alarm systems (electrical, pneumatic and hydraulic pressure)	Electrical, pneumatic and hydraulic pressure	Loss	–	*Y*	Indication of voltage may be replaced by indicating lamp
11 Miscellaneous					

Item	LCS		Mode of protective control action	Mode of alarm at BCS	Remark
	Display	Limit alarm			
1	2	3	4	5	6
Overriding function	–	When overriding is initiated	–	*S*	
Automatic systems	–	Failure	–	*Y*	Including electric power fault

4.3.5 Requirements for automation of small ships with class notation BRC

4.3.5.1 For small ships of less than 500 gross tonnage with the class notation BRC, only group alarms activated by Mode a and Mode b protective actions as defined in Table 4.3.4.1 of this Section are to be provided in the BRC.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2025

PART EIGHT ADDITIONAL REQUIREMENTS

CONTENTS

CHAPTER 1 ADDITIONAL REQUIREMENTS FOR FIRE-FIGHTING SHIPS 8-1
Section 1 GENERAL PROVISIONS 8-1
Section 2 BASIC REQUIREMENTS 8-2
Section 3 PROTECTION AND FIRE-FIGHTING EQUIPMENT 8-3
CHAPTER 2 ADDITIONAL REQUIREMENTS FOR LIVESTOCK CARRIERS 8-6
Section 1 GENERAL PROVISIONS 8-6
Section 2 HULL STRUCTURE AND ARRANGEMENT 8-6
Section 3 STABILITY 8-14
Section 4 PROVISION OF LIVESTOCK SERVICES 8-15
Section 5 FIRE-FIGHTING APPLIANCES 8-18
Section 6 ELECTRICAL EQUIPMENT 8-19
CHAPTER 3 ADDITIONAL REQUIREMENTS FOR OIL RECOVERY SHIPS 8-21
Section 1 GENERAL PROVISIONS 8-21
Section 2 CONSTRUCTION AND FIRE SAFETY 8-22
Section 3 MACHINERY INSTALLATIONS 8-25
Section 4 ELECTRICAL INSTALLATIONS 8-26
Section 5 OPERATING MANUAL 8-27
Section 6 OIL RECOVERY SHIPS CARRYING RECOVERED OIL HAVING A FLASH POINT EXCEEDING 60℃ 8-28
CHAPTER 4 SHIP BRIDGE DESIGN AND EQUIPMENT 8-30
Section 1 GENERAL PROVISIONS 8-30
Section 2 BRIDGE LAYOUT 8-31
Section 3 WORKING ENVIRONMENT 8-34
Section 4 WORKSTATIONS 8-35
Section 5 EQUIPMENT AND SYSTEMS 8-36
Section 6 SUPPLEMENTARY REQUIREMENTS FOR THE NOTATION BDE-2 8-38
Section 7 INTEGRATED BRIDGE SYSTEM (IBS) 8-39
CHAPTER 5 ADDITIONAL REQUIREMENTS FOR FISHING VESSELS 8-41
Section 1 GENERAL PROVISIONS 8-41
Section 2 SURVEYS DURING CONSTRUCTION 8-42
Section 3 SURVEYS AFTER CONSTRUCTION 8-43
Section 4 INTACT STABILITY 8-43
Section 5 DAMAGE STABILITY 8-44
Section 6 LOAD LINE MARKS AND MARKING 8-45
Section 7 STRUCTURAL ARRANGEMENT 8-45
Section 8 FIRE SAFETY 8-49
CHAPTER 6 ADDITIONAL REQUIREMENTS FOR OPEN-TOP CONTAINER SHIPS 8-57
Section 1 OPEN-TOP CONTAINER SHIPS ENGAGED IN UNRESTRICTED SERVICE 8-57
CHAPTER 7 ADDITIONAL REQUIREMENTS FOR PUSHER TUG-BARGE COMBINATIONS 8-62
Section 1 GENERAL PROVISIONS 8-62
CHAPTER 8 ADDITIONAL REQUIREMENTS FOR PUBLIC AFFAIR SHIPS 8-63
Section 1 GENERAL PROVISIONS 8-63
CHAPTER 9 ADDITIONAL REQUIREMENTS FOR SHIPS HAVING INDEPENDENT ICEBREAKING CAPABILITY 8-64
Section 1 GENERAL PROVISIONS 8-64
Section 2 ENGINE OUTPUT 8-64

Section 3 HULL STRUCTURE 8-65
CHAPTER 10 ADDITIONAL REQUIREMENTS FOR PETROLEUM ASPHALT CARRIERS 8-67
Section 1 GENERAL PROVISIONS 8-67
Section 2 CONSTRUCTION AND ARRANGEMENT OF SHIP 8-68
Appendix 1 DIRECT CALCULATION OF STRUCTURAL STRENGTH OF ASPHALT CARRIERS FITTED WITH INDEPENDENT CARGO TANKS 8-77
CHAPTER 11 DYNAMIC POSITIONING SYSTEMS 8-81
Section 1 GENERAL PROVISIONS 8-81
Section 2 SYSTEM ARRANGEMENT 8-84
Section 3 THRUSTER SYSTEM 8-87
Section 4 POWER SYSTEM 8-88
Section 5 CONTROL SYSTEM AND MEASURING SYSTEM 8-90
CHAPTER 12 IN-WATER SURVEY ARRANGEMENTS OF SHIPS 8-94
Section 1 GENERAL PROVISIONS 8-94
Section 2 DOCUMENTATION TO BE SUBMITTED 8-94
Section 3 STRUCTURAL DESIGN PRINCIPLES 8-94
CHAPTER 13 ADDITIONAL REQUIREMENTS FOR POLAR CLASS SHIPS 8-96
Section 1 GENERAL REQUIREMENTS FOR POLAR CLASS SHIPS 8-96
Section 2 STRUCTURAL REQUIREMENTS 8-97
Section 3 MACHINERY INSTALLATIONS 8-112
CHAPTER 14 REDUNDANT PROPULSION SYSTEMS 8-142
Section 1 GENERAL PROVISIONS 8-142
Section 2 SYSTEM ARRANGEMENT AND DESIGN 8-144
CHAPTER 15 ADDITIONAL REQUIREMENTS FOR ELECTRICALLY PROPELLED SHIPS 8-146
Section 1 GENERAL PROVISIONS 8-146
Section 2 ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION INSTALLATIONS 8-146
Section 3 STRUCTURAL REQUIREMENTS FOR PODDED PROPULSION UNITS 8-153
CHAPTER 16 MEASUREMENT OF VIBRATION AND NOISE 8-155
Section 1 GENERAL PROVISIONS 8-155
Section 2 NOISE 8-155
Section 3 VIBRATION 8-155
Section 4 MEASUREMENTS AND REPORTS 8-155
CHAPTER 17 ADDITIONAL REQUIREMENTS FOR GEOTEXTILES LAYERS 8-157
Section 1 GENERAL PROVISIONS 8-157
Section 2 HULL STRUCTURE AND ARRANGEMENT 8-157
Section 3 EQUIPMENT 8-158
CHAPTER 18 ADDITIONAL REQUIREMENTS FOR HEAVY EQUIPMENT CARRIER 8-159
Section 1 GENERAL PROVISIONS 8-159
Section 2 OUTFITTINGS 8-159
Section 3 INTACT STABILITY 8-159
Section 4 SPECIAL REQUIREMENTS FOR EXTRA BALLAST OPERATION 8-159
Section 5 EXTRA BALLAST OPERATIONAL PROCEDURE MANUAL 8-161
CHAPTER 19 AC SHORE CONNECTION SYSTEMS 8-163
Section 1 GENERAL PROVISIONS 8-163
Section 2 SYSTEM DESIGN 8-165
Section 3 ELECTRICAL EQUIPMENT 8-166
Section 4 SURVEY AND TESTING 8-168

CHAPTER 20 ADDITIONAL REQUIREMENTS FOR ANCHOR HANDLING 8-169
Section 1 GENERAL PROVISIONS 8-169
Section 2 HULL STRUCTURE 8-169
Section 3 ANCHOR HANDLING EQUIPMENT AND SUPPORTING STRUCTURES 8-169
CHAPTER 21 HULL MONITORING SYSTEMS 8-171
Section 1 GENERAL PROVISIONS 8-171
Section 2 SYSTEM DESIGN 8-172
Section 3 DATA PROCESSING AND STORAGE 8-173
Section 4 DISPLAY AND MONITORING 8-176
Section 5 COMPONENT REQUIREMENTS 8-177
CHAPTER 22 ADDITIONAL REQUIREMENTS FOR ERGONOMIC CONTAINER LASHING 8-179
Section 1 GENERAL PROVISIONS 8-179
Section 2 SAFE ACCESS DESIGN 8-179
Section 3 LASHING SYSTEMS 8-184
Section 4 LIGHTING DESIGN 8-185
Section 5 SPECIALIZED CONTAINER SAFETY DESIGN 8-185
CHAPTER 23 ADDITIONAL REQUIREMENTS FOR SHIPS OPERATING IN LOW AIR TEMPERATURE ENVIRONMENTS 8-186
Section 1 GENERAL PROVISIONS 8-186
Section 2 MATERIALS AND WELDING 8-188
Section 3 SHIP ARRANGEMENTS 8-192
Section 4 STABILITY 8-193
Section 5 WATERTIGHT AND WEATHERTIGHT INTEGRITY 8-194
Section 6 MACHINERY INSTALLATIONS 8-194
Section 7 FIRE FIGHTING 8-199
Section 8 LIFE-SAVING APPLIANCES AND ARRANGEMENTS 8-200
Section 9 NAVIGATIONAL SAFETY 8-201
Section 10 SHIP TYPE SPECIFIC ADDITIONAL REQUIREMENTS 8-201
Section 11 ANTI-ICING AND DE-ICING MEASURES 8-205
Section 12 SURVEY REQUIREMENTS FOR ANTI-COLD CLIMATE NOTATIONS 8-209
CHAPTER 24 ADDITIONAL REQUIREMENTS FOR STAND-BY SHIPS AND RESCUE SHIPS 8-212
Section 1 GENERAL PROVISIONS 8-212
Section 2 CONSTRUCTION AND ARRANGEMENT 8-212
Section 3 ACCOMMODATION SPACES FOR SURVIVORS 8-213
Section 4 RESCUE AND SAFETY EQUIPMENT 8-213
Section 5 NAVIGATION AND COMMUNICATION EQUIPMENT 8-215
CHAPTER 25 ADDITIONAL REQUIREMENTS FOR DIVING SUPPORT VESSELS 8-216
Section 1 GENERAL PROVISIONS 8-216
Section 2 SEA KEEPING OF VESSEL'S POSITION 8-217
Section 3 ARRANGEMENT OF DIVING SYSTEMS 8-217
Section 4 STRUCTURAL REQUIREMENTS 8-219
Section 5 FIRE-FIGHTING 8-219
Section 6 UNMANNED REMOTELY OPERATED VEHICLE SUPPORT 8-221
Section 7 SURVEY, INSPECTION AND TESTING 8-221
CHAPTER 26 ADDITIONAL REQUIREMENTS FOR INSTALLATION OF BALLAST WATER MANAGEMENT SYSTEMS 8-222
Section 1 GENERAL PROVISIONS 8-222

Section 2 INSTALLATION 8-225
Appendix 1 ADDITIONAL FIRE SAFETY MEASURES RELATED TO THE INSTALLATION OF BALLAST WATER MANAGEMENT SYSTEMS 8-233
Appendix 2 INSTALLATION OF ONE SINGLE BWMS ON TANKERS 8-239
CHAPTER 27 BOW LOADING SYSTEMS 8-259
Section 1 GENERAL PROVISIONS 8-259
Section 2 ARRANGEMENT 8-259
Section 3 EQUIPMENT AND OUTFITS 8-260
Section 4 PIPING SYSTEMS 8-260
Section 5 CONTROL AND MONITORING 8-261
Section 6 FIRE SAFETY 8-262
Section 7 OPERATION MANUAL 8-263
Section 8 TESTING AND SURVEY 8-263
Section 9 REQUIREMENTS FOR BOW LOADING SYSTEM 8-264
CHAPTER 28 ADDITIONAL REQUIREMENTS FOR CABLE LAYERS 8-265
Section 1 GENERAL PROVISIONS 8-265
Section 2 HULL STRUCTURE AND ARRANGEMENT 8-265
CHAPTER 29 ADDITIONAL REQUIREMENTS FOR PIPE LAYERS 8-267
Section 1 GENERAL PROVISIONS 8-267
Section 2 HULL STRUCTURE AND ARRANGEMENT 8-267
Section 3 EQUIPMENT 8-267
CHAPTER 30 ADDITIONAL PROVISIONS ON THE FUNCTIONALITY OF RO-RO PASSENGER SHIPS 8-268
Section 1 GENERAL PROVISIONS 8-268
Section 2 PASSENGER AND VEHICLE EMBARKATION AND DISEMBARKATION ARRANGEMENT 8-268
CHAPTER 31 NOTATIONS FOR OTHER EQUIPMENT 8-269
Section 1 GENERAL PROVISIONS 8-269
Section 2 NOTATION FOR VIDEO MONITORING SYSTEM 8-269
Section 3 NOTATION FOR NIGHT VISION EQUIPMENT 8-270
Section 4 NOTATION FOR FOG NAVIGATION ENHANCED SENSING 8-270
CHAPTER 32 TRANSVERSE PROPULSION ARRANGEMENT 8-273
Section 1 GENERAL PROVISIONS 8-273
Section 2 TRANSVERSE PROPULSION ARRANGEMENT 8-273
Section 3 CONTROL, MONITORING AND ALARM 8-274
CHAPTER 33 SHIP COMMUNICATION NETWORKS SATISFYING SPECIFIC NEEDS 8-275
Section 1 GENERAL PROVISIONS 8-275
Section 2 TECHNICAL REQUIREMENTS 8-275
Section 3 PLANS AND DOCUMENTS 8-276
Section 4 SURVEY AND TESTS 8-277
CHAPTER 34 ADDITIONAL REQUIRMENTS FOR ASSESSMENT OF ANTI-COLLISION CAPACITY OF SHIPS 8-278
Section 1 GENERAL PROVISIONS 8-278
Section 2 EVALUATION METHODS 8-279
Section 3 EVALUATION CRITERIA 8-281
Section 4 CRITICAL STRIKING SPEED CURVE 8-282
CHAPTER 35 SYSTEM AND EQUIPMENT READY 8-283
Section 1 GENERAL PROVISIONS 8-283
Section 2 READY CLASS NOTATIONS 8-283

Section 3 TECHNICAL REQUIREMENTS AND PLANS AND INFORMATION 8-283
CHAPTER 36 ONBOARD CARBON CAPTURE SYSTEM 8-284
Section 1 GENERAL PROVISIONS 8-284
Section 2 DESIGN AND ARRANGEMENT 8-284
Section 3 SURVEYS 8-285
CHAPTER 37 ADDITIONAL REQUIREMENTS FOR CARRYING DRY CARGO IN BULK 8-286
Section 1 GENERAL PROVISIONS 8-286
CHAPTER 38 ADDITIONAL REQUIREMENTS FOR WINDFARM SERVICE VESSELS 8-287
Section 1 GENERAL PROVISIONS 8-287
Section 2 HULL STRUCTURES 8-288
Section 3 SUBDIVISION AND STABILITY 8-289
Section 4 SYSTEMS AND EQUIPMENT 8-289
Section 5 SURVEYS 8-289

CHAPTER 1 ADDITIONAL REQUIREMENTS FOR FIRE-FIGHTING SHIPS

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 This Chapter applies to the fire-fighting ships applying for one of the class notations listed in 1.1.2 below.

1.1.1.2 The fire-fighting ships intended to extinguish the following fires respectively are divided into Grades 1, 2 and 3 in this Chapter:

Fire-fighting ships of Grade 1 are for early stage fire-fighting;

Fire-fighting ships of Grade 2 are for large fire-fighting;

Fire-fighting ships of Grade 3 are for large or oil fire-fighting.

1.1.1.3 The fire-fighting ships are to comply with the requirements of this Chapter and in addition, the applicable requirements in other PARTs of the Rules and the requirements of CCS Rules for Materials and Welding.

1.1.1.4 The minimum requirements for fire-fighting ships of Grades 1, 2 and 3 are listed in Table 1.1.1.4.

List of Minimum Requirements for Fire-Fighting Ships Table 1.1.1.4

Equipment	Grade of fight-fighting ships			
	1	2		3
Minimum number of water monitors	2	3	4	4
Minimum discharge rate per monitor, in m^3/h	1200	2400	1800	2400
Minimum number of fire pumps	1	2		2
Minimum total pump capacity, in m^3/h	2400	7200		9600
Performance of water monitors: Minimum height of trajectory of jets of monitors above sea level, in m	45	70		70
Minimum range of monitors jets, in m	120	150		150
Minimum fuel capacity for simultaneous working of all water monitors, in h	24	96		96
Fixed foam fire-extinguishing system: Minimum number of foam monitors	–	–		2
Minimum discharge rate per system, in m^3/h	–	–		300
Time of continuous foam production, in min	–	–		30
Mobile fire-fighting equipment: Portable foam generator Minimum foam capacity, in m^3/min	–	100		100
Time of continuous foam production, in min	–	30		30
Fire hoses Number of hose connections each side of ship	4	8		8
Number of fireman's outfits	4	8		8

1.1.1.5 Where it is necessary for fire-fighting ships to deviate from the requirements of this Chapter due to their specific missions such as geographical limitations or particular objects to be served, CCS may impose other requirements as appropriate on such ships. And individual requirements in this Chapter may also be relaxed subject to agreement of CCS.

1.1.2 Notations

1.1.2.1 For all grades of fire-fighting ships complying with the requirements in this Chapter, the following notations are to be granted respectively:

Fire-fighting ships of Grade 1: Fire-Fighting Ship 1;

Fire-fighting ships of Grade 2: Fire-Fighting Ship 2;

Fire-fighting ships of Grade 3: Fire-Fighting Ship 3.

1.1.2.2 For ships provided with a water spraying system complying with 1.3.1 of this Chapter for delivering efficient cooling water spraying over all the exposed vertical surfaces of the hull so as to enable the ship to approach the burning object for fire-fighting and/or rescue purposes, the notation of Water Spraying may be affixed to that mentioned in 1.1.2.1 of this Section.

1.1.3 Plans and documents to be submitted

1.1.3.1 In addition to those required in the relevant Chapters of the Rules, the following plans and documents are to be submitted for approval:

(1) Arrangement and specification of water monitor system (including capacity, range and jet trajectory of pumps and monitors);

(2) Plan of seating arrangements for water monitors;

(3) Arrangement of water spray systems (if provided);

(4) Arrangement and specification of fireman's outfits and air compressors;

(5) Arrangement and specification of searchlights;

(6) Plan of remote control system of monitors;

(7) Arrangement of hose connection positions and associated piping on each side of ship;

(8) Stability calculations for fire-fighting operations;

(9) Operation manual, including:

① detailed description of each fire-fighting system and equipment;

② instructions on use, test and maintenance of fire-fighting installations and equipment;

③ instructions on maneuvering of ship during fire-fighting.

1.1.3.2 In addition to the plans and documents required in the relevant Chapters of the Rules, the following documents are to be submitted for information:

(1) Particulars of the means of keeping the ship in position during fire-fighting operations;

(2) Estimation of fuel consumption during fire-fighting operations.

1.1.3.3 For fire-fighting ships of Grade 2 or Grade 3, in addition to the plans and documents required in 1.1.3.1 and 1.1.3.2, the following plans and documents are to be submitted for approval:

(1) For fire-fighting ships of Grade 2:

Arrangement and specification of mobile fire-fighting equipment;

(2) For fire-fighting ships of Grade 3:

① Arrangement and specification of mobile fire-fighting equipment;

② Plan of seating arrangements for foam monitors;

③ Arrangement and specification of foam systems;

④ Plan of remote control system of foam monitors.

1.1.3.4 Other plans and documents are to be additionally submitted for approval or for information where deemed necessary.

Section 2 BASIC REQUIREMENTS

1.2.1 Hull structure

1.2.1.1 The hull structure is to be strengthened if necessary to withstand the forces imposed by the fire-fighting systems when operating at their maximum capacity.

1.2.2 Stability

1.2.2.1 When all monitors are in operation at full capacity in the most adverse direction for the stability, the ship is to have satisfactory stability corresponding to the load conditions.

1.2.3 Maneuverability

1.2.3.1 The ships are to have side thrusters and propulsion machinery with sufficient power for adequate maneuverability during fire-fighting operations. However, if means are provided to keep the ship at a standstill during fire-fighting operations, side thrusters may not be provided.

1.2.3.2 Side thrusters (if any) and main propellers are to keep the ship at a standstill in calm waters at all combinations of capacity and direction of throw of the water monitors and foam monitors, and the most unfavourable combination is not to be more than 80% of the available propulsion force in any direction.

1.2.3.3 In order to prevent overloading during combined manoeuvring, means are to be provided for sending visual and audible alarms to the navigating bridge at 80% of the available propulsion power, and for automatically reducing the power at 100% of the available propulsion force, so as to prevent sudden or complete loss of power due to power overload.

1.2.3.4 A simple control system is to be provided for operating the main propulsion plant and side thrusters (if any) to adjust:

(1) the resultant thrust vector for the ship;

(2) the turning moment of the ship;

(3) the ship's heading.

1.2.4 Lighting

1.2.4.1 Two searchlights are to be provided to permit operations of the fire-fighting equipment at night.

1.2.4.2 The searchlights are to be capable of providing at a range of 250 m in clear atmospheric conditions a level of illumination of 50 lx within an area of not less than 11 m diameter. They are to be capable of being adjusted in the horizontal and vertical directions.

1.2.5 Fuel capacity and replenishment

1.2.5.1 The quantity of fuel oil for continuous fire-fighting operations at maximum required capacity is at least to comply with Table 1.1.1.4 of this Chapter.

1.2.5.2 The fuel capacity is to be additional to what is provided for normal operation of the ship, e.g. ship's propulsion.

1.2.5.3 Where necessary, consideration is to be given to the requirement that any fuel which may be required while the ship is operating on station can be safely received on board.

1.2.6 Operation manual

1.2.6.1 An approved operation manual is to be kept on board.

Section 3 PROTECTION AND FIRE-FIGHTING EQUIPMENT

1.3.1 Water spray systems

1.3.1.1 Where a fire-fighting ship is provided with a fixed water spray system, the system is to ensure a protection of all outside vertical areas of hull above waterline, including superstructures, deckhouses, seatings for water monitors and other fire-fighting equipment.

1.3.1.2 The water spray system is to have a capacity of at least 5 *l*/min per m^2 of the protected area which is internally insulated to A-60 class and at least 10 *l*/min per m^2 of other protected areas.

1.3.1.3 The pumping capacity is to be sufficient to supply simultaneously at the required pressure the sections which serve the maximum area exposed to radiant heat from a fire. Where the main fire pumps are used for this purpose, they are to be capable of operating this system, the water monitors and the hose stations simultaneously at the required pressure. A connection with an isolating valve is to be fitted between the piping system for the water monitors and the supply line for the water spray system.

1.3.1.4 The water spray system is to be divided into sections so that it will be possible to close down sections covering surfaces which are not exposed to radiant heat.

1.3.1.5 The nozzles of the water spray system are to be arranged to give an even distribution of water spray over the protected areas.

1.3.1.6 Deck scuppers and freeing ports are to be of sufficient area to ensure efficient drainage of water from decks and horizontal surfaces in all conditions when the water spray system is in operation.

1.3.1.7 Means are to be taken to ensure that necessary visibility from the navigation bridge and the remote-control station can be maintained during the water spray operations.

1.3.2 Water monitor systems

1.3.2.1 The minimum number of water monitors and their characteristics are to comply with Table 1.1.1.4 of this Chapter.

1.3.2.2 Arrangement of water monitor systems

(1) The water monitors are to be capable of being adequately adjusted in the vertical and horizontal directions to achieve the best target point of the jet, and to be so positioned that the jets will be unimpeded within the required range of operation.

(2) The water monitors are to be fitted on fixed and robust seatings so as to withstand the imposed forces from all modes of operation.

(3) At least two water monitors are to be equipped with a permanently fitted nozzle which can give solid or a spray jet as required.

1.3.2.3 Control of water monitors

In addition to the local manual operation, the monitors are to be capable of being activated and maneuvered by remote control from a protected position ensuring a good view of the monitors and of the area to be served.

1.3.2.4 Design and seating arrangements of water monitors

(1) The monitors are to be of robust construction to withstand shock loading when all the monitors are activated simultaneously.
(2) The seating arrangements of the monitors are to be of adequate strength for all modes of operation.

1.3.2.5 Pumps and piping systems

The pumps and piping systems are to comply with the relevant requirements of 1.3.4 of this Section.

1.3.3 Fixed foam monitor system

1.3.3.1 For fire-fighting ships of Grade 3, in addition to a water monitor system, a fixed low-expansion foam monitor system complying with this paragraph is to be provided.

1.3.3.2 Performance and capacity

(1) Two foam monitors are to be provided on board, each with a capacity not less than 300 m^3/h and a foam expansion ratio not more than 12:1.
(2) The arrangement and positions of the monitors and foam system are to be such that a height of throw at least 50 m above the sea level can be obtained, when both monitors are used simultaneously with maximum capacity.
(3) Sufficient foam concentrate is to be available for at least 30 min. of simultaneous operation of both monitors at maximum capacity. When determining the required capacity of the foam concentrate, the concentration ratio is to be assumed 5%.

1.3.3.3 Arrangement

(1) The foam generating system is to be of a fixed type, consisting of individual foam concentrate tank, foam-mixing unit and piping to the monitors.
(2) The system may be supplied by the pumps of water monitors. In such cases, the pump pressure is to be adjustable to ensure producing the maximum capacity of foam.

1.3.3.4 Control of foam monitors

In addition to the local manual control, foam monitors are to be provided with remote control which is to include the operation of the valves necessary for the control of both water and foam. The remote control of foam monitors is to be located at the same remote-control station for water monitors.

1.3.3.5 Design and seating arrangements of foam monitors

(1) The foam monitors are to be of robust construction.
(2) The seating arrangements of the monitors are to be of adequate strength for all modes of operation.

1.3.3.6 Pumps and piping systems

The pumps and piping systems are to comply with the relevant requirements of 1.3.4 of this Section.

1.3.4 Pumps and piping systems for water and foam

1.3.4.1 General requirements

(1) The pumps and piping systems conveying water and foam are not to be used for other services, except for the water spray system referred to in 1.3.1 of this Chapter and for the fire-extinguishing system of the ship itself.
(2) Where the pumps are used for the fixed water spray systems, the piping is to be independent from that serving the monitors.
(3) The piping system from the pumps to the water monitors is to be separate from the piping system to the hose connections required for the mobile fire-fighting equipment as specified in 1.3.5 of this Chapter.
(4) The piping systems are to have arrangements to avoid overheating of the pumps at low delivery rates.
(5) Suction lines are to be as short and straight as practicable. The design maximum water velocity in the suction lines is normally not to exceed 2 m/s.
(6) Piping between pumps and water monitors is to have a maximum design water velocity normally not exceeding 4 m/s.
(7) All piping from seawater inlets to water monitors is to be internally protected against corrosion. Piping exposed to the weather is to be protected also externally.

1.3.4.2 Arrangement of pumps

The pumps for fire-fighting systems and their prime movers are to be adequately protected, and so located that they will be easily accessible during operation and maintenance.

1.3.4.3 Seawater suctions

(1) Seawater suctions for the fire-fighting pumps are not to be used for other purposes.
(2) The seawater suction valve, pressure valve and the pump motor are to be operable from the same position. Valves with nominal diameter exceeding 450 mm are to be power actuated as well as manually operable.
(3) Starting of fire-fighting pumps when water inlet valves are closed is to be prevented either by an interlock system or by an audible and visual alarm.

(4) Seawater inlets and sea chests are to be of a design ensuring an even and sufficient supply of water to the pumps. The location of the seawater inlets and sea chests is to be such that the water supply is not impeded by the ship's motions or by the water flow to and from bow thrusters, side thrusters, azimuth thrusters or main propellers.
(5) Seawater suctions of the fire-fighting pumps are to be arranged as low as practicable to avoid icing.
(6) Seawater suctions are to be fitted with gratings having a free passage area not less than twice that of the sea suction valve, and efficient means are to be provided for cleaning the gratings in order to ensure the efficient operation of pumps.

1.3.5 Mobile fire-fighting equipment

1.3.5.1 For fire-fighting ships of Grade 2 or 3, the mobile fire-fighting equipment complying with 1.3.5.2 of this Section is to be provided.
1.3.5.2 High-expansion foam generator
(1) Where required in Table 1.1.1.4 of this Chapter, the mobile high-expansion foam generator is to be provided with a capacity not less than 100 m^3/min for fighting external fires.
(2) Foam-forming liquid is to be stored in portable containers of about 20 *l* individual capacities. The total capacity of foam-forming liquid is to be sufficient for 30 min of continuous foam production.

1.3.6 Fire Hoses

1.3.6.1 Hose stations are to be provided on each side of the ship in accordance with the number required in Table 1.1.1.4 of this Chapter.
1.3.6.2 Each hose station is to be provided with a hydrant, a hose and a nozzle capable of producing a jet or a spray and simultaneously a jet and a spray.
1.3.6.3 The hoses are in general to be 15 m in length and not less than 38 mm nor more than 65 mm in diameter.

1.3.7 Fireman's outfit

1.3.7.1 Fire-fighting ships are to be provided with fireman's outfit in accordance with Table 1.1.1.4 of this Chapter.
1.3.7.2 Each self-contained breathing apparatus is to have a capacity of at least 1,200 *l* of free air, and at least one spare air bottle is to be provided for each apparatus.
1.3.7.3 The fireman's outfit is to be stored in a safe position readily accessible from the open deck.
1.3.7.4 A suitable air compressor is to be provided for recharging the air cylinders. It is to be capable of recharging the cylinders used in the breathing apparatus of all the fireman's outfits required in Table 1.1.1.4 of this Chapter (excluding the spare air cylinders) within 30 min. The air quality in the recharged cylinders is to be suitable for human respiration.

CHAPTER 2 ADDITIONAL REQUIREMENTS FOR LIVESTOCK CARRIERS

Section 1 GENERAL PROVISIONS

2.1.1 Application

2.1.1.1 This Chapter applies to livestock carriers.

2.1.1.2 Livestock carriers complying with the requirements of this Chapter are eligible for the assignment of the notation: Livestock Carrier.

2.1.1.3 In addition to the provisions of this Chapter, livestock carriers are to comply with the applicable requirements for livestock carriers in other chapters of the Rules, CCS Rules for Materials and Welding and relevant requirements of the flag State Administration (if any).

2.1.1.4 The corresponding requirements of this Chapter may be relaxed or waived with the consent of CCS for livestock carriers which are expected to operate for not more than 24 hours.

2.1.2 Definitions

2.1.2.1 Livestock carrier refers to a sea-going steel ship constructed or adapted and used solely for the carriage of livestock cargoes. Livestock includes sheep, cattle, horses (mules or donkeys), pigs and camels, etc.

2.1.2.2 Secondary power source refers to the source of power which may supply independent power for livestock service systems if the main source of power is out of action.

2.1.3 Plans and documents

2.1.3.1 In addition to the plans and documents as specified in relevant chapters of the Rules, the following plans and documents are to be submitted for approval:

(1) Arrangement of access for people to livestock spaces;

(2) Arrangement of livestock pens and passageways;

(3) Constructions of livestock pens and passageways;

(4) Diagram of storage and distribution systems for fodder and water;

(5) Diagram of the water washing system;

(6) Diagram of the sewage drainage and discharge system;

(7) Arrangement of fire-fighting appliances in livestock spaces;

(8) Diagram of secondary power source system;

(9) Arrangement of secondary power sources spaces;

(10) Piping diagram related to secondary power sources;

(11) Cargo securing manual (if applicable).

2.1.3.2 The following plans and documents are to be submitted for information in addition to the plans and documents provided in the relevant chapters of the Rules:

(1) Diagram of the ventilation system, with indication of the gross volume and calculations of air change rates of the enclosed spaces;

(2) Specifications of fire-fighting appliances;

(3) Estimation of fuel consumption of secondary source of power and estimation of time for restarting (restoration) of secondary source of power (if applicable).

Section 2 HULL STRUCTURE AND ARRANGEMENT

2.2.1 Hull structure

2.2.1.1 The structure of livestock carriers is to comply with the relevant requirements of Chapter 2, PART TWO of the Rules.

2.2.1.2 Where superstructure deck is strength deck (contributing to the longitudinal strength), the thickness of deck plating, excluding that of the forecastle, is to comply with the requirements of 2.17.5.4 in Chapter 2 of PART TWO and the buckling strength requirements in respect to longitudinal strength of Section 2, Chapter 2 of PART TWO, but not less than 6 mm.

2.2.1.3 Where superstructure deck is strength deck (contributing to the longitudinal strength), the framing of superstructure deck is to comply with the relevant requirements of Section 8, Chapter 2 of PART TWO

and the buckling strength requirements in respect to longitudinal strength of Section 2, Chapter 2 of PART TWO.

2.2.2 Livestock arrangement and protection of livestock

2.2.2.1 The livestock is to be kept in pens. The dimensions of these pens are to be suitable for the livestock carried and are to comply with the requirements in this Section.

2.2.2.2 Arrangements for livestock are to protect livestock from injury, avoidable suffering and exposure to weather and sea.

2.2.2.3 On a ship, livestock, livestock structures, livestock equipment and arrangements for the carriage of livestock are not to:

(1) obstruct access to any accommodation space or working space necessary for the safe operation of the ship, or the means of egress from any hold or underdeck space;

(2) interfere with operation and running of life-saving or fire-fighting appliances;

(3) interfere with arrangement and operation of the tank or bilge sounding equipment ;

(4) interfere with the operation of closing appliances;

(5) interfere with the operation of freeing ports;

(6) interfere with the lighting or ventilation of other parts of the ships;

(7) interfere with the proper navigation of the ship.

2.2.2.4 If the casing or bulkhead of an engine room, boiler room or heated fuel tank forms the boundary of a space in which livestock is to be carried, appropriate heat insulation is to be provided.

2.2.2.5 The following measures are to be taken to avoid hurt to livestock from exposed steel structure during the movement of livestock:

(1) protective boards are to be fitted on both sides of upper and lower passageways;

(2) protective boards are to be fitted on pens adjacent to the bulkhead with stiffeners or similar structures.

2.2.3 Means of egress and access for people to livestock spaces

2.2.3.1 In a ship, there are to be at least 2 exits from each space where livestock is carried. The exits are to be widely separated and give access to an open deck.

2.2.3.2 If a person uses access on a ramp that is used for loading livestock onto the ship:

(1) there is to be protective fencing separating the person access from the livestock access that :

① is at least 1 m high; and

② has an intermediate horizontal rail at least 500 mm and not more than 600 mm above the walking surface; and

(2) the passageway is to be at least 550 mm wide and be fitted with treads at a suitable stepping distance.

2.2.3.3 A pen, stall or similar structure for the containment of livestock is to have a means of access for people, with a secure closing arrangement. The closing arrangement is to have a structural strength that corresponds to the strength of the part of the pen, stall or structure to which it connects.

2.2.3.4 The passageway between the ship's rail or bulwark and the rails of the pen, stall or structure is to be at least 750 mm wide . However, the passageway width may be reduced to less than 750 mm, but no less than 550 mm, by obstructions outside the pen rails such as receptacles, pipework or other objects for the provision of livestock services.

2.2.3.5 A passageway or walkway in a livestock area is to have a clear height of at least 2 m.

2.2.4 Access for livestock to and from the ship

2.2.4.1 For loading livestock onto the ship or unloading livestock from the ship, there is to be a ramp or other means of access suitable for the species. Downward sloping ramps are not considered suitable for camels when loading into a livestock space.

2.2.4.2 The ramp or other means of access is to:

(1) be load tested every 5 years and such tests are to comply with the requirements of 2.2.13;

(2) be set up so that there is no gap between it and the ship at any time the ramp is in use; and

(3) have an arrangement to close it off either at the top or the bottom:

① for livestock such as sheep, pigs or goats, the closing arrangement is to be a gate capable of being quickly closed;

② for cattle, horses or camels, the closing arrangement is to be a sliding gate capable of being quickly closed; and

③ for all species, the closing arrangement is to be positioned close to or at the entry point to the ship.

(4) for the species mentioned in Table 2.2.5.1, the ramp is to meet the requirements of this table;

(5) for species other than those mentioned in Table 2.2.5.1, the ramp is to:

① be set at a gradient suitable for the species to be loaded or unloaded;
② be fitted with side panels that are free of protrusions and strong and high enough to prevent escape of livestock; and
③ be fitted with a non-slip walking surface with battens suitable for the species.

2.2.4.3 A camel may be loaded onto a ship or unloaded from a ship with a camel harness. There is to be a clear height of no less than 2.4 m in any area of a ship that is used for access for camels.

2.2.4.4 Any ramp or other means of access that is part of the ship's equipment is to be designed to support a uniformly distributed load as given in Table 2.2.4.4.

Table 2.2.4.4

Species	Load(N/m^2)
Cattle, horses and camels	4700
Sheep, goats and pigs	2400

2.2.4.5 The permissible stress for material used in the construction of a ramp or other means of access is given in Table 2.2.4.5.

Table 2.2.4.5

Material	Permissible stress
Steel	$0.5R_{eH}$
Aluminium	$0.5R_{p0.2}$
Other	Subject to special consideration of CCS

Notes: R_{eH} — yield strength;
$R_{p0.2}$ — strength at the non-proportional elongation being 0.2% of the original gauge length.

2.2.5 Ramp for moving livestock between decks, pens or stalls

2.2.5.1 Any ramp on which livestock is moved between decks is to comply with the requirements of Table 2.2.5.1:

Table 2.2.5.1

Item	Requirement	Sheep, pigs and goats	Cattle	Horses
1	Gradient	≤1:2	≤1:2	≤1:2
2	Clear width	≥550mm	≥750mm	≥750mm
3	Height of sides measured perpendicular to ramp floor	≥900mm	≥1.4m	≥2m
4	Sides panelled or sheathed — height of sides measured perpendicular to ramp floor	—	≥1.2m	≥2m
5	Sides free from protrusions	Yes	Yes	Yes
6	Foot battens	Yes	Yes	Yes
7	Foot battens — height	≥25mm	≥50mm	≥50mm
8	Foot battens — width	≥10mm	≥25mm	≥25mm
9	Foot battens — well rounded edges	Yes	Yes	Yes
10	Spacing between foot battens	≤300mm	≤300mm	≤300mm
11	Distance from top or bottom end of ramp to first foot batten	≤100mm	≤200mm	≤200mm

2.2.5.2 A ramp for moving cattle between decks is to have a personnel ramp beside it that:
(1) is at least 500mm wide;
(2) has a guard rail 1m high on the side away from the cattle ramp;
(3) has access at each deck to avoid personnel having to cross the cattle race; and
(4) has foot battens or a non-skid surface.

2.2.5.3 The means of closing livestock access to a pen or stall could be a sliding or swinging gate or portable rails. The means is to:
(1) maintain continuity of strength and the alignment of the adjoining boundary; and
(2) be secured against accidental lifting or removal.
2.2.5.4 If pens or stalls are on an exposed deck, the uppermost pens or stalls on each deck are to be fitted with a roof that:
(1) ensures compliance with the minimum clear height requirement of pens or stalls for the species to be carried;
(2) is waterproof; and
(3) extends at least 450 mm beyond the deck area occupied by the pens or stalls.
2.2.5.5 Any pens or stalls for livestock that are at the forward end of a livestock structure, on or above the uppermost continuous deck, and their feeding and watering equipment, are to be screened effectively from sea spray, and protected, in any sea condition, from seawater entering any part of the pens, stalls or feeding and watering equipment.

2.2.6 Construction of pens for sheep, pigs and goats

2.2.6.1 The construction of pens for sheep, pigs and goats is to comply with the requirements in Table 2.2.6.1.

Table 2.2.6.1

Item	Detail of design	Dimension
1	Maximum breadth of pen	4.5m
2	Minimum breadth of pen	2.0m
3	Maximum length of pen	Not more than twice the breadth
4	Minimum length of pen	Not less than the breadth
5	Maximum clear floor area within pen	40.5m^2
6	Minimum clear height within pen	If a mechanical ventilation system is provided: 1.8m
		In any other case: 2.3m
7	Maximum clear vertical distance between rails	300mm
8	Maximum clear vertical distance between bottom edge of lowest rail of pen and deck level	200mm
9	Maximum clear vertical distance between bottom edge of lowest rail of upper pen and bottom of pen, unless a vertical plate or board is fitted in accordance with 2.2.7.2	50mm
10	Minimum height of top edge of uppermost rail above pen floor for sheep and pigs (900 mm, or less if the clear height above the uppermost rail is less than 300 mm)	900mm
11	Minimum width of adjacent passageway clear of receptacles and any other obstructions	550mm

Notes:
(1) For item 5, the clear floor area is the area of the pen excluding fixed receptacles, other objects or structures in the pen, but including fodder storage area that meets storage requirement.
(2) For an open structure above the weather deck, if pen rails or gates form the outer perimeter containment:
① the space between the bottom edge of the lowest rail and the deck is not to be more than 100 mm;
② the space between the rails above the bottom rail is not to be more than 200 mm; and
③ the railing is to continue to a height that is no more than 200 mm below the overhead structure of the ship.
(3) The decks for pens, passageways and ramps between decks are to have a surface that provides a non-slip foothold for sheep.
2.2.6.2 Rails and stanchions that form the boundary of a sheep, pig or goat pen is to be able to withstand a load calculated using the following formula:

$$F = 1668\ B\ (0.574 + 0.0252\ Z) \qquad \text{N/m}$$

where: F —boundary load, in N/m;
B—maximum breadth of the pen, in m;

Z—vertical distance from a point 0.5 m above the pen floor to the ship's waterline corresponding to the anticipated lightest load, in m.

Notes: (1) The approved stability booklet for the ship contains the information for the load calculation
(2) A rail the centre of which is more than 900 mm above the pen floor is not to be included in the load calculations.

2.2.6.3 Any two-thirds of the area of the floor of a sheep, pig or goat pen is to be able to withstand 100% of the floor load uniformly distributed over the area. The floor load is to be calculated according to the following formula:

$$F = 2500\ [1 + ((0.094 - 0.00035\ L)y + (7.4 - 0.016\ L))/d] \qquad \text{N/m}^2$$

where: F—floor load, in N/m^2;
d—draught of the ship corresponding to the anticipated lightest loaded waterline, in m;
L—length between the perpendiculars of the ship, in m;
y— longitudinal distance from the midpoint of the pen to amidships, in m.
Note: The approved stability booklet for the ship contains the information for the load calculation.

2.2.6.4 The permissible stress for a pen and pen area deck material is to meet the requirements in Table 2.2.6.4.

Table 2.2.6.4

Material	Permissible tensile stress	Permissible shear stress
Steel	$0.75R_{eH}$	$0.375R_{eH}$
Aluminium	$0.75R_{p0.2}$	$0.375R_{p0.2}$
Other	To be specially considered by CCS	To be specially considered by CCS

Notes: R_{eH} — yield strength;
$R_{p0.2}$ — strength at the non-proportional elongation being 0.2% of the original gauge length.

2.2.7 Additional requirements for pens, walkways and passageways for sheep, pigs and goats

2.2.7.1 There is to be a passageway on at least one side of each pen.
2.2.7.2 If a lower tiered pen has a water or food receptacle beside a passageway, the upper tiered pen above it is to have, fitted to the side adjoining the passageway, to prevent the fouling of food and water of livestock in lower tiers, a vertical plate or board which is at least 225 mm high.
2.2.7.3 If pens are constructed in more than 1 tier on a deck, walkways are to be provided so that no pen floor is more than 1.5m above the deck or a walkway.
2.2.7.4 The following additional requirements apply to pens used for the carriage of goats:
(1)There are to be pen rails to a height of at least 1.5 m above the pen floor, or to a height where the clear height above the uppermost rail is less than 300mm;
(2) For any goat pen that is not on the upper tier of a 2 tier structure:
① the space between the rails is to be closed off to contain goats in the pen, and for example, wire mesh is considered to be an effective means of containment; and
② food and water receptacles are to be located inside the pen.

2.2.8 Design of pens and passageways for cattle

2.2.8.1 The dimensions of a pen for cattle and adjacent passageways are to comply with Table 2.2.8.1.

Table 2.2.8.1

Item	Detail of design	Dimension
1	Maximum breadth of pen	4.5m
2	Minimum breadth of pen	2.1m
3	Minimum length of pen	2.3m
4	Maximum clear floor area within pen	21m^2
5	Maximum height of top edge of lowest rail above pen floor between pens	600mm
6	Maximum height of top edge of lowest rail above pen floor in boundaries of pen other than between pens	300mm
7	Maximum distance between 2 adjacent rails of pen	300mm
8	Maximum distance between top rail and overhead structure of the ship	300mm

	in open structures above the weather deck, where pen rails form the outer perimeter containment	
9	Minimum clear height within pen:	If a mechanical ventilation system is provided: 1.8m In any other case: 2.3m
10	Minimum width of adjacent passageway, measured clear between rails, if pens are on both sides of the passageway and cattle are loaded and discharged through the pens	1.0m
11	Minimum width of adjacent passageway, measured clear of any fixed structures, receptacles or other obstructions, if pens are on both sides of the passageway and cattle are loaded and discharged through the pens	0.7m
12	Minimum width of adjacent passageway, measured clear of any fixed structures, receptacles or other obstructions, if pens are on both sides of the passageway and cattle are loaded and discharged through the passageway	1.0m

Note: For item 4, the clear floor area is the area of the pen excluding fixed receptacles, other objects or structures in the pen, but including fixed fodder file.

2.2.8.2 If a water or food receptacle is fitted to the outside of a pen, or fodder is distributed on the floor outside a pen, a clear vertical space of not more than 500 mm may be provided between adjacent pen rails on the side of the pen adjoining the passageway, for watering or feeding livestock in the pen.

2.2.8.3 The deck for cattle pens, passageways and ramps between decks are to have a surface that provides a non-slip foothold for cattle.

2.2.8.4 Rails and stanchions that form boundary of a cattle pen or stall are to be able to withstand a load calculated using the following formula:

$$F = 3336\ B\ (0.574 + 0.0252\ Z) \qquad \text{N/m}$$

where: F—boundary load, in N/m;

B—maximum breadth of pen, in m;

Z—vertical distance from a point 0.75 m above the pen or stall floor to the ship's waterline corresponding to the anticipated lightest load, in m.

Notes: (1) The approved stability booklet for the ship contains the information for the load calculation.

(2)A rail the centre of which is more than 1.4 m above the pen or stall floor is not to be included in the load calculations.

2.2.8.5 Any two-thirds of the area of the floor of a cattle pen is to be able to withstand 100% of the floor load uniformly distributed over the area.The floor load is determined according to the following formula:

$$F = 5000\ [1 + ((0.094 - 0.00035\ L)y + (7.4 - 0.016\ L))/d] \qquad \text{N/m}^2$$

where: F—floor load, in N/m^2;

d—draught of the ship corresponding to the anticipated lightest loaded waterline, in m;

L—length between the perpendiculars of the ship, in m;

y—longitudinal distance from the midpoint of the pen to amidships, in m.

Note: the approved stability booklet for the ship contains the information for the load calculation.

2.2.8.6 The above 2.2.8.4 and 2.2.8.5 apply to the floor support of a cattle pen whether or not it also forms the top boundary of a pen on a lower deck.

2.2.8.7 The floor of a cattle stall is to be of substantially the same method of construction and of substantially the same scantlings as required for a cattle pen.

2.2.8.8 The stresses for materials used in the construction of boundaries and floors of a cattle pen are to comply with the requirements of Table 2.2.6.4.

2.2.8.9 There is to be a passageway and a means of access to cattle pens for the care and removal of cattle.

2.2.8.10 There is to be a means of access at the rear of each stall.

2.2.9 Design of horse stalls and passageways

2.2.9.1 The dimensions of a stall for horses and adjacent passageways are to comply with Table 2.2.9.1.

Table 2.2.9.1

Item	Detail of design	Category	Dimension
1	Maximum clear length within stall		Horses, 2.5m; Mules or donkeys, 2.3m
2	Minimum clear length within stall		2.3m
3	Minimum clear width of passage:	Between 2 rows of stalls and bounded by the front rails	Horses, 1.7m; Mules or donkeys, 1.5m
		Between 2 rows of stalls and bounded by front and back rails	1.2m
		In any other case	1.0m
4	Minimum clear width within stall	If the stall is aligned athwartships	0.7m
		If the stall is aligned fore and aft	0.9m
5	Height of uppermost front, back and side rail from floor to top edge		1.15m
6	Height of lowest front, back and side rail from floor to top edge		0.75m

2.2.9.2 The rails and stanchions of a horse stall are to be constructed of materials that have a strength of at least that of heavy gauge tubular steel pipe with a 50 mm nominal bore.

2.2.9.3 The floor of a horse stall is to have the strength to withstand a load calculated in accordance with 2.2.8.5.

2.2.9.4 A horse on a ship is to be in a separate stall.

2.2.9.5 There is to be a passageway at the front of each horse stall. There is to be a means of access to the rear of each horse.

2.2.9.6 The floor of a horse stall is to be constructed to facilitate drainage and cleaning.

2.2.9.7 If constructed of wood, the floor of a horse stall is to:

(1) have boards that are:

① close fitting at the front of the stall;

② spaced between 20 and 30 mm apart at the rear; and

③ secured against lifting

(2) have foot battens at the front and rear of the stall that:

① are at least 50 mm high;

② are at least 50 mm wide; and

③ have well rounded edges.

2.2.9.8 If constructed of concrete, the floor of a horse stall is to:

(1) have concrete that is finished off to provide a non-slip surface; and

(2) provide suitable standings.

2.2.9.9 If constructed of metal mesh, the floor of a horse stall is to:

(1) be made with rods with a diameter of between 8 and 10 mm;

(2) the rods are placed to provide openings of no more than 50 mm by 50 mm; and

(3) provide suitable standings.

2.2.9.10 A horse stall on an exposed deck is to:

(1) for a stall on an outer edge of the ship — have protective sheathing fitted on its outboard side; and

(2) for a stall the forward end of which is exposed — have protective sheathing fitted on its forward end.

2.2.9.11 The requirements for sheathing:

(1) may be portable if it can be fitted from outside a stall; and

(2) is to effectively screen the stall and its feeding and watering arrangements from sea spray; and

(3) is not to exclude natural ventilation.

2.2.9.12 If the back of a stall forms a boundary of a passageway or another stall, a kick rail or board is to be fitted to that end of the stall so that the clear space between rails, or rail and board, is not more than 150 mm.

2.2.9.13 The following measures are to be taken for restraint of a horse:

(1) The horse is to be fitted with a collar made of leather or other suitable material;

(2) Each stall is to have cross ties and suitable fastenings for use with the collar; and
(3) If the cross ties are made of chain, a set of bolt cutters that can cut the chain is to be carried onboard and kept readily available.

2.2.10 Design of camel pens and passageways

2.2.10.1 The dimensions of a pen for camels and adjacent passageways are to, in addition to the requirements of Table 2.2.8.1, also comply with the following requirements :
(1) the minimum clear height within the pen is to be at least 2.4 m; and
(2) if a water or food receptacle is fitted to the outside of the pen or feed is distributed on the floor outside the pen, there is to be a clear vertical space of at least 450mm and no more than 500 mm between 2 adjacent pen rails on the side of the pen adjoining the passageway.

2.2.10.2 If a camel pen has kickboards or is sheathed in mesh, the kickboards or mesh are to extend for at least 1 m above the pen floor to prevent camels from attacking people or chew parts of the ship, e.g. cabling or piping.

2.2.10.3 The structural strength requirements for camel pens are equivalent to those for cattle pens.

2.2.10.4 As camels are difficult to move around a ship, camel pens are to be located close to the entry point onto the ship.

2.2.10.5 Camel pens are tot be non-contiguous with pens carrying other livestock.

2.2.10.6 The camels in a pen are to be of a similar size and the same gender.

2.2.11 Requirements for carriage of other species of livestock

2.2.11.1 If livestock other than sheep, pigs, goats, cattle, horses or camels is to be carried:
(1) there are to be stalls or pens;
(2) the stalls or pens are to safely contain the livestock for the time of the voyage;
(3) the stalls or pens are to be constructed appropriately for the size, other characteristics and needs of the livestock and have arrangements to adequately feed, water and tend the livestock;
(4) other measures for the safety of the livestock, and of people near the livestock, are to be taken, in equivalence to the requirements of this Chapter; and
(5) there are to be appropriate hospital pens or stalls.

2.2.12 Hospital pens

2.2.12.1 A hospital pen is to comply with the following requirements:
(1) A hospital pen is to be clearly identified as a hospital pen;
(2) A hospital pen is to be constructed to the same standard as a pen for the species of livestock for which it is provided;
(3) Animals that are individually penned or stalled may be disregarded when calculating the number or area of hospital pens; and
(4) If a deck is divided into separate compartments by watertight doors, a hospital pen is to be provided in each compartment of the deck for each species carried in the compartment.

2.2.12.2 Hospital pens for sheep, pigs and goats:
(1) There are to be hospital pens equal in area to at least 0.25% of the pen area used for the carriage of sheep, pigs or goats;
(2) There is to be a hospital pen on each deck on which sheep, pigs or goats is carried; and
(3) If a hospital pen has a length and width not in accordance with Table 2.2.6.1, no side of the pen is to be less than 1.5 m long.

2.2.12.3 Hospital pens for cattle:
(1) There are to be hospital pens equal in area to at least 1% of the pen area used for the carriage of cattle;
(2) There is to be a hospital pen on each deck on which cattle are carried;
(3) However, if the pen area for the carriage of cattle on a deck is less than $500m^2$, the hospital pens may be sited on an adjacent deck above or below if they are easily accessible to cattle transferred from the other deck, and the transfer is not through a watertight opening; and
(4) If a hospital pen has a length and breadth not in accordance with Table 2.2.8.1, no side of the pen is to be less than 1.5 m long.

2.2.13 Testing of ramps for livestock

2.2.13.1 Ramps are to be tested in compliance with the designed operating requirements and according to the test loads specified in Table 2.2.13.1. The test procedures are to be subject to consent.

Table 2.2.13.1

Safe working load (kN)	Proof load (kN)
SWL≤196	1.25×SWL
196＜SWL≤490	SWL+49
SWL＞490	1.1×SWL

2.2.13.2 After testing, the ramp and its accessory gear are to be thoroughly examined for damage or permanent deformities.

Section 3 STABILITY

2.3.1 General requirements

2.3.1.1 The stability of livestock carriers is to comply with the requirements of this Section or relevant requirements of the flag State Administration.

2.3.1.2 The stability of livestock carriers is to comply with the requirements for cargo ships in Sections 9 and 10 of Chapter 1, PART TWO of the Rules.

2.3.2 Additional requirements for stability

2.3.2.1 The effects of the shift of livestock and fodder in pellet form (if any) and the effect of wind are to be taken into account for intact stability of livestock carriers. The following criteria are to be complied with for livestock carriers under intact condition:

(1) The angle of heel is not to exceed 10 degrees due to the effect of wind.

(2) The residual area A is to comply with the following requirements, taking into account the effects of the shift of livestock and fodder in pellet form and the effect of wind, as illustrated in Figure 2.3.2.1 below:

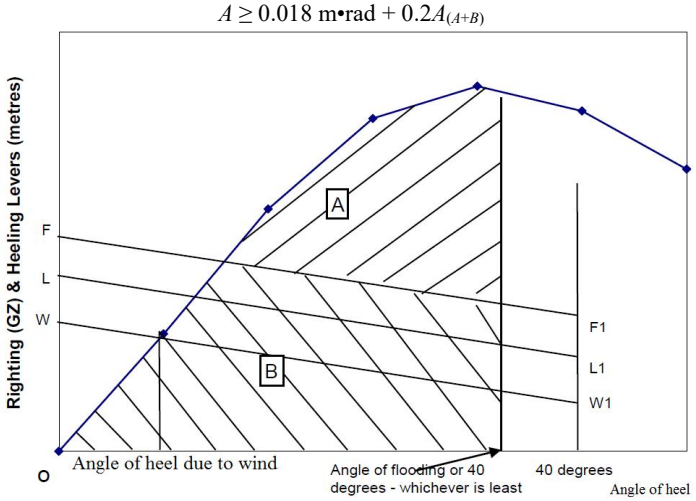


Figure 2.3.2.1 Rolling Criteria

where: $A_{(A+B)}$ is the sum of area A and area B under the righting lever curve, as illustrated in Figure 2.3.2.1. Definitions in Figure 2.3.2.1 are as follows:

OW — the heeling lever at 0° due to wind;
WW_1 — the heeling lever curve due to wind;
WL — the heeling lever at 0° due to the shift of livestock;
LL_1 — the heeling lever curve due to the combined effects of wind and the shift of livestock;
LF — the heeling lever at 0° due to the effect of shift of fodder;
FF_1 — the heeling lever curve due to the combined effects of wind and the shift of livestock and fodder;
θ — the angle of heel due to wind.

Note: If fodder is not pellet feed carried in bulk, the heeling lever due to shift of fodder will be zero.

(3) The heeling lever due to the effect of wind is to be determined according to the following requirements:

① The heeling lever due to the effect of wind at 0° is to be given by $OW = \frac{PAH}{\Delta}$,

where: Δ — displacement, in t;

P — wind pressure, 504 pa;

A — lateral area of the vessel above the waterline, in m^2;

H —vertical distance between the centroid of the lateral area of the vessel above the waterline and the centroid of the vessel's underwater lateral area. For most vessels the vertical position of the centroid of the underwater lateral area may be taken as half the draft to the underside of the keel at amidships.

② The heeling lever due to the effect of wind at 40° is to be given by 0.8 (heeling lever due to the effect of wind at 0°).

③ The heeling lever curve is to be taken as a straight line joining the heeling lever at 0° and the heeling lever at 40°.

(4) The heeling lever due to the shift of livestock is to be determined according to the following requirements:

① The heeling lever due to the shift of livestock at 0^o is to be given by $\frac{m \cdot C}{f \cdot \Delta}$,

where: m — average mass of livestock to be carried on the intended voyage, in t;

f — floor area required per head of average mass of the livestock to be carried on the intended voyage, in m^2;

C — livestock shift constant, $C = \frac{1}{6}\sum lb^2$, where l is length of each pen, in m; b is breadth of each pen, in m. For vessels with uniform breadth of pens, the livestock vessel constant becomes: 1/6 (breadth of pen × total floor area of pens). For vessels with varying breadths of pens, the largest breadth may be used and the livestock shift constant becomes: 1/6 (maximum breadth of pen × total floor area of pens).

② The heeling lever due to the shift of livestock at 40° is to be given by 0.8 (heeling lever due to the shift of livestock at 0°).

③ The heeling lever curve is to be taken as a straight line joining the heeling lever at 0° and the heeling lever at 40°.

(5) The heeling lever due to the shift of fodder is to be determined according to the following requirements:

① The heeling lever due to the shift of fodder at 0° is to be given by $\frac{M_f}{s \cdot \Delta}$,

where: M_f — the sum of the shift moment of each compartment, where the shift moment of each compartment is to be given by 0.044 lb^3, where: l is the maximum length of the compartment; and b is the maximum breadth of the compartment, in m. The use of volumetric shift moments for the fodder, where the surface is assumed to take up an angle of slope of 15° to the horizontal for full compartments and 25° to the horizontal for partly filled compartments, is an acceptable alternative method to obtain the total shift moment of fodder;

s — stowage factor (the volume of fodder in pellet form per unit weight).

② The heeling lever due to the shift of fodder in pellet form carried in bulk at 40° is to be given by 0.8 (heeling lever due to the shift of fodder at 0°).

③ The heeling lever curve is to be taken as a straight line joining the heeling lever at 0° and the heeling lever at 40°.

Section 4 PROVISION OF LIVESTOCK SERVICES

2.4.1 General requirements

2.4.1.1 Facilities or systems providing daily services for livestock are to be fitted in livestock spaces and these facilities or systems intended for:

(1) the supply of food, water and fresh air to the livestock;

(2) the cleaning of the livestock spaces and access;

(3) the internal collection, disposal, storage and satisfactory outside discharging of the sewage produced by the livestock.

2.4.1.2 In addition to the provisions of this Section, the piping is to comply with the applicable requirements of Chapter 2 and Chapter 3, PART THREE of the Rules.

2.4.2 Ventilation system

2.4.2.1 All spaces for the carriage of livestock, whether enclosed or not, are to be provided with a mechanical ventilation system that can change the total volume of air in those spaces in accordance with the requirements of Table 2.4.2.1.

Total volume of air **Table 2.4.2.1**

Item	Minimum clear height of the space (x)	Time within which complete air change must occur
1	x≤1.8m	at least every 2 minutes
2	x≥2.3m	at least every 3 minutes
3	1.8m<x<2.3m	proportionately between 2 and 3 minutes, specific time can be calculated by linear interpolation

2.4.2.2 A mechanical ventilation system is to distribute air so as to ensure that the whole of each livestock space is efficiently ventilated.

(1) For a livestock space, the following is to be ensured:

① the air is as clean and fresh as practicable; and

② there is minimal recirculation of intake and exhaust air.

Note: A vertical high velocity exhaust system may help prevent recirculation of exhaust and intake air.

(2) Exhaust air outlets are not to be sited near accommodation spaces, offices or air intakes on the ship.

(3) Ventilators serving livestock spaces are to remain in operation in all weather conditions.

2.4.2.3 The redundancy of the mechanical ventilation system is to comply with the following requirements:

(1) If a mechanical ventilation system is fitted, the ship is to carry, for each type of fan in the system, either:

① spare fans; or

② spare parts, including:

(a) a complete electrical motor;

(b) a complete rotor or impeller;

(c) any other parts required for repair.

(2) If a mechanical ventilation system is fitted on a ship, fan starters should have at least 2 group starter panels.

(3) Each group starter panel is to be:

① located in a space that is not adjacent to a space where another group starter panel is located;

② supplied with power from both the main and secondary sources of power; and

③ interlocked to prevent simultaneous supply of power from both main and secondary sources.

2.4.2.4 The main and secondary sources of power are to be as widely separated as practicable and neither passing through any space containing any part of the other source of power.

2.4.2.5 A ship is to have visual and audible alarms on the bridge to provide a warning as soon as there is a failure of any part of the ventilation system.

2.4.3 Fodder and water arrangements

2.4.3.1 Spaces intended for livestock (including pens, stalls or similar fittings) are to be provided with receptacles for feeding and watering the animals concerned.

2.4.3.2 The receptacles are to be capable of containing at least 33 per cent of the daily allowance of fodder and water for the number of animals contained in the space (pen, stall or similar fitting) except where the fodder or water is provided by an automatic system.

2.4.3.3 An animal's daily allowance for water and fodder is as follows:

(1) An animal's daily water allowance is:

① for cattle — 36 L per m^2 of pen area; and

② for sheep, pigs and goats — 6 L per head.

(2) An animal's daily fodder allowance is:

① for cattle — 5.7 kg per m^2 of pen area; and

② for sheep, pigs and goats — 4.8 kg per m^2 of pen area.

Note: Where not dry fodder is supplied, the allowance for water and fodder is to be estimated by the moisture content of the fodder.

2.4.3.4 The availability of water and fodder is to comply with the following requirements:

(1) Before livestock is loaded, automatic feeding and watering systems are to be turned on and capable of supplying water and fodder in accordance with 2.4.3.3.
(2) Water and fodder are to be provided to livestock within 12 hours after loading has commenced.
2.4.3.5 The distribution system for fodder is to be set up and comply with the following requirements:
(1) A ship is to have a storage and distribution system to provide fodder to livestock;
(2) If a fodder distribution system is powered electrically, it is to be able:
① to be powered by both the main and secondary sources of power; and
② to operate if a fire or other emergency occurs in the space containing the main source of power.
(3) Fodder stored in bulk on the ship is to be contained in at least 2 separate spaces.
(4) Fodder may be stored in an enclosed livestock space only if:
① the storage is consistent with the standards for ventilation, lighting and drainage; and
② it does not prevent compliance with the passageway requirements of Section 2 in this Chapter.
(5) The fodder, as a cargo unit, is to be loaded, stowed and secured in accordance with the Cargo Securing Manual.
2.4.3.6 Receptacles for fodder and water are to comply with the following requirements:
(1) Each pen is to have a receptacle for feeding livestock and a receptacle for watering livestock.
(2) However, a fodder receptacle is not required for a pen containing cattle if:
① the pen adjoins a passageway and the cattle can easily consume hay distributed on the floor of the passageway; and
② urine and faeces, or water used to wash pens, is prevented from fouling the passageway.
(3) A receptacle mentioned in (1) is to:
① be suitable for the species of livestock;
② be readily accessible to livestock;
③ be serviceable from outside the pen;
④ be installed so that it does not impede ventilation;
⑤ for adult sheep — be no more than 550 mm above the pen floor at the highest part of the receptacle; and
⑥ be constructed and positioned so that fodder dust is not disturbed by the ventilation flow.
(4) If a receptacle for water or fodder is inside a pen and is not portable, to minimise fouling of the receptacle, there is to be fitted a pipe or bar that:
① has an appropriate height for the species carried in the pen; and
② is at a horizontal distance from the edge of the receptacle of at least:
(a) for sheep — 75 mm; and
(b) for cattle — 150 mm.

2.4.4 Fresh water system

2.4.4.1 All livestock spaces are to be provided with fresh water service to provide fresh drinking water to livestock on board at all times. The water storage system is to have capacity for intended voyages. The water tanks for storage of drinking water for livestock are to maintain a sound condition to avoid water contamination.
2.4.4.2 The fresh water system is to include one main supply pump and one standby pump, of a capacity sufficient to continuously supply fresh water to the livestock.
When the water supply system is not automatic, the standby pump may be replaced by a portable pump ready to be connected to at least one fresh water tank.
The pumps are to comply with the following requirements:
(1) These pumps and the supply systems to which they connect are not to be configured for any purpose other than servicing the livestock water distribution system;
(2) At least 1 of the pumps is to be:
① located outside the space occupied by the main source of power; and
② able to maintain the distribution of water if there is any interruption to the main source of power.
2.4.4.3 If the fresh water system is dependent on electric power, it is to be powered by both the main and secondary sources of power and can continue to operate by secondary source of power if a fire or other casualty occurs in the space containing the main source of power.
2.4.4.4 When the water supply is automatic, water receptacles are to be fitted with means of automatic water level control and devices to avoid the return of water from the receptacle to the fresh water tank.
2.4.4.5 Emergency water reserve is to comply with the following requirements:

(1) The ships that are undertaking a voyage of not more than 14 days are to have capacity for 3 days supply of emergency drinking water for livestock:
(2) The ships that are undertaking a voyage of more than 14 days are to have capacity for 7 days supply of emergency drinking water for livestock.
Note: Capacity is assessed based on the daily water allowance for the number and kinds of livestock on a voyage.

2.4.5 Water washing system

2.4.5.1 A water washing system is to be provided with appropriate connections to wash the livestock spaces and accesses (including ramps).
2.4.5.2 Livestock spaces and accesses (including ramps) are to be provided necessary auxiliary disinfection measures which can be used in conjunction with the water washing system.
2.4.5.3 Necessary auxiliary drying measures for the areas mentioned in 2.4.5.1 above are to be considered.

2.4.6 Drainage and discharge of sewage

2.4.6.1 Each space intended for the livestock is to be fitted with a pipe or gutter of sufficient size to drain the sewage and the washing effluents. The drainage system for livestock sewage is to be kept separate from, and not connected in any way to, the livestock drinking water system.
2.4.6.2 Drainage arrangements are to be such that fluids drained from a pen are as far as practicable kept clear of other pens and associated working and access spaces.
Where necessary, drainage gutters and upper parts of the draining pipes are to be covered by a strainer plate. In addition, drainage pipelines are to be so arranged that the drainage system can still be used with the ship's trim by bow or stern.
2.4.6.3 The pipes and other components of the draining system are to be made of a material resistant to the corrosion due to the effluents.
2.4.6.4 Pumps and ejectors serving the drainage tanks or wells are to be capable of conveying semi-solid matter and evacuating the tank or well by lines other than the ship's bilge lines.
2.4.6.5 All electrical equipment involved in the sewage drainage and discharge system of sewage are to be capable of being operated by both the primary and the secondary sources of power.
2.4.6.6 A ship is to have a means of effectively draining fluids from a pen where livestock is carried, under any expected conditions of trim by the head or by the stern, or of angle of heel to either side.
2.4.6.7 Drains are to comply with the following requirements:
(1) The ship is to have drains at each corner of a pen or group of pens as follows:
① for a ship with a beam of more than 20 m:
(a) at least 3 drains fitted athwartships; and
(b) for every 5 m that the beam of the ship exceeds 20 m — an additional drain.
② no more than 20 m apart longitudinally in each hold or livestock space;
③ for a drain that consists of pipes to the deck below, on a ship that carries livestock other than sheep or goats:
(a) pipes with an internal diameter of at least 300 mm; and
(b) an outlet that is at least 250 mm above the deck or well below.
(2) If a drain is inside a pen, it is to be protected so that:
① livestock cannot get their feet caught in the drain; and
② any protection does not prevent the flow of effluent.
2.4.6.8 For inspection and cleaning, the following things are to be accessible from outside livestock pens:
(1) drainage tanks;
(2) wells;
(3) the tops of drainage pipes.

2.4.7 Provision of humane killing device

2.4.7.1 For a ship carrying livestock, there is to be on board a humane killing device that is suitable for each species carried.

2.4.8 Additional requirements for the automatic system

2.4.8.1 If any part of the normal means of feeding and watering livestock on the ship is by an automatic system, there is to be an alternative arrangement for feeding and watering in case there is a malfunction of the automatic system.

Section 5 FIRE-FIGHTING APPLIANCES

2.5.1 Fire hydrants and fire hoses

2.5.1.1 The number and position of the hydrants are to be such that at least two jets of water not emanating from the same hydrant may reach any part of the spaces intended for the livestock. At least one of these jets is to be from a single length of hose without the necessity for hoses to pass over or through pens.

2.5.1.2 A fire hose is to be provided in an enclosed space for each hydrant and in any other space or on a deck for each 50 m length, or part thereof, of space or deck.

2.5.1.3 Each fire hose is to be provided with the necessary connections and a nozzle capable of directing water in the form of a spray and a jet.

2.5.1.4 Each hose is to be capable of being connected to any hydrant and to any other hose (other than hydrants and hoses within the engine room or accommodation spaces).

2.5.1.5 Fire hoses are to be located in conspicuous locations, near the hydrants and close to the entrances or access to the spaces.

2.5.1.6 The hydrants are to be connected to the ship's fire main.

2.5.2 Additional fire-fighting means

2.5.2.1 Livestock structures, including livestock decks and containment structures but excluding livestock services such as water pipes and feed troughs, are to be constructed of non-combustible materials.

2.5.2.2 If hay, straw or bhusa is carried or used in a livestock space, one of the following fire-fighting means is to be provided:

(1) portable fire extinguishers:

① that use water as the extinguishing medium;

② with 1 extinguisher placed adjacent to an entrance to the space; and

③ with 1 extinguisher placed at least every 18 m of the space.

(2) an approved fire-fighting arrangement that uses water as the extinguishing medium.

2.5.2.3 Where electrical equipment other than that referred to in Section 6 of this Chapter is located in an enclosed livestock space, suitable fire-fighting means are to be provided in this respect as follows:

(1) portable fire extinguishers in sufficient numbers; or

(2) a fixed fire-fighting installation.

2.5.2.4 Notices are to be prominently displayed prohibiting smoking or the use of naked lights in livestock spaces and spaces used for storage of fodder, hay, straw, bhusa, bedding or other flammable material.

Section 6 ELECTRICAL EQUIPMENT

2.6.1 General requirements

2.6.1.1 In addition to the applicable requirements of PART FOUR of the Rules, electrical equipment of livestock carriers is to comply with the provisions of this Section.

2.6.2 Sources of electrical power for livestock carriers

2.6.2.1 The main source of power is to meet the following:

The main source of power as specified in 2.1.1.1 of Chapter 2, PART FOUR of the Rules is to be provided and all electrical services (including livestock services) necessary for maintaining the livestock carrier in normal operational and habitable conditions will be ensured without recourse to the emergency source of electrical power.

2.6.2.2 The secondary source of power is to meet the following requirements:

(1) The secondary source of power is to be located in a space that is not contiguous with any space containing the main source of power or part thereof, and be independent of any services provided from or through any such space. In case of a fire or other casualty in any space containing the main source of power or any part thereof, the secondary source of power must be capable of supplying power to livestock services for a period of 72 h.

(2) The prime mover of secondary source of power is to be capable of supplying power to the system within 30 min in the failure of main source of power. The prime mover may be started by an effective arrangement powered by an independent source of energy or the emergency source of power complying with the requirements of paragraphs 1.1, 1.4 and 2 of SOLAS regulation II-1/43.

(3) Instructions are to be provided for the changeover between main and secondary sources of power and vice-versa. A copy of such instructions is to be posted in the space containing the livestock source of power, and is to be readable under the emergency lighting required by SOLAS regulation II-1/43.2.2. The instructions are to detail, among other things, starting method, switchboard changeover and electrical supply changeover to livestock services.
(4) Cables of secondary source of power are to be kept away from cables of main source of power in so far as practicable and generally they do not pass through the same space.

2.6.3 Lighting

2.6.3.1 Livestock spaces, passageways between pens and access routes between or to those spaces are to be adequately lit.
2.6.3.2 An emergency lighting system that is automatically activated on the failure of the main electrical installation is to be provided in all parts of a vessel where livestock is carried, passageways between pens and access routes between or from those parts, and is to be capable of giving a level of illumination in all passageways and access routes for a continuous period of not less than 15 min. The lamp casings on light fittings for the emergency lighting system are to be painted red for ease of identification.
2.6.3.3 If fixed lighting is provided in a part of a vessel above the uppermost continuous deck, that lighting is to be capable of being controlled from the navigating bridge.
2.6.3.4 Light fittings is to be of sufficient strength and fitted with protective sheathing outside to resist damage by livestock and placed beyond possible contact by livestock.

2.6.4 Electrical equipment for use in dust laden atmospheres

2.6.4.1 Electrical equipment and cables installed in areas where flammable dusts may be present (such as spaces used for the storage or handling of bulk fodder) are to comply with the requirements of 2.18.3.2 of Chapter 2, PART FOUR of the Rules.
2.6.4.2 Lighting, or power points for portable lighting, in a space used for carriage of fodder in bulk, are to be controlled by switches situated on the navigating bridge or at the fodder-handling machinery control station and indicator lights are to be provided to show when power is supplied to the lighting or power points.

CHAPTER 3 ADDITIONAL REQUIREMENTS FOR OIL RECOVERY SHIPS

Section 1 GENERAL PROVISIONS

3.1.1 General requirements

3.1.1.1 The requirements of Sections 1 to 5 of this Chapter apply to steel ships equipped for the recovery of oil floating on the sea with a flash point not exceeding 60℃ (closed-cup test) and a Reid vapour pressure below atmospheric pressure, as required for the class notations in paragraphs 3.1.2.1 and 3.1.2.2.

The requirements of Section 6 of this Chapter apply to steel ships equipped for the recovery of oil floating on the sea with a flash point exceeding 60℃ (closed-cup test) and a Reid vapour pressure below atmospheric pressure, as required for the class notation in paragraph 3.1.2.3.

3.1.1.2 The ship is to be capable of the following operations at a safe distance from the source of oil spill:

(1) recovery of floating oil from the surface of the sea;

(2) handling, storage and transportation of the recovered oil.

3.1.1.3 The other auxiliary ships associated with operations of oil recovery ships may be dealt with by referring to this Chapter.

3.1.2 Class notations

3.1.2.1 Oil recovery ships equipped with means for the recovery and discharge of oil as well as with tanks for storing the recovered oil and complying with the requirements of Sections 1 to 5 of this Chapter will be assigned the class notation Oil Recovery Ship with Cargo Tank.

3.1.2.2 Oil recovery ships without tanks for storing the recovered oil equipped with means for the recovery, but not for discharge of oil and complying with the requirements of Sections 1 to 5 of this Chapter will be assigned the class notation Oil Recovery Ship without Cargo Tank.

3.1.2.3 Oil recovery ships equipped with means for the recovery of oil and complying with the requirements of Section 6 of this Chapter will be assigned the class notation Oil Recovery Ship not suitable for products with a flash point of 60℃ and less.

3.1.3 Definitions

3.1.3.1 Oil recovery ship means a steel ship specially or also engaged in the recovery of oil floating on the sea.

3.1.3.2 Gas-hazardous zone means an area in which flammable or explosive gas or vapor is liable to accumulate to a dangerous concentration. The gas-hazardous zones may be divided into the following categories:

(1) Hazardous zone of Category 0 means an area in which the mixture of flammable or explosive gas or vapor with air exists continuously or for long time.

(2) Hazardous zone of Category 1 means an area in which the mixture of flammable or explosive gas or vapor with air may occur during normal operation.

3.1.3.3 Source of oil spill means the source from which the oil floating on the sea originates, e.g. from an oil tanker, a submarine oil pipeline or an offshore drilling unit.

3.1.4 Division of gas-hazardous zones and safe areas

3.1.4.1 The following areas or spaces of oil recovery ships are to be regarded as gas-hazardous zones:

(1) Hazardous zones of Category 0:

① recovered oil tanks;

② the interiors of piping systems and containers of the containment system for recovered oil.

(2) Hazardous zones of Category 1:

① cofferdams or other spaces adjacent to any recovered oil tank (except for 3.2.2.6);

② enclosed or semi-enclosed spaces in which pipe flanges, valves, hoses, pumps and other equipment for handling of recovered oil are located;

③ spaces including semi-enclosed spaces on open deck within a 3 m radius of the separator, the hoses and valves used for oil recovery, the openings of recovered oil tanks and the openings of spaces within the hazardous zones of Category 1 such as recovered oil pump rooms or cofferdams. In addition, the relevant provisions for venting outlets of covered oil tanks are to be considered (refer to 3.3.3.2 of this Chapter);

④ space on open deck above recovered oil tanks, extending 3 m respectively fore and aft of this area to a height of 2.4 m;

⑤ any enclosed space outside a recovered oil tank, through which recovered oil piping passes or in which such piping terminates, may be excluded, provided that ventilation is fitted as specified in 3.2.5.4 of Section 2;

⑥ enclosed or semi-enclosed spaces which can be entered directly from hazardous zones of Category 1 (without air lock) or which have openings into hazardous zones of Category 1 may be excluded, provided that ventilation is fitted as specified in 3.2.5.4 of Section 2.

3.1.4.2 The areas outside the above-mentioned gas-dangerous zones are safe areas.

3.1.5 Plans and documents

3.1.5.1 The relevant plans and documents as specified in the relevant chapters of the Rules and in addition, the following ones are to be submitted for approval:

(1) General arrangement of equipment for oil recovery operations;

(2) Details of access doors (including air locks) and openings used in normal recovery operations and not fitted with gastight sealing;

(3) Details of access doors and openings closed gastight in oil recovery operations;

(4) Details of arrangement and capacity of recovered oil tanks;

(5) Division of gas-hazardous zones;

(6) Drawing of power system of the equipment used for oil recovery operations;

(7) Details of arrangement of piping, pumping and handling systems for recovered oil;

(8) Arrangement of venting system of recovered oil tank;

(9) Arrangement of electrical equipment in gas-hazardous zones;

(10) Operating manual (see Section 5 of this Chapter);

(11) Other plans and documents as deemed necessary.

Section 2 CONSTRUCTION AND FIRE SAFETY

3.2.1 Hull structures

3.2.1.1 The structures of oil recovery ships are to comply with the relevant requirements of Chapter 2, PART TWO of the Rules.

3.2.1.2 For integral recovered oil tanks, the thickness of the plane oiltight bulkhead plating is to comply with the requirements of 3.2.1.3 and 3.2.1.4, and other structural members of bulkhead are to comply with the relevant requirements of Chapters 5 and 6, PART TWO of the Rules.

3.2.1.3 The thickness t of the plane oiltight bulkhead plating of integral recovered oil tanks is not to be less than that obtained from the following formula:

$$t = 3.75s\sqrt{h} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, from lower edge of the plate in a strake to the tank top, but not less than $0.4D$.

3.2.1.4 The thickness t of the plane oiltight bulkhead plating of integral recovered oil tanks is also to comply with the following requirements:

(1) Where vertical stiffeners are fitted on the bulkhead:

$t \geq s/86$ mm, for the upper 3/4 of the bulkhead

$t \geq s/74$ mm, for the lower 1/4 of the bulkhead.

(2) Where horizontal stiffeners are fitted on the bulkhead:

$t \geq s/98$ mm, for the upper 3/4 of the bulkhead

$t \geq s/84$ mm, for the lower 1/4 of the bulkhead

where: s — spacing of stiffeners, in mm.

3.2.2 Arrangement of recovered oil tanks

3.2.2.1 Any tanks, which are also intended for other purposes and will not be utilized during oil recovery operations, are to be arranged so that recovered oil cannot be transferred to them inadvertently.

3.2.2.2 The position of tanks for recovered oil is to satisfy the following requirements:

(1) they are to be located outside the accommodation and machinery spaces;

(2) they are not to be located below the accommodation and machinery spaces;

(3) they are to be located forward or aft of the accommodation and machinery spaces of category A.

3.2.2.3 Except where permitted by 3.2.2.6, tanks for recovered oil are to be separated from accommodation and machinery spaces by cofferdams. Oil fuel tanks, settling tanks, tanks for ballast water or anti-pollution liquid, enclosed spaces where oil recovery handling equipment is stored, pump rooms for recovered oil and dry compartments other than accommodation spaces may be considered as a cofferdam. When oil fuel tanks or settling tanks are used as cofferdams, only one common boundary can be provided between each oil fuel tank or settling tank and the tank for recovered oil. The continuous butt welding is to be used for the bulkhead plating of the common boundary. Full penetration welding is to be used for the fillet weld at the connection of the bulkhead to the deck.

3.2.2.4 Cofferdams are to be at least one frame spacing in length (600 mm minimum) and are to cover the whole area of the boundary under consideration.

3.2.2.5 The height of tanks for recovered oil is not to be less than 1.5 m. Internal obstructions in the tanks are to be avoided to ensure a full flow of recovered oil. Adequate drainage openings are to be provided to ensure free flow of residues to assist in cleaning and gas freeing on completion of recovery operations. Any coating in the walls of tanks for recovered oil is to be of an oil and dispersion resistant type.

3.2.2.6 Where cofferdams are impractical to arrange in accordance with the requirements of 3.2.2.3 on board, any tank adjacent to other machinery spaces (except for machinery spaces of category A) or pipe tunnel may be accepted for storage of recovered oil, provided that:

(1) tank bulkheads are easily accessible for inspection;

(2) the continuous butt welding is to be used for the bulkhead plating, except that full penetration welding is used for the fillet weld at the connection of the bulkhead to the deck;

(3) other machinery spaces or pipe tunnels are to be fitted with mechanical ventilation giving at least 20 air changes per hour (calculated based on the tank capacity) and alarms for ventilation failure. The number of air changes required above is to be maintained in case of failure of any ventilation fan. Ventilation fans are to be of non-sparking type. The electric motor fitted in the ventilation duct is to be of certified safe type;

(4) tanks are to be subject to hydraulic testing at special surveys;

(5) the common boundary of tanks is to be subject to thickness measurement at special surveys if necessary.

3.2.2.7 All openings (sounding pipes, hatches for the deployment of portable recovered oil pumps and hoses) to tanks for recovered oil are to be located on open deck to prevent accumulation of oil vapour.

3.2.2.8 Tanks for recovered oil are to have suitable access from open deck for cleaning and gas-freeing, or small dedicated hatches for cleaning.

3.2.2.9 Tanks for recovered oil are in general to be provided with wash bulkheads in one of the following cases:

(1) 0.5*B* (*B* being breadth of the ship) is exceeded; or

(2) 0.1*L* (*L* being length of the ship) or 10 m is exceeded, whichever is the greater.

3.2.3 Access and other openings

3.2.3.1 Ventilation openings to safe spaces such as accommodation, service and machinery spaces, control stations and navigation bridge are not to be located inside gas-hazardous zones.

3.2.3.2 In general, no access door or any opening other than access openings and ventilation openings is to be permitted between safe spaces (such as accommodation, service and machinery spaces, control stations and navigation bridge) and gas-hazardous zones.

(1) Access doors may be accepted between such safe spaces and gas-hazardous zones of Category 1, provided that the following conditions are met:

① an air lock is to consist of two steel doors substantially gastight which are to be spaced not less than 1.5 m apart (watertight doors may be considered as gastight doors);

② safe spaces are under positive pressure mechanical ventilation in relation to the gas-hazardous zones;

③ the doors are to be self-closing and without any holding back arrangements;

④ signs are provided to warn that the doors are to be kept closed during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks.

(2) Any opening other than access openings and ventilation openings may be accepted between such safe spaces and gas-hazardous zones of Category 1, provided that the following conditions are met:

① the closing appliance is to be confirmed as gastight;

② signs are provided to warn that they are to be kept closed during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks, and means are provided to prevent unauthorized opening.

3.2.3.3 Where the access doors mentioned in 3.2.3.2 above are not used as the means of escape specified in statutory requirements and they will not be used (opened) during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks (including accidental and emergency conditions the ship might encounter during the operations), air locks may not be fitted. In addition to complying with the requirement that the doors are to be self-closing and without any holding back arrangements, the following requirements are at least to be met:
(1) gastight closing can be achieved, which has been confirmed;
(2) signs are provided to warn that the doors are to be kept closed during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks, and means are provided to prevent unauthorized opening.
3.2.3.4 Oil handling spaces on deck are to be provided with a coaming around all recovered oil pumps, transfer flanges and other connections. Each coaming is to have a height sufficient to prevent recovered oil from entering accommodation, machinery, control and service spaces or passing overboard. The coaming is to have a height of at least 150 mm. Where drains are provided for the coaming, closing devices for these drains are to be permanently attached.

3.2.4 Fire protection and extinction

3.2.4.1 For vessels with tanks for recovered oil forward of superstructures, exterior boundaries of superstructures and deckhouses enclosing accommodation, including any overhanging decks which support such accommodation, are to be insulated to A-60 class standard for all parts which face deck areas where there are arrangements for collection, handling and transfer of recovered oil as well as exterior surfaces within 3 m from the ends of boundaries facing these areas. The requirement is also applicable for access doors in such boundaries.
3.2.4.2 For vessels with tanks aft of superstructures, exterior boundaries of superstructures and deckhouses enclosing accommodation, situated within 10 m of the nearest tank for recovered oil, including any overhanging decks which support such accommodation, are to be insulated to A-60 class standard for all parts which face deck areas where there are arrangements for collection, handling and transfer of recovered oil as well as exterior surfaces within 3 m from the ends of boundaries facing these areas.
3.2.4.3 Portholes or windows in the exterior boundaries which are required to be insulated to A-60 class standard, as referred to in 3.2.4.1 of this Section, are to be of fixed (non-opening) type and are to be insulated to A-60 class standard, except for those in the navigation bridge.
3.2.4.4 As an alternative to compliance with 3.2.4.1 and 3.2.4.2, a fixed water spraying system may be used to protect all boundaries, portholes or windows which may, in this case, be insulated to A-0 class standard. The system is to be capable of delivering water at a rate of 10 *l*/min per m^2 at least and is to be readily available.
3.2.4.5 Working deck areas used for oil recovery operations, where there are arrangements for the collection, handling and transfer of recovered oil, are to be provided with the following fire-extinguishing equipment:
(1) two dry powder fire-extinguishers, each at least 50 kg capacity. The fire-extinguishers are to be located near the working deck and are to be fitted with discharge hoses having a length sufficient to reach the arrangements for the collection, handling and transfer of recovered oil;
(2) a large fire-extinguishing foam installation fitted with at least one portable foam applicator. The foam installation is to be so arranged that it is capable of applying foam to any part of the working deck. The capacity of any applicator is to be not less than 400 *l* /min of foam solution and the applicator throw in still air conditions is to be not less than 15 m. Sufficient foam concentrate is to be provided for at least 0.4 *l* /m^2 of the working deck area with a minimum quantity of 200 *l*. The foam expansion ratio is generally not to exceed 12 to 1.
3.2.4.6 Each recovery oil pump-room is to be provided with a fixed fire-extinguishing system suitable for machinery spaces of category A. The system controls are to be operated from a readily accessible position outside the pump-room. Where a carbon dioxide system is used, the quantity of carbon dioxide is to be sufficient to give a minimum volume of free gas equal to 45% of the gross volume of the tanks for recovered oil. A notice is to be exhibited at the controls stating that, due to the electrostatic ignition hazard, the system is to be used only for fire extinguishing and not for inerting purposes.
3.2.4.7 Oil recovery ships are to carry at least four fire-fighter's outfits.

3.2.5 Mechanical ventilation

3.2.5.1 The design, type and structure of mechanical ventilation systems may be dealt with in accordance with the relevant requirements for oil tankers.

3.2.5.2 Spaces with access to hazardous zones of Category 1 are to be kept under positive pressure mechanical ventilation during oil recovery operations, with the air intake located inside a safe area.
3.2.5.3 Spaces in hazardous zones of Categories 0 and 1 that are not frequently used during oil recovery operations are not to be ventilated, provided that the equipment therein is provided with the required explosion protection. For safety reasons, spaces in hazardous zones of Categories 0 and 1 that must be accessible at all times are to be equipped with a ventilation system of the extraction type, ensuring at least 8 air changes per hour.
3.2.5.4 Hazardous zones of Category 1 as specified in 3.1.4.1(2)⑤, ⑥ of Section 1 of this Chapter may be accepted as safe areas, provided that the following special ventilation requirements are complied with and positive pressure mechanical ventilation is maintained:
(1) the ventilation airflow is to be at least 20 air changes per hour;
(2) the arrangement of ventilation inlet and outlet openings in a space is to be such that the entire space is efficiently ventilated, taking special consideration to locations where gas may be released or may accumulate;
(3) the air intake is to be located in a safe area.
3.2.5.5 For the spaces required to be under positive pressure ventilation, audible and visual alarms are to be initiated at the navigation bridge or other suitable positions in case of loss of positive pressure ventilation.

3.2.6 Gas detection and alarm system
3.2.6.1 For the purpose of explosion protection, the ship is to be equipped with a permanently installed gas detection system, which will actuate an audible and visual alarm at the navigation bridge, open deck or other suitable positions when a concentration of hydrocarbon gas or similar products equal to 30% of the lower explosion limit (LEL) is exceeded.
Detection points may be arranged according to specific circumstances, generally close to ventilation air intakes, in air locks and on the main deck (at least one at the fore end and one at the aft end of the ship).
3.2.6.2 In addition to the above gas detection system, at least one portable instrument is to be available on board for gas detection.

Section 3 MACHINERY INSTALLATIONS

3.3.1 General requirements
3.3.1.1 All machinery equipment used in gas-hazardous zones during oil recovery operations is to be suitable for operation in gas contaminated atmosphere.
3.3.1.2 The exhaust lines of diesel engines, the flue ducts of boilers and the vents of diesel engine crankcases are to be led to a position outside the gas-hazardous zones as described in 3.1.4 of Section 1.
3.3.1.3 The exhaust lines of diesel engines and the flue ducts of boilers are to be provided with effective spark arresters.

3.3.2 Transfer system for recovered oil
3.3.2.1 A fixed transfer system for recovered oil is to be provided. The transfer system is to be arranged such that simultaneous filling and discharge will be possible. Unless provided otherwise, the transfer system for recovered oil is to be independent of all other piping systems onboard.
3.3.2.2 For coupling of portable skimming equipment, one or maximum two filling connections with branch pipes to all recovered oil tanks are to be arranged on deck.
3.3.2.3 Where recovered oil transfer pumps are driven by shafting which passes through a pump room bulkhead or deck, gastight glands are to be fitted to the shaft at the pump room plating. The glands are to be capable of being lubricated from outside the pump room and are to be so designed as to prevent overheating. The seal parts of the glands are to be of materials that will not initiate sparks. Where a bellows piece is incorporated in the design, it is to be hydraulically tested to 0.34 MPa before being fitted.
3.3.2.4 All recovered oil transfer pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be so arranged as to discharge back to the suction side of the pump, and to effectively limit the pump discharge pressure to the design pressure of the system.
3.3.2.5 One pressure gauge for each recovered oil transfer pump is to be located at the pump discharge and, where the pumps are capable of being operated from outside the pump room, an additional gauge is to be provided which is to be visible from the operating station.

3.3.2.6 Piping systems related to oil recovered are to be arranged as follows:
(1) piping systems related to oil recovered are not to pass through machinery and accommodation spaces;
(2) piping systems related to oil recovered are not to pass through drinking water tanks, boiler water tanks or other tanks. Where it is unavoidable for piping systems to pass through other tanks, the portions of pipelines within tanks are to be all-welded extra thick pipes without valves, flanges, fittings or slip joints (see for wall thickness requirements in Table 5.3.4.2 of Chapter 5, PART THREE of the Rules).

3.3.3 Venting arrangements of tanks for recovered oil

3.3.3.1 Every tank for recovered oil is to be fitted with a vent pipe or other equivalent venting arrangement. The vent pipes are to be sized for 125% of the maximum loading rate to prevent the pressure in any recovered oil tank from exceeding the design pressure; however, the diameter of each vent pipe is to be not less than 60 mm. Venting outlets are to be led to open deck. Gas from the outlets is to be discharged directly upwards.
3.3.3.2 The outlets are to have a minimum height of 2.4 m above deck and be located at a minimum horizontal distance of 5 m away from openings to accommodation and other gas-safe spaces, ventilation intakes for accommodation and machinery spaces and non-certified safe electrical equipment.
3.3.3.3 The end of vent pipes is to be fitted with a corrosion resistant flameproof wire gauze capable of being easily renewed.
3.3.3.4 Vent pipes are also to comply with the applicable requirements of Chapter 3, PART THREE of the Rules.
3.3.3.5 For multi-purpose oil recovery ships, portable vent pipes intended for use during oil recovery operations only, may be accepted.

3.3.4 Other systems related to recovered oil

3.3.4.1 Tanks for recovered oil are to be fitted with suitable means for determining the level within the tanks. Sounding pipes, if fitted for this purpose, are to terminate in the open air above freeboard deck. The internal diameter of sounding pipes is not to be less than 50 mm.
3.3.4.2 Provisions are to be made to guard against liquid rising in recovered oil tanks to a height which would exceed the design head of the tanks. This may be accomplished by high-level alarms or overflow control systems or other equivalent means, together with independent gauging devices and tank filling procedures. The high level alarm is to be capable of giving an audible and visual alarm at the recovered oil control station.
3.3.4.3 The heating systems and other steam pipelines fitted to recovered oil tanks are to comply with the relevant requirements of Chapter 5, PART THREE of the Rules.
3.3.4.4 Bilge drainage of the recovered oil transfer pump room and the cofferdam within the gas-hazardous zones is to be effected by powered pumps or bilge ejector suctions independent of the bilge drainage system of safe spaces. The pump room bilge is to be drained into the tanks for recovered oil.
For oil recovery ships of not more than 500 gross tons, the pump room bilge may be drained by a hand pump having at least a 50 mm bore suction.
3.3.4.5 The ballast piping system serving gas-hazardous zones is to be independent of that serving safe spaces. The ballast pump is to be located in the recovered oil pump room or other suitable gas-hazardous space.

3.3.5 Machinery equipment and systems in gas-hazardous zones

3.3.5.1 The oil recovery equipment and hoses are to be electrically bonded into the ship's hull. The cross-sectional area of the metallic bonding strap is to be not less than 10 mm^2.
3.3.5.2 Hoses are to be electrically well conductive.
3.3.5.3 No sparks are allowed during operation of the oil recovery equipment.
3.3.5.4 Surface temperature of the equipment is not to exceed 200℃.

Section 4 ELECTRICAL INSTALLATIONS

3.4.1 General requirements

3.4.1.1 Unless specified otherwise in this Section, electrical equipment, cables and distribution systems are to comply with the relevant requirements of Section 16, Chapter 2 of PART FOUR of the Rules.
3.4.1.2 The equipment used for oil recovery operation and deck areas used for storing hoses are to have adequate lighting.

3.4.1.3 The power distribution systems of oil recovery ships having the notation Oil Recovery Ship without Cargo Tank are to comply with Section 4, Chapter 2 of PART FOUR of the Rules.

3.4.2 Electrical equipment in gas-hazardous zones

3.4.2.1 The use of electrical appliances in gas-hazardous zones as specified in 3.1.4 of Section 1 is to be restricted to operationally essential equipment and is to comply with Table 3.4.2.1.

Electrical Equipment Permitted in Gas-Hazardous Zones Table 3.4.2.1

Category of hazardous zones	Type of electrical equipment	Cable
0	Intrinsically safe Ex" ia"	Cables associated with intrinsically safe equipment in such zones
1	Intrinsically safe Ex" ia", Ex" ib"	Cables associated with the equipment in such zones; through runs of cables
	Flameproof Ex" d"	
	Increased safety Ex" e"	
	Pressurized enclosure Ex" p"	
	Powder filled Ex" q"	
	Encapsulated Ex" m"	

3.4.2.2 The explosion-proof electrical equipment listed in Table 3.4.2.1 is to meet at least the following requirements:

Temperature class T3;

Equipment group II A.

3.4.2.3 All equipment not complying with 3.4.2.1 of this Section and located in the gas-hazardous zones as specified in 3.1.4 of Section 1 are to be disconnected during oil recovery operation. The switches for such disconnection are to be safeguarded against unintentional re-connection and appropriately marked to that effect.

3.4.2.4 The flexible cables without armor or metal braid may be applied in zones of Category 1, provided that the construction and installation of such cables are to comply with acceptable standards①, as appropriate.

3.4.2.5 Portable oil recovery equipment and recovered oil pumps are to comply with the following requirements:

(1) Portable oil recovery equipment and recovered oil pumps are to be supplied from a permanently installed distribution box or socket outlet.

(2) Socket outlets for power circuits are to be interlocked in such a way that the plug can be neither inserted nor withdrawn when the socket contacts are live.

(3) The socket outlet as the separate final sub-circuit is to be provided with a circuit breaker capable of overcurrent and short-circuit protection in each insulated phase. The supply to the socket-outlet is to be permanently installed.

(4) Socket outlets are to be located at easily accessible places and in such a way that flexible cables are not carried through doors or portlights leading from working deck to machinery or accommodation spaces.

Section 5 OPERATING MANUAL

3.5.1 Operating manual

3.5.1.1 The ship is to be provided with an approved operating manual. In general, the operating manual is to contain a description of the safety precautions needed when preparing for and carrying out oil recovery operations.

3.5.1.2 The operating manual for oil recovery ships is to include:

(1) Equipment and arrangement

① arrangement of recovered oil tanks;

② transfer system for recovered oil;

③ gas-measuring instrument;

④ other associated units of equipment.

(2) Preparations for operation

---

① Refer to IEC publication 60079-14: Explosive atmospheres – Part 14: Electrical installations design, selection and erection.

① checking all equipment on board to determine compliance with 3.3.1.1 of Section 3 and 3.4.2.1 of Section 4;
② mounting and fastening of non-permanent equipment;
③ blanking off particular pipes;
④ assembling air pipes;
⑤ disconnecting power supply to those electrical installations not complying with 3.4.2.1 of Section 4;
⑥ closing openings between safe areas and gas-hazardous zones;
⑦ starting up additional ventilation equipment;
⑧ changeover to low suction for cooling water pumps;
⑨ displaying signs to the effect that open flame, non-certified explosion-proof electrical equipment, etc. are prohibited.

(3) Oil recovery operation
① guidance on safe distance from an oil spill source and relevant notes;
② gas measurements during operation (on open deck and in spaces where gas may accumulate). If gas is traced on open deck, the ship is to move away immediately;
③ actions to be taken for cleaning, ventilation, emptying adjacent tanks, etc., if gas is traced in any enclosed space;
④ emergency measures to be taken in case of failure of positive pressure ventilation;
⑤ precautions against overfilling of recovered oil tanks;
⑥ discharging.

(4) Cleaning and gas-freeing of recovered oil tanks and pipes.

Section 6 OIL RECOVERY SHIPS CARRYING RECOVERED OIL HAVING A FLASH POINT EXCEEDING 60℃

3.6.1 General requirements

3.6.1.1 Ships engaged exclusively in the recovery of oil having a flash point exceeding 60℃ are to comply with the relevant requirements of Sections 1 (excluding paragraph 3.1.4) and 5 of this Chapter, and the following additional requirements.

3.6.2 Construction and fire safety

3.6.2.1 Ships engaged exclusively in the recovery of oil having a flash point exceeding 60℃ are to comply with the requirements of Chapter 2, PART TWO of the Rules.

3.6.2.2 The fire safety of ships engaged exclusively in the recovery of oil having a flash point exceeding 60℃ are to comply with the relevant requirements for cargo ships and the following additional requirements:

(1) In working deck areas, fire-extinguishing equipment required in 3.2.4.5 of this Chapter is to be provided in lieu of the fixed fire-extinguishing system required for cargo spaces of cargo ships.

(2) All openings of tanks for recovered oil are to be located in accordance with the requirements of 3.2.2.7 of this Chapter.

(3) Spill coamings and drains are to be provided in accordance with the requirements of 3.2.3.4 of this Chapter.

(4) Fire-fighter's outfits are to be provided in accordance with the requirements of 3.2.4.7 of this Chapter.

(5) At least one portable instrument is to be available on board for gas detection.

3.6.3 Machinery installations

3.6.3.1 For ships engaged exclusively in the recovery of oil having a flash point exceeding 60℃, paragraphs 3.3.2.1, 3.3.2.2, 3.3.2.4, 3.3.2.5, 3.3.2.6, 3.3.4.1, 3.3.4.2 and 3.3.4.3 of this Chapter are applicable. However, subparagraph 3.3.2.6(1) may be replaced by the following:

(1) piping systems related to oil recovered are not to pass through machinery and accommodation spaces as far as practicable; where this is unavoidable, the arrangement of such piping systems within machinery spaces is to comply with the requirements for fuel oil piping systems.

3.6.3.2 The venting arrangements of tanks for recovered oil are to comply with the requirements of 3.3.3 of this Chapter, or the requirements for fuel oil tanks in Chapter 3, PART THREE of the Rules.

3.6.4 Electrical installations

3.6.4.1 The additional requirements for electrical installations of ships engaged exclusively in the recovery of oil having a flash point exceeding 60℃ are to be in compliance with 2.16.7 of Section 16, Chapter 2, PART FOUR of the Rules.

CHAPTER 4 SHIP BRIDGE DESIGN AND EQUIPMENT

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.1 This Chapter applies to ships applying for the notations as specified in 4.1.2 of this Chapter..

4.1.1.2 The provisions of this Chapter are not to prevent the ship from complying with the relevant IMO conventions, codes and requirements of the Administration of the Flag State.

4.1.2 Notations

4.1.2.1 Ships of which bridge design and equipment installed complying with the following provisions may be assigned with the following notations upon application:

(1) BDE-1 is applicable to ships complying with the basic design requirements, working environment and the required equipment to be installed in Sections 1 to 5 of this Chapter;

(2) BDE-2 is applicable to ships complying with the requirements in Sections 1 to 6 of this Chapter;

(3) BDE-3 is applicable to ships of which the bridge is fitted with the Integrated Bridge System (IBS) complying with requirements in Sections 1 to 7 of this Chapter.

4.1.3 Definitions

4.1.3.1 For the purpose of this Chapter:

(1) Workstation means position at which one, or several tasks constituting a particular activity are carried out.

(2) Navigator means person navigating, operating bridge equipment and manoeuvring the ship.

(3) Back-up navigator means any individual, generally an officer, who has been designated by the ship’s master to be on call if assistance is needed on the navigation bridge.

(4) Officer of the watch means person responsible for operating of bridge equipment and manoeuvring of the ship.

(5) Bridge means that area from which the navigation and control of the ship is exercised, including the wheelhouse and bridge wings.

(6) Wheelhouse means enclosed area of the bridge.

(7) Bridge wings are those parts of the bridge on both sides of the ship’s wheelhouse which, in general, extend to the ship’s side.

(8) Field of vision means angular size of a scene that can be observed from a position on the ship’s bridge.

(9) Lookout means activity carried out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision.

(10) Watch alarm means alarm that is transferred from the bridge to the master and the back-up navigator in case of any officer of the watch deficiency (absence, lack of alertness, no response to another alarm/warning, etc.).

(11) Workstation for navigation manoeuvring means a workstation with a commanding field of vision used by a navigator during course monitoring, traffic monitoring, course change and speed change, which can monitor the ship's safety condition.

(12) Workstation for monitoring means a workstation that facilitates the operation of equipment and observation of the ship's heading, speed, water and traffic with a commanding field of vision, including means necessary for route monitoring, to be used by the officer of the watch, backup navigator or pilot as needed for effective bridge team operation. The station may be considered as part of the workstation for navigation manoeuvring when paper charts or ECDIS are used for route monitoring.

(13) Workstation for manual steering means a workplace where the helmsman manually controls the ship's required ield of vision, indicators and equipment according to the instructions given by the navigator in charge of bridge operation.

(14) Workstation for docking means a workplace on the bridge wing that provides the field of vision and information required to control ship manoeuvring, tug operation and mooring operation along the berth.

(15) Workstation for plan development means a workplace used to plan the route of the entire voyage from place of departure to place of destination and to record the bridge operations during the voyage.

(16) Workstation for safe operation means a workplace dedicated to the organization and control of onboard emergency and distress operations with easy access to external and internal communications and information relevant to the safe status of the ship.

(17) Workstation for communication means a workplace for the operation and control of Global Maritime Distress and Safety System (GMDSS) equipment and on-board communications for ship operation under normal and emergency conditions.
(18) Commanding field of vision means the field of view within which there is no obstacle to the ability of the on-duty navigator and pilot to perform their main tasks, and it is at least to provide the field of vision required by the safe performance of collision avoidance function. It is required that the sea field of vision from the front of the bow to 10° of either side of the ship is not to be obscured by more than two ship's lengths or 500 m, whichever is less, and that the horizontal view extends to a sector of at least 225°, that is, from dead ahead to either side of the ship is not less than 22.5° abaft the beam.
(19) Command position means a position located in the bridge, to monitor and guide the ship through the narrow water and buoy channel by visual observation, and provide the commanding field of vision, close field of vision of the sea surface and the information needed for maneuvering.
(20) Ship length means the length as defined in Reg.3.10, Chapter 1 of the International Regulation for Prevention Collision at Sea, 1972 , i.e. overall length of the ship.

4.1.4 Plans and documents

4.1.4.1 The following plans and documents are to be submitted for approval:
(1) Bridge visibility calculations, including scantlings of bridge, inclination and dimensions of windows and dimensions of consoles and so on;
(2) Arrangement of bridge, including positions of workstations, navigational equipment and consoles etc.;
(3) Arrangement of console panels;
(4) Diagram of power supply system for navigational equipment, internal communication equipment etc.;
(5) layout and power supply of cameras, where applicable.

Section 2 BRIDGE LAYOUT

4.2.1 General requirements

4.2.1.1 The bridge configuration, the arrangement of consoles and equipment locations is to enable the officer of the watch to perform navigational duties and other functions allocated to the bridge as well as maintain a proper lookout from a convenient position on the bridge.
4.2.1.2 A workstation for navigation manoeuvring is to be arranged to enable efficient operation by one person under normal operating conditions. All relevant instrumentation and controls are to be easily visible, audible and accessible from related workstations.
4.2.1.3 The bridge layout and design of workstations are to enable the ship to be navigated and manoeuvred safely by two navigators in cooperation.
4.2.1.4 External sound signals and fog signals from outside the ship that are audible on the open deck, are also to be audible inside the wheelhouse; a transmitting device is to be provided to reproduce such signals inside the wheelhouse (recommended frequency range: 70 Hz to 700 Hz).
4.2.1.5 A workstation for navigation manoeuvring is to be arranged on the starboard side near the center line, where applicable..
4.2.1.6 A workstation for monitoring is to be arranged on the port side near the center line, where applicable..
4.2.1.7 A Workstation for manual steering is to generally be located at the center line of the ship.
4.2.1.8 Sufficient manoeuvring positions are to be provided near the middle front window. If the view in the center line is obstructed by large masts, cranes, etc., two manoeuvring positions with a clear forward view are to be provided, one at the left side of the center line and the other at the right side, spaced not more than 5 m.

4.2.2 Field of vision

4.2.2.1 In order to obtain sufficient field of vision for safe navigation and manoeuvring of the ship, every effort is to be made to place the bridge above all other decked superstructures.
4.2.2.2 The view of the sea surface from the workstations for navigation manoeuvring is not to be obscured by more than two ship's lengths or 500 m, whichever is less, forward of the bow to 10º on either side, irrespective of the ship's draught, trim and deck cargo, as shown in Figure 4.2.2.2.

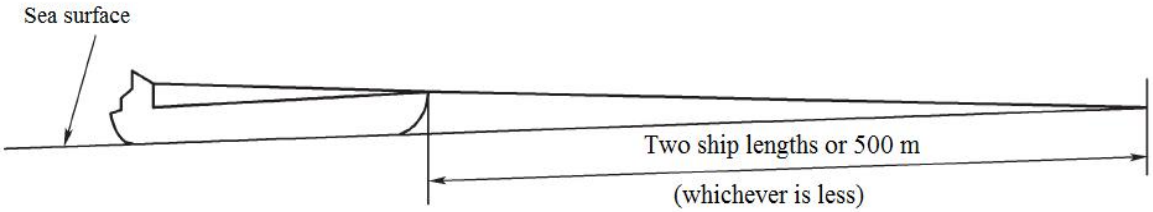


Figure 4.2.2.2 Forward View

4.2.2.3 No blind sector caused by cargo, cargo gear or other obstructions outside of the wheelhouse forward of the beam which obstructs the view of the sea surface as seen from the workstations for navigation manoeuvring is not to exceed 10º. The total arc of blind sectors is not to exceed 20º. The clear sectors between blind sectors are to be at least 5º. However, in the view described in 4.2.2.2, each individual blind sector is not to exceed 5º.

4.2.2.4 The horizontal field of vision from the workstations for navigation manoeuvring is to extend at least over an arc from 22.5º abaft the beam on one side, through forward, to 22.5º abaft the beam on the other side, as shown in Figure 4.2.2.4.

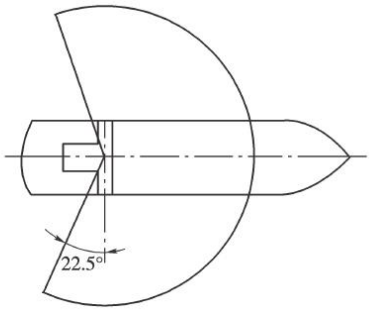


Figure 4.2.2.4 Field of Vision from the Workstations for Navigation Manoeuvring

4.2.2.5 The horizontal field of vision from the workstation for manual steering is to extend over an arc from right ahead to at least 60º on each side of the ship, as shown in Figure 4.2.2.5.

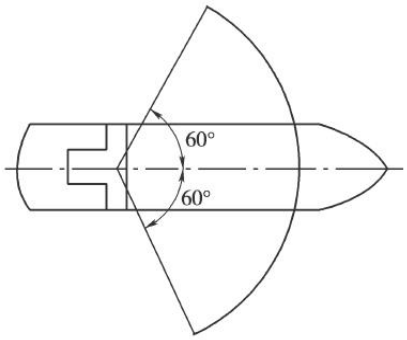


Figure 4.2.2.5 Horizontal Field of Vision from the Workstation for Manual Steering

4.2.2.6 The horizontal field of vision from workstation for docking is to extend over an arc from 45º on the opposite bow through dead ahead and then aft to 180º from dead ahead, as shown in Figure 4.2.2.6.

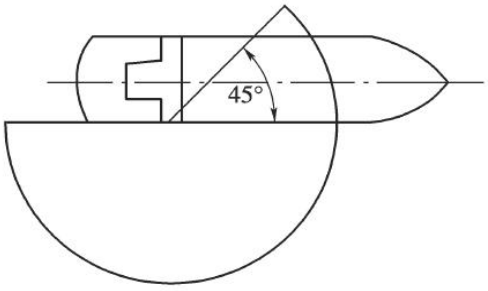


Figure 4.2.2.6 Horizontal Field of Vision From the Workstation for Docking

4.2.2.7 At a workstation for monitoring, the field of vision is to enable the officer of the watch to maintain a proper lookout. The field of vision is to extend at least over an arc from 90º on port bow, through forward, to 22.5º abaft the beam on starboard, as shown in Figure 4.2.2.7.

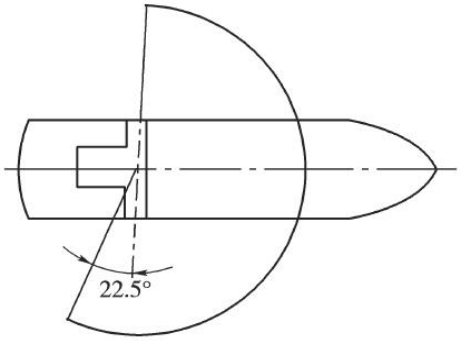


Figure 4.2.2.7 Field of Vision form Workstations for Monitoring

4.2.2.8 The ship's side is to be visible from the bridge wing.①

4.2.3 Windows

4.2.3.1 All windows in the wheelhouse are to be of shatter-proof reinforced glass, the thickness of which is to comply with acceptable standards②. Polarized and stained glass windows are not to be installed.

4.2.3.2 Windows are to be as wide as possible. Framing between windows is to be kept to a minimum and not installed immediately forward of any workstation.

4.2.3.3 To help avoid reflections, the bridge front windows are to be inclined as possible from the vertical plane top out, at an angle of not less than 10º and not more than 25º. Alternative means are to be approved by CCS.

4.2.3.4 The height of the lower edge of front windows is to allow a forward view above the bow from the workstation for navigation manoeuvring. To achieve this, the height of the lower edge above the deck is not to exceed 1 m as practicable.

4.2.3.5 The upper edge of the navigation bridge front windows are to allow a forward view of the horizon, for a person with a height of eye of 1.8 m above the bridge deck at the conning position, when the ship is pitching in heavy seas. If deemed that a height of eye of 1.8 m is unreasonable and impractical, reduction of the height of eye may be allowed, but not to less than 1.6 m.

4.2.3.6 At all times, regardless of weather conditions, at least two windows in front of the workstations for navigation manoeuvring, monitoring and docking (if practical) are to provide a clear view.

4.2.3.7 To ensure a clear view in bright sunshine, sunscreens of roller blind type with minimum colour distortion are to be affixed to windows that are within the required field of vision from the workstations. Such screens are to be readily removable and not to be permanently fixed.

4.2.3.8 At least two windows in front of the workstations for navigation manoeuvring, monitoring and docking (where applicable) are to be provided with efficient cleaning, de-icing and de-misting systems to ensure a clear view under all operating conditions.

4.2.3.9 A safe external passageway or similar arrangement is to be provided under the bridge front window to enable cleaning in the event of failure of the systems specified in 4.2.3.8 of this Section.

4.2.4 Layout and dimensions

4.2.4.1 The design of the net height of the wheelhouse ceiling is to take into account the overhead mounted panels and equipment. There is to be at least 2.25 m between the wheelhouse deck and the ceiling beams. The lower edge of ceiling mounted equipment is to be at least 2.1 m above the deck of open areas, walkways and standing-type workstations.

4.2.4.2 Workstations are to be divided into two areas as far as possible:

(1) the vertical (tilted) part so that the display is in a position that is easy to read;

(2) the horizontal part (table top) so that the controller, switch and button are within easy reach of the working position.

---

① Refer to IMO MSC.1/Circ.1350/Rev.1.

② Refer to ISO 21005 Ships and marine technology − Thermally toughened safety glass panes for windows and sidescuttles.

4.2.4.3 The height of the console desktop of the workstation for navigation manoeuvring and the workstation for monitoring is to make it easy to use the equipment required for safe execution of the tasks performed from the standing and sitting positions.
4.2.4.4 The chart table is to be large enough to accommodate all nautical chart sizes in common use internationally, and appropriate lighting is to be provided.
4.2.4.5 Instruments and equipment operated by the navigator at the workstation for navigation manoeuvring are to be within reach of the manoeuvring.
4.2.4.6 Instruments, indicators and displays providing information considered essential for the safe and efficient performance of tasks at the workstation for navigation manoeuvring are to be easily readable from this workstation.

4.2.5 Passageways

4.2.5.1 A passageway through the wheelhouse from bridge wing to bridge wing is to be provided. The width of the passageway is to be at least 1200 mm, but if there are obstacles on the route of the passageway, the width of the passageway at the obstacle can be reduced to 700 mm without affecting the staggered passage of two wheelhouse personnel.
4.2.5.2 The distance between adjacent workstations is to be sufficient to allow the unimpeded passage of persons not working at the station. The passage space of the corridor between different workstation areas is to be at least 700 mm. The workstation operation area is to be a part of the workstation, not a passageway.

4.2.6 Doors

4.2.6.1 Doors to the bridge are to be capable of being secured from inside and manually operated. Doors to the bridge wings are not to be self-closing and means are to be made to keep them open.

Section 3 WORKING ENVIRONMENT

4.3.1 Lighting

4.3.1.1 An adequate level of lighting facilitating the performance of all bridge tasks at daytime and nighttime is to be provided. With illumination inside the equipment or the lighting system in the wheelhouse, controls, indicators, instruments, keyboard etc. are to be clearly visible.
4.3.1.2 All lighting of instruments, keyboards and controls are to be adjustable down to zero, except the lighting of alarm indicators and the control of dimmers, which are to remain readable.
4.3.1.3 The lighting on the bridge is to be supplied by two exclusive circuits, with one of which fed from an emergency source of electrical power, in such a way that failure of any one of the circuits does not leave the bridge in darkness.
4.3.1.4 The lighting on the bridge is to be designed so as not to impair the night vision of the officer on watch. Lighting used in areas and at items of equipment requiring illumination whilst the ship is navigating is to be such that night vision adaptation is not impaired, e.g. red lighting. Such lighting is to be arranged so that it cannot be mistaken for a navigation light by another ship. It is to be noted that red lighting is not to be fitted over the chart table so that possible confusion in colour discrimination is avoided.
4.3.1.5 High contrast between the brightness of the working area and the surrounding environment is to be avoided, that is, the brightness of the working area is not to be greater than 3 times the average brightness of the surrounding area.
4.3.1.6 Lighting sources are to be designed and positioned to avoid glare on working and display surfaces. The light sources are not to produce a detectable flicker.

4.3.2 Personnel safety precautions

4.3.2.1 The bridge area is to be free of physical hazards to bridge personnel. There are to be no sharp edges or protuberances which could cause injury to personnel. The wheelhouse, bridge wings and bridge deck are to be free of trip hazards and to have a non-slip surface whether it is wet or dry.
4.3.2.2 Sufficient hand-rails or equivalent thereto are to be fitted in the wheelhouse and around workstations to enable personnel to move or stand safely in bad weather. Special consideration is to be given to the protection of stairway openings.
4.3.2.3 For seating in the wheelhouse, means for securing are to be provided.
4.3.2.4 All safety equipment on the bridge is to be clearly identified and easily accessible and its storage location is to be clearly indicated.

4.3.3 Temperature and humidity

4.3.3.1 According to climate, adequate air-conditioning or mechanical ventilation system and efficient heating system are to be provided to maintain the temperature in the wheelhouse within the range of 14℃~ 30℃. The controls of these systems are to be fitted in the wheelhouse.
4.3.3.2 Air flow from air conditioning and heating systems to the workplace is to be avoided.

4.3.4 Noise
4.3.4.1 The noise level on the bridge is not to interfere with verbal communication, mask audible alarms or be uncomfortable to bridge personnel. The noise level in the wheelhouse is not to exceed 65 dB(A) in good weather. However, the noise level in the communication workstation) is not to exceed 60dB(A).

4.3.5 Vibration
4.3.5.1 The vibration level on the bridge is not to be uncomfortable to the bridge personnel.

4.3.6 Glare-free
4.3.6.1 A glare-free coating is to be applied on the front surface of bulkheads, deckhead, consoles, chart table and other essential equipment. Means are to be provided to prevent dimming of the information shown by visual displays and instruments covered by transparent sheeting.

Section 4 WORKSTATIONS

4.4.1 General requirements
4.4.1.1 According to its functions, the ship bridge can be divided into workstation for navigation manoeuvring, workstation for monitoring, workstation for manual steering, workstation for planning development, workstation for communication, workstation for docking and workstation for safe operation.
4.4.1.2 The workstation for navigation manoeuvring, workstation for monitoring and workstation for manual steering are functionally related and generally close to each other, so there is no need to re-equip these stations with relevant equipment.

4.4.2 Workstation for navigation manoeuvring
4.4.2.1 The workstation for navigation manoeuvring is generally to be provided with the following equipment:
(1) radar / ARPA;
(2) display of positioning system;
(3) depth indicator;
(4) speed and distance indicator;
(5) display of gyro compass system;
(6) wind direction and speed indicator;
(7) indicator of steering gear and rudder angle;
(8) rate-of-turn indicator;
(9) course and track monitoring system;
(10) controls and indicators for main and athwartship propulsion;
(11) verification device and manually activating device used for bridge navigation watch alarm system (BNWAS);
(12) an internal communication system (see 4.5.5);
(13) VHF radiotelephone installation;
(14) clock;
(15) window wipe and wash control device;
(16) navigation light control;
(17) whistle control device;
(18) Morse lamp key;
(19) lighting control of wheelhouse and equipment;
(20) display for the Automatic Identification System (AIS)；
(21) a device that stops sending Long-Range Identification and Tracking (LRIT) messages, if applicable;
(22) Electronic Chart Display and Information System (ECDIS);
(23) night vision equipment, if applicable.
4.4.2.2 The ship is to be provided with two separate and independent radar systems. At least one of the radars is to operate within the X-band. The radars are to be capable of detecting and clearly indicating any

input signal loss (e.g. video or azimuth signal). The ship is also to be equipped with an ARPA system which may be independent or built into the radar equipment.
4.4.2.3 At least two positioning systems capable of continuously displaying latitude and longitude are to be fitted, one of which is to be electronic positioning system with global coverage and the other is to be electronic positioning system with differential correction function.
4.4.2.4 An off-course alarm independent of automatic steering system is to be provided. Where an automatic track-keeping system is provided, an off-course alarm may be initiated by the positioning system in case of deviation from the planned route to the set distance.
4.4.2.5 Where an automatic track-keeping system is provided, a pre-warning is to be given at the approach of a way-point so that the back-up navigator will have sufficient time to reach the wheelhouse for acknowledging course alteration in case of any officer of the watch deficiency. The course is not to be automatically altered without prior confirmation.

4.4.3 Workstation for monitoring

4.4.3.1 The workstation for monitoring is generally to be provided with the following equipment:
(1) radar /ARPA;
(2) the display of the depth sounder;
(3) speed and log display;
(4) compass display;
(5) steering gear and rudder angle indicator;
(6) rotation rate indicator;
(7) controllers and indicators for main propulsion and side push;
(8) BNWAS confirmation device and manual starting device;
(9) Internal communication system (see 4.5.5);
(10) VHF radio telephone;
(11) time indicator;
(12) window cleaning controller;
(13) air whistle controller.

4.4.4 Workstation for manual steering

4.4.4.1 The workstation for manual steering is generally to be provided with the following equipment:
(1) steering wheel/helmsman's handle;
(2) steering gear selection switch;
(3) compass display;
(4) steering gear and rudder angle indicator;
(5) rotation rate indicator.

4.4.5 Workstation for plan development

4.4.5.1 The workstation for plan development is to enable the following tasks to be performed:
(1) determining the ship’s position;
(2) planning the forthcoming voyage and estimating time of arrival at various way-points;
(3) indicating time.
4.4.5.2 The time indication at the workstation for plan development is to be derived from the same system as the workstation for navigation manoeuvring.

Section 5 EQUIPMENT AND SYSTEMS

4.5.1 Basic requirements for equipment

4.5.1.1 Navigation equipment is to be subject to type approval and the performance standards are not to be inferior to those of IMO in force.
4.5.1.2 All instruments and panels are to be permanently mounted in consoles or at other appropriate places, taking into account both operational and environmental conditions.
4.5.1.3 When siting equipment which is to be used in an exposed position, special care is to be taken to ensure that the siting does not impair the performance of the equipment.
4.5.1.4 Antenna and sensor arrangements which are part of navigational instruments, are to be widely separated from radio communications systems.
4.5.1.5 Antenna units are to be sited so as not to constitute a hazard to personnel working in the vicinity.

4.5.1.6 Satcom and radar antenna units are required to have a warning label, detailing safe distances, posted in the vicinity or on the equipment.
4.5.1.7 Above-deck equipment is to be sited so as to prevent the installation from being affected by vibration.
4.5.1.8 Instruments to be installed are to be located away from excessive heat sources, such as a heating vent or equipment heat exhaust.
4.5.1.9 Instruments to be fitted into a bridge instrument console are to be protected from excessive heat by conduction or, if necessary, by forced air flow.
4.5.1.10 Equipment not specifically designed for outdoor installation is not to be installed near a doorway, open window or hatch opening.
4.5.1.11 When equipment is being installed, care is to be taken to ensure that the accuracy of the ship's magnetic compasses is adequately safeguarded.

4.5.2 Computer-based systems and software

4.5.2.1 Computer-based systems are subject to type approval, and are to comply with the applicable requirements of Section 6, Chapter 2, PART SEVEN of the Rules.
4.5.2.2 Where failure in computer-based systems may affect safe navigation and manoeuvring of the ship, back-up systems are to be available for changeover.
4.5.2.3 Adequate filtering of analogue and digital input signals is to be provided.
4.5.2.4 Software and data necessary to ensure satisfactory performance of the computer system are to be stored in a non-volatile memory, or a volatile memory with an uninterruptible power supply.
4.5.2.5 Access to the computer's operating system is to be restricted, and any alteration of system software after final inspection and testing on board is to be subject to prior approval by CCS.
4.5.2.6 Necessary quality attributes for software are reliability, safeguard against error and misuse, fault detection and correction.
4.5.2.7 Where computerized equipment are interconnected through a computer network, failure of the network is not to prevent individual equipment from performing their individual functions.

4.5.3 Alarm system

4.5.3.1 Alarms released by navigation equipment are to be both audible and visual and to be displayed as group alarm for easy identification.
4.5.3.2 Alarms are to be set for the following as a minimum:
(1) the closest point of approach;
(2) insufficient depth of water;
(3) approach of a way-point;
(4) yaw;
(5) off-track;
(6) steering gear failure;
(7) navigation light failure;
(8) gyrocompass failure.

4.5.4 BNWS

4.5.4.1 The wheelhouse is to be provided with a BNWAS, the performance of which is to comply with the requirements of IMO resolution MSC.128(75).

4.5.5 Communication

4.5.5.1 A telephone system is to be provided for two-way speech communication between the bridge and at least the following (the telephone system is to function properly in case of loss of main power supply):
(1) engine control station;
(2) emergency steering position in steering gear room;
(3) cabins of captain and officers, offices, mess and public areas.
4.5.5.2 The bridge is to have priority over the communication system.
4.5.5.3 All extension numbers are to be shown at any telephone.

4.5.6 Power supply

4.5.6.1 Local distribution panels are to be arranged for all items of electrically operated navigational equipment etc. These panels are to be supplied by two exclusive circuits, one fed from the main source of electrical power and the other fed from an emergency source of electrical power. Each item of navigational equipment is to be individually connected to its distribution panel. The power supplies to the distribution

panels are to be arranged with automatic changeover facilities between the two sources. Failure of any power source is to initiate an audible and visual alarm.
4.5.6.2 Following a loss of power which has lasted for 45s or less, all primary functions are to be readily reinstated. Following a loss of power which has lasted for more than 45s, as many as practical primary functions are to be readily reinstated.

4.5.7 Man-machine interface

4.5.7.1 All instruments are to be logically grouped according to their functions within each workstation. Their location and design are to give consideration to the physical capabilities of the human operator and comply with accepted ergonomic principles.
4.5.7.2 The amount of information to be presented for conducting various tasks as well as the methods of displaying the information needed are to give consideration to the capabilities of the human operator to percept and process the information made available.
4.5.7.3 Instruments or displays providing visual information to more than one person are to be located for easy viewing by all users concurrently. If this is not possible, the instruments or displays are to be duplicated.
4.5.7.4 The method of presentation is to ensure that the instrument data is clearly visible to the observer at a practicable distance in the light conditions normally experienced on the bridge by day and by night.
4.5.7.5 Means are to be provided for the manual adjustment of the brightness of each visual display unit.
4.5.7.6 All information is to be presented on a background of high contrast, emitting as little light as possible by night.
4.5.7.7 Paged displays are to be presented in a way which allows the operator to find quickly the information needed. An overview page is to be easily available to remind the operator of the paging system.
4.5.7.8 Each page is to have a unique identifying label on the screen.
4.5.7.9 The function and layout of control elements are to be logically coordinated.
4.5.7.10 Maloperation of a computer-based bridge instrument is not to cause any loss of data, damage of programmes or malfunction of the system.
4.5.7.11 Default values, where applicable, are to be indicated by the system when requesting operator input.
4.5.7.12 If an input error is detected by the system, the operator is to be allowed to correct the error immediately.
4.5.7.13 The system is to require confirmation from the operator for critical actions, e.g. they are not to rely on single keystrokes.

Section 6 SUPPLEMENTARY REQUIREMENTS FOR THE NOTATION BDE-2

4.6.1 General requirements

4.6.1.1 Ships applying for the notation BDE-2 are to comply with the requirements of this Section in addition to the applicable requirements of other sections of this Chapter.

4.6.2 Field of vision

4.6.2.1 It is to be possible to observe all objects of interest for the navigation, such as other traffic and navigation marks, in any direction from inside the wheelhouse. Bearing this in mind, the observer is to obtain a 360º field of vision from inside the wheelhouse when moving within a certain range there. For rear view, other measures of the equivalent level of safety are acceptable, such as cameras with redundancy covering any obstructing view or blind area, if the 360° field of vision requirement around the ship cannot be met.
4.6.2.2 At the workstation for navigation manoeuvring, in the horizontal plane to vertical 5° above the line of sight, there is to be no obstruction; any structure/equipment or cargo obstructing the sea surface near the vessel in excess of 1000 m within a 180º sector in front of the lateral vessel in a line of sight from the horizontal plane to 5° below vertical is to be considered a blind area and the necessary calculations is to be carried out (eye height 1800 mm).
4.6.2.3 In all draft, trim and deck cargo conditions, the wheelhouse from the commanding position is to be able to observe all objects, shoreline and water at least 500 m from the hull within a sector of 10º to 90° on each side of the bow. If the vessel cannot meet the above requirements, measures of the equivalent level of safety are acceptable, such as cameras with redundancy covering any obstructing view or blind area.

4.6.2.4 In the process of ship manoeuvring, the navigator at the workstation for docking is to be able to observe the parallel ship side (eye height: 1600 mm). The total length of visibility on the ship's side is not to be less than 1/2 of the ship length.

4.6.3 Windows

4.6.3.1 To prevent reflection, the rear and side windows are to be tilted outwards at an angle of not less than 5° at the top of the vertical plane. The window in the bridge wing door may be exempted from this requirement.

4.6.4 Layout and dimensions

4.6.4.1 To provide accessibility from a standing position, the height of the console table top above the wheelhouse deck surface is to be not higher than 800 mm and not lower than 750 mm. For easy operation of the control device from the sitting position, it is to be possible to adjust the sitting height so that the elbow height is 50 mm higher than the console table.

4.6.4.2 The console in front of the work seat is to provide sufficient legroom to facilitate access to the equipment and control equipment to be used.

4.6.4.3 The shape of the console and the position of the display are to be designed to provide the user with the information required to perform the primary functions of the workstation within a viewing angle of 95° per side from the front.

4.6.4.4 If the seat is installed in the station used for standing and sitting operation, the seat is to be attached to the slide rail so that the seat can move back and forth to make it easy to operate the equipment while sitting, and there is enough space to stand in front of the console when the seat is pushed back, generally 700 mm. It is to be possible to adjust the height of the seat to accommodate users of different heights to obtain the best view and to achieve the best range of sight. Armrests (if provided) are to be of folding type and adjustable in height. Seats are to be equipped with adjustable trestles.

4.6.5 Passageways

4.6.5.1 The height of the entrance and door from the adjacent passageway to the wheelhouse is not to be less than 2.0 m.

4.6.5.2 At the workstation for docking, the distance between the bridge wing bulwarks, bulkheads and bridge wing consoles is to be as small as possible and the passageway is to be wide enough for one person to pass comfortably through the consoles. The width of the passageway is to be at least 600 mm.

4.6.6 Workstation for docking

4.6.6.1 The workstation for docking is to be capable of ship manoeuvring and is generally to be provided with the folloing equipment:

(1) compass display;
(2) wind speed and direction indicator;
(3) steering gear and rudder angle indicator;
(4) rotation rate indicator;
(5) controllers and indicators for main and side propulsion;
(6) BNWAS confirmation device and manual starting device;
(7) internal communication system.

Section 7 INTEGRATED BRIDGE SYSTEM (IBS)

4.7.1 General requirements

4.7.1.1 This Section applies to ships fitted with an IBS.

4.7.1.2 The layout of the IBS is to be such that the failure of one sub-system is immediately brought to the attention of the officer of the watch through auditory and visual alarms, and will not lead to the failure of any other sub-systems. If one part of an integrated navigation system (INS) fails, every other piece of equipment or every other part of the system is to be able to operate separately.

4.7.1.3 The performance criteria of the IBS is to comply with the requirements of IMO SN.1/Circ.288 Guidelines for Bridge Equipment and Systems, their Arrangement and Integration.

4.7.1.4 Ships applying for the notation BDE-3 are to comply with the requirements of this Section in addition to the applicable requirements of other sections of this Chapter.

4.7.2 Equipment

4.7.2.1 Two gyrocompasses capable of continuously displaying heading information and providing navigation equipment with corresponding input information are to be installed.
4.7.2.2 Only one gyrocompass is to be used at any time for main display and control purposes. The navigating officer is to be able to switch between compasses at any time and the non-selected compass is to be used automatically as the independent heading source for the off-course warning.
4.7.2.3 It is to be possible to compare readings from each gyrocompass via the navigation workstation displays. Automatic comparison between the compasses is to be provided and an alarm given, should the difference between heading signals exceed a pre-set value.

4.7.3 Alerts and management thereof

4.7.3.1 Navigation and operation workstations are to have a Bridge Alert Management (BAM) system that meets the requirements of IMO resolution MSC.302(87).
4.7.3.2 The BAM system is to provide the following alerts as a minimum:
(1) deviation from the route;
(2) close to the waypoint;
(3) incorrect or lost position;
(4) loss of heading input;
(5) equipment or sub-system failure;
(6) incompatibility of the compass.
4.7.3.3 Alerts are to be prioritized according to the type of emergency and response required by the navigation and operating workstations.
4.7.3.4 Within each priority, alerts will be arranged in groups to reduce the amount of information provided to the operator. However, the following alerts cannot be grouped:
(1) emergency alarm.
(2) a separate set of alarms related to a failure requiring reduction of speed or power or automatic shutdown of propulsion machinery.
(3) steering gear alarm.
(4) navigation light fault alarm.
4.7.3.5 The alerts are to be presented grouped in order of priority. Within the priorities the alerts are to be displayed in the order in which they occur (sequence). The visual display unit will provide an immediate display of new information, regardless of the currently selected information display.
4.7.3.6 Unacknowledged alerts can be distinguished by flashing text or by flashing markers adjacent to the text, not just by color changes. Acknowledged alerts can be distinguished by steady illuminated text or steady illuminated markers adjacent to the text.

CHAPTER 5 ADDITIONAL REQUIREMENTS FOR FISHING VESSELS

Section 1 GENERAL PROVISIONS

5.1.1 General requirements

5.1.1.1 The provisions of this Chapter apply to fishing vessels.

5.1.1.2 Fishing vessels complying with the provisions of CCS Rules for Construction of Ocean-going Steel Fishing Vessels and this Chapter are to be assigned the Fishing Vessel class notation.

5.1.1.3 Unless expressly provided by this Chapter, fishing vessels are to comply with the relevant requirements of PART ONE of the Rules.

5.1.2 Definitions

5.1.2.1 The definitions of this Chapter are as the following:

(1) Length L_L: refers to 96% of the total length of the waterline at 85% of the minimum moulded depth on the upper edge of the keel plate, or the length along the waterline from the leading edge of the bow to the center of the rudder stock, whichever is greater. For fishing vessels without rudder stock, the length L_L is taken as 96% of the total length of the waterline at 85% of the smallest depth. If the shape of the bow above the waterline at the minimum depth of 85% is concave, the foremost end of the total length and the front edge of the bow shall be measured from the point where the last point of the shape of the bow above the waterline is projected vertically on the waterline (see figure 5.1.2.1-1).For fishing vessels whose keel is designed to be inclined, the waterline for measuring this length should be parallel to the design waterline at 85% of the minimum moulded depth D_{min}. The waterline is obtained by drawing a tangent line parallel to the keel line of the fishing vessel and tangent to the depth arc of the working deck in the figure below. In this case, the minimum depth is the vertical distance measured from the upper edge of the keel plate to the upper side of the beam at the side of the working deck at the tangent point (see figure 5.1.2.1-2).

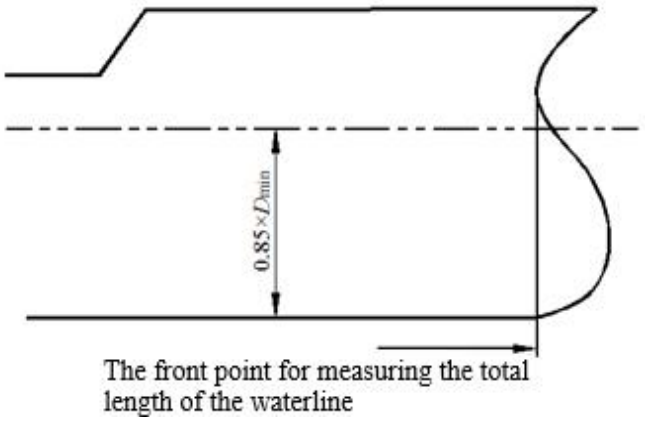


Figure 5.1.2.1-1 The front point for measuring the total length of the waterline, for fishing vessels with recessed bow shape.

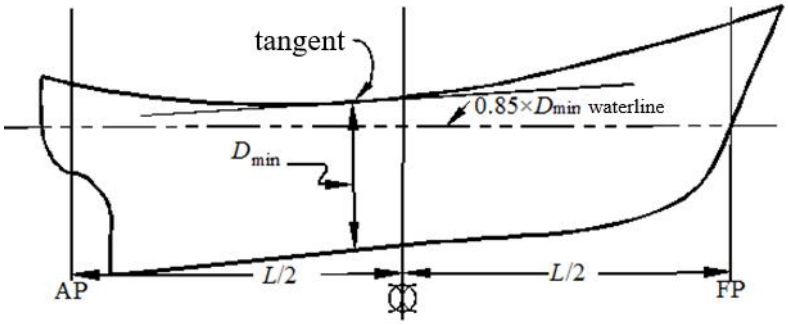


Figure 5.1.2.1-2 The length of a leaning keel fishing vessel

(2) Keel line: refers to the line that passes through the following specific points in the vessel and is parallel to the slope of the keel: for metal hull fishing vessels, it is the line of the upper edge of the keel or the line of intersection between the inner edge of the hull plate and the keel; if there is a bar keel, then it is the intersection point between the bar keel extension line and the inner side of the hull plate. For non-metallic fishing vessels, it is the intersection of the respective extension lines of the outer surface of the bottom and the outer surface of the bar keel; if there is no bar keel, it is the bottom point.
(3) Breadth B: refers to the maximum width in a fishing vessel. For a metal shell, the breadth is measured at the midship to the inner surface of the hull; for a fishing vessel with other material shells, the breadth is measured at the midship to the outer surface of the hull.
(4) Depth D: the vertical distance measured from the upper edge of the keel plate to the upper edge of the beam at the side of the working deck. For fishing vessels with wooden and mixed material structures, the vertical distance is measured from the lower edge of the keel notch. If the shape of the lower part of the midship section is concave, or when thickened keel wing panels are installed, the vertical distance is measured from the point where the inward extension line of the flat part of the bottom of the ship intersects with the side of the keel. If the working deck is stepped and its raised part extends beyond the point that determines the moulded depth, the moulded depth shall be measured to the extended dashed line of the lower part of the deck, which is parallel to the raised part of the deck. If there are no special regulations, it generally refers to the depth of the middle of the ship.
(5) Working deck: is generally the lowest complete deck above the deepest operating waterline from which fishing is undertaken. In vessels fitted with two or more complete decks, the lower deck as a working deck provided that the deck is situated above the deepest operating waterline.
Where the lowest complete deck above the deepest operating waterline is stepped, the lowest line of the deck and the continuation of that line parallel to the upper part of the deck is taken as the working deck.
Discontinuous working deck, stepped working deck,

① Where a recess in the working deck does not extend to the sides of the ship, the upper part of the deck is taken as the working deck (see figure 5.1.2.1-3).

② Recesses not extending from side to side in a deck below the exposed deck, designated as the working deck, may be disregarded, provided all openings in the weather deck are fitted with weathertight closing appliances.

③ Recesses not extending from side to side in a deck below the exposed deck, designated as the working deck, may be disregarded, provided all openings in the weather deck are fitted with weathertight closing appliances.

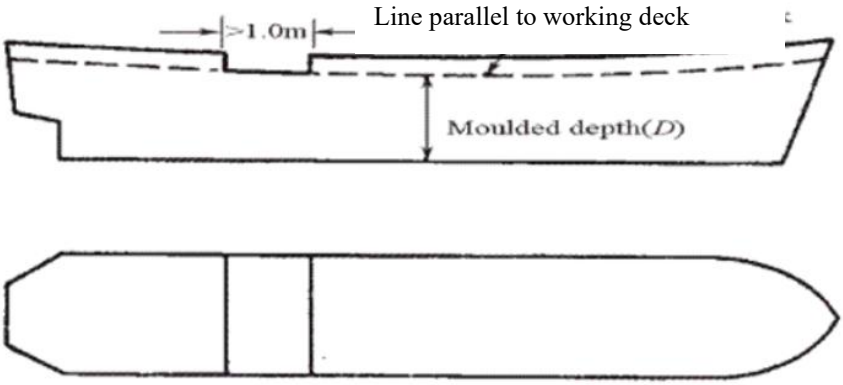


Figure 5.1.2.1-3 the working deck of a recess

Section 2 SURVEYS DURING CONSTRUCTION

5.2.1 Requirements for surveys and tests of fishing vessels

5.2.1.1 Unless expressly provided by this Section, surveys and tests of fishing vessels are to comply with the provisions of Sections 1 and 2, Chapter 4, PART ONE of the Rules.

5.2.1.2 Unless expressly provided by the flag State, the list of certification for statutory products of fishing vessels is to comply with the relevant requirements of Chapter 3 , PART ONE of the Rules.

5.2.1.3 Tests of fishing vessels are to comply with the requirements of 4.2.3, Section 2, Chapter 4, PART ONE of the Rules, except that 4.2.3.3(3) is not applicable. The tightness tests of compartments are to comply with the requirements of Part B, Annex 1, Section 3, Chapter 4, PART ONE of the Rules.
5.2.1.4 For hull surveys carried out in accordance with Appendix 1, Chapter 4, PART ONE of the Rules, statutory requirements of relevant SOLAS regulations corresponding to tightness test and structural test in Table 1 of this Appendix may not apply. Statutory requirements of SOLAS or ILLC '66 corresponding to other shipbuilding function in Table 1 are to be replaced by relevant requirements of the Administration of the flag State.
Annex 2 of Appendix 1, Chapter 4, PART ONE of the Rules is not applicable to fishing vessels.
5.2.1.5 Unless expressly provided, Appendix 2 , Chapter 4 , PART ONE of the Rules is not applicable to fishing vessels.
5.2.1.6 At surveys during construction of fishing vessels, survey items are at least to include:
(1) inspecting the hull structure of fish hold to ensure that the materials, scantlings, construction, arrangement and installation are in accordance with the approved plans, diagrams, specifications, calculations and other technical documentation and that the workmanship is in all respects satisfactory;
(2) confirming the validity of the fish hold polyurethane foam test report;
(3) confirming the availability of the alarm system fitted in the refrigerated room and fish hold.

Section 3 SURVEYS AFTER CONSTRUCTION

5.3.1 General requirements

5.3.1.1 For the purpose of maintaining the validity of certificates, fishing vessels which have been classed with CCS are to be subject to the surveys as specified in this Section.
5.3.1.2 Unless expressly provided by this Section, surveys after construction of fishing vessels are to comply with the provisions of Chapter 5, PART ONE of the Rules.
5.3.1.3 The following requirements in Chapter 5, PART ONE of the Rules are not applicable to surveys after construction of fishing vessels:
(1) provisions of Sections 3, 5, 6, 7, 8, 16, 17 and 18;
(2) Appendixes 2, 3, 6, 10, 11, 12, 13, 17, 18, 19 and 20.
5.3.1.4 At surveys after construction of fishing vessels, survey items are at least to include:
(1) inspecting the general conditions of fish hold;
(2) confirming the availability of the alarm system fitted in the refrigerated room and fish hold.

Section 4 INTACT STABILITY

5.4.1 General requirements

5.4.1.1 Compliance with the requirements for intact stability is a condition for classification of ships.
5.4.1.2 The intact stability of fishing vessels is to comply with the requirements of this Section, or it is to be demonstrated that their intact stability is in compliance with the requirements of the flag State Administration.
5.4.1.3 This Section applies to ocean-going fishing vessels of 24 m and over in length L_L.

5.4.2 Plans and documents

5.4.2.1 The following plans and documents are to be submitted for approval or confirmation:
(1) Stability calculations for loading conditions or loading manual;
(2) Curves or table of allowable height of center of gravity or allowable initial metacentric height;
(3) Coordinates of opening of flooding angles and curves or table of flooding angles.
5.4.2.2 The following plans and documents are to be submitted for information:
(1) General arrangement;
(2) Lines and offsets;
(3) Hydrostatic curves or table;
(4) Stability cross curves or table;
(5) Capacity curves or table;
(6) Arrangement of bilge keels;
(7) Plan of load line marks and draught;
(8) Auxiliary calculations for windage area and moment of area, icing, etc.;
(9) Cross-sectional area (if applicable);

(10) Arrangement of fixed ballast (if applicable);
(11) Approved inclining test report or light ship survey report;
(12) Arrangement of portable fish-hold divisions (if applicable);
(13) Arrangement of fishing machinery (if applicable).
5.4.2.3 The above information may be reduced as appropriate for fishing vessels of which the intact stability has been approved.

5.4.3 Requirements for intact stability

5.4.3.1 The intact stability of fishing vessels is to comply with the relevant requirements of IMO resolution MSC.267(85) – International Code on Intact Stability, 2008 (2008 IS Code), Part B. For fishing vessels with B/D ≥ 2.5, the requirements of 2.2.3 of Part A of the Code may be substituted by the following criteria:
(1) The heeling angle corresponding to the maximum righting lever is not to be less than 15°;
(2) The area under the curve of righting levers is not be less than 0.07 m·rad up to an angle of 15° when the maximum righting lever occurs at 15º and 0.055 m·rad up to an angle of 30º when the maximum righting lever occurs at 30º or above. Where the maximum righting lever occurs at angles of between 15º and 30º, the corresponding area under the righting lever curve is to be:

$$0.055+0.001（30° -\varphi_{max}）\text{m} \cdot \text{rad}$$

where: φ_{max}——The heeling angle corresponding to the maximum righting lever（° ）.
5.4.3.2 The angle of heel at which progressive flooding of fish-holds could occur through hatches which remain open during fishing operations and which cannot rapidly be closed shall be at least 20° unless the stability criteria of the righting lever curve of 5.4.3.1 can be satisfied with the respective fish-holds partially or completely flooded.
5.4.3.3 Vessels engaged in particular fishing methods where additional external forces are imposed on the vessel during fishing operations, shall take account of the effects of external forces on stability.
5.4.3.4 For special type fishing vessels such as beam trawler, net vessel, cage vessel etc, the special requirements (if applicable) of the Administration shall be satisfied.
5.4.3.5 For fishing vessels, the condition where ice accretion is likely to occur will have bad effects on the stability, so icing should be taken into account in the analysis of loading conditions. The following allowance shall be made in the icing calculations:
(1) 30kg/m^2 on exposed weather decks;
(2) 7.5kg/m^2 for projected lateral area of each side of the vessel above the water plane;
(3) the icing weight of the projected lateral area of rails, all kinds of booms, girder (except masts) and rigging, and the icing weight of the projected lateral area of other small objects shall be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.
If there is a significant difference between the icing conditions and the above requirements, the icing standard may be 0.5 to 2 times the required; if the expected icing exceeds 2 times the above-mentioned requirement, more stringent requirements can be adopted.

Section 5 DAMAGE STABILITY

5.5.1 General requirements

5.5.1.1 Compliance with the applicable requirements for damage stability is a condition for classification of vessels.
5.5.1.2 The damage stability of vessels is to comply with the requirements of this Section, or it is to be demonstrated that their damage stability is in compliance with the requirements of the flag State Administration.
5.5.1.3 Vessels of 100 m in length and over and the total number of persons carried is 100 or more should be checked for damage stability according to the requirements of this section.

5.5.2 Plans and documents

5.5.2.1 The following plans and documents are to be submitted for approval or confirmation:
(1) Calculations of damage stability;
(2) Damage control plan.
5.5.2.2 The following plans and documents are to be submitted for information:

(1) General arrangement of doors and windows;
(2) General arrangement of scuttles, ventilators and air pipes;
(3) Plans and documents stated in 5.4.2 of this Chapter.

5.5.3 Requirements for damage stability

5.5.3.1 The damage stability of vessels is to comply with the relevant requirements of Regulation 14, Chapter III of the 1993 Torremolinos Protocol Relating to the 1977 Torremolinos International Convention for the Safety of Fishing Vessels as amended by the Cape Town Agreement of 2012 (hereinafter referred to as Convention for the Safety of Fishing Vessels).

Section 6 LOAD LINE MARKS AND MARKING

5.6.1 Load line marks

5.6.1.1 The load line marks and marking for ocean-going fishing vessels are to comply with the provisions of Section 11, Part 2 of this Rule.
5.6.1.2 If the load lines of certain seasons are not applicable due to the particularity of the fishing vessel or the nature of the business or restricted by navigation, these load line segments may not be mapped.

Section 7 STRUCTURAL ARRANGEMENT

5.7.1 General Provisions

5.7.1.1 The provisions of this section apply to ocean-going steel fishing vessels of 24 m and over in length.

5.7.2 Arrangement of watertight bulkheads

5.7.2.1 Fishing vessels shall be fitted with a collision bulkhead and at least watertight bulkhead in the before and after end of the main machinery space. Such watertight bulkheads shall be extended up to the working deck.
5.7.2.2 Watertight subdivision bulkhead whether transverse or longitudinal shall be prevented ingress of water from any direction in the water pressure produced in intact and damage condition. In all cases, watertight subdivision bulkheads shall be capable of supporting at least the pressure due to a head of water up to the working deck. In damage condition，water pressure shall be taken into account in the balance , including the worst condition of intermediate stage of flooding.
5.7.2.3 Steps and recesses in watertight bulkheads shall be as strong as the bulkhead at the place where each occurs.

5.7.3 Arrangement of collision bulkheads

5.7.3.1 The distance between collision bulkheads and forward perpendicular of fishing vessels shall be meets the following requirements:
(1) not less than 0.05*L* and not more than 0.08*L* for vessels of 45m in length and over;
(2) not less than 0.05*L* and not more than 0.05*L* plus 1.35m for vessels of less than 45m and more than 24m in length, expect as may be allowed by CCS;
(3) less than 2.0m for vessels of 24m in length and over.
5.7.3.2 Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g., a bulbous bow, the distances specified in paragraph 5.7.3.1 of this Section shall be measured from a point at mid-length of the extension forward of the forward perpendicular or from a point 0.015*L* forward perpendicular, whichever is lesser.
5.7.3.3 The bulkhead may have steps or recesses provided they are within the limits prescribed in paragraph 5.7.3.1 of this Section.
5.7.3.4 Where a long forward superstructure is fitted, the collision bulkhead shall be extended weathertight to the deck next above the working deck. The extension and collision bulkhead can be fitted on the different cross section provided it is located within the limits given in paragraph 5.7.3.1 of this Section and the part of the deck which forms the step is made effectively weathertight.
5.7.3.5 The pipes piercing the collision bulkhead shall be fitted with stop values capable of being operated from above the working deck, the valve being located inside the forepeak at the collision bulkhead with a indicator being used for show that the value turn on or off. The fitting of the valve without

institution operated from above the working deck on the after side of the collision bulkhead shall be authorized, provided that the valve is readily accessible under all service conditions and the space in which it is located is not a cargo space. All valves shall be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

5.7.3.6 No doors, manholes, access openings, or any other openings shall be fitted in the collision bulkhead below the working deck The number of openings in the collision bulkhead above the working deck shall be restricted to the minimum compatible with the design and normal operation of the vessels. All such openings shall be capable of being closed weathertight.

5.7.4 Stern tubes

5.7.4.1 In all cases stern tubes shall be enclosed in watertight spaces of moderate volume, to minimize the danger of water penetrating into the ship in case of damage to stern tube arrangements.

5.7.5 Openings and their closing appliances

5.7.5.1 The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the fishing vessels. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

5.7.5.2 The acceptability height of hatchways coamings and sills for openings are to comply with the requirements in Table 5.7.5.2:

The acceptability height of hatchways coamings and sills for openings Table 5.7.5.2

Item \ Opening position	Position 1	Position 2
Superstructure and deckhouse sill (mm)	380	300/150
Sill of companionways (mm)	380	300/150
Machinery space opening (mm)	600	300
Height of hatch coamings (mm)	600	450/300

5.7.5.3 Weathertight doors

(1) all access openings in bulkheads of enclosed superstructure and other outer structures through which water could enter and endanger the vessel, shall be fitted with doors permanently attached to the bulkhead, framed and stiffened so that the whole structure is of equivalent strength to the unpierced structure, and weathertight when closed. As an alternative measure, where the stairway in deckhouse could be enclosed in substantially constructed companionways fitted with weathertight door, the outer door need not to be weathertight. The means for securing these doors weathertight shall consist of gaskets and clamping devices or other equivalent means and shall be permanently attached to the bulkhead or to the doors themselves, and shall be so arranged that they can be operated from each side of the bulkhead;

(2) weathertight doors directly access to exposed space are to open outwards.

5.7.5.4 Fish-holds and other hatchways, miscellaneous openings in working deck and superstructure decks are to comply with the following requirements:

(1) the hatchways coamings are to have substantially constructed according to its positions. Where operating experience has shown justification, the height of these coamings may be reduced, or the coamings omitted entirely, provided that the safety of vessels is not thereby impaired. In this case, the hatchway openings shall be kept as small as practicable and the covers be permanently attached by hinges or equivalent means and be capable of being rapidly closed and battened down;

(2) the structure of hatchways closed by wood covers in Positions 1 and 2 and the means for keeping them weathertight are to comply with the relevant requirements of Regulation 15 of the Amendments to Annex I of Annex B to the Protocol of 1988 Relating to the *International Convention on Load Lines, 1966*;

(3) the structure of hatchways closed by covers other than wood in Positions 1 and 2 and the means for keeping them weathertight are to comply with the relevant requirements of Regulation 6 of Chapter II of *Convention for the Safety of Fishing Vessels*.

5.7.5.5 Machinery space openings are to comply with the following requirements:

(1) machinery space openings are to be appropriate framed and efficiently enclosed by steel casings. Where machinery casings are not protected by other structures，the strength shall be considered specially. Access openings in such casings are to be fitted with weathertight doors, the sills of which are not less than 600 mm. Where machinery casings are not protected by other structures, double watertight doors are to be required for ships assigned freeboards less than those based on relevant requirements. An inner sill is not

less than 230mm in conjunction with the outer sill of 600 mm; The non-return valve which is to be closed directly and controlled locally shall be provided for sea inlet and discharge of the enclosure space between the double doors;
(2) opening shall be fitted with hatchway covers permanently attached to the bulkhead, framed and stiffened so that the whole structure is of equivalent strength to the unpierced structure, and weathertight when closed except access opening.
5.7.5.6 Other deck openings are to comply with the following requirements:
(1) where it is essential for fishing operations, flush deck scuttles of the screw, bayonet or equivalent type and manholes may be fitted provided these are capable of being closed watertight and such devices shall be permanently attached to the adjacent structure, except secured by closely spaced bolts. Having regard to the size and disposition of the openings and the design of the closing devices, metal-to-metal closures may be fitted that they are effectively watertight;
(2) openings other than hatchways, machinery space openings, manholes and flush scuttles in the working or superstructure deck shall be protected by enclosed structures fitted with weathertight doors or their equivalent. Companionways shall be situated as close as practicable to the centerline of the vessels.
5.7.5.7 Ventilators are to comply with the following requirements:
(1) ventilators to spaces below working deck or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck. For vessels of 45m in length and over, the height above deck of ventilators coamings shall be at least 900mm on the working deck and at least 760mm on the superstructures deck. For vessels of less than 45m in length, the height of these coamings shall be 760mm and 450mm respectively;
(2) coamings of ventilators shall be of equivalent strength to the adjacent structure and capable of being closed weathertight by closing appliances permanently attached to the ventilators or adjacent structure. The closing appliances shall be permanently attached to the ventilators; Where other vessels such not fitted as this, the closing appliances shall be stored near the specified ventilators and convenient for use. Where the coaming of any ventilators exceeds 900mm in height, it shall be specially supported.
The thickness of ventilator coamings shall be not less than the requirements in Table 5.7.5.7, but need not exceed that of the deck.

Thickness of Ventilator Coamings **Table 5.7.5.7**

Internal diameter of coaming (mm)	Thickness of coaming (mm)	Internal diameter of coaming (mm)	Thickness of coaming (mm)
≤200	7.5	350	9.0
250	8.0	400	9.5
300	8.5	≥450	10.0

(3) the coamings of ventilators extend to more than 4.5 m above the working deck, and the coamings of ventilators extend to more than 2.3 m above the superstructures deck, need not be fitted with closing arrangements for vessels of 45m in length and over. The coamings of Ventilators extend to more than 3.4 m above the working deck, and the coamings of Ventilators extend to more than 1.7 m above the superstructures deck, need not be fitted with closing arrangements for vessels of less than 45m in length;
(4) Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the working deck.
5.7.5.8 Air pipes are to comply with the following requirements:
(1) where air pipes to tanks and void spaces below deck extend above the working or the superstructure decks, the exposed parts of the pipes shall be of strength equivalent to the adjacent structures and fitted with appropriate protection. Openings of air pipes shall be provided with means of closing, permanently attaches to the pipe or adjacent structure.
The minimum wall thickness of air pipes above weather deck is to be:
6.0 mm for pipes of 80 mm external diameter or smaller;
8.5 mm for pipes of 165 mm external diameter or greater.
Intermediate minimum thicknesses are to be determined by linear interpolation;
(2) the height of air pipes above deck to the point where water may have access below shall be at least 760mm on the working deck and at least 450mm on the superstructure deck.
5.7.5.9 Freeing ports are to comply with the following requirements:
(1) where bulwarks on weather parts of the working deck or superstructures deck form wells, sufficient measures shall be provided to discharge of shipped water rapidly and freed of water;
(2) freeing ports area of bulwarks are to comply with the requirements of Regulation 14 of Chapter II of *Convention for the Safety of Fishing Vessels*.

5.7.5.10 Fish-holds gangway and other similar openings are to comply with the following requirements:
(1) fish-holds gangway of both sides of the vessels below working deck and other similar openings shall be fitted with the door open outwards, which are designed to ensure that they have equivalent watertight and structural integrity to the adjacent shell plating. The number of openings above is to be kept to a minimum compatible with the design and proper working of the fishing vessels;
(2) the lower edge of opening mentioned in(1) shall not be lower than the parallel of the side working deck, and the lowest point of the parallel shall be fitted at least 230mm above the top edge of the deepest operating waterline.

5.7.6 **Arrangement of double bottoms**

5.7.6.1 For vessels of 45m in length and over but less than 60m, a double bottom shall be fitted at least between front bulkhead of engine and collision bulkhead or close to these place as far as possible; For vessels of 60m in length and over but less than 75m, a double bottom shall be fitted in the area except engine at least, and that is to be extended to the collision bulkhead and the afterpeak bulkhead or close to these place as far as possible; For vessels of 45m in length and over, a double bottom shall be fitted in the midship that is to be extended to the collision bulkhead and the afterpeak bulkhead or close to these place as far as possible.
5.7.6.2 Where a double bottom is required to be fitted the inner bottom shall be continued out to the vessel's sides in such a manner as to protect the bottom to the turn of the bilge. Such protection will be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, h is to be less than *B/20*. However, in no case is the value of h to be less than 760 mm, and need not be taken as more than 2,000 mm.
5.7.6.3 A double bottom need not be fitted in way of watertight tanks, including dry tanks of moderate size, provided the safety of the vessel is not impaired in the event of bottom or side damage.
5.7.6.4 Small wells constructed in the double bottom in connection with drainage arrangements of fish-holds shall not extend downward more than necessary. A well extending to the outer bottom is, however, permitted at the after end of the shaft tunnel. Other wells (e.g. for lubricating oil under main engines) may be permitted if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with the requirements of this section. The vertical distance from the bottom of such a well to a plane coinciding with the keel line shall not be less than 500 mm.

5.7.7 **Arrangement of cofferdams**

5.7.7.1 Cofferdams are to be provided between compartments intended for fuel oil in double bottom and those intended for fresh water for boilers and drinking.
5.7.7.2 Cofferdams are only required between fuel oil tanks in double bottom and tanks immediately above where the inner bottom plating is subjected to the head of fuel oil contained therein, as in the case of a double bottom with its top raised at the sides. Where a corner to corner situation occurs for such tanks, they are not considered to be adjacent.
5.7.7.3 Cofferdams are to be provided between non-edible oil tanks, fish tanks and fresh water tanks; if the spaces between the fish tanks and non-edible oil tanks meet the requirements specified in 3.3.1.2, 3.3.1.3 or 3.3.1.4 of Part 1 of *Rules for Construction of Ocean-going Steel Fishing Vessels*, cofferdams are not needed.

5.7.8 **Arrangement of chain lockers**

5.7.8.1 Spurling pipes and cable lockers are to be watertight up to the deck exposed to weather. However, the bulkhead between separate chain lockers (Figure 5.7.8.1(1)) or the common bulkhead between adjacent lockers (Figure 5.7.8.1(2)) need not be watertight.
5.7.8.2 Where means of access are provided, they are to be closed by a substantial cover and secured by closely spaced bolts.
5.7.8.3 Where a means of access to spurling pipes or cable lockers is located below the weather deck, the manhole covers and securing appliances are to be in consistence with recognized standards① , or equivalent to the watertight manhole covers. The use of butterfly nuts and/or hinged bolts as the securing appliances of manhole covers is prohibited.

---

① E.g., i) ISO 5894: 2018; ii) China: CB/T4392-2014 “Marine manhole cover”; iii) India: IS 15876-2009 “Ship and Marine Technology manholes with bolted covers”; iv) Japan: JIS F2304: 2015, “Ship’s Manholes” and JIS F2329: 1975, “Marine Small Size Manhole”; v) Korea: KS V ISO 5894: 2012; vi) Norway: NS 6260: 1985 "Manhole cover - overview"; vii) Russia: GOST 2021-90 “Ship’s steel manholes, Specifications”.

5.7.8.4 Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances (e.g. steel plates in halves hooked over the spurling pipe tops, or canvas covers lashed) to minimize water ingress.

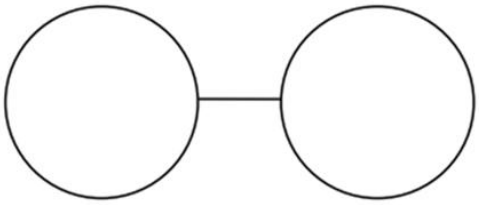


Figure 5.7.8.1(1)

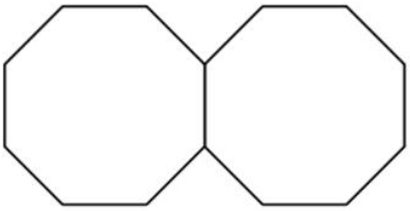


Figure 5.7.8.1(2)

Section 8 FIRE SAFETY

5.8.1 General requirements

5.8.1.1 This Section applies to ocean-going fishing vessels of 24m in length and over.

5.8.1.2 The fire safety of fishing vessels is to meet the requirements of this Section, taking into account the requirements of the flag State Administration, if any.

5.8.1.3 The fire safety of fishing vessels of 45m in length and over is to comply with the relevant provisions of Convention for the Safety of Fishing Vessels.

5.8.2 Plans and documents

5.8.2.1 The following plans and documents are to be submitted for approval or confirmation:

(1) Fire protection zone division plan and typical fire protection node plan;

(2) Fire insulation arrangement plan, deck covering arrangement plan and fire door arrangement plan;

(3) Ventilation system arrangement plan;

(4) Fixed fire extinguishing system arrangement plan and fire extinguishing dose calculation sheet;

(5) Water fire extinguishing system arrangement plan;

(6) Arrangement plan of fixed fire detection and alarm system;

(7) Control system diagram of quick closing valve for fuel and lubricating oil tanks;

(8) Fire control plan;

(9) Other plans and documents considered necessary by CCS.

5.8.3 Product certificate

5.8.3.1 All the main materials, equipment and devices used for fire protection of fishing vessels are to have corresponding CCS product certificates. For details, please refer to the relevant requirements in Appendix 1 B List of Requirements for Certification of Ship's Statutory Products of Chapter 3, Part 1 of this Rules.

5.8.4 Use of substitutes

5.8.4.1 Any special type of equipment, appliance, fire extinguishing agent or device mentioned in this Section may be replaced by other types of equipment without reducing efficiency, but relevant calculation, test or use experience are to be provided.

5.8.5 Fire safety requirements for fishing vessels of 30m in length and over but less than 45m

5.8.5.1 Structural fire protection

(1) The hull, superstructure, decks and deckhouses are to be constructed of non-combustible materials.

(2) The decks and bulkheads separating machinery spaces of category A from accommodation spaces, service spaces or control stations are to be constructed to "A-0" class standard. Decks and bulkheads separating other machinery spaces from accommodation, service spaces and control stations are to be "A-0" class standard. Decks and bulkheads separating the skipper's cabin from the wheelhouse, control stations from accommodation and service spaces are to be constructed to "B" class standard.

(3) The bulkheads of corridors serving accommodation spaces, service spaces and control stations are to be

of "B-0" class divisions.
(4) Any bulkhead of corridor serving accommodation spaces, service spaces and control stations is to extend from deck to deck unless a continuous ceiling of the same class as the bulkhead is fitted on both sides of the bulkhead, in which case the bulkhead may terminate at the continuous ceiling.
(5) Interior stairways serving accommodation spaces, service spaces or control stations are to be made of steel or other equivalent material. Such stairways are to be within enclosures constructed of "B-15" class divisions, provided that, where a stairway penetrates at least two decks.
(6) Doors and other closures of openings in bulkheads and decks referred to in 5.8.5.1 (2) to (4) of this Section, doors fitted to stairway enclosures referred to in 5.8.5.1 (5) of this Section, and doors fitted in engine and boiler casings, are to be as far as practicable equivalent in resisting fire to the divisions in which they are fitted. Doors to machinery spaces of category A are to be self-closing.
(7) Lift trunks which pass through the accommodation and service spaces are to be constructed of steel or other equivalent material and to be provided with means of closing which will permit control of draught and smoke.
(8) The boundary bulkheads and decks of spaces containing any emergency source of power, and bulkheads and decks between galleys, paint rooms, lamp rooms or any store-rooms which contain appreciable quantities of highly flammable materials and accommodation spaces, service spaces or control stations, are to be constructed of "A" class divisions. However, "B-15" class divisions between a galley and accommodation spaces, service spaces and control stations may be accepted when the galley contains electrically heated furnaces, electrically heated hot water appliances or other electrically heated appliances only.
(9) Highly flammable products are to be carried in suitably sealed containers.
(10) When bulkheads or decks required by this Section to be "A" or "B" class divisions, are penetrated for the passage of by electrical cables, pipes, trucks, ducts, etc., arrangements are to be made to ensure that the fire integrity of the division is not impaired.
(11) Air spaces enclosed behind ceilings, panellings or linings in accommodation spaces, service spaces and control stations are to be divided by close-fitting draught stops spaced not more than 7 m apart.
(12) Windows and skylights to machinery spaces are to be as follows:

① where skylights can be opened, they are to be capable of being closed from outside the space. Skylights containing glass panels are to be fitted with external shutters of steel or other equivalent material permanently attached;

② glass or similar materials are not to be fitted in machinery space boundaries. This does not preclude the use of wire-reinforced glass for skylights and glass in control rooms within the machinery spaces; and

③ wire-reinforced glass is to be used in skylights referred to in 5.8.5.1(12) ① of this Section.

(13) Insulating materials in accommodation spaces, service spaces except domestic refrigerating compartments, control stations and machinery spaces are to be non-combustible. The surface of insulation fitted on the internal boundaries of machinery spaces of category A is to be impervious to oil or oil vapours.
(14) Within compartments used for stowage of fish, combustible insulation are to be protected by close-fitting cladding.

5.8.5.2 Ventilation system

(1) Except ventilators serving spaces in which stoves are installed can have no closing appliances in accordance with 5.8.5.3 (2) of this Section, means are to be provided to stop fans and close main openings to ventilation systems from outside the spaces served .
(2) Means are to be provided for closing, from a safe position, the annular spaces around funnels.
(3) Ventilation openings may be permitted in and under the doors in corridor bulkheads except that such openings are not to be permitted in and under stairway enclosure doors. The openings are to be provided only in the lower half of a door. Where such opening is in or under a door, the total net area of any such opening or openings is not to exceed 0.05m^2. When such opening is cut in a door, it is to be fitted with a grille made of non-combustible material.
(4) Ventilation ducts for machinery spaces of category A or galleys are not to, in general, pass through accommodation spaces, service spaces or control stations. If the ducts are to be constructed of steel or equivalent material and arranged to preserve the integrity of the divisions, this arrangement can be permitted.
(5) Ventilation ducts of accommodation spaces, service spaces or control stations are not to, in general, pass through machinery spaces of category A or through galleys. If the ducts are to be constructed of steel or equivalent material and arranged to preserve the integrity of the divisions, this arrangement can be permitted.
(6) Store-rooms containing flammable products and exceeding 4m^2 are to be provided with ventilation

arrangements which are separate from other ventilation systems. Ventilation are to be arranged at high and low levels and the inlets and outlets of ventilators are to be positioned in safe areas. Suitable wire mesh guards to arrest sparks are to be fitted over inlet and outlet ventilation openings.
(7) Ventilation systems serving machinery spaces are to be independent of systems serving other spaces.
(8) Where trunks or ducts serve spaces on both sides of "A" class bulkheads or decks, dampers are to be fitted so as to prevent the spread of fire and smoke between compartments. Manual dampers are to be operable from both sides of the bulkhead or the deck. Where the trunks or ducts with a free cross-sectional area exceeding $0.02m^2$ pass through "A" class bulkheads or decks, automatic self-closing dampers are to be fitted. Where the trunks with a free cross-sectional area exceeding $0.02m^2$ serving compartments situated only on one side of such bulkheads, unless the ducts are of steel in the vicinity of passage through the deck or bulkhead, the openings are to be lined with a steel sheet sleeve and comply in that portion of the duct with the following:

① for ducts with a free cross-sectional area exceeding $0.02m^2$, the sleeves are to have a thickness of at least 3 mm and a length of at least 0.9m. When passing through bulkheads, this length are to preferably be divided evenly on each side of the bulkhead. Ducts or sheet sleeve fitted to these ducts are to be provided with fire insulation. The insulation are to have at least the same fire integrity as the bulkhead or deck through which the duct passes. Equivalent penetration protection may be provided; and

② ducts with a free cross-sectional area exceeding $0.075m^2$ are to be fitted with fire dampers in addition to the requirements of ① above. The fire damper is to operate automatically, but is also to be capable of being closed manually from both sides of the bulkhead or deck. The damper is to be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by "A" class divisions, without serving those spaces, provided those ducts have the same fire integrity as the bulkheads which they penetrate.

5.8.5.3 Heating installations
(1) Electric radiators are to be fixed in position and so constructed as to reduce fire risks to a minimum. No such radiator are to be fitted with an element so exposed that clothing, curtains or other similar materials can be scorched or set on fire by heat from the element.
(2) Heating by means of open fires are not to be permitted. Heating stoves and other similar appliances are to be firmly secured and adequate protection and insulation against fire are to be provided beneath and around such appliances and in way of their uptakes. Uptakes of stoves which burn solid fuel are to be so arranged and designed as to minimize the possibility of becoming blocked by combustion products and are to have a ready means for cleaning. Dampers for limiting draughts in uptakes are still to leave an adequate area open when in the closed position. Spaces in which stoves are installed are to be provided with ventilators of sufficient area to provide adequate combustion-air for the stove. Such ventilators are to have no means of closure and their position is to be such that closing appliances in accordance with 5.7.5.7 in Section 7 of this Chapter are not required.
(3) Open flame gas appliances, except cooking stoves and water heaters, are not to be permitted. Spaces containing any such stoves or water heaters are to have adequate ventilation to remove fumes and possible gas leakage to a safe place. All pipes conveying gas from container to stove or water heater are to be of steel or other approved material. Automatic safety gas shut-off devices are to be fitted to operate on loss of pressure in the gas main pipe or flame failure on any appliance.
5.8.5.4 Miscellaneous items
(1) Exposed surfaces within accommodation spaces, service spaces, control stations, corridor and stairway enclosures and the concealed surfaces behind bulkheads, ceilings, panellings and linings in accommodation spaces, service spaces and control stations are to have low flame-spread characteristics.
(2) Paints, varnishes and other finishes used on exposed interior surfaces are not to be capable of producing excessive quantities of smoke or toxic gases or vapours.
(3) Primary deck coverings within accommodation and service spaces and control stations, are to be of approved material which will not readily ignite or give rise to toxic or explosive hazards at elevated temperatures.
(4) In accommodation and service spaces and control stations, pipes penetrating "A" or "B" class divisions are to be of approved materials capable of withstanding the temperature required by the division. Due to arrangement reasons, the pipes conveying oil or combustible liquids that pass through accommodation and service spaces are to be approved fire-resistant material.
(5) Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

(6) All waste receptacles, other than those used in fish processing, are to be constructed of non-combustible materials with no openings in the sides and bottom.
(7) Machinery driving fuel oil transfer pumps, fuel oil unit pumps and other similar fuel pumps are to be fitted with remote controls situated outside the space concerned so that they can be stopped in the event of a fire arising in the space in which they are located.
(8) Drip trays are to be fitted, where necessary, to prevent oil leaking into bilges.

5.8.5.5 Storage of gas cylinders and dangerous materials

(1) Cylinders for compressed, liquefied or dissolved gases are to be clearly marked by means of prescribed identifying colours, have a clearly legible identification of the name and chemical formula of their contents and be properly secured.
(2) Cylinders containing flammable or other dangerous gases and expended cylinders are to be stored, properly secured, on open decks and all valves, pressure regulators and pipes leading from such cylinders are to be protected against damage. Cylinders are to be protected against excessive variations in temperature, direct rays of the sun, and accumulation of snow. Due to arrangement reasons, such cylinders an be permitted to be stored in compartments complying with the requirements of 5.8.5.5 (3) to (5) of this Section.
(3) Spaces containing highly flammable liquids, such as volatile paints, paraffin, benzol, etc., and, where permitted, liquefied gas, are to have direct access from open decks only. Pressure-adjusting devices and relief valves are to exhaust within the compartment. Where boundary bulkheads of such compartments adjoin other enclosed spaces, they are to be gastight.
(4) Except as necessary for service within the space, electrical wiring and fittings are not to be permitted within compartments used for the storage of highly flammable liquids or liquefied gases. Where such electrical fittings are installed, they are to be approved safety devices. Sources of heat are to be kept clear of such spaces and "No smoking" and "No naked light" notices are to be displayed in a prominent position.
(5) Separate storage are to be provided for each type of compressed gas. Compartments used for the storage of such gases are not to be used for storage of other combustible products nor for tools or objects not part of the gas distribution system.

5.8.5.6 Means of escape

(1) Stairways and ladders leading to and from all accommodation spaces and in spaces in which the crew is normally employed, other than machinery spaces, are to be so arranged as to provide ready means of escape to the open deck and, thence, to the survival craft:

① at all levels of accommodation at least one means of escape is be provided. Where two or more means of escape are provided, they are to be as widely separated as possible, which include the normal means of access from each restricted space or group of spaces;
② a corridor or a part of a corridor from which there is only one route of escape is not to preferably exceed 5 m in length and, in no case, be greater than 7 m in length; and
③ stairways and corridors used as means of escape are not to be less than 700 mm in clear width, and are to have a handrail on one side. Stairways and corridors with a clear width of 1800mm and over are to have handrails on both sides. "Clear width" is considered the distance between the handrail and the bulkhead on the other side or between the handrails on both sides. The angle of inclination of stairways is to be, in general, 45° but not greater than 50° and in machinery spaces and small spaces not more than 60°. Doorways which give access to a stairway is to be of the same size as the stairway.

(2) Two means of escape are to be provided from every machinery space of category A which are to be as widely separated as possible. Vertical escapes are to be by means of steel ladders. Where the size of the machinery spaces makes it impracticable, one of these means of escape may be omitted. Where the length of machinery space of category A is less than 7m, one means of escape can be permitted.

5.8.5.7 Automatic fire detection and alarm system

(1) Where appreciable amounts of combustible materials are used on the construction of accommodation spaces, service spaces and control stations, special consideration are to be given to the installation of an automatic fire detection and alarm system in those spaces, having due regard to the size of those spaces, their arrangement and location relative to control stations.

5.8.5.8 Fire pump

(1) Each fishing vessel is to be equipped with water fire extinguishing system. The minimum number and type of fire pumps to be fitted are to be as follows:

① one power pump not dependent upon the main machinery for its motive power; or
② one power pump driven by main machinery, provided that the propeller shafting can be readily disconnected or provided that a controllable pitch propeller is fitted.

(2) Sanitary, bilge, ballast, general service or any other pumps may be used as fire pumps if they comply with the requirements of this chapter and do not affect the ability to cope with pumping of the bilges. Fire pumps are to be so connected that they cannot be used for pumping oil or other flammable liquids.
(3) Centrifugal pumps or other pumps connected to the fire main through which backflow could occur are to be fitted with non-return valves.
(4) The total capacity of main power-operated fire pumps are to be at least:

$$Q=(0.15\sqrt{L(B+D)}+2.25)^2 \quad m^3/h$$

Where: L——Length, m
B——Breadth, m
D——Depth, m.
(5) Where two independent power-operated fire pumps are fitted, the capacity of each pump is not to be less than 40% of the quantity required by 5.8.5.8(4) of this Section.
(6) When main power fire pumps are delivering the quantity of water required by 5.8.5.8(4) of this Section through the fire main, fire hoses and nozzles, the pressure maintained at any hydrant is not to be less than $0.20N/mm^2$.
(7) The emergency fire pump of fishing vessel is to be fitted are to be as follows:
① if a fire in any one compartment could put all the fire pumps out of action, there is generally to be an emergency fire pump. This emergency fire pump can be portable.
② the emergency fire pump is to be capable of delivering water through the jet required by 5.8.5.10 (1) of this Section.
③ the fixed emergency fire pump can be driven by diesel engine or motor, and is to meet the requirements as follows:
——the emergency fire pump is generally to be capable of maintaining a water jet with a range of 12m and over from the fire hydrant at the highest position of the fishing vessel (the number of fire hydrants is set as the following provision), and the pressure at the hydrant is not to be less than the provisions in 5.8.5.8(6) of this Section;
——when the emergency fire pump runs, the number of fire hydrants used at the same time is not to be less than one;
——the outlet pipe of the emergency fire pump is to be connected to the fire main;
——the emergency fire pump is to be located outside the engine room and within spaces easily accessible, and be set above working deck as far as possible, and supplied water by an independent submarine valve located outside the main fire pump space.The locations of the pump and its suction are to be such that the pump can still run effectively at the lowest draught that may be encountered in the operation of fishing vessels. The emergency fire pump is to be self-priming;
——if the emergency fire pump is driven by motor, it is to be powered by emergency power supply and the continuous running time is not to be less than 3 hours when the main power supply is cut off;
——if the emergency fire pump is directly driven by the diesel engine or indirectly driven by the emergency diesel generator set, the diesel engine is to be capable of being readily started in its cold condition down to the temperature of 0℃, and its fuel flash point (closed cup test) is not to be lower than 43℃, and fuel tank is to contain sufficient fuel to enable the pump to run on full load for at least 3 h. In addition sufficient reserves of fuel is to be available to enable the pump to be run on full load for an additional 9 h.
④ portable power emergency fire pump is suitable to be driven by diesel engine. fuel tank is to contain sufficient fuel to enable the pump to run on full load for at least 3 h. In addition sufficient reserves of fuel is to be available to enable the pump to be run on full load for an additional 9 h. The pump is to be equipped with necessary accessories.
⑤ for the emergency fire pump which is allowed to use portable power, the permanent sea connection device for emergency use is generally to be set outside the machinery space. The use of hose to absorb water directly from the outboard is to be approved by CCS.
⑥ the suction pipeline of emergency fire pump is to be designed to minimize the loss of suction head.
⑦ the emergency fire pump along with its submarine valve and other necessary valves are to be operable from outside compartments containing main fire pumps in a position not likely to be cut off by a fire in those compartments.
5.8.5.9 Fire mains
(1) Where more than one hydrant is required to provide the number of jets specified in 5.8.5.10 (1) of this Section, a fire main is to be provided.

(2) Materials readily rendered ineffective by heat are not to be used for fire mains, unless adequately protected.
(3) Where fire pump delivery pressure can exceed the designed working pressure of fire mains, relief valves is to be fitted.
(4) Fire mains are not to have any connection to any system other than those required for fire fighting, except for the purpose of washing the deck and anchor chains and operation of bilge ejectors, subject to the efficiency of the fire-fighting system being maintained.
(5) Where fire mains are not self-draining, suitable drain cocks is to be fitted where frost damage may be expected.

5.8.5.10 Fire hydrant, fire hose and water nozzles

(1) Fire hydrants are to be positioned so as to allow easy and quick connection of fire hoses and so that at least one jet can be directed into any part of the vessel which is normally accessible during navigation.
(2) The jet required in 5.8.5.10 (1) of this Section is to be from a single length of fire hose.
(3) In addition to the requirements of 5.8.5.10 (1) of this Section, machinery spaces of category A are to be provided with at least one hydrant complete with fire hose and dual purpose nozzle. The fire hydrant is to be located outside the space and near the entrance.
(4) For every required fire hydrant, there is to be one fire hose. At least one spare fire hose is to be provided in addition to this requirement.
(5) Single length of fire hose is not to exceed 20 m.
(6) Fire hoses is to be of an approved material. Each fire hose is to be provided with couplings and a jet /water mist dual-purpose nozzle.
(7) Except where fire hoses are permanently attached to the fire main, the couplings of fire hoses and nozzles are to be completely interchangeable.
(8) The nozzles, as required by 5.8.5.10 (6) of this Section are to be appropriate to the delivery capacity of the fire pumps fitted, but in any case are to have a diameter of not less than 12 mm.

5.8.5.11 A sufficient number of approved portable fire extinguishers are to be provided in control stations and accommodation and service spaces to ensure that at least one extinguisher of a suitable type is readily available for use in any part of such spaces. The total number of extinguishers in these spaces is not to be less than three.

5.8.5.12 Fire-extinguishing appliances in machinery spaces

(1) Water fire-extinguishing system is to be provided in machinery spaces.
(2) Machinery spaces are to be provided with at least a 45L foam extinguisher or its equivalent, so that foam or its equivalent can be directed onto parts of fire hazards.

5.8.5.13 One of the portable fire extinguishers intended for use in any space is to be stowed near an entrance to that space.

5.8.5.14 Fire-extinguishing appliances are to be kept in good order and available for immediate use at all times.

5.8.6 Fire safety requirements for fishing vessels of less than 30m in length

5.8.6.1 Structural fire protection

(1) The hull, superstructure, structural bulkheads, decks and deckhouses are to be constructed of steel or other equivalent materials.
(2) The surface of insulation fitted on the internal boundaries of machinery spaces of category A and spaces where oil products may enter is to be impervious to oil or oil vapours.
(3) All thermal insulation of accommodation spaces is to be constructed of non-combustible materials. Within compartments used for stowage of fish, combustible insulation are to be protected by close-fitting cladding.
(4) Doors between machinery spaces and accommodation spaces are to be steel or other equivalent materials. A door may be allowed between the kitchen and the dining room, but it is to be made of non-combustible materials; the kitchen and the dining room can be regarded as one common lounge and divided into two appropriate cabins where only electrically cooking appliances are fitted in the kitchen.

5.8.6.2 Ventilation system

(1) Ventilation systems serving machinery spaces are to be independent of systems serving other spaces, and the main air inlets and outlets are to be able to be closed from outside the spaces, and the ventilation ducts are not to, as far as possible, pass through other spaces.
(2) Ventilation ducts are to be made of steel or other non-combustible materials.
(3) All power ventilations are to be able to be stopped from easily accessible positions outside the spaces serviced.

5.8.6.3 Heating installations

(1) Electric radiators are to be fixed in position and so constructed as to reduce fire risks to a minimum. No such radiator are to be fitted with an element so exposed that clothing, curtains or other similar materials can be scorched or set on fire by heat from the element.
(2) Heating by means of open fires are not to be permitted. Heating stoves and other similar appliances are to be firmly secured and adequate protection and insulation against fire are to be provided beneath and around such appliances and in way of their uptakes. Uptakes of stoves which burn solid fuel are to be so arranged and designed as to minimize the possibility of becoming blocked by combustion products and are to have a ready means for cleaning. Dampers for limiting draughts in uptakes are still to leave an adequate area open when in the closed position. Spaces in which stoves are installed are to be provided with ventilators of sufficient area to provide adequate combustion-air for the stove.
(3) Open flame gas appliances, except cooking stoves and water heaters, are not to be permitted. Spaces containing any such stoves or water heaters are to have adequate ventilation to remove fumes and possible gas leakage to a safe place. All pipes conveying gas from container to stove or water heater are to be of steel or other approved material. Automatic safety gas shut-off devices are to be fitted to operate on loss of pressure in the gas main pipe or flame failure on any appliance.

5.8.6.4 Miscellaneous items

(1) Exposed surfaces within accommodation spaces, service spaces, control stations, corridor and stairway enclosures and the concealed surfaces behind bulkheads, ceilings, panellings and linings in accommodation spaces, service spaces and control stations are to have low flame-spread characteristics.
(2) Paints, varnishes and other finishes used on exposed interior surfaces are not to be capable of producing excessive quantities of smoke or toxic gases or vapours.
(3) Primary deck coverings within accommodation and service spaces and control stations, are to be of approved material which will not readily ignite or give rise to toxic or explosive hazards at elevated temperatures.
(4) In accommodation and service spaces and control stations, pipes penetrating "A" or "B" class divisions are to be of approved materials capable of withstanding the temperature required by the division. Due to arrangement reasons, the pipes conveying oil or combustible liquids that pass through accommodation and service spaces are to be approved fire-resistant material.
(5) Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.
(6) All waste receptacles, other than those used in fish processing, are to be constructed of non-combustible materials with no openings in the sides and bottom.
(7) Machinery driving fuel oil transfer pumps, fuel oil unit pumps and other similar fuel pumps are to be fitted with remote controls situated outside the space concerned so that they can be stopped in the event of a fire arising in the space in which they are located.
(8) Drip trays are to be fitted, where necessary, to prevent oil leaking into bilges.

5.8.6.5 The storage of gas cylinders and dangerous materials is to meet the requirements of 5.8.5.5 of this Section.

5.8.6.6 Means of escape

(1) At least one entrance together with necessary stairways or staircases from all accommodation spaces and in spaces in which the crew is normally employed, other than machinery spaces, are to be so arranged as to lead to the open deck.
(2) At least one means of escape is to be provided from every machinery space of category A.
(3) A corridor or a part of a corridor from which there is only one route of escape is not to exceed 5 m in length.

5.8.6.7 Fire pump

(1) At least one power fire pump is to be provided, which can be driven by independent power or driven by main machinery.
(2) The capacity of fire pump is to be at least calculated according to the following formula, but it is not to be less than 16m^3/h and not to exceed 30 m^3/h in any case.

$$Q=(0.15\sqrt{L(B+D)}+2.25)^2 \quad m^3/h$$

Where: L——Length, m
B——Breadth, m
D——Depth, m.

(3) Sanitary, bilge, ballast or general service pumps may be used as fire pumps if they cannot be often used for pumping oil. If they are occasionally used for lightering or pumping fuel oil, suitable conversion devices are to be installed.

5.8.6.8 Fire mains
(1) Where more than one hydrant is required to provide the number of jets specified in 5.8.6.9 (1) of this Section, a fire main is to be provided.
(2) Materials readily rendered ineffective by heat are not to be used for fire mains, unless adequately protected.
(3) Where fire pump delivery pressure can exceed the designed working pressure of fire mains, relief valves is to be fitted.
(4) Fire mains are not to have any connection to any system other than those required for fire fighting, except for the purpose of washing the deck and anchor chains and operation of bilge ejectors, subject to the efficiency of the fire-fighting system being maintained.
(5) Where fire mains are not self-draining, suitable drain cocks is to be fitted where frost damage may be expected.
5.8.6.9 Fire hydrant, fire hose and water nozzles
(1) Fire hydrants are to be positioned so as to allow easy and quick connection of fire hoses and so that at least one jet can be directed into any part of the vessel which is normally accessible during navigation.
(2) The jet required in 5.8.6.9 (1)of this Section is to be from a single length of fire hose.
(3) In addition to the requirements of 5.8.6.9 (1) of this Section, machinery spaces of category A are to be provided with at least one hydrant complete with fire hose and dual purpose nozzle. The fire hydrant is to be located outside the space and near the entrance.
(4) For every required fire hydrant, there is to be one fire hose. At least one spare fire hose is to be provided in addition to this requirement.
(5) Single length of fire hose is not to exceed 20 m.
(6) Fire hoses is to be of an approved material. Each fire hose is to be provided with couplings and a jet /water mist dual-purpose nozzle.
(7) Except where fire hoses are permanently attached to the fire main, the couplings of fire hoses and nozzles are to be completely interchangeable.
(8) The nozzles, as required by 5.8.6.9 (6) of this Section are to be appropriate to the delivery capacity of the fire pumps fitted, but in any case are to have a diameter of not less than 12 mm.
5.8.6.10 A sufficient number of approved portable fire extinguishers are to be provided in control stations and accommodation and service spaces to ensure that at least one extinguisher of a suitable type is readily available for use in any part of such spaces. The total number of extinguishers in these spaces is not to be less than three.
5.8.6.11 Fire-extinguishing appliances in machinery spaces
(1) Water fire-extinguishing system is to be provided in machinery spaces.
(2) Machinery spaces are to be provided with two foam extinguishers or its equivalent equipment, so that foam or its equivalent can be directed onto parts of fire hazards.
5.8.6.12 One of the portable fire extinguishers intended for use in any space is to be stowed near an entrance to that space.
5.8.6.13 Fire-extinguishing appliances are to be kept in good order and available for immediate use at all times.

CHAPTER 6 ADDITIONAL REQUIREMENTS FOR OPEN-TOP CONTAINER SHIPS

Section 1 OPEN-TOP CONTAINER SHIPS ENGAGED IN UNRESTRICTED SERVICE

6.1.1 Application

6.1.1.1 This Section applies to open-top container ships of 500 gross tonnage and over, engaged in unrestricted service.

6.1.1.2 Open-top container ships are to be designed in compliance with IMO MSC/Circ.608/Rev.1.

6.1.1.3 Open-top container ships are to comply with the requirements of this Chapter and in addition, the applicable requirements of the Rules and the requirements of CCS Rules for Materials and Welding.

6.1.2 Definitions

6.1.2.1 For the purpose of this Chapter:

(1) Open-top container ship means a containership especially designed so that one or more of the cargo holds need not be fitted with hatch covers.

(2) Freeboard is the distance between the assigned load line and freeboard deck.

(3) Freeboard deck of open-top container ships engaged on international voyages, for the purposes of Chapters I and II of Annex I of the International Convention on Load Lines, 1966 (hereinafter referred to as the LL 1966), is the freeboard deck according to the LL 1966 as if hatch covers are fitted on top of the hatch coamings.

(4) Maximum sustained speed is defined as the maximum service speed taking into account speed loss due to resistance increase in regular waves. Voluntary speed loss is not taken into consideration.

(5) Minimum ship manoeuvring speed is defined to be the minimum speed which maintains directional control and is consistent with the operating characteristics of the ship.

(6) Green water is sea water other than spray shipped aboard the ship under normal operating conditions.

(7) Hold freeing ports are openings penetrating the hull on both sides of the ship above full load waterline within hold area, fitted with non-return valves through which water in a hold overflows outboard while external seawater will not enter the hold in any case.

(8) Permeability of a space is the percentage of that space which can be occupied by water.

6.1.3 Class notation

6.1.3.1 Open-top container ships complying with the requirements of this Chapter are to be assigned the Open-Top Container Ship class notation.

6.1.4 Plans and documents

6.1.4.1 In addition to the plans and documents specified in the relevant PARTs and Chapters of the Rules, the following are to be submitted for approval:

(1) Calculations of general and local strength of hull in full-load flooded condition;

(2) Calculations of capacity of bilge pumping system.

6.1.5 Freeboard and ship arrangement

6.1.5.1 Minimum freeboard is to be determined by seakeeping characteristics, stability (both intact and damage stability) and structural strength, and the greatest value obtained thereby is to be taken.

6.1.5.2 Seakeeping characteristics are to be obtained by model tests, and the following are to be submitted:

(1) measured data for the maximum hourly rate of ingress of green water likely to be shipped into each cargo hold;

(2) evaluation of the adequacy of the discharge rates from cargo hold freeing ports (if they are fitted).

6.1.5.3 In all loading conditions other than those assuming the hold being flooded, the assigned freeboard and the bow height are to be not less than the corresponding ones determined from the LL 1966 assuming hatch covers being fitted.

6.1.5.4 The assigned freeboard and the bow height according to 6.1.5.3 are to be not less than the corresponding ones for which the model tests are carried out. The maximum hourly rate of ingress of green

water in any one open hold determined from model testing is not to exceed the open hatch area multiplied by 400 mm/h.

6.1.5.5 All seasonal freeboards are to be omitted unless any corresponding seasonal freeboards for which the ship is eligible are greater than the freeboard for which the model tests are carried out.

6.1.5.6 Where an individual hold is fitted with hatch covers, the hold may be simulated as having containers being carried on the hatch covers with no seawater being shipped into the hold during the model test.

6.1.5.7 Container cell guides are to be fitted in the hold, except for ships engaged on short international voyages.

6.1.5.8 The stowage of containers with dangerous goods in ships carrying such containers is to comply with the requirements of 6.1.12 and 6.1.13 of this Section.

6.1.5.9 No freeing port is to be fitted on the hatch coaming of an open hold.

6.1.6 Procedure of model tests

6.1.6.1 The model experiments are to be carried out in long-crested, irregular waves.

6.1.6.2 The Pierson–Moskovitz, JONSWAP or Bretschneider spectrum is to be used for these experiments. Other spectra may be allowed for ships operating in restricted areas only.

6.1.6.3 The wave spectrum generated for the purpose of these experiments is to have a significant wave height of approximately 8.5 m at the most unfavorable realistic wave period (zero crossing).

6.1.6.4 The effect of wind generated spray need not be simulated during the tests.

6.1.6.5 The model experiments are to be carried out for at least the following wave directions:

(1) following seas (0°/360°);

(2) quarter following seas (45°/315°);

(3) beam seas (90°/270°);

(4) quarter head seas (135°/225°);

(5) head seas (180°).

6.1.6.6 The model experiments are to be carried out for at least the following speeds:

(1) maximum sustained speed in head seas and quarter head seas;

(2) minimum ship manoeuvring speed in quarter following seas and following seas;

(3) zero ship speed (dead ship condition) in beam seas.

6.1.6.7 The model experiments are to be carried out with a self-propelled, unrestrained model without the necessity to change course and the time period of each experiment is to correspond to at least one hour real time.

6.1.6.8 The loading condition used for the tests is to correspond at least to the maximum loaded draught with designed trim. If operational trim values differ substantially from designed trim, additional trim values are to be included in the model test programme.

6.1.6.9 The height of centre of gravity (*KG* value) selected is to correspond to the actual value most likely to be encountered during the ship's service. If *KG* values which may be expected during the operation of the ship differ substantially from this selected *KG* value, additional *KG* values are to be included in the model test programme.

6.1.6.10 For each test condition, the cargo hold which ships most water is to be determined by preliminary tests for each combination of heading, trim and *KG*. In running tests for the full duration specified above, this least favorable hold is to be simulated as having no containers, whilst other cargo holds (each cargo hold as a separate entity) may be simulated as completely fully loaded with containers above the line of the weather deck (or hatch coaming where applicable). Containers are not to be used as a means to prevent shipping of water into an empty hold where they are stacked outboard of the open hold. Rain covers for the open holds are not to be simulated in the model tests.

6.1.6.11 In addition to the usual parameters measured (ship motions, ship speed, relative motions, rudder angles, etc.), the volume of water entering all open cargo holds is to be measured for each experiment. The quantities of water taken aboard the model are to be removed and measured after each test run so that the metacentric height, moment of inertia and displacement are not appreciably disturbed by any accumulation of water during the testing programme.

6.1.6.12 Where freeing ports are fitted, an additional model test to comply with 6.1.5.2(2) is to be conducted at a draught which corresponds to the condition of a departing ship fully loaded with cargo and open holds flooded to the static equilibrium level with freeing ports open. A hold permeability of 70% by volume is to be assumed. Tests are to be conducted at zero speed in beam seas to verify that the capacity of freeing ports is such that the ship will not capsize.

6.1.7 Strength and construction

6.1.7.1 The hull strength and structure of open-top container ships are to be calculated and checked in accordance with Chapters 2 and 7 of PART TWO of the Rules.
6.1.7.2 The general and local strength of the hull is to be sufficient in all loading conditions (including those indicated in 6.1.8.2). In loading conditions indicated in 6.1.8.2, the following requirements are to be satisfied:
(1) Where the still water bending moment in flooded condition exceeds the allowable value, or the draught in flooded condition is greater than the scantling draught, the actual still water bending moment and/or draught in flooded condition is to prevail. Hull girder longitudinal strength (including ultimate strength) is to be checked in accordance with Section 2, Chapter 7, PART TWO of the Rules.
(2) Where the draught in flooded condition is greater than the scantling draught, the former is to prevail. Local strength is to be checked in accordance with relevant sections of Chapters 2 and 7, PART TWO of the Rules.
(3) For hull structures forming watertight boundaries of open-top holds, requirements in Section 13 Deep Tanks, Chapter 2, PART TWO of the Rules are to be satisfied, where the design pressure head h is the vertical distance from the calculation point to the highest point of down flooding height specified in 6.1.8.2.
6.1.7.3 When checking the general strength of open-top container ships, the hatch deformation due to hydrodynamic torque need not be considered.

6.1.8 Intact stability
6.1.8.1 The intact stability of the ship is to meet the relevant requirements for container ships of IMO resolution MSC.267(85) "The International Code on Intact Stability, 2008" and the amendments thereto.
6.1.8.2 Unless specified in 6.1.8.1, with all open holds completely filled with water (permeability of 0.70 for container holds) to the level of the top of the hatch side or hatch coaming or, in the case of a ship fitted with cargo hold freeing ports, to the level of those ports, the stability of the fully laden ship in the intact condition is to meet the survival criteria (with factor $S = 1$) in SOLAS II-1, Part B-1, as amended.
6.1.8.3 The intermediate conditions of hold flooding are also to be considered.

6.1.9 Damage stability
6.1.9.1 The damage stability is to comply with the subdivision and damage stability criteria in SOLAS II-1, Part B to B-4, as amended. The top of coamings of open-top holds is to be considered as the location from which downflooding begins.

6.1.10 Open hold bilge dewatering system and freeing ports
6.1.10.1 The bilge pumping system is to have sufficient capacity to pump:
(1) the maximum hourly rate of green water shipped in seagoing conditions as established by the comprehensive model testing;
(2) an amount equal to rainfall of 100 mm/hour regardless of the installation of rain covers;
(3) the hourly amount of shipped green water measured during the seakeeping model tests for the dead ship condition in beam seas, multiplied by safety factor 2;
(4) four-thirds of the amount of water required for fire-fighting purposes in the largest hold;
(5) an amount equal to the capacity required for ships with closed cargo holds,
whichever is the greater.
6.1.10.2 The pumping of hold bilges is to be possible by at least three bilge pumps.
6.1.10.3 At least one of these pumps is to have a capacity of not less than the required capacity as defined in 6.1.10.1 and is to be dedicated to bilge and ballast service only. The pump is to be located in such a way that it will not be affected by a fire or other casualty to the space containing the pumps required in 6.1.10.4 below or the space containing the main source of power and is to be supplied from the emergency switchboard required by SOLAS Reg. II-1/43, as amended.
6.1.10.4 The combined output of at least two further pumps is not to be less than the required capacity as defined in 6.1.10.1. These pumps are to be supplied from the main source of electrical power required by SOLAS Reg. II-1/41, as amended, or any other source of power independent of the emergency switchboard required by SOLAS Reg. II-1/43, as amended.
6.1.10.5 The bilge pumping system, including the piping system, is to incorporate sufficient redundancy features so that the system will be safely operational and capable of dewatering the hold spaces at the required capacity in the event of failure of any one system component.
6.1.10.6 The bilge pumping system is to be arranged to be effective within the limiting angles of inclination required for the emergency source of electrical power by SOLAS, as amended, and bilge wells are to be readily accessible for cleaning.

6.1.10.7 All open cargo holds are to be fitted with high bilge level alarms. The alarms are to initiate visual and audible warnings in the engine room and the manned control locations (navigation bridge, control stations or machinery space) and be independent of bilge pump controls.
6.1.10.8 If the loss of suction prevents the proper functioning of the bilge system, special measures to prevent this are to be considered, for instance, the installation of level indicators.
6.1.10.9 Open cargo hold drain wells are to be designed to ensure unobstructed discharge of water and easy access for cleaning under all conditions.
6.1.10.10 If provided, freeing ports are to be fitted on both sides of each open cargo hold, subject to the following:
(1) The number, size and location of the freeing ports on each side of each open hold are to be sufficient to prevent the accumulation of water above the level defined in 6.1.6.12 of this Section.
(2) Efficient means of closure to prevent the accidental ingress of water are to be provided. Such means are to be operated from above the freeboard deck. In the case of a ship operating in areas where icing is likely to occur, these arrangements are to be suitable to enable the ports to operate efficiently under such conditions.

6.1.11 Fire protection requirements

6.1.11.1 The fire protection system for open-top container holds is to be based on the philosophy of containing the fire in the bay of origin and to cool adjacent areas to prevent structural damage.
6.1.11.2 Open-top container holds are to be protected by a fixed water spray system. The system is to be capable of spraying water into the cargo hold from deck level downward. The system is to be designed and arranged to take account of the specific hold and container configuration. Where necessary a full-scale test may be required.
6.1.11.3 The water spray system is to be able to effectively contain a fire in the container bay of origin. The spray system is to be subdivided, with each subdivision to consist of a ring-line at deck level in an open cargo hold around a container bay.
6.1.11.4 The water spray system is to be capable of spraying the outer vertical boundaries of each container bay in an open cargo hold and of cooling the adjacent structure. The uniform application density is to be not less than 1.1 l/min/m^2. At least one dedicated fire-extinguishing pump for the hold water spray system with a capacity to serve all container bays in any one open-top container hold simultaneously is to be provided. These pumps are to be installed outside the open-top area. The availability of water to the water spray system is to be at least 50% of the total capacity, with adequate spray patterns in the open-top container hold, and with any one dedicated pump inoperable. For the case of a single dedicated water spray pump this may be accomplished by an interconnection to an alternative source through a hose from the weather deck.
6.1.11.5 Whenever a fire detection system is required in the open hold area, the fire detection system is to be designed and arranged to take account of the specific hold and container configuration and ventilation arrangement.

6.1.12 Carriage of dangerous goods

6.1.12.1 Dangerous goods for which “on deck only” stowage is specified in the International Maritime Dangerous Goods Code (IMDG Code), are not to be carried in or vertically above open-top container holds.
6.1.12.2 In addition to the requirements of 6.1.12.1 above, containers with dangerous goods extending more than 1 m above the top of the watertight upper boundary around an open-top container hold and containing liquids, gases or vapors heavier than air and for which “on deck only” stowage is specified, are not to be carried within one container space① horizontally from the boundary of the open-top container holds.
6.1.12.3 Dangerous goods other than those described in 6.1.12.1 above are not to be carried in or vertically above open-top container holds unless such holds are in full compliance with SOLAS Reg. II-2/19, as amended, applicable to enclosed container cargo spaces, as appropriate for the cargo carried.

6.1.13 Segregation of dangerous goods

6.1.13.1 The segregation of dangerous goods for open-top container holds is to comply with Table 6.1.13.1 instead of the table of segregation of freight containers on board container ships contained in section 7.4.3.3 of the IMDG Code.

---

① Defined in 7.4.3.1.1 of the International Maritime Dangerous Goods Code (IMDG Code), i.e. container space is a space of at least 6 m lengthways and at least 2.4 m athwart. See also the latest definition in the IMDG Code.

Table of Segregation of Freight Containers in Holds of Open-Top Container Ships[①] Table 6.1.13.1

Segregation requirement	Vertical			Horizontal							
					Closed versus closed		Closed versus open		Open versus open	
	Closed versus closed	Closed versus open	Open versus open		On deck	Under deck	On deck	Under deck	On deck	Under deck
1 "Away from"	Superimposition allowed	Open above closed allowed, otherwise as open versus open	Not on the same vertical line	Fore and aft	No restriction	No restriction	No restriction	No restriction	One container space	One container space or one bulkhead
				Athwartships	No restriction	No restriction	No restriction	No restriction	One container space	One container space
2 "Separated from"	Not on the same vertical line	As open versus open		Fore and aft	One container space	One container space or one bulkhead	One container space	One container space or one bulkhead	One container space and not in or above the same hold	One bulkhead
				Athwartships	One container space	One container space	Two container spaces	Two container spaces	Two container spaces and not in or above the same hold	One bulkhead
3 "Separated by a complete compartment or hold from"				Fore and aft	One container space and not in or above the same hold	One bulkhead	One container space and not in or above the same hold	One bulkhead	Two container spaces and not in or above the same hold	Two bulkheads
				Athwartships	Two container spaces and not in or above the same hold		Two container spaces and not in or above the same hold		Three container spaces and not in or above the same hold	Two bulkheads
4 "Separated longitudinally by an intervening complete compartment or hold from"	Prohibited			Fore and aft	At least 24 m horizontally and not in or above the same hold	One bulkhead and at least 24 m horizontally[②]	At least 24 m horizontally and not in or above the same hold	Two bulkheads	At least 24 m horizontally and not in or above the same hold	Two bulkheads
				Athwartships	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited

Note: ① All bulkheads and decks are to be resistant to fire and liquid.
② Containers are to be at least 6 m from the bulkhead.

CHAPTER 7 ADDITIONAL REQUIREMENTS FOR PUSHER TUG-BARGE COMBINATIONS

Section 1 GENERAL PROVISIONS

7.1.1 Application

7.1.1.1 Additional requirements for pusher tug-barge combinations are given in Section 2, Chapter 7, PART TEN of the Rules.

CHAPTER 8 ADDITIONAL REQUIREMENTS FOR PUBLIC AFFAIR SHIPS

Section 1 GENERAL PROVISIONS

8.1.1 General requirements

8.1.1.1 This Chapter applies to public affair ships. Public affair ships mean ships used for the purpose of government administrative management.

8.1.1.2 Public affair ships are, in addition to provisions of this Chapter, to comply with applicable provisions of other PARTs and Chapters of the Rules.

8.1.1.3 Where special provisions for public affair ships are specified by the Administration of the flag State, such provisions are to be implemented.

8.1.2 Class notation

8.1.2.1 Public affair ships complying with requirements of this Chapter are to be assigned the following class notation:

Public Affair Ship

8.1.3 Hull structures

8.1.3.1 Hull structures are to satisfy the requirements of CCS Guidelines for Hull Structures of Public Affair Ships at Sea.

CHAPTER 9 ADDITIONAL REQUIREMENTS FOR SHIPS HAVING INDEPENDENT ICEBREAKING CAPABILITY

Section 1 GENERAL PROVISIONS

9.1.1 General requirements

9.1.1.1 This Chapter applies to ships not specially designed for icebreaking duties and navigating in first year ice conditions, complying with the ice strengthening requirements of PART TWO and PART THREE of the Rules for B1*, B1, B2 and B3 notations and having an independent icebreaking capability. Ships assigned ice class notation B1* in accordance with the provisions of Section 2, Chapter 4, PART TWO of the Rules, already have the capability of independent navigation in ice corresponding to the ice class notation without the assistance of an icebreaker. For ships complying with the requirements of this Chapter, their independent icebreaking capability is to be better than that of the ships assigned B1* notation in accordance with the provisions of PART TWO and PART THREE of the Rules, i.e. having the icebreaking capacity of removing obstacles for other ships navigating in ice.

9.1.1.2 When approaching ice-infested waters, the ship's speed is to be reduced appropriately. The vertical extent of ice strengthening for ships intended to operate at speeds exceeding 15 kn in areas containing isolated ice floes is to be increased appropriately.

9.1.1.3 The ship is to have a hull form at the fore end adapted to break ice effectively. Bulbous bows are not to be fitted for ships having higher ice class notations. The stern of the ship is to have a form such that broken ice is effectively displaced. Whenever practicable, transverse framing is to be selected. Where it is desired to make provision for tow operations, the bow area is to be suitably reinforced. In addition, local reinforcement is to be made in way of the stern fork.

9.1.2 Class notations

9.1.2.1 For a ship complying with the requirements for ice strengthening and the requirements of this Chapter, the special features notation "Icebreaking" is to be added before its type notation, together with a corresponding ice class notation, e.g. Icebreaking Tug, Ice Class B1.

Section 2 ENGINE OUTPUT

9.2.1 Output of propulsion machinery

9.2.1.1 The output of propulsion machinery of the ship is to be greater than that required for icebreaking as determined in accordance with 9.2.1.2.

9.2.1.2 The output N_1 required for icebreaking is not to be less than that determined in accordance with the following formula:

$$N_1 = 0.736 f_1 f_2 f_3 f_4 [240 B h_0 (1 + h_0 + 0.035 v^2) + 70 S_c \sqrt{L}] \quad \text{kW}$$

where: B — breadth of the ship, in m;

L — length of the ship, in m;

f_1 — coefficient, to be calculated as below and taken not less than 1.0:

$$f_1 = \frac{1.2\,B}{\sqrt[3]{\Delta}}$$

where Δ means displacement, in t, see 4.2.2.2 of Section 2, Chapter 4 of PART TWO of the Rules;

f_2 — coefficient, to be taken as 0.9 for controllable pitch propeller and 1.0 for fixed pitch propeller;

f_3 — coefficient, to be taken as 0.9 when entry angle of the portion of the fore-body below the waterline is 45ºor less, and 1.0 when the angle is greater than 45º, and the product $f_2 f_3$ is not to be taken less than 0.85;

f_4 — coefficient, to be taken as 1.1 with bulbous bow and 1.0 without bulbous bow;

h_0 — ice thickness, in m, see Table 4.2.4.2(1) of Section 2, Chapter 4 of PART TWO of the Rules;

v — ship speed, in kn, when breaking ice of thickness h_0, not to be taken less than 5 kn;

S_c — depth of snow cover, in m, not to be taken less than 0.3 m.

Section 3 HULL STRUCTURE

9.3.1 General requirements

9.3.1.1 In respect to the strengthening requirements for ships having an icebreaking capability where the ice load is calculated in accordance with Section 2, Chapter 4 of PART TWO of the Rules, the actual output power of the main engine at MCR is not to be less than that required for icebreaking in Section 2 of this Chapter.

9.3.2 General requirements for side framing

9.3.2.1 Where a frame or longitudinal frame intersects a boundary between two of the hull regions (see Section 2, Chapter 4 of PART TWO of the Rules), the scantling requirements applicable will be those for the greater region.

9.3.2.2 Extent of tripping brackets: B1* — all regions; B1— forward and midship regions; B1 and B3 — forward region.

9.3.2.3 The effective weld area attaching ice frames or longitudinal frames to primary members is not to be less than the shear area for the frames or longitudinal frames.

9.3.3 Ice stringers

9.3.3.1 The webs of primary longitudinal members supporting transverse ice frames are to be stiffened and connected to the main or intermediate frames so that the distance s between such stiffeners is not greater than that determined in accordance with the following formula:

$$s = 17.06 \frac{t}{\eta} \sqrt{\frac{t}{F_l}} \qquad \text{mm}$$

where: t — thickness, in mm, of the primary longitudinal member adjacent to the shell plating.

F_l — longitudinal distribution coefficient, see Table 9.3.3.1.

Table 9.3.3.1

Ice class	F_l		
	Fore	Midship	Aft
B1*	1.00	0.98	0.89
B1	0.87	0.75	0.64
B2	0.78	0.64	0.51
B3	0.68	0.53	0.37

η — coefficient,

for forward region, one of the following values is to be taken, whichever is the least:

$$\eta_1 = 0.653 + 3.217 \frac{\sqrt{P\Delta}}{10^5}$$

$$\eta_2 = 0.876 + 9.908 \frac{\sqrt{P\Delta}}{10^6}$$

$$\eta_3 = 1;$$

for midship and aft regions, one of the following values is to be taken, whichever is less:

$$\eta_1 = 0.653 + 9.908 \frac{\sqrt{P\Delta}}{10^6}$$

$$\eta_2 = 1.$$

P — actual output power of the main engine at MCR, not to be less than that required for icebreaking in Section 2 in this Chapter.

Δ — displacement, in t, see 4.2.2.2, Section 2, Chapter 4 of PART TWO of the Rules.

9.3.4 Stem

9.3.4.1 The section moduls W of the stem in the fore and aft direction is not to be less than that determined in accordance with the following formula:

$$W = 1500 F_l^{1.5} \eta^3 \qquad \text{cm}^3$$

where: F_l, η — see 9.3.3.1.

9.3.4.2 The thickness t of side plates of a welded stem constructed as shown in Figure 9.3.4.2 is to be determined in accordance with the following formula:

$$t = 31\eta\sqrt{F_l} \qquad \text{mm}$$

where: F_l, η — see 9.3.3.1.

The dimension of a welded stem is to be determined in accordance with Figure 9.3.4.2.

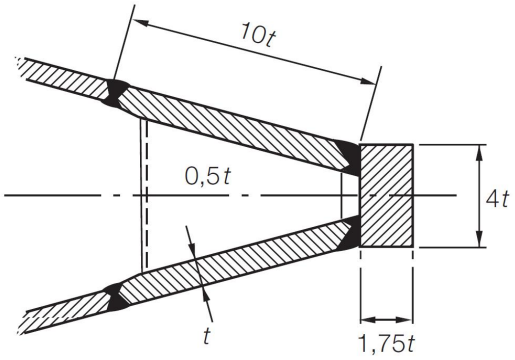


Figure 9.3.4.2 Welded Stem

CHAPTER 10 ADDITIONAL REQUIREMENTS FOR PETROLEUM ASPHALT CARRIERS

Section 1 GENERAL PROVISIONS

10.1.1 Application

10.1.1.1 These requirements apply to ships having one of the class notations specified in 10.1.2, specialized in carrying melted petroleum asphalt in bulk in unrestricted service.

10.1.1.2 Unless specified otherwise, asphalt carriers are to comply with the requirements for tankers carrying petroleum products having a flash point exceeding 60℃. Where the maximum cargo temperature cannot be at least 15℃ lower than the flash point of petroleum asphalt, the requirements for tankers carrying petroleum products having a flash point less than 60℃are to be complied with.

10.1.1.3 Calculation of temperature field and analysis of thermal stress required by this Chapter are to comply with the relevant requirements of Section 24, Chapter 2 of PART TWO of the Rules.

10.1.1.4 In the structural calculation of asphalt carriers, the sloshing loads of asphalt cargo need not be considered.

10.1.2 Class notations

10.1.2.1 For classed asphalt carriers fitted with integral tanks and complying with the requirements of this Chapter, the following notation is to be assigned: Asphalt Carrier (Integral tank, Max. Cargo Temperature ≤ XXX℃), F.P. > 60℃, ESP, or Asphalt Carrier (Integral tank, Max. Cargo Temperature ≤×××℃)， F.P. ≤ 60℃, ESP.

10.1.2.2 For classed asphalt carriers fitted with independent tanks and complying with the requirements of this Chapter, the following notation is to be assigned: Asphalt Carrier (Independent tank, Max. Cargo Temperature ≤×××℃), F.P. > 60℃ or Asphalt Carrier (Independent tank, Max. Cargo Temperature ≤×××℃), F.P. ≤ 60℃.

10.1.2.3 If requirements of Section 24 of Chapter 2, PART TWO of the Rules are complied with, notation for thermal stress calculation “Thermal stress calculation” may be added.

10.1.2.4 If the arrangement of cargo tanks, including independent and integral tanks, of asphalt carriers comply with the following requirements, Double Hull notation may be assigned:

(1) for asphalt carriers of 5,000 tonnes deadweight and above, the distance *W* between the side plate of the cargo tank or the inner shell of the side tank and the shell plating as well as the distance h between the bottom plate or inner double plate of the cargo tank and the bottom plating comply with the requirements of 1.12.12.1, Section 12, Chapter 1, PART TWO of the Rules;

(2) for asphalt carriers of less than 5,000 tonnes deadweight, the distance *W* between the side plate of the cargo tank or the inner shell of the side tank and the shell plating complies with the requirements of 1.12.12.4, Section 12, Chapter 1, PART TWO of the Rules, and the distance *h* between the bottom plate or inner double plate of the cargo tank and the bottom plating complies with the requirements of 1.12.12.2, Section 12, Chapter 1, PART TWO of the Rules.

10.1.3 Definitions

10.1.3.1 For the purpose of this Chapter:

(1) Petroleum asphalt means co-product of petroleum crude oil extracted to petroleum product such as gasoline, coal oil, diesel oil and lubricating oil, and then treated.

(2) Independent tank means a cargo tank which is not connected with or is not a component part of the hull structure. The independent tank is not necessary to the structural integrity of hull. The independent tank is to be connected to the hull by means of supporting structures to prevent slippage and deflection of the tank. Supporting structures are to include vertical supports, anti-rolling arrangements, anti-pitching arrangements and anti-flotation arrangements.

(3) Integral tank means a cargo tank which is a component part of the hull structure and is subjected to the same load with adjacent portions of the hull structure in the same manner. It is usually necessary to the structural integrity of hull.

(4) Hold space is the space enclosed by the ship’s structure in which an independent cargo tank is fitted.

10.1.4 Plans and documents

10.1.4.1 For all petroleum asphalt carriers, the following plans and documents are to be submitted for approval:

(1) Structural plan of cargo tank;

(2) Arrangement plan of cargo tank;
(3) Arrangement plan of heat-insulating material on cargo tank;
(4) Arrangement of means of access for inspections;
(5) Drawing of thermal oil heating system;
(6) Drawings and arrangement diagrams of monitoring and alarm systems related to liquid cargo;
(7) Arrangement of thermal oil boiler room;
(8) Diagram of control system of remotely controlled valve of thermal oil system;
(9) Diagram of fuel oil system of thermal oil boiler.
In addition, the following documents are to be submitted for information:
(1) Cargo information (type and property of cargoes allowed to be carried, e.g. specific gravity, flash point, temperature of cargo being carried, are to be indicated in the "Hull Specification");
(2) Calculations of heat-insulating performance of cargo tank.
10.1.4.2 For petroleum asphalt carriers fitted with integral tanks, the following plans and documents are to be additionally submitted for information:
(1) Calculations for thermal stress analysis of hull structural members (in full and half load conditions), in respect to the temperature of cargo being carried over 80℃.
10.1.4.3 For petroleum asphalt carriers fitted with independent tanks, the following plans and documents are to be additionally submitted for approval:
(1) Arrangement plan of cargo tank and its supporting structures (vertical supports, anti-rolling arrangements, anti-pitching arrangements and anti-flotation arrangements);
(2) Drawing and arrangement diagram of high level alarm system for cargo tank bilge well.
In addition, the following documents are to be submitted for information:
(1) Strength calculations for cargo tank supporting structures;
(2) When temperature of cargo being carried is over 180℃, thermal field distribution calculation of cargo tank is to be submitted. Where the thermal field analysis shows that temperature transmitting to main hull structure is over 80℃, analysis of thermal stress of cargo tank area is to be submitted.

10.1.5 Direct calculation of hull structural strength

10.1.5.1 For longitudinally framed single bottom asphalt carriers 90 m or over in length with independent cargo tanks, primary members (longitudinal and transverse) of the cargo area are to be directly calculated according to Appendix 1 of this Chapter.
10.1.5.2 For asphalt carriers of 150 m or above in length with independent cargo tanks, primary members (longitudinal and transverse) of the cargo area are to be directly calculated according to Appendix 1 of this Chapter.

Section 2 CONSTRUCTION AND ARRANGEMENT OF SHIP

10.2.1 Hull structure

10.2.1.1 The hull structure of asphalt carriers fitted with independent tanks is to comply with the relevant requirements in Chapter 2 of PART TWO of the Rules.
10.2.1.2 The hull structure of asphalt carriers fitted with integral tanks is, as appropriate, to comply with the relevant requirements in Chapters 5 and 6 of PART TWO of the Rules.
10.2.1.3 For asphalt carriers fitted with independent tanks and also with the single bottom of which is longitudinally framed and double sides of which are longitudinally framed, the following requirements are to be complied with:
(1) the minimum thickness: within the cargo tank region, the minimum thickness of primary member webs and face plates, shell plating, deck plating, and inner hull plating is not to be less than that obtained from the following formula:

$$t = 6.5 + L/50 \quad \text{mm, but not less than 7.5 mm}$$

where: L — length of ship, in m, taken not greater than 300 m.
The minimum thickness of secondary structural members are also to comply with the requirements mentioned above, but need not be greater than 11 mm.
The minimum thickness of the members in pump rooms, cofferdams and other void spaces may be 1 mm less than that required above, but not less than 7.5 mm.
(2) shell plating and deck plating: the longitudinally framed shell plating and deck plating of the cargo tank region are to comply with the requirements of Sections 3 and 4, Chapter 2, PART TWO of the Rules respectively;

(3) bottom framing:
(a) The section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = \frac{8.5}{1.73 - F_b}(d + h_1)sl^2K \qquad \text{cm}^3$$

where: s — spacing of longitudinals, in m;
l — span of longitudinal, in m, but not less than 1.5 m;
d — draught, in m;
F_b — reduction factor, see 2.2.5.6 of Chapter 2 of PART TWO;
h_1 — see 2.3.1.2 of Chapter 2 of PART TWO;
K — material factor.

The connections of bottom longitudinals to bulkheads are to provide adequate fixity and continuity of longitudinal strength. Where higher tensile steels are adopted, longitudinals are to be continuous through the transverse bulkheads. Where the bottom longitudinals are cut in way of the bulkheads, the longitudinals are to be bracketed to the bulkheads. The scantlings of the bracket are to comply with the requirements of 1.2.6 of Chapter 1 of PART TWO, and the flange width of the bracket is not to be less than 8 times the thickness of the bracket.
Bottom longitudinals are to be welded to the web and vertical stiffeners of bottom transverses.
(b) The solid floor is to be spaced not greater than 3.6 m, in line with side transverse web, to form a ring system. The spacing between the center and side keelsons is in general not to be greater than 2.5 m;
The size of solid floors, bottom centerline girder and bottom side girders are to be determined by direct calculation method, which is to comply with the requirements of Appendix 1 of this Chapter.
(c) The web depth of the solid floors is not to be less than 2.5 times the depth of the slot for the bottom longitudinals. The web thickness is not to be less than s/80 (s being the spacing of stiffeners).
The face plate of the solid floor is, within two frame spacing, to be gradually widened to not less than twice its original width at the longitudinal bulkhead, and to be welded to the bulkhead.
(d) The web depth of the bottom centerline girder is not to be greater than that of the bottom transverses. The web thickness of the bottom centerline girder is not to be less than that of the bottom transverses plus 2 mm. The web thickness and face plate scantlings of the intercostal bottom side girders are to be the same as those of the bottom transverses in way, while the depth may be half of that of the bottom transverses. Strengthening and end connections of bottom centreline girder are to comply with the requirements of 6.3.5 of Section 3 of Chapter 6 of PART TWO.
(4) side framing: for double side framing, where the side tanks are used as ballast tanks, the inner hull structure, watertight diaphragms and stiffeners are also to comply with the deep tank requirements of Section 13, PART TWO of the Rules.

10.2.2 Arrangement of ship

10.2.2.1 The hold type of independent tank is recommended.
10.2.2.2 For asphalt carriers fitted with integral tanks carrying cargo at a temperature over 80℃, tank boundaries are not to be in direct contact with seawater.
10.2.2.3 Passages for inspection in independent cargo areas are to comply with the following requirements:
(1) where it is required to pass between the surface to be inspected, flat or curved, and structures such as deck beams, stiffeners, frames, girders, etc., the distance between that surface and the free edge of the structural elements is to be at least 380 mm. The distance between the surface to be inspected and the surface to which the above structural elements are fitted, e.g. deck, bulkhead or shell, is to be at least 450 mm for a curved tank surface, or 600 mm for a flat tank surface (see Figure 10.2.2.3(1));

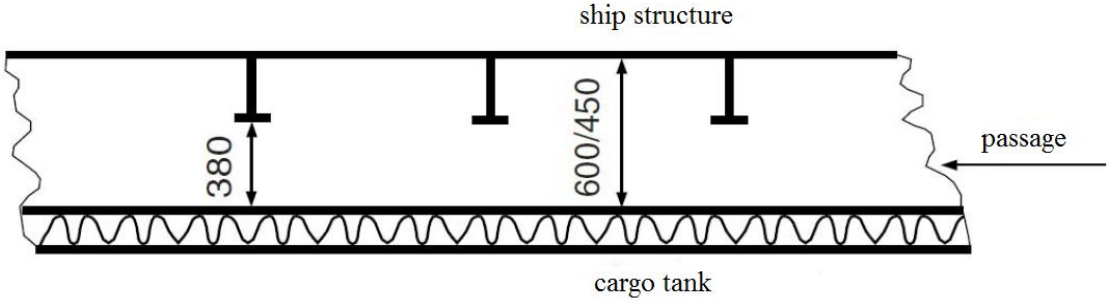


Figure 10.2.2.3(1)

(2) where it is not required to pass between the surface to be inspected and any part of the structure, for visibility reasons the distance between the free edge of that structural element and the surface to be inspected is to be at least 50 mm or half the breadth of the structure's face plate, whichever is the larger (see Figure 10.2.2.3(2));

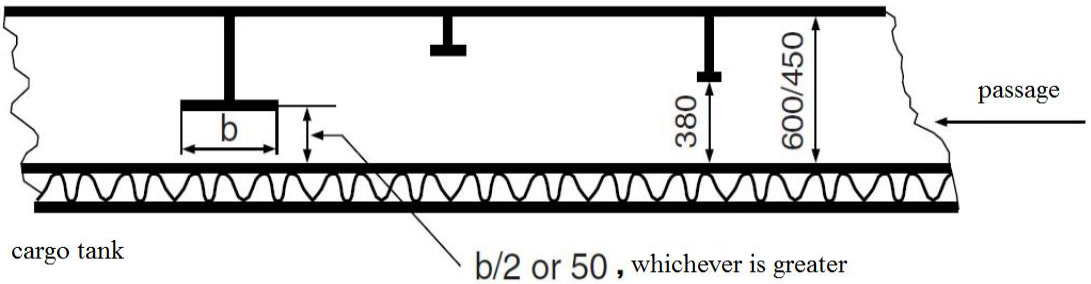


Figure 10.2.2.3(2)

(3) if for inspection of a curved surface where it is required to pass between that surface and another surface, flat or curved, to which no structural elements are fitted, the distance between both surfaces is to be at least 380 mm (see Figure 10.2.2.3(3)). Where it is not required to pass between that curved surface and another surface, a smaller distance than 380 mm may be accepted taking into account the shape of the curved surface;

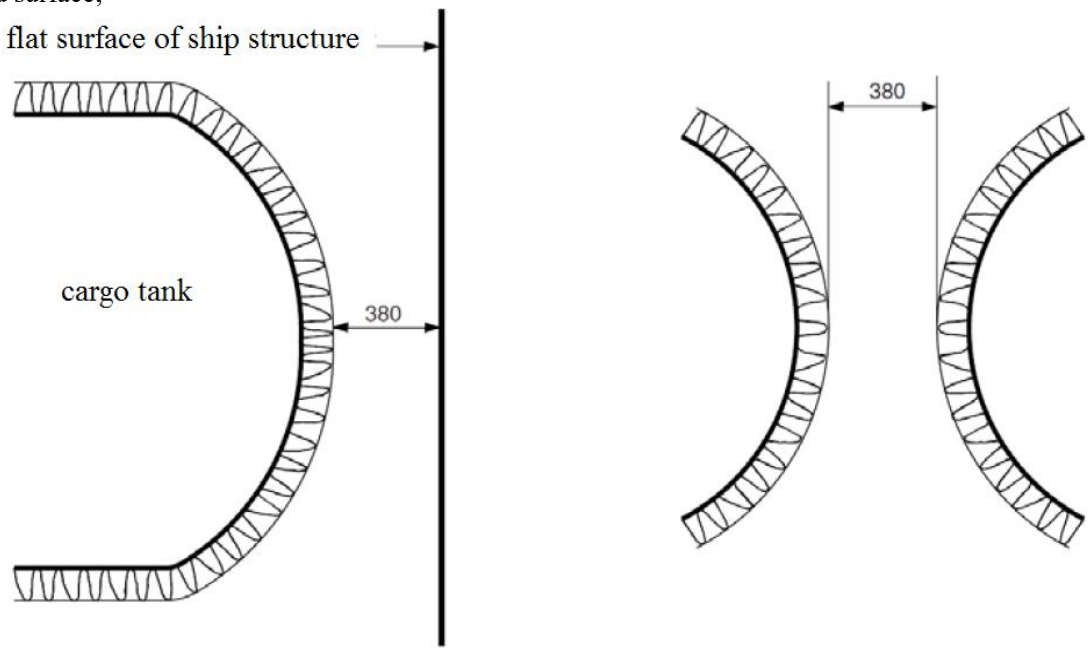


Figure 10.2.2.3(3)

(4) if for inspection of an approximately flat surface where it is required to pass between two approximately flat and approximately parallel surfaces, to which no structural elements are fitted, the distance between those surfaces is to be at least 600 mm. If the plane of inner shell plating (including upper and lower sloping plate) within the double hull has been subject to strict rust cleaning, painted with epoxy resin or other equivalent anti-corrosion paint, and the condition of inner shell plating can be inspected within the double hull, the above mentioned minimum distance may be reduced. Where fixed access ladders are fitted, a clearance of at least 450 mm is to be provided for access (see Figure 10.2.2.3(4));

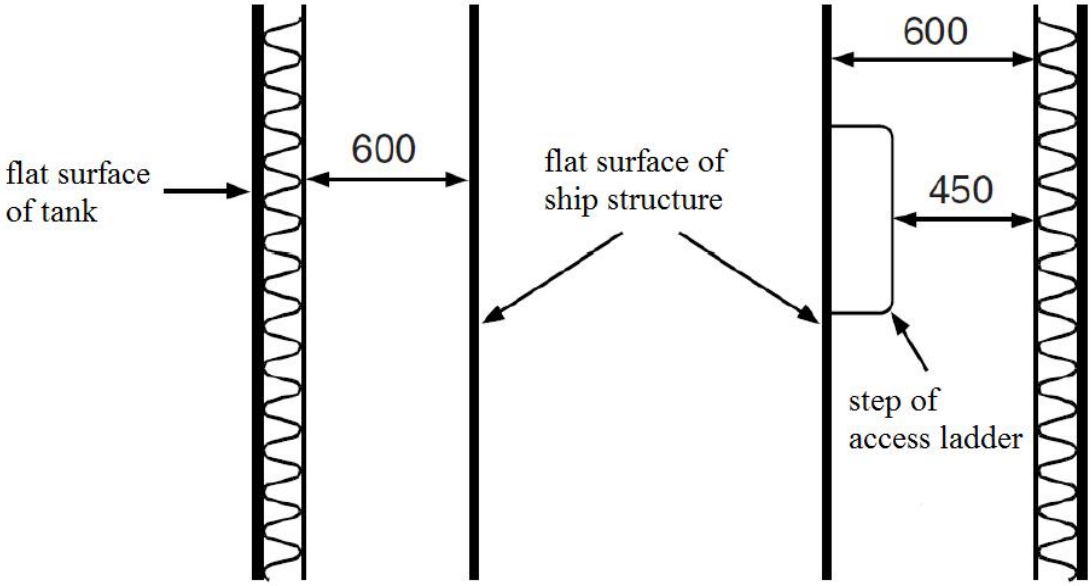


Figure 10.2.2.3(4)

(5) the minimum distances between a cargo tank sump and adjacent double bottom structure in way of a suction well are not to be less than those shown in figure 3.5 (Figure 10.2.2.3(5) shows that the distance between the plane surfaces of the sump and the well is a minimum of 150 mm and that the clearance between the edge between the inner bottom plate, and the vertical side of the well and the knuckle point between the spherical or circular surface and sump of the tank is at least 380 mm). If there is no suction well, the distance between the cargo tank sump and the inner bottom is not to be less than 50 mm;

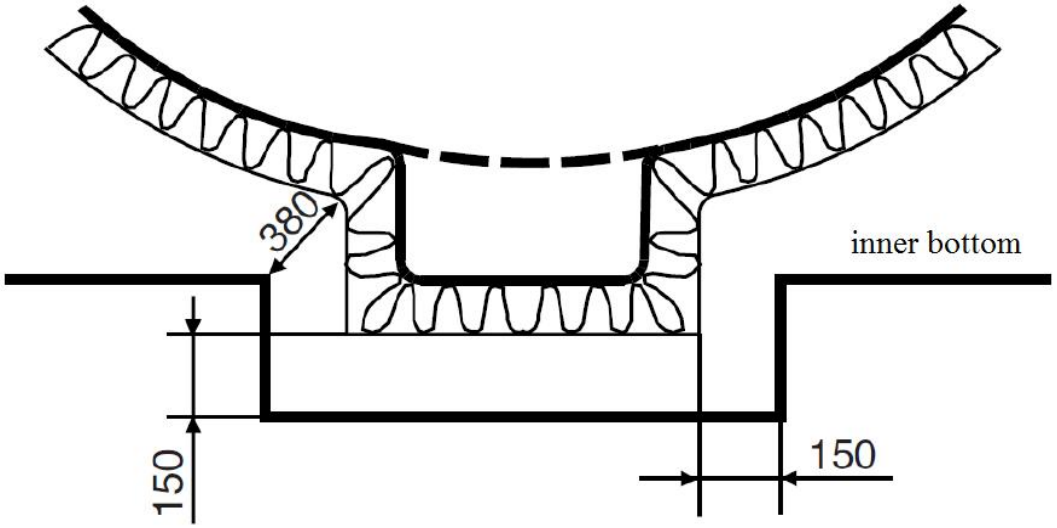


Figure 10.2.2.3(5)

(6) the distance between a cargo tank dome and deck structures is not to be less than 150 mm (see Figure 10.2.2.3(6));

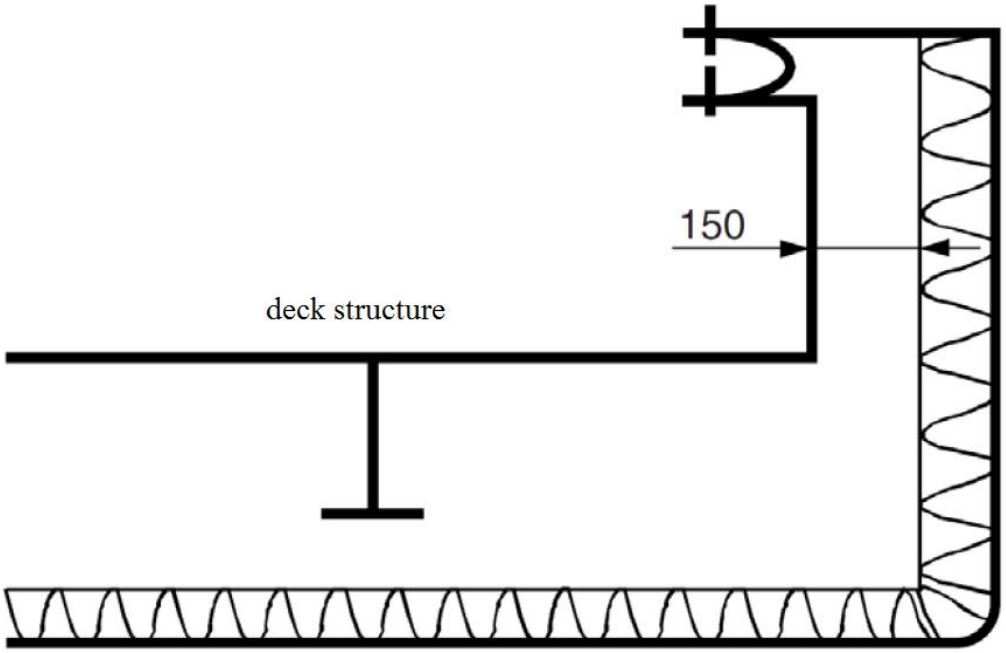


Figure 10.2.2.3(6)

(7) fixed or portable staging is to be installed as necessary for inspection of cargo tanks, cargo tank vertical supports, anti-rolling arrangements, anti-pitching arrangements, anti-flotation arrangements, cargo tank insulation etc. This staging is not to impair the clearances specified in 10.2.2.3(1) to 10.2.2.3(4);

(8) if fixed or portable ventilation ducting is to be fitted, such ducting is not to impair the distances required under 10.2.2.3(1) to 10.2.2.3(4).

10.2.2.4 The corrosion protection of ballast tanks is to satisfy the requirements of Section 6, Chapter 1 of PART TWO of the Rules. In addition, if a ballast tank is adjacent to a cargo tank, epoxy resin or other equivalent anti-corrosion paint is to be coated on the inside bulkheads of such ballast tank.

10.2.2.5 A separate cargo pump room may not be arranged in an asphalt carrier. For asphalt carriers fitted with independent tanks, cargo pumps may be arranged in hold space. For asphalt carriers fitted with integral tanks, if the cargo pump room is adjacent to a cargo tank, heat insulation means or an empty tank is to be provided.

The space where cargo pumps are located is to have good ventilation, normally with 30 to 45 air changes per hour.

10.2.3 Constructional material

10.2.3.1 The independent tank may be of low carbon or higher tensile steel. Considering the decrease of mechanical properties of material caused by high temperature, for members under high temperatures (100℃ and above), the high temperature material coefficient K_T is to be taken as the material coefficient K in the design and is to be calculated as follows:

$$K_T = max\left\{K, \frac{235}{R_{eH}^T}\right\}$$

where: K — material coefficient, see Table 1.3.1.7, Chapter 1, PART TWO of the Rules;

R_{eH}^T —high temperature yield stress, in N/mm^2, see Table 10.2.3.1.

If the independent tank is of any other material, tensile test is to be carried out to determine the high temperature yield stress R_{eH}^T.

High Temperature Yield Stress under Design Working Temperature R_{eH}^T Table 10.2.3.1

	Tensile strength under room temperature R_{eH} (N/mm^2)	R_{eH}^T (N/mm^2)				
		100℃	150℃	200℃	250℃	300℃
Carbon steel and carbon manganese steel	235	220	210	200	190	180
	315	295	280	265	250	235
	355	330	313	297	282	267
	390	364	344	327	311	295

Note: Intermediate values of the temperature may be obtained by linear interpolation.

10.2.4 Independent tank

10.2.4.1 If the independent tank is mainly of plane construction, its boundary structure is to be designed according to the requirements of 10.2.6, and the design vapor pressure (gauge pressure) is not to be more than 0.07 MPa.

10.2.4.2 Externally insulated independent tanks are to be supported and keyed so as to permit free expansion in all directions and eliminate heat bridges which may transmit thermal stresses to the hull of the ship.

10.2.4.3 The independent tank is to be insulated with an approved heat-insulating material. After the heat-insulating material is laid, the temperature in hold space at ambient temperature (with atmospheric pressure being 1 HPA, air temperature being 0℃ and seawater temperature being 0℃) is not to exceed 180℃.

10.2.4.4 If cargo pumps are located outside the hold space, not less than 20 air changes per hour are to be given in the hold space.

10.2.4.5 Heat-insulating material is to be fixed on the outside surface of the independent tank with welts and wrapped with galvanized steel plate or other equivalent material. Prior to the laying of heat-insulating material, the outside surface of the independent tank is to be coated with high-temperature resistant antirust paint.

10.2.4.6 The independent tank is to be supported by adequate vertical supports such that it is not connected with the hull structure directly. The vertical supports are generally to be of a material with good heat insulation. If the mechanical and physical properties of such material may change at high temperature, effective measures are to be taken to ensure that the mechanical and physical properties will not be decreased significantly.

10.2.4.7 Multi-fulcrum supporting is recommended for the supporting of bottom of the independent tank so as to evenly transfer the weight of the independent tank and the cargo therein to the bottom structure. Supports are to be fitted on primary structural members of the independent tank and hull.

10.2.4.8 Longitudinal and transverse limiting devices are to be provided at suitable positions of the independent tank so that the tank expansion at high temperature will extend in the expected direction.

10.2.4.9 Suitable anti-pitching arrangements are to be provided to withstand a longitudinal collision force acting on the independent tank corresponding to the total weight of the tank and 1/2 cargo in the forward direction and the total weight of the tank and 1/4 cargo in the aft direction without deformation likely to endanger the tank structure. On calculating supporting force, friction force is to be included.

The above-mentioned supports may be taken into consideration together with locating devices.

10.2.4.10 Suitable anti-rolling arrangements are to be provided to prevent the independent tank from slipping transversely and turning over. In general, supports are to be provided at high level to prevent the tank from turning over and stoppers to be provided at low level to prevent the tank from slipping. The stress calculation may be referred to the calculation of cargo securing force as specified in CCS Guidelines for Preparation of Cargo Securing Manual.

The above-mentioned supports may be taken into consideration together with locating devices.

10.2.4.11 In design, loads mentioned in 10.2.4.9 and 10.2.4.10 need not be combined with other stresses.

10.2.4.12 Anti-flotation arrangements are to be provided for independent tanks. The anti-flotation arrangements are to be suitable to withstand an upward force caused by an empty tank in a hold space flooded to the summer load draught of the ship.

The design clearance between anti-flotation arrangements and hull is generally taken between 40 to 60 mm.

10.2.5 Integral tank

10.2.5.1 The boundary structure of the integral cargo tank is to be designed according to the requirements of 10.2.6.

10.2.5.2 For asphalt carriers fitted with integral tanks, hull structural members are to be subject to thermal stress analysis to check the local strength and longitudinal stress in each loading condition. The hull is also to be subject to analysis of temperature field and thermal transmission in full load or half load condition. In the analysis, properties changes of material at high temperature are to be taken into consideration.

10.2.5.3 For spaces of heat-insulating layers of asphalt carriers fitted with integral tanks, provision is to be made to prevent over- or under-pressure caused by temperature variations.

10.2.6 Boundary structure of cargo tanks

10.2.6.1 The thickness t of the tank top plates forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formula:

$$t = t_0\sqrt{K} + t_c \qquad \text{mm}$$

where: t_0 — thickness, in mm, and whichever greater in the following formulae is to be taken:

$$t_0 = 39.5s\sqrt{P_V - 0.02}$$

$$t_0 = 2.8s\sqrt{\rho h}$$

$$t_0 = 4.5s$$

K — material factor, and the effect of high temperature on the material yield strength is to be considered as appropriate, see 10.2.3.1 of this Chapter;

t_c — corrosion addition, in mm, for carbon steel, t_c = 2.5 mm;

s — spacing of longitudinals, in m;

P_V — maximum pressure (gauge pressure), in MPa, to be taken as not less than 0.02 MPa;

ρ — the maximum cargo density, in t/m^3, to be taken as not less than 1.025 t/m^3;

h — height measured from top of the overflow to the deck, in m.

10.2.6.2 The thickness t of the tank bottom plates and plane bulkhead plates forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formula:

$$t = t_0\sqrt{K} + t_c \qquad \text{mm}$$

where: t_0 — thickness, in mm, and whichever greater in the following formulae is to be taken:

$$t_0 = 3.95s\sqrt{\rho h_1 + 100(P_V - 0.02)}$$

$$t_0 = 2.8s\sqrt{\rho h}$$

$$t_0 = 2.9s\sqrt{2.45 + h_1}$$

K — material factor, see 10.2.6.1 of this Section;

t_c — corrosion addition, in mm, t_c = 2.5 mm;

s — spacing of stiffeners, in m;

ρ — the maximum cargo density, in t/m^3, to be taken as not less than 1.025 t/m^3;

h_1 — vertical distance measured from the lower edge of the plate to the tank top, in m;

P_V — maximum pressure (gauge pressure), in MPa, to be taken as not less than 0.02 MPa;

h — vertical distance measured from the lower edge of the plate to top of the overflow, in m.

10.2.6.3 The section modulus W of stiffeners forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formulae:

$$W = 8Ksl^2\left[\rho h_1 + 100(P_V - 0.02)\right] \qquad \text{cm}^3$$

$$W = 4Ks\rho hl^2 \qquad \text{cm}^3$$

$$W = 4.2Ksl^2(2.45 + h_1) \qquad \text{cm}^3$$

where: K — material factor, see 10.2.6.1 of this Section;

s — spacing of stiffeners, in m;

l — span of stiffeners, in m;

ρ — the maximum cargo density, in t/m^3, to be taken as not less than 1.025 t/m^3;

h_1 — vertical distance measured from the mid-point of span of stiffener to the tank top, in m;

P_V — maximum pressure (gauge pressure), in MPa, to be taken as not less than 0.02 MPa;

h —vertical distance measured from the mid-point of span of stiffener to top of the overflow, in m.

10.2.6.4 The section moment of inertia I of stiffeners forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formula:

$$I = 2.3\frac{Wl}{K} \qquad \text{cm}^4$$

where: W — section modulus of stiffeners obtained in accordance with 10.2.6.3, in cm^3;

l — see 10.2.6.3;

K — material factor, see 10.2.6.1 of this Section.

10.2.6.5 The section modulus W of plane bulkhead girders forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formulae:

$$W = 11.7Kbl^2\left[\rho h_1 + 100(P_V - 0.02)\right] \qquad \text{cm}^3$$

$$W = 6Kb\rho hl^2 \qquad \text{cm}^3$$

$$W = 6.3Kbl^2(2.45 + h_1) \qquad \text{cm}^3$$

where: K — material factor, see 10.2.6.1 of this Section;

b — breadth of area supported by the girder, in m;

l — span of girders, in m;

ρ— the maximum cargo density, in t/m^3, to be taken as not less than 1.025 t/m^3;

h_1— vertical distance measured from the mid-point of span of girder to tank top, in m;

P_V— maximum pressure (gauge pressure), in MPa, to be taken as not less than 0.02 MPa;

h— vertical distance measured from the mid-point of span of girder to top of the overflow, in m.

10.2.6.6 The section moment of inertia I of plane bulkhead girders forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formula:

$$I = 2.5\frac{Wl}{K} \qquad \text{cm}^4$$

where: W— section modulus of girders obtained in accordance with 10.2.6.5, in cm^3;

l— see 10.2.6.5;

K— material factor, see 10.2.6.1 of this Section.

10.2.6.7 The thickness t of symmetrical corrugated bulkheads forming part of the boundary structure of cargo tanks is not to be less than the values obtained according to 10.2.6.1. In calculation, s is to be substituted by breadth of corrugation plane a or breadth of corrugation bevel face b, whichever is the greater, and in addition, the following formula is to be complied with:

$$t \geq \frac{s}{70\sqrt{K}} \qquad \text{mm}$$

where: s— breadth of corrugation plane a or breadth of corrugation bevel face b, whichever is the greater, in mm, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

K— material factor, see 10.2.6.1 of this Section. For high strength steel grade, the K value of the lower strength steel may be taken from the formula in 10.2.3.1 of this Chapter provided that the plate buckling check requirements (see Section 5, Chapter 1, PART TWO of the Rules) in direct calculation with that lower K value are satisfied.

10.2.6.8 The section modulus W of symmetrical corrugated bulkheads forming part of the boundary structure of cargo tanks is not to be less than the values obtained from the following formulae:

$$W = KCsl^2\left[\rho h_1 + 100(P_V - 0.02)\right] \qquad \text{cm}^3$$

$$W = 0.50KCs\rho hl^2 \qquad \text{cm}^3$$

$$W = 0.53KCsl^2(2.45 + h_1) \qquad \text{cm}^3$$

where: $W = d_w t(a + \frac{b}{3})$, in cm^3, section modulus of breadth of one corrugation;

s— breadth of one corrugation, in m, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

a— breadth of corrugation plane, in m, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

b— breadth of corrugation bevel face, in m, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

d_w— depth of corrugation, in mm, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

t— thickness of corrugated bulkheads, in mm, see Figure 1.2.4.3, Chapter 1, PART TWO of the Rules;

K— material factor, see 10.2.6.1 of this Section;

C— coefficient, to be taken according to the end fixity as specified in Table 2.13.3.1, Section 13, Chapter 2, PART TWO of the Rules;

l— span of corrugations, i.e. distance between supporting points, in m;

ρ— the maximum cargo density, in t/m^3, to be taken as not less than 1.025 t/m^3;

P_V— maximum pressure (gauge pressure), in MPa, to be taken as not less than 0.02 MPa;

h_1— vertical distance measured from the mid-point of span of corrugation to tank top, in m;

h— vertical distance measured from the mid-point of span of corrugation to top of the overflow, in m.

Where the corrugated bulkhead span is more than 15 m, a diaphragm plate is to be fitted near the mid-span point.

10.2.6.9 Where lower stools are fitted, scarfing brackets aligned with vertical webs of corrugated bulkheads are to be provided in the lower stools as far as practicable. Where lower stools are not provided, double bottom floors are generally to be aligned with face plates of vertical corrugated transverse bulkheads, and double bottom girders are generally to be aligned with face plates of vertical corrugated longitudinal bulkheads; scarfing brackets aligned with vertical corrugated webs are to be provided under the inner bottom and hopper as far as practicable. Where transverse bulkheads are in the form of horizontal corrugation, primary members are generally to be aligned with face plates of corrugated bulkheads at the intersection of corrugated bulkheads and inner shell, and longitudinal bulkheads; and scarfing brackets aligned with vertical webs of corrugated bulkheads are to be provided as far as practicable.

10.2.7 Piping

10.2.7.1 Bilge water of hold space is to be discharged overboard by a pump and the pump may be the bilge pump in the machinery space. High-level alarm is to be provided near the bilge suction, audible and visual high-level alarms and controls are to be provided in the navigation bridge and cargo control room (if provided), and it is recommended that such alarm signal and control extend to the central control cabin of the engine room.

10.2.7.2 When the temperature of asphalt needed to be heated is more than that of the saturated vapor, the heating medium is to be hot oil.

10.2.7.3 Cargo pump, cargo piping and cargo operating valve, etc., outside cargo tanks are to be heated.

10.2.8 Electrical installations

10.2.8.1 Electrical installations (except for sensors), cables and attachments are not to be installed in cargo tanks.

10.2.8.2 Cables in the cargo tank necessary to be connected with electrical installations (such as sensors) are not to contact with liquid cargo but to be laid in a gastight steel tube with thick wall.

10.2.9 Monitoring alarm related to liquid cargo

10.2.9.1 The fixed liquid cargo depth detector may be of radar type, capacitance type or pressure type. If radar type depth detector is adopted, other devices or structural members are not to be arranged in depth detecting area.

10.2.9.2 High temperature alarms for liquid cargo are to be provided. When the temperature exceeds the set value, audible and visual alarm is to be given.

10.2.9.3 High level alarms for cargo tanks are to be provided. When the loading level exceeds the high level of normal full loading, an audible and visual alarm is to be given.

10.2.9.4 Temperature monitoring indicator is to be provided outside heat-insulating layer at the bottom of independent cargo tank.

10.2.9.5 Alarm controls and temperature monitoring indicator are to be installed in the liquid cargo control station, and each alarm signal is to extend to the navigation bridge one by one or in a group.

Appendix 1 DIRECT CALCULATION OF STRUCTURAL STRENGTH OF ASPHALT CARRIERS FITTED WITH INDEPENDENT CARGO TANKS

1 General provisions

1.1 Application

1.1.1 This Appendix is applicable to direct calculation of structural strength of asphalt carriers fitted with independent cargo tanks as required in 10.1.5 of this Chapter.

1.1.2 For asphalt carriers to which this Appendix is applicable, the direct strength analysis for cargo tank hull structure, independent tanks as well as supporting structures is to be carried out according to this Appendix.

1.1.3 Where the temperature of carried liquid cargo is above 180℃, the distribution of temperature field of cargo tanks and associated structures is to be calculated through heat transferring analysis. If temperature field analysis indicates that the temperature that is transferred to the main hull structure exceeds 80℃, thermal stress in cargo tank area is to be further calculated, as given in Section 24, Chapter 2, PART TWO of the Rules. Where the actual means of loading may cause relatively big temperature difference for the cargo tank structure (such as asymmetrical loading of two adjacent cargo tanks along the ship breadth, remarkable level difference between two adjacent cargo tanks during loading and unloading operations, as well as alternate cargo loading along the ship's length), thermal stress analysis and calculation may be required in cargo tank area.

1.1.4 For cargo tanks to be partially loaded with other petroleum products, sloshing assessment is to be carried out for cargo tank boundary structure according to CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks. The approved loading limits are to be included in the Loading Manuel as the operation guides.

1.1.5 For those not specified by this Appendix, the applicable requirements in Section 5, Chapter 1 and Appendix 1, Chapter 5 of PART TWO of the Rules are to be complied with.

2 Structural modelling

2.1 Model and element

2.1.1 Normally, the longitudinal extent of the model is to cover the length of 1/2 cargo tank + 1 cargo tank + 1/2 cargo tank within the cargo area amidships, the transverse extent is the full breadth, and the vertical extent is the moulded depth.

2.1.2 The model is to include hull structure, independent tanks as well as supporting structures. However, the global load condition model does not need to include the independent tanks in the fore and aft cargo tank areas as well as supporting structures.

2.1.3 The element is to be meshed according to the provisions in 1.5.6.3 to 1.5.6.6, Chapter 1, PART TWO of the Rules. The supporting structures of the independent tanks are normally designed as not carrying any tension. Therefore, the rigidity of the supporting structures is to be simulated by rod elements but the tensile stress is not to occur in these rod elements.

2.2 Boundary condition

2.2.1 The boundary conditions depend on the model extent and calculation conditions. As the application methods of the global load condition and the local load condition are different, paragraph 4.2, Appendix 1, Chapter 5, PART TWO of the Rules is to be referred to.

3 Loads and conditions

3.1 General requirements

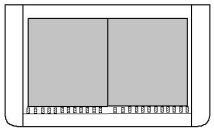
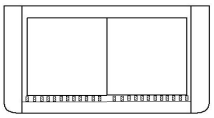
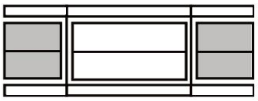
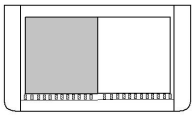
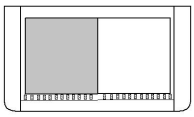
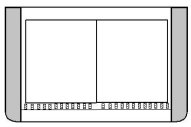
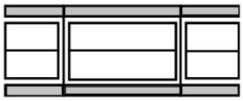
3.1.1 In the assessment condition of cargo tank structure, global load and local load are to be considered, including vertical bending moment, external sea water pressure, liquid pressure of the cargo tank; in the assessment of the supporting structure, the local loads are considered, the inertia force in the forward and aft direction generated by the cargo tank and the cargo due to the collision of hull is assumed, and the upward force acting on the independent tank due to flooding of hull is assumed.

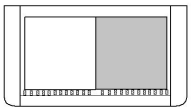
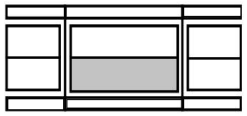
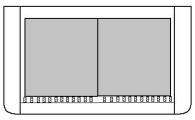
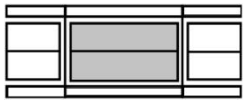
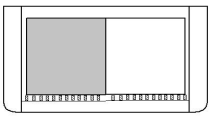
3.1.2 Normally, the hull structure and independent tank structure are to be checked according to the assessment conditions listed in Tables 3.2.1 and 3.2.3. For more severe loading conditions in the loading manual not covered by the tables above, direct calculation of structural strength in those more severe loading conditions are to be carried out.

3.2 Calculation conditions

3.2.1 The tank structural assessment is to be carried out according to the applicable conditions in Table 3.2.1. For conditions LC3, LC4, LC6 and LC8, where the centerline bulkhead has asymmetrical structure, cargo tanks at port and starboard sides are to be calculated separately for separate loading modes.

Assessment Conditions of Cargo Tank Structure **Table 3.2.1**

<table>
<tr><td colspan="5">Seagoing conditions</td><td colspan="2"></td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC1</td><td>d</td><td>$\overline{M_s} + M_w$</td><td>P_e</td><td>P_i</td><td>  </td><td> </td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC2</td><td>d</td><td>$\overline{M_s} + M_w$</td><td>P_e</td><td>P_i</td><td>  </td><td>  </td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC3</td><td>d</td><td>$\overline{M_s} + M_w$</td><td>P_e</td><td>P_i</td><td>  </td><td> </td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC4</td><td>d</td><td>$\overline{M_s} + M_w$</td><td>P_e</td><td>P_i</td><td>  </td><td> </td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Internal pressure: $P_i = \rho(g + 0.5 a_v)(h + 25 f_r)$, where a_v is according to 1.5.2.2(8), Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC5</td><td>d_b</td><td>$\overline{M_s} + M_w$</td><td>P_e</td><td>P_i</td><td>  </td><td>  </td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Loading pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td colspan="5">Harbour conditions</td><td colspan="2"></td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
</table>

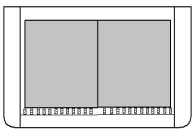
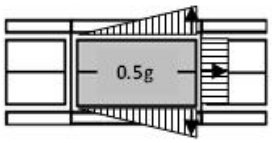
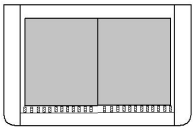
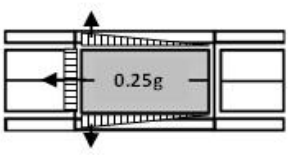
LC6	0.35*D*	$\overline{M}_{sp}$	P_e	P_i		
External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules						
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading	
LC7	0.35*D*	$\overline{M}_{sp}$	P_e	P_i		
External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules						
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading	
LC8	0.25*D*	$\overline{M}_{sp}$	P_e	P_i		
External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules						
Note: For conditions LC3, LC4, LC6 and LC8, where the centerline bulkhead has asymmetrical structure, cargo tanks at port and starboard sides are to be calculated separately for separate loading modes.						

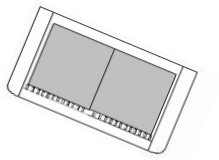
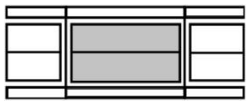
3.2.2 Fine mesh assessment is to be carried out for areas with supporting structures. For possible high stress areas, the element size is to accurately simulate the structural shape. It is recommended that the size is not greater than *s*/8, where *s* is the spacing of members.

3.2.3 The assessment of supporting structures is also to be carried out according to the applicable conditions in Table 3.2.3. All conditions are local load conditions, among which LC1 and LC2 are anti-pitching conditions, LC3 is anti-rolling condition and LC4 is anti-flotation condition.

Assessment Conditions of Supporting Structures

Table 3.2.3

Assessment conditions of supporting structures					
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading
LC1	NA	NA	NA	P_i	 
Internal pressure $P_i = \rho g(h + 2.5 f_r) + \rho \times (0.5g)x$, for aft bulkhead, *x* is 0, for forward bulkhead, *x* is to be taken as the length of the independent tank					
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading
LC2	NA	NA	NA	P_i	 
Internal pressure $P_i = \rho g(h + 2.5 f_r) + \rho \times (0.25g)x$, for aft bulkhead, *x* is to be taken as the length of the independent tank, for forward bulkhead, *x* is 0					
Condition	Draught	Bending	External	Internal	Pattern of loading

		moment	pressure	pressure		
LC3	d	NA	P_e	P_i		

NA—Not applicable;

External pressure $P_e = \rho g\left[(d-z)\cos\varphi + |y|\sin\varphi\right]$ starboard side (water entry side)

$=\rho g\left[(d-z)\cos\varphi - |y|\sin\varphi\right]$ port side (water exit side), and not less than 0;

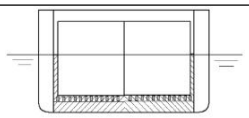
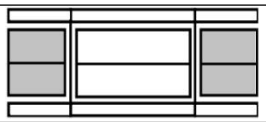
where:

y — transverse distance measured from the considered point to the centreline;

z — vertical distance measured from the considered point to the baseline.

φ — the maximum roll angle, to be taken as not greater than 30°.

Internal pressure $P_i = \rho g(h+2.5f_r) + \rho\times(0.5g)h_y$, where h_y is the transverse distance from the pressure calculation point to the highest point of the top left corner of the independent tank.

Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading	
LC4	d	NA	NA	P_i		

Internal pressure $P_i = \rho g d$

4 Yield and buckling strength assessment

4.1 Yield strength assessment

4.1.1 For hull structures, the stress components generated by the global load condition and local load condition are to be combined to check the strength. For independent cargo tank structures, strength assessment is carried out only to the stress of the local load condition.

4.1.2 See Table 5.1.2, Appendix 1, Chapter 5, PART TWO of the Rules for the permissible stress of each primary member. The permissible equivalent stress of independent cargo tank structures is to be taken as $175/K_T$, for K_T see 10.2.3.1 of this Chapter.

4.1.3 For the refined analysis of the supporting structures assessment condition, the permissible stress is to be taken as follows:

$$\text{permissible equivalent membrane stress}=\begin{cases}1.4 \text{ times the permissible stress of the cargo tank model,}\\ \quad\text{the element size of the fine area is } s/8\\ 1.6 \text{ times the permissible stress of the cargo tank model,}\\ \quad\text{the element size of the fine area is } s/16\end{cases}$$

4.2 Buckling strength assessment

4.2.1 See paragraph 6, Appendix 1, Chapter 5, PART TWO of the Rules for the requirements for buckling strength assessment.

CHAPTER 11 DYNAMIC POSITIONING SYSTEMS

Section 1 GENERAL PROVISIONS

11.1.1 General requirements

11.1.1.1 This Chapter applies to dynamic positioning (DP) systems installed on board ships or offshore units (hereinafter referred to as vessels).

11.1.1.2 A vessel with a dynamic positioning system, for which no class notation is requested, may be designed and equipped by reference to the applicable requirements of this Chapter.

11.1.1.3 For the equipment or system not complying with the requirements for the class notations, CCS may issue upon request a Declaration of Compliance showing general or partial compliance of the vessel/system with this Chapter. CCS will not monitor or follow up the condition of the vessel thereafter.

11.1.1.4 CCS will give appropriate consideration to novel designs and special functions of dynamically positioned vessels or relevant equipment. If such designs and functions comply with the intention of this Chapter, they are to be accepted.

11.1.1.5 This Chapter is based on the assumption that operation and maintenance of the dynamic positioning system is carried out by qualified crew. This Chapter specifies requirements for drawing submission and technical design.

11.1.2 Class notations

11.1.2.1 When dynamic positioning systems have been designed, constructed and tested in accordance with the requirements of this Chapter and relevant chapters, upon request of the owner and in accordance with different redundancy degrees of the dynamic positioning systems, the following class notations will be assigned:

(1) DP-1: Vessels with dynamic positioning systems can automatically keep their position and heading within specified environmental conditions. Vessels are allowed to lose their position and heading in case of a single failure.

(2) DP-2: Vessels with dynamic positioning systems can automatically keep their position and heading in case of a single failure (excluding loss of a compartment or compartments) within specified environmental conditions and operating limits. Detailed redundancy design principles are given in 11.2.2 of this Chapter.

(3) DP-3: Vessels with dynamic positioning systems can automatically keep their position and heading in case of any single failure, including total loss of a compartment caused by fire or flooding, within specified environmental conditions and operating limits. Detailed redundancy design principles are given in 11.2.2 of this Chapter.

11.1.3 Definitions

11.1.3.1 For the purpose of this Chapter, the following definitions apply:

(1) Dynamic positioning means the provision of a hydrodynamic system with automatic and/or manual control capable of maintaining the heading and position of the ship during operation within specified operating limits and environmental conditions.

(2) Specified operating limits are those for specified allowable position deviations from a set point.

(3) Specified environmental conditions are the specified wind speed, sea current and wave height under which the vessel is designed to carry out its intended operations. Ice load, if any, may be specially considered.

(4) Dynamically positioned vessel is a vessel which automatically maintains its position and heading (fixed location, relative location or predetermined track) exclusively by means of thruster force.

(5) Dynamic positioning system means the complete installation necessary for dynamically positioning a vessel, comprising the following sub-systems:

① thruster system;

② power system;

③ control system and measuring system.

(6) Thruster system means the thrusters and their controls used for dynamic positioning, including:

① thrusters with drive units, including main propellers and rudders if these are under the control of the DP system;

② thruster control system and manual controls;

③ associated cabling and cable routing;

④ auxiliary systems supporting the systems above.

(7) Power system means all components and systems necessary to supply the DP system with power, comprising the following components or systems:

① prime movers;

② generators;

③ switchboards;

④ uninterruptible power supplies (UPSs) and batteries;

⑤ distribution system including cabling and cable routing;

⑥ for DP-2 and DP-3 notations: power management system;

⑦ auxiliary systems supporting the systems above.

(8) DP control system means all control components and systems, hardware and software necessary to dynamically position the vessel. The DP control system consists of the following:

① computer system;

② control stations and display system (operator panels);

③ position reference system;

④ sensor system;

⑤ associated cabling and cable routing;

⑥ networks.

(9) Computer system means a system consisting of one or more computers, including hardware, software, peripherals and interfaces.

(10) Position reference system means the system to measure the ship's position.

(11) Sensor system means a system used to measure parameters such as heading, ship's motion (e.g. rolling, pitching, heaving, etc.), wind velocity and direction.

(12) Position keeping means maintaining a desired position within the normal operating limits of the control system and the environmental conditions.

(13) Loss of position means that the vessel's position and/or heading is outside the limits set for carrying out the DP activity in progress.

(14) Reliability means the ability of a system or component to perform its required function without failure during a specified time interval.

(15) Redundancy means the ability of a component or system to maintain or restore its function when a single failure has occurred. Redundancy can be achieved, for instance, by installation of multiple components, systems or alternative means of performing a function.

(16) Redundancy group means systems simultaneously affected by a single failure, usually categorized as thruster group, power generator group or switchboard group.

(17) Single failure means a failure in a component causing one or both of the following effects:

① function loss of a component or system;

② deterioration of functional capability to such an extent that the safety of the vessel, personnel, or environment is significantly reduced.

(18) Worst-Case Failure (WCF) means the identified single fault in the DP system resulting in maximum detrimental effect on DP capability as determined through the failure mode and effect analysis (FMEA) for class notations DP-2 and DP-3.

(19) Worst-Case Failure Design Intent (WCFDI) means the specified minimum DP system capabilities to be maintained following the worst-case failure. The positioning-keeping capability of a dynamically positioned vessel usually relates to the number of thrusters and generators that can simultaneously fail.

(20) Hidden failure means a failure that is not immediately evident during normal operations or maintenance and has the potential for failure of equipment to perform an on-demand function.

(21) Safe termination time means the minimum amount of time required in an emergency to safely cease and/or evacuate DP operations in process.

(22) Consequence analysis means a software function continuously verifying that the vessel will remain in position if the WCF occurs. An alarm is to be released if positioning is not possible.

(23) Joystick is a device for readily setting of vectorial thrust output including turning moment.

(24) Operational mode is the manner of control under which the DP system may be operated, e. g.:

① automatic operation mode (automatic position and heading control);

② joystick operation mode (manual position control with selectable automatic or manual heading control);

③ manual operation mode (individual control of pitch and speed, azimuth, start and stop of each

thruster);

④ other operation modes, such as autopilot, etc.

11.1.4 Plans and documents

11.1.4.1 For dynamically positioned vessels, the following plans and documents are to be submitted for approval:

(1) Technical description of the DP system, at least including the following:

① function description of the power system and power management;

② system arrangement and configuration: physical separation (DP-3), thruster, switchboard, power generator set, auxiliary system;

③ redundancy groups (DP-2/3);

④ WCFDI (DP-2/3);

⑤ safe termination time (DP-2/3, if applicable).

(2) System diagram of the DP system, including the power arrangement and connection between systems (at least including power unit, control unit, auxiliary system etc.).

(3) Load balance calculations in DP operation. For class notations DP-2 and DP-3, power consumption after the WCF is to be indicated.

(4) Arrangement of the DP control station; arrangement of the back-up control station is also to be included for class notation DP-3.

(5) List of indication and alarm items at DP control consol.

(6) For class notation DP-3, categorization plan of redundancy groups; equipment or systems of different redundancy groups are to be identified in the general arrangement plan in different colours and fire and watertight division between different areas are to be marked in the plan.

(7) For class notation DP-3, cable routing drawing and cable list, where all cables related to the DP system are to be included.

(8) For class notations DP-2 and DP-3, function description of consequence analysis.

(9) For class notations DP-2 and DP-3, failure mode and effect analysis (FMEA) reports.

(10) FMEA redundancy test procedure for class notations DP-2 and DP-3 (to be reviewed by the attending Surveyor).

11.1.4.2 The following plans and documents are to be submitted for information:

(1) Operation manual for the DP system.

(2) Capability analysis of position-keeping, including:

① DP capability when all thrusters are operational, illustrated through description and capability plot;

② for class notations DP-2 and DP-3, DP capability after WCF, illustrated through description and capability plot;

③ environmental conditions are to be categorized using the standard Beaufort scale or other recognized methods;

④ environmental forces (wind, waves, current) and thruster force are to be evaluated by wind tunnel and tank tests or other recognized methods.

11.1.4.3 For novel designs, CCS may raise additional requirements for drawing approval according to the specific design.

11.1.5 Failure mode and effect analysis (FMEA)

11.1.5.1 For class notations DP-2 and DP-3, DP FMEA is required.

11.1.5.2 The purpose of DP FMEA is to analyse and demonstrate whether a DP vessel can keep its position in case of a single failure and whether the system can satisfy the redundancy design intention.

11.1.5.3 The FMEA report is to be a complete and detailed document covering but not restricted to the following:

(1) basic particulars and information of the vessel;

(2) description of system boundary and acceptance criteria;

(3) description of system arrangement and configuration, categorization of redundancy groups, description WCFDI, requirement for safe termination time;

(4) description of all main components of the system and functional block diagram showing interactions between them;

(5) analysis of single failure (including common mode failure, hidden failure), the causes for failures, methods for failure detection, impacts of failures on the DP system locally and globally;

(6) for class notation DP-3, compartment failure analysis (or equivalent methods);

(7) conclusion, which is to include summary of each sub-system and the overall DP system.

11.1.5.4 The test of system redundancy is to be tested under each failure mode. The test program is to be based on the simulation of failure modes, and the tests are to be carried out in the actual DP operation mode.
11.1.5.5 The as-built FMEA(s) and redundancy test program(s) is(are) to be kept on board. The FMEA(s) and redundancy test program(s) is (are) at all times to be updated to cover alterations to the DP system hardware or software, according to the actual condition.

Section 2 SYSTEM ARRANGEMENT

11.2.1 General requirements

11.2.1.1 This Section specifies the requirements for system arrangement of a general type and unless expressly stated otherwise, these requirements apply to all vessels with DP class notations. Specific requirements for each sub-system will be specified below.
11.2.1.2 In accordance with different class notations, the design of DP arrangement is to meet the requirements of Table 11.2.1.2.

Arrangement of DP System **Table 11.2.1.2**

Equipment \ Class notation		DP-1	DP-2	DP-3	
Thruster system	Thruster arrangement	Non-redundant	Redundant	Redundant, separate compartments	
	Manuel control of thrusters	Yes	Yes	Yes (main DP control station)	
Power system	Generator & prime mover	Non-redundant	Redundant	Redundant, separate compartments	
	Switchboard	1	1	2, separate compartments	
	Power management system	-	Redundant	Redundant, separate compartments	
	UPS	1	2	2+1, separate compartments	
Control system and measurement system	Automatic control, number of computer systems	1	2	3 (one located in back-up control station)	
	Independent joystick system	1	1	1	
	Position reference systems	2	3	2 + 1	one located in back-up control station
	Vertical reference systems	1	3	2 + 1	
	Heading sensor systems	1	3	2 + 1	one connected to back-up control station
	Wind speed & direction sensor systems	1	2	1+1	
Back-up DP control station		-	-	Yes	
Alarm printer		1	1	1	

11.2.1.3 Under special environmental conditions for operation, the DP system may be so designed that it has remote control of the length and tension of individual chains where position mooring equipment is used to assist in DP. In accordance with the operation conditions, the consequence of chain fracture or thruster failure is to be analyzed.
11.2.1.4 If external forces from mission-related system (lifting, pipe lay, external fire extinguishing, etc.) have a direct impact on DP performance, the influence of these systems is to be considered and factored into the DP system design.

11.2.2 Redundancy design principles for class notations DP-2 and DP-3

11.2.2.1 To realize the redundancy requirements for the class notations specified in 11.1.2, the DP system is to be arranged as follows:
(1) for class notation DP-2, redundancy of all active components or systems;
(2) for class notation DP-2, redundancy of static components that may immediately affect position keeping capabilities upon failure and is not properly documented with respect to protection;
(3) Active components or systems normally include generator set, switchboard, UPS, thruster, control system, etc. Static components normally include cables, piping, etc.;
(4) If a single operation results in the result exceeding WCFDI, the operation is to be protected, such as double - clicking or additional mechanical protection;
(5) for class notation DP-3, redundancy of all active or static components and A-60 fire separation between the redundancy groups. If such separation is below the damaged waterline, the corresponding watertight separation requirements are also to be met, and the area above the damaged waterline is subject to the FMEA to determine the flooding effect on redundancy and whether watertight separation is required.
(6) When redundancy is considered unnecessary or impossible for some components or systems, further consideration is to be given to the reliability of these components or systems and the effects of failures of them. Where the reliability of these components or systems is sufficient or the effects of failures are

negligible, such specific arrangement may be accepted upon analysis and test results.
11.2.2.2 The system is to be composed of at least two redundancy groups. In case of a single failure (including WCF), redundancy groups are to be immediately available (i.e. hot standby required) and with such quantity, capacity and capability that the DP operation can be continued and/or safely terminated.
11.2.2.3 Restarting the system after it has been fully stopped is not to be considered as the contribution to redundancy concept, which includes but is not limited to thrusters, generator sets, auxiliary systems directly connected to the DP system. Redundancy groups are to be immediately available without the need for manual intervention The transfer of control is to be smooth and changes in position and heading are within acceptable limitations of the operation(s).
11.2.2.4 To prevent failure propagation between different redundant sets, different redundant sets are to be mutual independent from each other, for DP-2 common connections of electrical and pipe systems should be avoided, furthermore for DP-3 common spatial connections should be avoided. If such connections are unavoidable, the influence of fault propagation on different redundant groups is to subject to the FMEA analysis and conclusion is subject to test.
11.2.2.5 For systems which are not directly forming part of the DP system, but may affect the DP system (HVAC systems, common fire suppression systems, ventilator and oil pump remote shutoff, emergency shutdown systems, fire and gas control system, etc.) in the event of activation or failure, they are also to be arranged with adequate redundancy and reliability.
11.2.2.6 If the WCF is obtained according to the FMEA and test result, the result is to be input into the consequence analysis software of the DP control system. Only modes that have been subject to the FMEA and test can be input into consequence analysis.
11.2.2.7 Where the FMEA shows that a hidden failure will result in a loss of redundancy, sufficient and effective measures are to be taken to remind the crew to avoid hidden failures.

11.2.3 Dynamic positioning control station

11.2.3.1 The DP control station for DP operating and controlling is to be fitted on dynamically positioned vessels. The relevant indicators, alarms, control panel and communication system are to be fitted at the control station.
11.2.3.2 The DP control station is to be located such as to suit main operational activities of the vessel and so arranged that the operator has a good view of the vessel's exterior limits and surrounding areas and is aware of any activity relevant to the DP operation.
11.2.3.3 The main DP control station where the DP operator normally operates is to be provided with the following equipment:
(1) DP control system operator station;
(2) independent joystick operator station;
(3) thruster control mode selection devices;
(4) manual thruster levers and indication;
(5) thruster emergency stops;
(6) internal communications; and
(7) position reference systems' HMI.
11.2.3.4 For class notation DP-3, a back-up DP control station is to be fitted. The separation between the back-up control station and the main control station is to meet the requirement of A-60 class fire division. In an emergency, the operator is to be able to easily move from the main DP control station to the back-up DP control station.
11.2.3.5 The back-up control station is to provide a good view of the vessel's exterior limits and surrounding areas. Where physical arrangement cannot satisfy the field of vision requirement, alternative measures such as CCTV may be used, which are to be functional in case that the main DP control station needs to be evacuated.
11.2.3.6 Consideration is to be given to the environmental conditions of the DP control station. If the normal DP operation can be kept only upon necessary measures, redundancy of these measures is required for class notations DP-2 and DP-3.

11.2.4 Display and alarm arrangements

11.2.4.1 The DP control station is to display information from the DP system, to ensure the normal operation of these systems. Information necessary to safely operate the DP system is to be available at all times.
11.2.4.2 Failures of the DP system and the equipment controlled by it are to initiate audible and visual alarms. The occurrence and status of these failures are to be permanently recorded. The record is to be made by means of an alarm printer. If other means are to be used, they are to be subject to special

consideration and with the approval of CCS.

11.2.4.3 Each DP control station is to be fitted with alarms and displays as specified in Table 11.2.4.3.

Alarm and Display at DP Control Station **Table 11.2.4.3**

System	Monitored parameters	Alarm	Display
Thruster system	Combined thrusters force, direction and turning moment(mimic showing the relative position on the vessel)		√
	Individual thruster force, percentage and direction of each thruster (mimic showing the relative position on the vessel)		√
	Thruster allocation mode (fixed, bias, etc.)		√
	Thruster order and feedback indication (including pitch, speed, azimuth etc.)		√
	Load limitation on thruster (overload, insufficient available power, system failure, etc.)	√	
	Thruster status (running, stopped, ready, in command, failure)	√	√
Power system	Status of ACB (including thruster, generator, bus tie as a minimum)		√
	Consumed power and available power of the on-line generator		√
Control system and measurement system	Set points, present position and heading, including the deviation in between		√
	Exceeding operating limits/set point (position, heading)	√	
	Operation status of and position information from position reference system		√
	Position reference system failure	√	
	Operation status of and heading information from heading reference system		√
	Heading reference system failure	√	
	Operation status of and motion information from vertical reference system		√
	Vertical reference system failure	√	
	Operation status of and wind speed/direction information from anemometer		√
	Anemometer failure	√	
	Operation status of consequence analysis software (DP-2/DP-3)		√
	Alarm provided by consequence analysis (DP-2/DP-3)	√	
	Thruster control mode selection device (if computer system) failure, DP control system failure, independent joystick control system failure	√	

11.2.4.4 Where alarms and displays required in 11.2.4.3 are impracticable or unnecessary or equivalent arrangements are available, they may be reduced as appropriate, subject to agreement by CCS.

11.2.4.5 Alarms and displays specified in 11.2.4.3 may be realized by different systems. If one display is used for alarms and other functions, the alarm information is to have higher priority than other information, and is not to be inhibited/overlapped by other information and operations.

11.2.4.6 If the alarms at the DP control station are slave signals of other alarm systems, there is to be a local acknowledgement and silencing device. If the alarms of the thruster system and power system at the DP control station shown in Table 11.2.4.3 are presented as group alarms, the individual alarm is to be indicated locally, however the shutdown alarm is to be separated from other alarm groups. The silence device is not to cause inhibiting of any new alarms.

11.2.5 Arrangement of control panels

11.2.5.1 Indicators and control panels of the DP control station are to be based on ergonomic principles. Indicators and control panels are to be arranged in logical groups, and to be coordinated with the geometry of the vessel when this is relevant. The requirement also applies to indication on displays.

11.2.5.2 Easy switch-over between operational modes are to be provided. Active mode is to be positively indicated. Consistent indications of the operational status of the different sub-systems are to be given.

11.2.5.3 If control of the system and its sub-systems can be carried out from alternate control stations, positive indication of the station in charge is to be provided.

11.2.5.4 The information sources like displays, indicators, etc. are to provide information in a readily usable form. The operator is to be provided with immediate information of the effect of his actions. Generally, feedback signals or other confirmations of actions carried out are to be displayed, not only the initial command.

11.2.5.5 Precautions are to be taken to avoid inadvertent operation of control panels if this may result in a critical situation. Such precautions may be proper location of handles etc, recessed or covered switches, or logic requirements to operations.
11.2.5.6 Interlocks are to be arranged, if erroneous sequence of operation may lead to a critical situation or damage of equipment.
11.2.5.7 Controls and indicators placed in the navigation bridge are to be sufficiently illuminated. Lights for such purpose are to be provided with dimming facilities. Alarm indications is not to be dimmed to zero.

11.2.6 Arrangement of data communication
11.2.6.1 When two or more thrusters and their manual controls are using the same data communication link, this link is to be arranged with redundancy.
11.2.6.2 When the automatic DP control system uses a data communication link, this link is to be separate from the communication link(s) for manual control.
11.2.6.3 For class notations DP-2 and DP-3, the data communication link of the DP control system is to be arranged with technical redundancy and physical separation.
11.2.6.4 The independent joystick system may share the data link with the manual control, but not with the automatic DP control system.
11.2.6.5 For class notations DP-2 and DP-3, a single failure is not to affect the redundant data communication link.

11.2.7 Physical separation arrangement for class notation DP-3
11.2.7.1 A-60 division is to be kept between redundancy groups. If such redundancy groups are below the damaged waterline, adequate watertight separation is also to be ensured. Redundancy groups are composed of equipment, cables and piping systems.
11.2.7.2 For common spaces connected to different redundancy groups, the effects of fire and flooding in such spaces are to be considered. Requirements equivalent to 11.2.7.1 are to be met.
11.2.7.3 Cables for redundant equipment or systems are not to be routed together with those for the main systems through the same compartments. Where this is unavoidable, such cables may run together in ducts of A-60 class fire division provided that this applies only to cables arranged in spaces without high fire risk. Cable connection boxes are not allowed in such ducts.
11.2.7.4 Redundant piping systems (for fuel, lubrication, hydraulic oil, cooling water and pneumatic control) are not to be routed through the same compartment together with the main system. Where this is unavoidable, such pipes may run together in ducts of A-60 class fire division. Such method is only applicable to piping systems not arranged in spaces with high fire risks.
11.2.7.5 The systems, which are not directly part of the DP system, but which in the event of failure could cause failure of the DP system (e.g. common fire suppression systems, engine ventilation systems, shut-down systems, etc.), are also to comply with the relevant requirements of this Chapter.

11.2.8 Internal communication system
11.2.8.1 Two way communication is to be provided between the DP control station and the following locations:
(1) navigation bridge;
(2) engine control room;
(3) control rooms related to DP operations, e.g. cargo control room, drilling control cabin, etc.
11.2.8.2 The power supply of the communication system is to be independent of the main power of the vessel.

Section 3 THRUSTER SYSTEM

11.3.1 General requirements
11.3.1.1 The thrusters mentioned in this Section are pipe tunnel thrusters, azimuth thrusters, thrusters for fixed or variable pitch blades, driven by electric motors, diesel engines, or hydraulically. Other types of thrusters will be specially considered in each case.
11.3.1.2 Unless expressly provided otherwise in this Section, the design and manufacture of the thruster system including prime mover, gearbox, shafting and propeller are to comply with the applicable requirements of PART THREE of the Rules. Electrical installations and automation are to comply with the applicable requirements of PARTs FOUR and SEVEN of the Rules.

11.3.1.3 Thruster systems used in dynamic positioning are to meet the requirements for long-time operations.
11.3.1.4 When the steering gear is included under DP control, it is also to be designed for continuous operation. In DP automatic operation mode, if the rudder is not under control of DP system (not on-line) and not in zero position, an alarm is to be released at the DP control system.

11.3.2 Thruster arrangement

11.3.2.1 The location of thrusters is to be arranged to minimize interference with other thrusters and hull.
11.3.2.2 Thruster intakes are to be located at sufficient depth to reduce the possibility of ingesting floating debris and vortex formation.
11.3.2.3 The number and capacity of thrusters are to meet the following requirements:
(1) In the specified environmental conditions, the thruster system is to provide adequate thrust in longitudinal and lateral directions and yawing moment for heading control;
(2) For class notations DP-2 and DP-3, where the arrangement of thrusters is provided with redundancy, there are to be adequate thrust in longitudinal and lateral directions and yawing moment for heading control after failure of any one of the redundant thrusters.
11.3.2.4 If necessary, the values of the thruster forces used in the consequence analysis are to be corrected for interference between thrusters and other effects which will reduce the effective force.

11.3.3 Manual thruster control

11.3.3.1 Manual operation of each thrusters for start, stop, azimuth and pitch/speed control is to be arranged at the DP control station. Azimuth, pitch and speed control are to be non-follow up control.
11.3.3.2 Running, stopped, operation mode, azimuth feedback, pitch feedback and speed feedback status for each thruster is to be continuously and clearly displayed at the DP control station.
11.3.3.3 Failure of the closed loop control system (including feedback devices) is not to affect the indication of azimuth, pitch and speed.
11.3.3.4 It is to be possible to control thrusters manually at all times, also in case failure of DP and independent joystick control systems.
11.3.3.5 Failure of a manual thruster control system including azimuth, pitch, speed control, is not to cause a change in thrust direction and/or an increase in thrust force.
11.3.3.6 It is to be possible to stop thrusters individually from the main DP control station by independent emergency stop devices. The emergency stop of any thruster is not to affect other thrusters. The emergency stop device is to be independent of the DP control system, independent joystick control system and manual thruster control system. The emergency stop is to be arranged with separate cables and control circuit for each thruster.
11.3.3.7 For class notations DP-2 and DP-3, the emergency stop device is to have loop monitoring, including monitoring of power loss, broken wire and short circuit as a minimum. An alarm is to be initiated upon loop failure which is not to affect the running thrusters. For class notation DP-3, the design of the emergency stop device is also to consider the effects of fire and flooding.
11.3.3.8 Alarms related to the thruster system are to be continuously displayed at the manual thrusters control location. Such alarms may arranged to be group alarms, however the shutdown alarm point (if provided) is to be separated from other alarm points.

Section 4 POWER SYSTEM

11.4.1 General requirements

11.4.1.1 Unless expressly provided otherwise in this Chapter, the power system is to comply with the applicable requirements for electrical installations in PARTs THREE and FOUR of the Rules.
11.4.1.2 Automatic load limitation or other automatic measures are to be taken to prevent the active or reactive overload of the power system, in order to prevent partial or total loss of power. This requirement is also applicable to scenario when a single failure leads to tripping of more than one generators (unless there is no generator connected to the bus-bar after the failure). If this requirement is realized by multiple systems, the settings of each system are to be coordinated with each other.
11.4.1.3 For class notation DP-1, the power system needs not to be designed with redundancy.
11.4.1.4 For class notation DP-2, the power system should be divisible into two or more systems so that, in the event of failure of one sub-system, at least one other system will remain in operation and provide sufficient power for station keeping. The power system(s) may be run as one system during operation, but should be arranged by bus-tie breakers(s) to separate the system automatically upon failures which could be

transferred from one system to another, including, but not limited to, overloading, grounding and short circuits, which is to be identified by failure mode and impact analysis.

11.4.1.5 For class notation DP-3, the power system should be divisible into two or more systems so that, in the event of failure of one system, at least one other system will remain in operation and provide sufficient power for station keeping. The divided power system should be located in different spaces separated by A-60 class divisions. Where the power systems are located below the damage waterline, the separation should also be watertight. But-tie breakers of systems should be open unless equivalent integrity of power operation can be accepted, for detailed principles refer to 11.4.4.7.

11.4.2 Number and capacity of generators

11.4.2.1 When starting thruster motors, especially when one generator is out of service, transient voltage drop caused in the main bus-bar system during starting periods is not to be in excess of 15% of the rated voltage.

11.4.2.2 The high reactive load demands which may occur in DP thruster operation are to be considered when selecting number and type of generators.

11.4.2.3 For class notations DP-2 and DP-3, the redundancy is to be based on the running generator sets, and the number and capacity of generator sets are to meet the requirement for redundancy and capacity after a single failure.

11.4.2.4 Special considerations are to be made when energy storage facilities, such as battery systems, are used to power thrusters during DP operation. Where the energy storage facilities are used as one of the power system redundancy groups of the power system, the corresponding redundancy design principles are to be complied with.

11.4.3 Power management system

11.4.3.1 For class notations DP-2 and DP-3, an automatic power management control system is to be arranged to perform load-dependent starting and stop of generators. This system is to block starting of large consumers when there is not adequate running generator capacity, and to start up back-up generators as required, and hence to permit requested loads start to proceed.

11.4.3.2 The power management system is to satisfy the redundancy requirement of the corresponding notations and is able to maintain power management function after a single failure.

11.4.3.3 An alarm is to be initiated when the total electrical load exceeds a preset percentage of the running generator(s) capacity. This alarm is to be adjustable between 50% and 100% of the running capacity and is to be set with regard to the number of generators in service and the effect of the loss of any one generator.

11.4.3.4 A failure in the power management system is not to cause alteration to the online power generation, and is to initiate an alarm at the crew normal on-watch position in the.

11.4.3.5 It is to be possible to operate the switchboards manually after the power management system stops operation.

11.4.4 Switchboard arrangement for class notations DP-2 and DP-3

11.4.4.1 For class notation DP-2, the switchboard is to be so arranged that no single failure will give a total blackout. A single failure in this case is defined as any system or component breakdown of technical nature. The possibility of short circuit on the bus-bar is to be considered. For vessels with class notation DP-3, single failures also include the failures caused by flooding and fire incidents. The immediate consequence of this is that physical separation of redundant components/systems must be used to limit the effects of flooding and fire incidents.

11.4.4.2 A main bus-bar system is to consist of at least two sections (or parts). Where a circuit breaker is capable of breaking the maximum short circuit current in the system, the sections may be connected with the breaker. This breaker is to be appropriately protected and is to comply with the requirements for selectivity.

11.4.4.3 For class notation DP-2, the switchboard sections of different redundancy groups may be so arranged in one switchboard that adequate capacity is available in case of loss of any section due to any reason and that the vessel's position can be kept within specified environmental conditions and operating limits.

11.4.4.4 For class notation DP-3, switchboards of different redundancy groups are to be isolated from the other(s) by A-60 class fire division. If the switchboards are located below the waterline, the separation is also to be watertight. Adequate capacity is to be available to keep the vessel's position within specified operating limits after loss of any compartments due to fire or flooding. For switchboards of different redundancy groups, there is to be a bus-tie breaker on each side.

11.4.4.5 Power supply for the power system and thruster system need to be originated from their respective redundancy groups and their arrangements need to satisfy the redundancy design principles of the corresponding notations.
11.4.4.6 The online power reserve, i.e. the difference between online generator capacity and consumed power at any time is to be continuously displayed at the DP control station. For split-bus power arrangements, indications are to be provided for individual bus-bar sections.
11.4.4.7 For class notation DP-3, to realize the equivalent integrity required by 11.4.1.5, the following analysis and tests are to be carried out as a minimum:
(1) It is FMEA's responsibility to identify all possible failure modes, failure propagation, consequence of failure; the definition of failure mode is unlimited, including any active, static components failure, common mode failure, hidden failure, loss of an entire compartment due to fire or flooding (including failures of all systems inside the compartment). Computer simulation and other methods are needed to simulate the dynamic response of the DP system during failure condition.
(2) When the FMEA identifies that the occurrence of some failure modes will directly affect positioning, at least two sets of protection are to be provided for this failure mode, and the two sets of protection are to be mutual independent from each other. When both protection are performed, the result cannot exceed the WCFDI.
(3) Automatic blackout recovery of bus-bar of each section and start of all thrusters (except for the faulty bus-bar) need to be arranged. Except manual enabled thrusters into DP control, all other functions must be automatic. The recovery times is to be as fast as possible, and in any case should not exceed 60 seconds, such function is to be verified onboard.
(4) Test need to be carried out according to the FMEA conclusion, in order to verify the functionality of the protection, failure ride through capability, independence between protection function, coordination between various protection and failure monitoring. The test scope is to be defined according to the result of the FMEA, computer simulation and calculation, is to include at least live test such as short circuit, earth fault, governor fault, AVR fault, phase imbalance and PMS fault. The test results need to be recorded and compared with the theoretical analysis to determine whether each case can be accepted.

11.4.5 Control power

11.4.5.1 The computer system, operator station, position reference system, sensor system and printers for DP control system are to be supplied from UPSs. The arrangement and number of UPSs are to be in accordance with Table 11.2.1.2 of this Chapter.
11.4.5.2 For class notation DP-1, at least one UPS is to be provided. For class notations DP-2 and DP-3, the number of UPS is to be determined according to the FMEA results. For class notation DP-2, at least two UPSs are to be provided; for class notation DP-3, at least three UPSs are to be provided, one of which is to be located in a separate compartment separated by A-60 class division from other UPSs.
11.4.5.3 For class notations DP-2 and DP-3, the power supply to the computer system, operator station, position reference system, sensors are to be distributed according to the redundancy design principle to ensure the capability to keep DP position in case of a single failure of the UPS system.
11.4.5.4 For class notation DP-2, the power supply to the redundant UPS is to be derived from different parts of the main switchboard. For class notation DP-3, the power supply to the redundant UPS for the main DP control system is to be derived from different parts of the main switchboard. A single failure cannot cause simultaneous power loss of main and back-up DP control systems.
11.4.5.5 The power supply for the independent joystick system is to be independent of UPS for the DP control system.
11.4.5.6 For the thruster system and power system, the power supply for UPS is to be derived from different redundancy groups if the control power of such systems is supplied by UPS.
11.4.5.7 The battery capacity of each UPS is to be maintained at least 30 min. Alarms are to be initiated in case of charging failure.

Section 5 CONTROL SYSTEM AND MEASURING SYSTEM

11.5.1 General requirements

11.5.1.1 Unless expressly provided otherwise in this Chapter, control systems and measuring systems are to comply with the applicable requirements for automation system in PART SEVEN of the Rules.
11.5.1.2 The control systems and measuring systems of this Chapter includes the following equipment and functions:
(1) DP control system;

(2) independent joystick controls;
(3) thruster control mode selection device.

11.5.2 Arrangement of control systems

11.5.2.1 For class notation DP-1, one DP control system and one independent joystick system with automatic heading control are to be fitted.

11.5.2.2 For class notation DP-2, a redundant DP control system and one joystick system with automatic heading control are to be fitted. Should one automatic DP control system fail, control is to be automatically transferred to another one.

11.5.2.3 For class notation DP-3, triple redundant DP control systems and one joystick system with automatic heading control are to be fitted. The two automatic DP control systems are to be arranged such that, should one fail, control is automatically transferred to another one. The third automatic DP control system is to be located in the back-up control station and transfer of control to it is to be initiated in case of failure of both main control systems.

11.5.2.4 Where two or more computer systems are operated simultaneously, means are to be provided for self-monitoring and comparison between systems so as to initiate an alarm when any significant difference is detected in orders for thrusters or positions or heading. This function is not to endanger the independence of each system or cause any risk of the common mode failure.

11.5.3 Automatic DP control

11.5.3.1 The DP control system is to have thrusters automatic operation mode and is able to keep vessel's position/heading, the set points for position/heading can be selected individually.

11.5.3.2 The DP control system located in the main DP control station is to have joystick operation mode.

11.5.3.3 The relative or absolute position and heading of the ship are to be displayed, including deviations from set points. Audible and visual alarms are to be initiated when the ship deviates from the set points.

11.5.3.4 The automatic DP control is to consist of one or more computer system, comprising processing units, input/output devices, and storage devices.

11.5.3.5 The computer systems are to perform self-check routines for detection of failure. Alarms are to be initiated when critical failures are detected.

11.5.3.6 Each DP computer system is to be isolated from other on-board computer systems and communication systems to ensure the integrity of the DP system. This isolation may be fulfilled via hardware, software systems or physical separation which based on specific design.

11.5.3.7 For class notation DP-1, the following requirements are to be complied with:

(1) The computer system for automatic thruster control is to give pitch/speed and azimuth commands. These commands are transmitted to the individual thruster control units.

(2) The computer system is to perform self-check routines that are to bring the computer system to stop when critical failure conditions are detected.

(3) When stopped, either by automatic or manual means, the computer system is to set speed/pitch commands to zero.

(4) The computer system and operator station of the DP control system is not required to be redundant.

11.5.3.8 For class notation DP-2, the following requirements are to be complied with:

(1) applicable requirements under 11.5.3.7.

(2) Redundant computer systems are to be arranged with automatic command transfer after a detected failure in one of the computer systems and an alarm is to be initiated. Common facilities, such as self-checking routines, data transfer arrangements and interfaces, are not to cause the failure of two/all systems.

(3) One computer system may be selected as the on-line system and other systems are in hot standby condition. The changeover from one system to another is able to be manually and automatically. In case of automatic changeover upon failure detection, the system that was online is to remain unavailable after repair, and it can be selected to be online only manually.

(4) The automatic transfer of control from one computer system to another is to be smooth and the position/heading excursion is to be within the acceptable limitations of the operation.

(5) The above requirements are also applicable to the operator station located at the DP control station.

(6) If any failure of a standby DP control system, the standby sensors or position reference systems connected to it, an alarm is to be initiated.

(7) When a computer system consists of three or more computers, an online voting algorithm maybe used to determine the failed computer and automatically switchover is to be carried out.

11.5.3.9 For class notation DP-3, the following requirements are to be complied with:

(1) applicable requirements under 11.5.3.8.

(2) The back-up DP control system is to be located in a compartment, separated by A-60 division from the main DP control system.
(3) If three independent computer systems are chosen for the main system, one of these computers may serve as the back-up, provided that the necessary independence as required for the back-up is achieved.
(4) There is to be at least one position reference system and one sensor system connected to the back-up system, independent of the main system.
(5) During DP operation, this back-up control system is to be continuously updated by input from the sensors, position reference systems, thruster feedback, etc., and to be ready to take over control.
(6) The back-up computer control system is to have real-time communication with the computer system of the main DP control system. An alarm is to be initiated if any significant difference of parameter is detected or the back-up control station is not ready to take control.
11.5.3.10 For class notations DP-2 and DP-3, the computer system is to include a software function, known as online consequence analysis which at least fulfills with the following requirements:
(1) to continuously verify that the vessel will remain in position even if the WCF occurs under the current environmental conditions. If the left thrusters cannot generate the same resultant thruster force and moment as required before the failure, the consequence analysis is to initiate an alarm.
(2) to calculate the effects of available power of the generator sets and thruster sets on positioning after the WCF, and the principles in 11.2.2.7 of the Chapter need to be followed.
(3) For operations which will take a long time to safely terminate, the consequence analysis is to include a function which simulates the thrust and power remaining after the WCF, based on manual input of weather information.
(4) When other forms of energy storage devices are used as redundancy groups of the DP system, such as battery systems to power thrusters, consequence analysis is to consider the relationship between the time required to safely terminate the operation and the duration of energy storage devices, and the consequence analysis alarm setting is to be less than the expected discharge time.
(5) The operation status of the online consequence analysis is to be continuously and clearly displayed at the DP control station.

11.5.4 Independent joystick control

11.5.4.1 The joystick is to enable the control of longitudinal and transverse thruster forces, turning moments, and all combinations of these thruster force components. The system is to include selectable automatic heading control.
11.5.4.2 The independent joystick control system is to be independent of the DP control system. In case of any failure of the DP control system, independent joystick control of all thrusters is still to be able to be performed.
11.5.4.3 Any failure in the independent joystick control system is to initiate an alarm.
11.5.4.4 Any failure causing operator loss of control of the thrusters in the independent joystick control system is to set the thrust commands to zero. If the failure affects only a limited number of thrusters, the command to these affected thrusters is to be automatically set to zero, while keeping the other unaffected thrusters in joystick control.

11.5.5 Thruster control mode selection device

11.5.5.1 The command transfer between different control systems (e.g. manual thruster control system, DP control system, independent joystick control system, etc.) for thrusters is to be selectable by a simple device located in the DP control station. The device may consist of a single selector switch, or individual selectors for each thruster.
11.5.5.2 In the DP or independent joystick mode, the mode selection device is to be so arranged that it is always possible to select manual controls of thrusters after any single failure in the DP control mode.
11.5.5.3 For class notations DP-2 and DP-3, the mode selection device is to be so designed that no single failure will deselect all thrusters from the automatic operation mode. The results are not to exceed the WCF defined by the system.
11.5.5.4 For class notation DP-3, it is to be possible to transfer the command responsibility to the back-up control at the DP back-up control station, and the mode selection device failure (electrical failure, fire, etc.) will not result in simultaneous failure of the main or back-up DP control.

11.5.6 Position reference systems

11.5.6.1 The position reference systems are to produce position data with adequate accuracy for the intended DP operation to satisfy the corresponding operational requirements.
11.5.6.2 For class notation DP-1, at least two independent position reference systems are to be provided.

11.5.6.3 For class notations DP-2 and DP-3, at least three position reference systems are to be installed. For class notation DP-3, one of the position reference systems is to be connected to the back-up DP control station and separated by A-60 class fire division from other position reference systems.
11.5.6.4 The position reference systems' HMI is to be arranged at the DP control station, which can display the position information and operation status. The HMI is to be independent from the DP operator station. For class notations DP-2 and DP-3, the arrangement for the HMI is to meet the corresponding redundancy requirements. For class notation DP-2, at least two sets of HMI are to be arranged, and for class notations DP-3, one more set of HMI is to be arranged in the back-up control station.
11.5.6.5 For class notations DP-2 and DP-3, the position reference systems' power supply, signal transmission and interface with the DP control system are to meet the system's redundancy arrangement and separation requirements.
11.5.6.6 When two or more position reference systems are required, they are to be based on different principles. For class notation DP-1, if only one principle is used, the design is subject to special consideration and approval from CCS.
11.5.6.7 The data of the position reference systems are to be processed. In case of abnormal conditions such as freezing, jumping, fluctuation or decreased accuracy, such data are to be rejected by the control system through certain means and an alarm is to be initiated. This requirement applies to all online and stand-by position reference systems.
11.5.6.8 The operating status of the position reference systems are to be clearly indicated, such as running, online, failure, and rejected by the control system.
11.5.6.9 When one or more position reference systems are selected/dis-selected, the output of the thrusters should not change significantly. When the last reference system is lost, the output of the thrusters should not change significantly immediately.
11.5.6.10 When an acoustic reference system is used, a hydrophone is to be chosen to minimize the influence of mechanical and acoustic disturbance on transmission channels.
11.5.6.11 When a taut wire system is used, materials used for wire rope, tensioning and auxiliary equipment are to be appropriate for marine service.
11.5.6.12 When the signals from the position reference system are changed by the movement of the vessel (rolling, pitching), the position is to be automatically corrected.
11.5.6.13 The electrical and mechanical parameters of the position reference systems, such as energy, pressure and temperature, are to be monitored and the failure of the position reference systems are to be monitored in so far as practicable.

11.5.7 Sensor systems

11.5.7.1 The sensor systems are to produce heading and other necessary data with adequate accuracy for the DP operation to satisfy the corresponding operational requirements.
11.5.7.2 Sensors are to be provided in accordance with the requirements of Table 11.2.1.2 of this Chapter.
11.5.7.3 For class notations DP-2 and DP-3, where the DP control system relies on the correction signals of sensors, at least three systems are necessary for the same type of sensors.
11.5.7.4 For class notation DP-3, one of the sensor systems is to be directly connected to the back-up control system and separated from the other sensors by A-60 class fire division.
11.5.7.5 For class notations DP-2 and DP-3, the sensor systems' power supply, signal transmission and interface with the DP control system are to meet the system redundancy arrangement and separation requirements.
11.5.7.6 The data of the sensor systems are to be processed. In case of abnormal conditions such as freezing, jumping, fluctuation or decreased accuracy, such data are to be rejected by control system and an alarm is to be initiated. This requirement applies to all online and stand-by sensor systems.
11.5.7.7 The operating status of the position reference systems are to be clearly indicated, such as running, online, failure, and rejected by the control system.
11.5.7.8 The electrical and mechanical parameters of the sensor systems, such as energy, pressure and temperature, are to be monitored and the failure of the sensor systems are to be monitored in so far as practicable.

CHAPTER 12 IN-WATER SURVEY ARRANGEMENTS OF SHIPS

Section 1 GENERAL PROVISIONS

12.1.1 Application

12.1.1.1 This Chapter applies to ships classed with CCS and intended to be assigned the In-Water Survey class notation.

Section 2 DOCUMENTATION TO BE SUBMITTED

12.2.1 Plans/Manuals

12.2.1.1 Detailed plans of the hull and hull appendages below the waterline are to be submitted for approval. These plans are to indicate the location and/or general arrangement of:

(1) all shell openings;
(2) stem and sternpost;
(3) rudder and fittings;
(4) propeller, including the means used for identifying each blade;
(5) anodes, including securing arrangements;
(6) bilge keel;
(7) welded seams and butts;
(8) marking system.

12.2.1.2 The drawings are also to include the necessary instructions to facilitate the divers' work, especially for taking clearance measurements.

12.2.1.3 A plan for evaluating rudder pintle and bearing clearances while the ship is afloat is to be submitted for examination and approval.

12.2.1.4 The underwater portion of the hull is to be coated with a high resistant paint. Details of the high resistant paint are to be submitted to CCS for information.

12.2.2 Photographs

12.2.2.1 As far as practicable, a photographic documentation, used for reference during in-water surveys, of the following hull parts is to be submitted:

(1) propeller boss;
(2) rudder pintles, where clearance is measured;
(3) typical sea connection;
(4) adjustable propeller, if any;
(5) other details, as deemed necessary on a case by case basis.

12.2.3 Documentation on board

12.2.3.1 The plans and photographs required in 12.2.1 and 12.2.2 are to be kept on board by the owner and made available to the Surveyor and the divers when an in-water survey is carried out.

Section 3 STRUCTURAL DESIGN PRINCIPLES

12.3.1 Marking

12.3.1.1 Identification marks and system are to be supplied to facilitate the in-water survey. The following positions are at least to be included:

(1) ship bottom: connections of bulkhead or watertight floors and girders;
(2) both sides: in way of watertight transverse bulkheads and connections of inner bottom plating to watertight floors.
(3) all shell plating openings below the waterline.

12.3.1.2 The marking is at least to be 300 mm in length and 30 mm in width, which is to be painted in a contrasting colour. The marking may be made in the form of a raised character or made using any other equivalent method which ensures that the marking is not easily expunged. The marking may be replaced by

the anodes (e.g. zinc blocks) or external appendages on the hull, provided that they are indicated accordingly in the plans/manuals submitted for approval in accordance with 12.2.1.

12.3.2 Rudder arrangements

12.3.2.1 Rudder arrangements are to be such that rudder pintle clearances can be checked while the ship is afloat.

12.3.3 Oil sealing glands of propeller shafts or tube shafts

12.3.3.1 The oil sealing glands of propeller shafts or tube shafts is to be such that clearances between propeller shafts or tube shafts and bearings can be checked while the ship is afloat.

12.3.4 Grating of sea chest

12.3.4.1 The grating of sea chest are to be connected by hinges or equivalent means, so as to facilitate the examination of internal conditions of the sea chest.

CHAPTER 13 ADDITIONAL REQUIREMENTS FOR POLAR CLASS SHIPS

Section 1 GENERAL REQUIREMENTS FOR POLAR CLASS SHIPS

13.1.1 Application

13.1.1.1 This Chapter for Polar Class applies to ships constructed of steel and intended for independent navigation in ice-infested polar waters.

13.1.1.2 Ships that comply with the requirements of Sections 2 and 3 of this Chapter can be considered for a Polar Class notation “PC x” (where x is the corresponding class number) as listed in Table 13.1.2.1. The requirements of Sections 2 and 3 are in addition to the open water requirements. If the hull and machinery are constructed such as to comply with the requirements of different polar classes, then both the hull and machinery are to be assigned the lower of these classes in the classification certificate. Compliance of the hull or machinery with the requirements of a higher Polar Class is also to be indicated in the classification certificate or the equivalent. Where a higher Polar Class is used for one or more longitudinal hull areas (see 13.2.2.1 for definitions of hull area division in the longitudinal direction) of the polar class ships, the class notation of “PC X(y)” may also be assigned where y refers to the longitudinal hull areas, to be taken as B: bow region, BI: bow intermediate region, M: midbody region, S: stern region.

13.1.1.3 Ships which are assigned a Polar Class notation and complying with the relevant requirements of Sections 2 and 3 of this Chapter may be given the additional notation “Icebreaker”. “Icebreaker" refers to any ship having an operational profile that includes escort or ice management functions, having powering and dimensions that allow it to undertake aggressive operations in ice-covered waters, and having a class certificate endorsed with this notation.

13.1.1.4 For ships which are assigned a Polar Class notation, the hull form and propulsion power are to be such that the ship can operate independently and at continuous speed in a representative ice condition, as defined in Table 13.1.2.1 for the corresponding Polar Class. For ships and ship-shaped units which are intentionally not designed to operate independently in ice, such operational intent or limitations are to be explicitly stated in the classification certificate or the equivalent.

13.1.1.5 For ships which are assigned a Polar Class notation PC 1 through PC 5, bows with vertical sides, and bulbous bows are generally to be avoided. Bow angles should in general be within the range specified in 13.2.3.1(5).

13.1.1.6 For ships which are assigned a Polar Class notation PC 6 and PC 7, and are designed with a bow with vertical sides or bulbous bows, operational limitations (restricted from intentional ramming) in design conditions are to be stated in the classification certificate or the equivalent.

13.1.2 Polar class

13.1.2.1 The Polar Class (PC) notations and descriptions are given in Table 13.1.2.1. It is the responsibility of the owner to select an appropriate Polar Class. The descriptions in Table 13.1.2.1 are intended to guide owners, designers and administrations in selecting an appropriate Polar Class to match the requirements for the ship with its intended voyage or service.

Polar Class Description **Table 13.1.2.1**

Polar Class	Ice Description (based on WMO Sea Ice Nomenclature)
PC1	Year-round operation in all polar waters
PC2	Year-round operation in moderate multi-year ice conditions
PC3	Year-round operation in second-year ice which may include multi-year ice inclusions
PC4	Year-round operation in thick first-year ice which may include old ice inclusions
PC5	Year-round operation in medium first-year ice which may include old ice inclusions
PC6	Summer/autumn operation in medium first-year ice which may include old ice inclusions
PC7	Summer/autumn operation in thin first-year ice which may include old ice inclusions

13.1.2.2 The Polar Class notation is used throughout this Chapter for Polar Class ships to convey the differences between classes with respect to operational capability and structural strength.

13.1.3 Upper and lower ice waterlines

13.1.3.1 The upper and lower ice waterlines upon which the design of the vessel has been based are to be indicated in the classification certificate. The upper ice waterline (UIWL) is to be defined by the maximum

draughts fore, amidships and aft. The lower ice waterline (LIWL) is to be defined by the minimum draughts fore, amidships and aft.

13.1.3.2 The lower ice waterline (LIWL) is to be determined with due regard to the ship's ice-going capability in the ballast loading conditions. The propeller is to be fully submerged at the lower ice waterline(LIWL).

13.1.3.3 When the upper ice waterline (UIWL) is lower than the summer fresh water loadline draught, an ice class draught mark is to be provided in accordance with the requirements of 4.2.1.4, Section 2, Chapter 4, PART TWO of the Rules.

Section 2 STRUCTURAL REQUIREMENTS

13.2.1 Application and definitions

13.2.1.1 This Section applies to Polar Class ships as specified in Section 1 of this Chapter.

13.2.1.2 The length L_{UI} is the distance, in m, measured horizontally from the fore side of thestem at the intersection with the upper ice waterline (UIWL) to the after side of the rudder post, or the centre of the rudder stock if there is no rudder post. L_{UI} is not to be less than 96%, and need not be greater than 97%, of the extreme length of the upper ice waterline (UIWL) measured horizontally from the fore side of the stem. In ships with unusual stern and bow arrangement the length L_{UI} will be specially considered.

13.2.1.3 The ship displacement D_{UI} is the displacement, in kt, of the ship corresponding to the upper ice waterline (UIWL). Where multiple waterlines are used for determining the UIWL, the displacement is to be determined from the waterline corresponding to the greatest displacement.

13.2.2 Hull areas

13.2.2.1 The hull of all Polar Class ships is divided into areas reflecting the magnitude of the loads that are expected to act upon them. In the longitudinal direction, there are four regions: bow, bow intermediate, midbody and stern. The bow intermediate, midbody and stern regions are further divided vertically into the bottom, lower and ice belt regions. The extent of each hull area is illustrated in Figure 13.2.2.1.

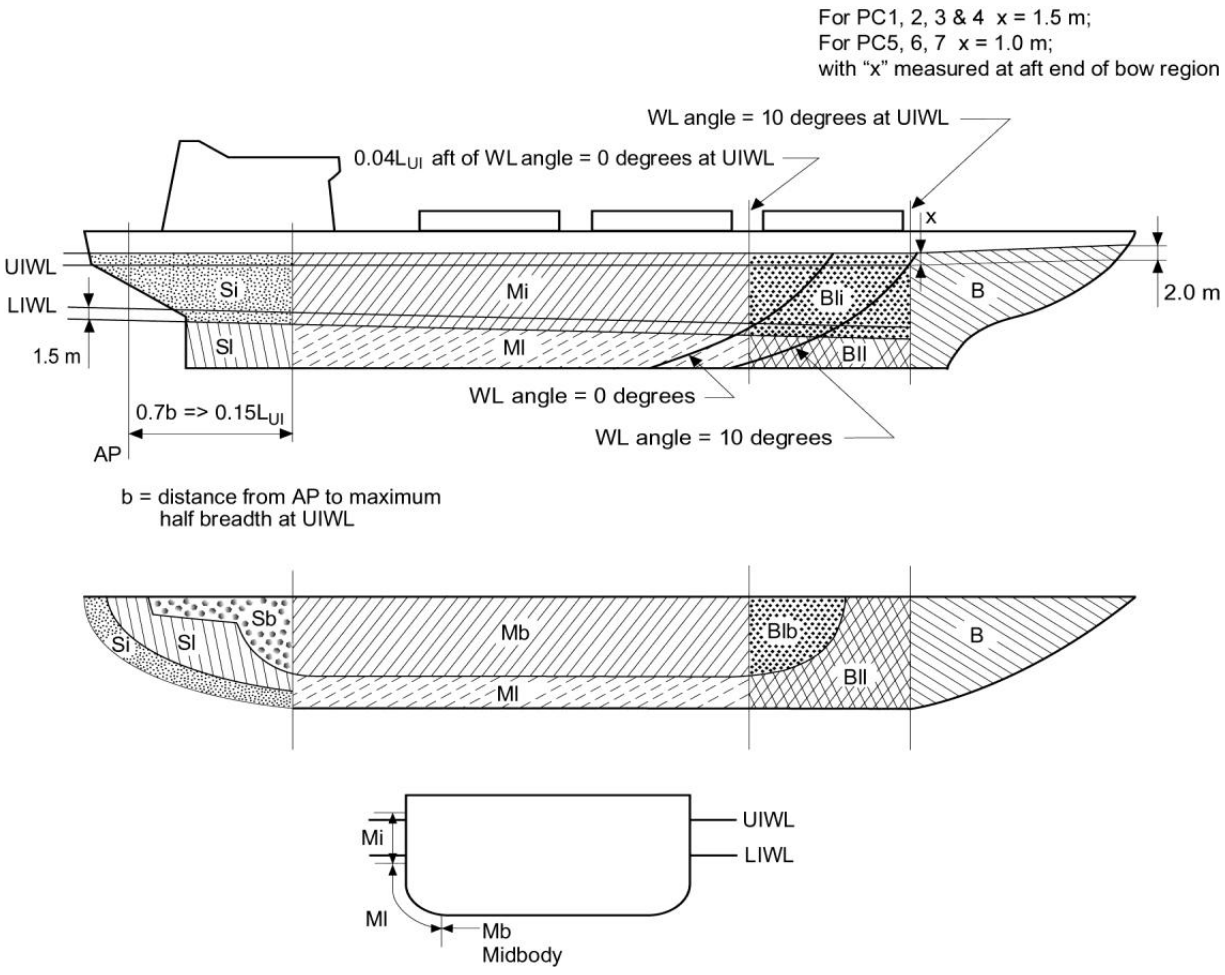


Figure 13.2.2.1 Extent of Hull Areas

13.2.2.2 The upper ice waterline (UIWL) and lower ice waterline (LIWL) are as defined in 13.1.3.
13.2.2.3 Figure 13.2.2.1 notwithstanding, at no time is the boundary between the bow and bow intermediate regions to be forward of the intersection point of the line of the stem and the ship baseline.
13.2.2.4 Figure 13.2.2.1 notwithstanding, the aft boundary of the bow region need not be more than 0.45 L_{UI} aft of the fore side of the stem at the intersection with the upper ice waterline (UIWL).
13.2.2.5 The boundary between the bottom and lower regions is to be taken at the point where the shell is inclined 7° from horizontal.
13.2.2.6 If a ship is intended to operate astern in ice regions, the aft section of the ship is to be designed using the bow and bow intermediate hull area requirements.
13.2.2.7 Figure 13.2.2.1 notwithstanding, for ships assigned the additional notation "Icebreaker", the forward boundary of the stern region is to be at least $0.04L_{UI}$ forward of the section where the parallel ship side at the upper ice waterline (UIWL) ends.

13.2.3 Design ice loads

13.2.3.1 General
(1) For all Polar Class ships, a glancing impact on the bow is the design scenario for determining the scantlings required to resist ice loads.
(2) The design ice load is characterized by an average pressure (P_{avg}) uniformly distributed over a rectangular load patch of height (b) and width (w).
(3) Within the bow area of all Polar Class ships, and within the bow intermediate ice belt area of Polar Class PC6 and PC7, the ice load parameters are functions of the actual bow shape. To determine the ice load parameters (P_{avg}, b and w), it is required to calculate the following ice load characteristics for sub-regions of the bow area; shape coefficient (fa_i), total glancing impact force (F_i), line load (Q_i) and pressure (P_i).
(4) In other ice-strengthened areas, the ice load parameters (P_{avg}, b_{NonBow} and w_{NonBow}) are determined independently of the hull shape and based on a fixed load patch aspect ratio, AR = 3.6.
(5) Design ice forces calculated according to 13.2.3.2(1)③ are applicable for bow forms where the buttock angle γ at the stem is positive and less than 80°, and the normal frame angle β' at the centre of the foremost sub-region, as defined in 13.2.3.2 (1)①, is greater than 10°.
(6) Design ice forces calculated according to 13.2.3.2(1)④ are applicable for ships which are assigned the Polar Class PC6 or PC7 and have a bow form with vertical sides. This includes bows where the normal frame angles β' at the considered sub-regions, as defined in 13.2.3.2(1)①, are between 0° and 10°.
(7) For ships which are assigned the Polar Class PC6 or PC7, and equipped with bulbous bows, the design ice forces on the bow are to be determined according to 13.2.3.2(1)④. In addition, the design forces are not to be taken less than those given in 13.2.3.2(1)③, assuming fa = 0.6 and AR = 1.3.
(8) For ships with bow forms other than those defined in (5) to (7), design forces are to be specially considered by CCS.
(9) Ship structures that are not directly subjected to ice loads may still experience inertial loads of stowed cargo and equipment resulting from ship/ice interaction. These inertial loads, as referred to acceleration calculation in 13.3.6 of Section 3, are to be considered in the design of these structures.
13.2.3.2 Glancing impact load characteristics
The parameters defining the glancing impact load characteristics are reflected in the class factors listed in Tables 13.2.3.2(1) and 13.2.3.2(2).

Class Factors To Be Used in 13.2.3.2(1)③ **Table 13.2.3.2(1)**

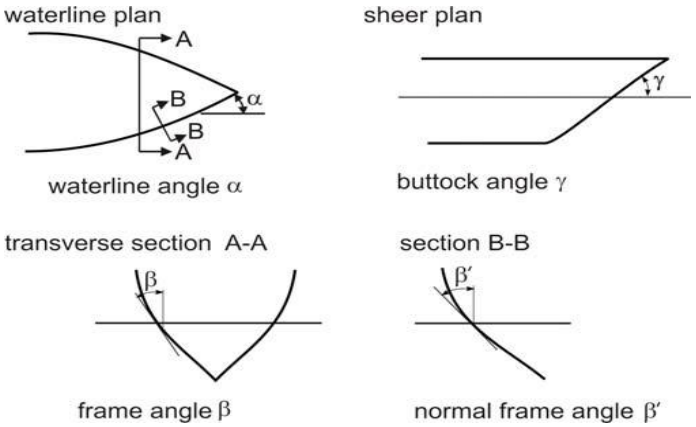
Polar Class	Crushing failure class factor (CF_C)	Flexural failure class factor (CF_F)	Load patch dimensions class factor (CF_D)	Displacement class factor (CF_{DIS})	Longitudinal strength class factor (CF_L)
PC1	17.69	68.60	2.01	250	7.46
PC2	9.89	46.80	1.75	210	5.46
PC3	6.06	21.17	1.53	180	4.17
PC4	4.50	13.48	1.42	130	3.15
PC5	3.10	9.00	1.31	70	2.50
PC6	2.40	5.49	1.17	40	2.37
PC7	1.80	4.06	1.11	22	1.81

Class Factors To Be Used in 13.2.3.2(1)④ **Table 13.2.3.2(2)**

Polar Class	Crushing failure class factor (CF_{CV})	Line load class factor (CF_{QV})	Pressure class factor (CF_{PV})
PC6	3.43	2.82	0.65
PC7	2.60	2.33	0.65

(1) Bow area

① In the Bow area, the force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) associated with the glancing impact load scenario are functions of the hull angles measured at the upper ice waterline (UIWL). The influence of the hull angles is captured through calculation of a bow shape coefficient (fa). The hull angles are defined in Figure 13.2.3.2.



Notes: β' — normal frame angle at upper ice waterline [°];
α — upper ice waterline angle [°];
γ — buttock angle at upper ice waterline (angle of buttock line measured from horizontal) [°];
$\tan(\beta) = \tan(\alpha)/\tan(\gamma)$;
$\tan(\beta') = \tan(\beta)\cdot\cos(\alpha)$.

Figure 13.2.3.2 Definition of Hull Angles

② The waterline length of the bow region is generally to be divided into 4 sub-regions of equal length. The force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) are to be calculated with respect to the mid-length position of each sub-region (each maximum of F, Q and P is to be used in the calculation of the ice load parameters P_{avg}, b and w).

③ The bow area load characteristics for bow forms defined in 13.2.3.1(5) are determined as follows:

(a) Shape coefficient, fa_i, is to be taken as:

$$fa_i = \min(fa_{i,1}, fa_{i,2}, fa_{i,3})$$

where: $fa_{i,1} = \dfrac{\left[0.097 - 0.68\left(\dfrac{x}{L_{UI}} - 0.15\right)^2\right]\alpha_i}{(\beta_i')^{0.5}}$;

$fa_{i,2} = \dfrac{1.2CF_F}{[\sin(\beta_i')\cdot CF_C \cdot D_{UI}{}^{0.64}]}$;

$fa_{i,3} = 0.60$;

(b) Force, F:

$$F_i = fa_i \cdot CF_C \cdot D_{UI}{}^{0.64} \quad \text{MN}$$

(c) Load patch aspect ratio, AR:

$$AR_i = 7.46\sin(\beta_i') \geq 1.3$$

(d) Line load, Q:

$$Q_i = F_i^{0.61} \cdot CF_D / AR_i^{0.35} \quad \text{MN/m}$$

(e) Pressure, P:

$$P_i = F_i^{0.22} \cdot CF_D^2 \cdot AR_i^{0.3} \quad \text{MPa}$$

where: i — sub-region considered;

L_{UI} — length, in m, as defined in 13.2.1.2;
x — distance from the fore side of the stem at the intersection with the upper ice waterline (UIWL) to station under consideration, in m;
α — waterline angle [°], see Figure 13.2.3.2;
β' — normal frame angle [°], Figure 13.2.3.2;
D_{UI} — displacement as defined in 13.2.1.3, in kt, not to be taken less than 5 kt;
CF_C — crushing failure class factor from Table 13.2.3.2(1);
CF_F — flexural failure class factor from Table 13.2.3.2(1).
CF_D — load patch dimensions class factor from Table 13.2.3.2(1);

④ The bow area load characteristics for bow forms defined in 13.2.3.1(6) are determined as follows:

(a) Shape coefficient, fa_i, is to be taken as:

$$fa_i=\alpha_i/30$$

(b) Force, F_i:

$$F_i = fa_i \cdot CF_{CV} \cdot D_{UI}^{0.47} \quad \text{[MN]}$$

(c) Line load, Q_i:

$$Q_i=F_i^{0.22}\cdot CF_{QV} \quad \text{[MN/m]}$$

(d) Pressure, P_i:

$$P_i=F_i^{0.56}\cdot CF_{PV} \quad \text{[MPa]}$$

where: i — sub-region considered;
α — waterline angle [°], see Figure 13.2.3.2;
β' — normal frame angle [°], Figure 13.2.3.2;
D_{UI} — displacement as defined in 13.2.1.3, in kt, not to be taken less than 5 kt;
CF_{CV} — crushing failure class factor from Table 13.2.3.2(2);
CF_{QV} — line load class factor from Table 13.2.3.2(2).
CF_{PV} — pressure class factor from Table 13.2.3.2(2);

(2) Hull areas other than the bow

① In the hull areas other than the bow, the force (F_{NonBow}) and line load (Q_{NonBow}) used in the determination of the load patch dimensions (b_{NonBow}, w_{NonBow}) and design pressure (P_{avg}) are calculated as follows:

(a) Force, F_{NonBow}:

$$F_{\text{NonBow}}=0.36CF_C\cdot DF \quad \text{MN}$$

(b) Line load, Q_{NonBow}:

$$Q_{\text{NonBow}} = 0.639(F_{\text{NonBow}})^{0.61}\cdot CF_D \quad \text{MN/m}$$

where: CF_C — crushing force class factor from Table 13.2.3.2(1);
DF — ship displacement factor, taken as follows:

$$D_{UI}^{0.64} \quad \text{if } D_{UI} \le CF_{DIS}$$

$$CF_{DIS}^{0.64} + 0.10(D_{UI} - CF_{DIS}) \quad \text{if } D_{UI} > CF_{DIS}$$

D_{UI} — displacement as defined in 13.2.1.3, in kt, not to be taken less than 10 kt;
CF_{DIS} — displacement class factor from Table 13.2.3.2(1);
CF_D — load patch dimensions class factor from Table 13.2.3.2(1).

13.2.3.3 Design load patch

(1) In the bow area, and the ice belt area of intermediate bow for ships with class notation PC6 and PC7, the design load patch has dimensions of width, w_{Bow}, and height, b_{Bow}, defined as follows:

$$w_{\text{Bow}} = F_{\text{Bow}} / Q_{\text{Bow}} \quad \text{m}$$
$$b_{\text{Bow}} = Q_{\text{Bow}} / P_{\text{Bow}} \quad \text{m}$$

where: F_{Bow} — maximum F_i in the bow area, in MN;
Q_{Bow} — maximum Q_i in the bow area, in MN/m;
P_{Bow} — maximum P_i in the bow area, in MPa.

(2) In hull areas other than those covered by 13.2.3.3(1), the design load patch has dimensions of width, w_{Bow}, and height, b_{Bow}, defined as follows:

$$w_{NonBow} = F_{NonBow} / Q_{NonBow} \qquad \text{m}$$

$$b_{NonBow} = w_{NonBow} / 3.6 \qquad \text{m}$$

where: F_{NonBow} — force determined using 13.2.3.2(2)①(a), in MN;

Q_{NonBow} — line load determined using 13.2.3.2(2)①(b), in MN/m.

13.2.3.4 Pressure within the design load patch

(1) The average pressure, P_{avg}, within a design load patch is determined as follows:

$$P_{avg} = F / (b \cdot w) \qquad \text{MPa}$$

where: F — F_{Bow} or F_{NonBow} as appropriate for the hull area under consideration, in MN;

b — b_{Bow} or b_{NonBow} as appropriate for the hull area under consideration, in m;

w — w_{Bow} or w_{NonBow} as appropriate for the hull area under consideration, in m.

(2) Areas of higher, concentrated pressure exist within the load patch. In general, smaller areas have higher local pressures. Accordingly, the peak pressure factors listed in Table 13.2.3.4 are used to account for the pressure concentration on localized structural members.

Peak Pressure Factors **Table 13.2.3.4**

Structural member		Peak pressure factor (PPF_i)
Plating	Transversely-framed	$PPF_p = (1.8 - s) \geq 1.2$
	Longitudinally-framed	$PPF_p = (2.2 - 1.2\ s) \geq 1.5$
Frames in transverse framing systems	With load distributing stringers	$PPF_t = (1.6 - s) \geq 1.0$
	With no load distributing stringers	$PPF_t = (1.8 - s) \geq 1.2$
Frames in bottom structures		$PPF_s = 1.0$
Load carrying stringers Side longitudinals Web frames		$PPF_s = 1.0$, if $S_w \geq 0.5w$ $PPF_s = 2.0 - 2.0\ S_w/w$, if $S_w < (0.5w)$

where: s — frame or longitudinal spacing, in m;

S_w — web frame spacing, in m;

w — ice load patch width, in m.

13.2.3.5 Hull area factors

(1) Associated with each hull area is an area factor that reflects the relative magnitude of the load expected in that area. The area factor (AF) for each hull area is listed in Table 13.2.3.5(1).

(2) In the event that a structural member spans across the boundary of a hull area, the largest hull area factor is to be used in the scantling determination of the member.

(3) Due to their increased manoeuvrability, ships having propulsion arrangements with azimuthing (geared and podded) thrusters are to have stern ice belt (S_i) and stern lower (S_l) hull area factors AF listed in Table 13.2.3.5(3).

(4) For ships assigned the additional notation “Icebreaker”, the area factor (AF) for each hull area is listed in Table 13.2.3.5(4)-1. For propulsion arrangements with azimuthing (geared and podded) thrusters, the area factor (AF) for each hull area is listed in Table 13.2.3.5(4)-2.

Hull Area Factors **Table 13.2.3.5(1)**

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Ice belt	BI_i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	BI_l	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	BI_b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Midbody (M)	Ice belt	M_i	0.70	0.65	0.55	0.55	0.50	0.45	0.45
	Lower	M_l	0.50	0.45	0.40	0.35	0.30	0.25	0.25
	Bottom	M_b	0.30	0.30	0.25	**	**	**	**
Stern (S)	Ice belt	S_i	0.75	0.70	0.65	0.60	0.50	0.40	0.35
	Lower	S_l	0.45	0.40	0.35	0.30	0.25	0.25	0.25
	Bottom	S_b	0.35	0.30	0.30	0.25	0.15	**	**

Notes: * — See 13.2.3.1（3）.

** — Indicates that strengthening for ice loads is not necessary.

Hull Area Factors **Table 13.2.3.5(3)**

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (*B*)	All	*B*	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (*BI*)	Ice belt	BI_i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	BI_l	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	BI_b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Midbody (*M*)	Ice belt	M_i	0.70	0.65	0.55	0.55	0.50	0.45	0.45
	Lower	M_l	0.50	0.45	0.40	0.35	0.30	0.25	0.25
	Bottom	M_b	0.30	0.30	0.25	**	**	**	**
Stern (*S*)	Ice belt	S_i	0.90	0.85	0.80	0.75	0.65	0.55	0.50
	Lower	S_l	0.60	0.55	0.50	0.45	0.45	0.40	0.40
	Bottom	S_b	0.35	0.30	0.30	0.25	0.15	**	**

Notes: * — See 13.2.3.5(1).

Hull Area Factors (*AF*) for ships with additional notation "Icebreaker" **Table 13.2.3.5(4)-1**

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (*B*)	All	*B*	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (*BI*)	Ice belt	BI_i	0.90	0.85	0.85	0.85	0.85	1.00	1.00
	Lower	BI_l	0.70	0.65	0.65	0.65	0.65	0.65	0.65
	Bottom	BI_b	0.55	0.50	0.45	0.45	0.45	0.45	0.45
Midbody (*M*)	Ice belt	M_i	0.70	0.65	0.55	0.55	0.55	0.55	0.55
	Lower	M_l	0.50	0.45	0.40	0.40	0.40	0.40	0.40
	Bottom	M_b	0.30	0.30	0.25	0.25	0.25	0.25	0.25
Stern (*S*)	Ice belt	S_i	0.95	0.90	0.80	0.80	0.80	0.80	0.80
	Lower	S_l	0.55	0.50	0.45	0.45	0.45	0.45	0.45
	Bottom	S_b	0.35	0.30	0.30	0.30	0.30	0.30	0.30

Hull Area Factors (*AF*) for ships with additional notation "Icebreaker" **Table 13.2.3.5(4)-2**

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (*B*)	All	*B*	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (*BI*)	Ice belt	BI_i	0.90	0.85	0.85	0.85	0.85	1.00	1.00
	Lower	BI_l	0.70	0.65	0.65	0.65	0.65	0.65	0.65
	Bottom	BI_b	0.55	0.50	0.45	0.45	0.45	0.45	0.45
Midbody (*M*)	Ice belt	M_i	0.70	0.65	0.55	0.55	0.55	0.55	0.55
	Lower	M_l	0.50	0.45	0.40	0.40	0.40	0.40	0.40
	Bottom	M_b	0.30	0.30	0.25	0.25	0.25	0.25	0.25
Stern (*S*)	Ice belt	S_i	0.95	0.90	0.80	0.80	0.80	0.80	0.80
	Lower	S_l	0.70	0.65	0.60	0.60	0.60	0.60	0.60
	Bottom	S_b	0.35	0.30	0.30	0.30	0.30	0.30	0.30

13.2.4 Shell plate requirements

13.2.4.1 The required minimum shell plate thickness, *t*, is given by:

$$t = t_{net} + t_s \quad \text{mm}$$

where: t_{net} — plate thickness required to resist ice loads according to 13.2.4.2, in mm;

t_s — corrosion and abrasion allowance according to 13.2.11, in mm.

13.2.4.2 The thickness of shell plating required to resist the design ice load, t_{net}, depends on the orientation of the framing.

In the case of transversely-framed plating ($\Omega \geq 70°$), and all bottom plating, i.e. plating in hull areas B_{Ib}, M_b and S_b, the net thickness is given by:

$$t_{net} = 500s[(AF \cdot PPF_p \cdot P_{avg}) / R_{eH}]^{0.5} / [1 + s/(2b)] \quad \text{mm}$$

In the case of longitudinally-framed plating ($\Omega \geq 20°$), when $b \geq s$, the net thickness is given by:

$$t_{net} = 500s[(AF \cdot PPF_p \cdot P_{avg}) / R_{eH}]^{0.5} / [1 + s/(2l)] \quad \text{mm}$$

In the case of longitudinally-framed plating ($\Omega \leq 20°$), when $b < s$, the net thickness is given by:

$$t_{net} = 500s[(AF \cdot PPF_p \cdot P_{avg}) / R_{eH}]^{0.5} \cdot [2b/s - (b/s)^2]^{0.5} / [1 + s/(2l)] \quad \text{mm}$$

In the case of obliquely-framed plating (70°> Ω > 20°), linear interpolation is to be used.

where: Ω — smallest angle between the chord of the waterline and the line of the first level framing, [°], illustrated in Figure 13.2.4.2;

s — transverse frame spacing in transversely-framed ships or longitudinal frame spacing in longitudinally-framed ships, in m;

AF — hull area factor from Table 13.2.3.5(1) or Table 13.2.3.5(4);

PPF_p — peak pressure factor from Table 13.2.3.4;

P_{avg} — average patch pressure according to 13.2.3.4, in MPa;

R_{eH} — yield stress of the material, in N/mm^2;

b — height of design load patch, in m, where b is to be taken not greater than ($l - s/4$) in the case of determination of the net thickness for transversely-framed plating;

l — distance between frame supports, in mm, i.e. equal to the frame span as given in 13.2.5.5, but not reduced for any fitted end brackets. When a load-distributing stringer is fitted, the length l need not be taken larger than the distance from the stringer to the most distant frame support.

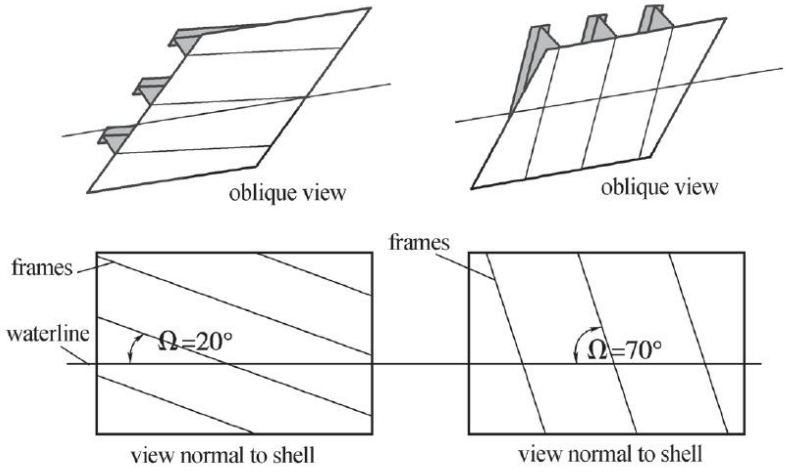


Figure 13.2.4.2 Shell Framing Angle Ω

13.2.5 Framing – General

13.2.5.1 Framing members of Polar Class ships are to be designed to withstand the ice loads defined in 13.2.3.

13.2.5.2 The term “framing member” refers to transverse and longitudinal local frames, load-carrying stringers and web frames in the areas of the hull exposed to ice pressure, see Figure 13.2.2.1. Where load-distributing stringers have been fitted, they are generally fitted at or near the midpoint of the span of the frame, and web height of stringers is not to be less than 0.8 times the web height of the frame.

13.2.5.3 The strength of a framing member is dependent upon the fixity that is provided at its supports. Fixity can be assumed where framing members are either continuous through the support or attached to a supporting section with a connection bracket. In other cases, simple support is to be assumed unless the connection can be demonstrated to provide significant rotational restraint. Fixity is to be ensured at the support of any framing which terminates within an ice-strengthened area.

13.2.5.4 The details of framing member intersection with other framing members, including plated structures, as well as the details for securing the ends of framing members at supporting sections, are to be in accordance with the relevant requirements of Chapter 1, PART TWO of the Rules.

13.2.5.5 The effective span of a framing member is to be determined on the basis of its moulded length. If brackets are fitted, the effective span may be reduced in accordance with the relevant requirements of Chapter 1, PART TWO of the Rules. Brackets are to be configured to ensure stability in the elastic and post-yield response regions.

13.2.5.6 When calculating the section modulus and shear area of a framing member, net thicknesses of the web, flange (if fitted) and attached shell plating are to be used. The shear area of a framing member may include that material contained over the full depth of the member, i.e. web area including portion of flange, if fitted, but excluding attached shell plating.

13.2.5.7 The actual net effective shear area, A_w, of a transverse or longitudinal local frame is given by:

$$A_w = h\, t_{wn} \sin\varphi_w / 100 \qquad \text{cm}^2$$

where: h — height of stiffener, in mm, see Figure 13.2.5.7;

t_{wn} — net web thickness, in mm:

$t_{wn} = t_w - t_c$

where: t_w —as-built web thickness, in mm, see Figure 13.2.5.7;

t_c —corrosion deduction to be subtracted from the web and flange thickness, in mm, as specified in 13.2.11.3;

φ_w — smallest angle between shell plate and stiffener web, [°], measured at the midspan of the stiffener, see Figure 13.2.5.7. The angle φ_w may be taken as 90° provided the smallest angle is not less than 75°.

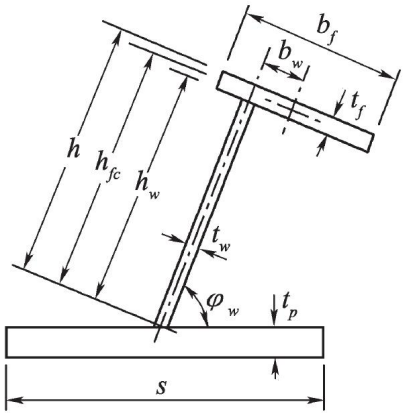


Figure 13.2.5.7 Stiffener Geometry

13.2.5.8 When the cross-sectional area of the attached plate flange exceeds the cross-sectional area of the local frame, the actual net effective plastic section modulus, Z_p, of a transverse or longitudinal frame is given by:

$$Z_p = (A_{pn}t_{pn}/20) + \frac{h_w^2 t_{wn}\sin\varphi_w}{2000} + A_{fn}(h_{fc}\sin\varphi_w - b_w\cos\varphi_w)/10 \qquad \text{cm}^3$$

where: h, t_{wn}, t_c and φ_w — as given in 13.2.5.7, s — as given in 13.2.4.2;

A_{pn} — net cross-sectional area of attached plate, in cm^2;

t_{pn} — net thickness of fitted shell plate, in mm (complying with t_{net} as required by 13.2.4.2);

h_w — height of local frame web, in mm, see Figure 13.2.5.7;

A_{fn} — net cross-sectional area of local frame flange, in cm^2;

h_{fc} — height of local frame measured to center of the flange area, in mm, see Figure 13.2.5.7;

b_w — distance from mid thickness plane of local frame web to the center of the flange area, in mm, see Figure 13.2.5.7.

When the cross-sectional area of the local frame exceeds the cross-sectional area of the attached plate flange, the plastic neutral axis is located a distance z_{na} above the attached shell plate, given by:

$$z_{na} = \left(100A_{fn} + h_w t_{wn} - 1000t_{pn} s\right)/\left(2t_{wn}\right) \qquad \text{mm}$$

and the net effective plastic section modulus, Z_p, of a transverse or longitudinal frame is given by:

$$Z_p = t_{pn}\cdot s\cdot(z_{na} + \frac{t_{pn}}{2})\sin\phi_w + \left\{\begin{array}{l} \dfrac{[(h_w - z_{na})^2 + z_{na}^2]t_{wn}\sin\phi_w}{2000} \\ +A_{fn}[(h_{fc} - z_{na})\sin\phi_w - b_w\cos\phi_w]/10 \end{array}\right\} \qquad \text{cm}^3$$

13.2.5.9 In the case of oblique framing arrangement (70° > Ω > 20°, where Ω is defined as given in 13.2.4.2), linear interpolation is to be used.

13.2.6 Framing – Local frames in bottom structures and in transversely-framed side structures

13.2.6.1 The local frames in bottom structures (i.e. hull areas B_{lb}, M_b and S_b) and in transversely-framed side structures (i.e. hull areas B_{lb}, M_b and S_b) are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism. For bottom structure the patch load is to be applied with the dimension (b) parallel with the frame direction.

13.2.6.2 The actual net effective shear area of the frame, A_w, as defined in 13.2.5.7, is to comply with the following condition: $A_w \geq A_t$, where:

$$A_t = 100^2 \cdot 0.5LL \cdot s\left(AF \cdot PPF_t \cdot P_{avg}\right) / \left(0.577R_{eH}\right) \quad \text{cm}^2$$

where: LL — length of loaded portion of span, in m, to be taken as the lesser of a and b;
a — local frame span as defined in 13.2.5.5, in m;
b — height of design ice load patch according to 13.2.3.3(1) or (2), in m;
s — spacing of local frame, in m;
AF — hull area factor from Table 13.2.3.5(1) or Table 13.2.3.5(4);
PPF_t — peak pressure factor, PPF_t or PPF_s as appropriate, from Table 13.2.3.4;
P_{avg} — average pressure within load patch according to 13.2.3.4, in MPa;
R_{eH} — yield stress of the material, in N/mm^2.

13.2.6.3 The actual net effective plastic section modulus of the plate/stiffener combination, Z_p, as defined in 13.2.5.8, is to comply with the following condition: $Z_p \geq Z_{pt}$, where Z_{pt} is to be the greater calculated on the basis of two load conditions: a) ice load acting at the midspan of the local frame, and b) the ice load acting near a support. The A_1 parameter in the equation below reflects the two conditions:

$$Z_{pt} = 100^3 \cdot LL \cdot Y \cdot s(AF \cdot PPF_t \cdot P_{avg})a \cdot A_1 / (4R_{eH}) \quad \text{cm}^3$$

where: AF, PPF_t, P_{avg}, LL, s, a and R_{eH} — as given in 13.2.6.2;
Y = 1 − 0.5(LL/a);
A_1 — maximum of:
$A_{1A} = 1/\{1+j/2+ (k_w j/2) [(1-a_1^2)^{0.5}-1]\}$
$A_{1B} = [1-1/ (2a_1 \cdot Y)]/ (0.275+1.44k_z^{0.7})$
where:
j = 1 for a local frame with one simple support outside the ice-strengthened areas;
= 2 for a local frame without any simple supports;
$a_1 = A_t / A_w$
where:
A_t — minimum shear area of the local frame as given in 13.2.6.2, in cm^2;
A_w — effective net shear area of the local frame (calculated according to 13.2.5.7), in cm^2;
$k_w = 1/(1+2A_{fn}/A_w)$, with A_{fn} as given in 13.2.5.8;
k_z — z_p / Z_p, in general;
= 0.0, when the frame is arranged with end bracket;
where:
z_p — sum of individual plastic section moduli of flange and shell plate as fitted, cm^3;
$= (b_f \ t_{fn}^2/4 + b_{eff} \ t_{pn}^2/4)/1000$
where:
b_f — flange breadth, in mm, see Figure 13.2.5.7;
t_{fn} — net flange thickness, in mm, see Figure 13.2.5.7;
$= t_f - t_c$ (t_c as given in 13.2.5.7)
where:
t_f — as-built flange thickness, in mm, see Figure 13.2.5.7;
t_{pn} — the fitted net shell plate thickness, in mm, (not to be less than as t_{net} given in 13.2.4);
b_{eff} — effective width of shell plate flange, in mm:
= 500 s;
Z_p — net effective plastic section modulus of the local frame (calculated according to 13.2.5.8), in cm^3.

13.2.6.4 The scantlings of the local frame are to meet the structural stability requirements of 13.2.9.

13.2.7 Framing – Longitudinal local frames in side structures

13.2.7.1 Longitudinal local frames in side structures are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism.

13.2.7.2 The actual net effective shear area of the frame, A_w, as defined in 13.2.5.7, is to comply with the following condition: $A_w \geq A_L$, where:

$$A_L = 100^2 (AF \cdot PPF_s \cdot P_{avg}) 0.5 b_1 \cdot a / (0.577 R_{eH}) \quad \text{cm}^2$$

where: AF — hull area factor from Table 13.2.3.5(1) or Table 13.2.3.5(4);
PPF_s — peak pressure factor from Table 13.2.3.4;
P_{avg} — average pressure within load patch according to13.2.3.4, in MPa;
b_1 $= k_0 b_2$, in m
where: $k_0 = 1 - 0.3/b'$;
where: $b' = b/s$
where: b — height of design ice load patch from 13.2.3.3 (1) or (2), in m;
s — spacing of longitudinal frames, in m;
$b_2 = b(1 - 0.25b')$, in m, if $b' < 2$;
$= s$, in m, if $b' \geq 2$;
a — effective span of longitudinal local frame as given in 13.2.5.5, in m;
R_{eH} — yield stress of the material, in N/mm^2.

13.2.7.3 The actual net effective plastic section modulus of the plate/stiffener combination, Z_p, as defined in 13.2.5.8, is to comply with the following condition: $Z_p \geq Z_{pL}$, where:

$$Z_{pL} = 100^3 (AF \cdot PPF_s \cdot P_{avg}) b_1 \cdot a^2 \cdot A_4 / (8 R_{eH}) \quad \text{cm}^3$$

where: AF, PPF_s, P_{avg}, b_1, a and R_{eH} — as given in 13.2.7.2;

$A_4 = 1/\{2 + k_{wl}[(1 - a_4^2)^{0.5} - 1]\}$;

$a_4 = A_L / A_w$

where: A_L — minimum shear area for longitudinal, in cm^2, as given in 13.2.7.2;
A_w — net effective shear area of longitudinal (calculated according to 13.2.5.7), in cm^2;
$k_{wl} = 1/(1 + 2A_{fn}/A_w)$, with A_{fn} as given in 13.2.5.8.

13.2.7.4 The scantlings of the longitudinals are to meet the structural stability requirements of 13.2.9.

13.2.8 Framing – Web frame and load-carrying stringers

13.2.8.1 Web frames and load-carrying stringers are to be designed to withstand the ice load patch as defined in 13.2.3. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimized.

13.2.8.2 Web frames and load-carrying stringers are to be dimensioned such that the combined effects of shear and bending do not exceed the yield strength of the material. Where these members form part of a structural grillage system, appropriate methods of analysis are to be used. Where the structural configuration is such that members do not form part of a grillage system, the appropriate peak pressure factor (*PPF*) from Table 13.2.4.3 is to be used. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

13.2.8.3 For determination of scantlings of load carrying stringers, web frames supporting local frames, or web frames supporting load carrying stringers forming part of a structural grillage system, appropriate methods as outlined in 13.2.17 are normally to be used.

13.2.8.4 The scantlings of web frames and load-carrying stringers are to meet the structural stability requirements of 13.2.9.

13.2.9 Framing – Structural stability

13.2.9.1 To prevent local buckling in the web, the ratio of web height (h_w) to net web thickness (t_{wn}) of any framing member is not to exceed:

For flat bar sections: $h_w/t_{wn} \leq 282/(R_{eH})^{0.5}$

For bulb, tee and angle sections: $h_w/t_{wn} \leq 805/(R_{eH})^{0.5}$

where: h_w — web height;
t_{wn} — net web thickness;
R_{eH} — yield stress of the material, in N/mm^2.

13.2.9.2 Framing members for which it is not practicable to meet the requirements of 13.2.9.1 (e.g. load carrying stringers or deep web frames) are required to have their webs effectively stiffened. The scantlings of the web stiffeners are to ensure the structural stability of the framing member. The minimum net web thickness for these framing members is given by:

$$t_{wn} = 2.63\times10^{-3} c_1 \sqrt{R_{eH}/(5.34+4(c_1/c_2)^2)} \quad \text{mm}$$

where: c_1 $= h_w - 0.8h$, in mm;

where: h_w—web height of stringer / web frame, in mm, see Figure 13.2.9.2;

h — height of framing member penetrating the member under consideration (0 if no such framing member), in mm, see Figure 13.2.9.2;

c_2 — spacing between supporting structure oriented perpendicular to the member under consideration, in mm, see Figure 13.2.9.2;

R_{eH} — yield stress of the material, in N/mm^2.

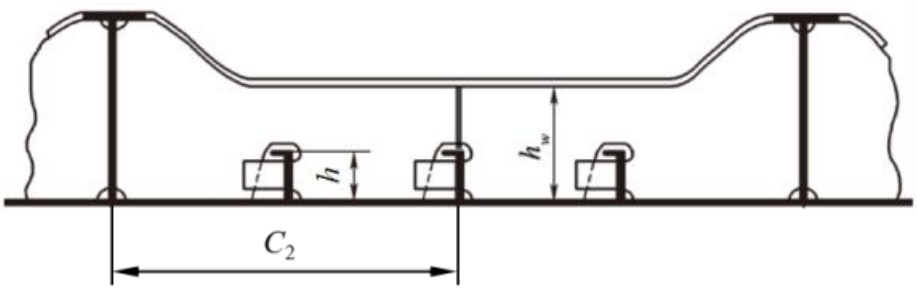


Figure 13.2.9.2 Parameter Definition for Web Stiffening

13.2.9.3 In addition, the following is to be satisfied:

$$t_{wn} \geq 0.35 t_{pn} (R_{eH}/235)^{0.5}$$

where: R_{eH} — yield stress of the shell plate in way of the framing member, in N/mm^2;

t_{wn} — net thickness of the web, in mm;

t_{pn} — net thickness of the shell plate in way the framing member, in mm.

13.2.9.4 To prevent local flange buckling of welded profiles, the following are to be satisfied:

(1) the flange width, b_f, in mm, is not to be less than five times the net thickness of the web, t_{wn};

(2) the flange outstand, b_{out}, in mm, is to meet the following requirement:

$$b_{out}/\ t_{fn} \leq 155/(R_{eH})^{0.5}$$

where: t_{fn}— net thickness of flange, in mm;

R_{eH}— yield stress of the material, in N/mm^2.

13.2.10 Plated Structures

13.2.10.1 Plated structures are those stiffened plate elements in contact with the hull and subject to ice loads. These requirements are applicable to an inboard extent which is the lesser of:

(1) web height of adjacent parallel web frame or stringer; or

(2) 2.5 times the depth of framing that intersects the plated structure.

13.2.10.2 The thickness of the plating and the scantlings of attached stiffeners are to be such that the degree of end fixity necessary for the shell framing is ensured.

13.2.10.3 The stability of the plated structure is to adequately withstand the ice loads defined in 13.2.3.

13.2.11 Corrosion/abrasion additions and steel renewal

13.2.11.1 Effective protection against corrosion and ice-induced abrasion is recommended for all external surfaces of the shell plating for all Polar Class ships.

13.2.11.2 The values of corrosion/abrasion additions, t_s, to be used in determining the shell plate thickness for each polar class are listed in Table 13.2.11.2.

Corrosion/Abrasion Additions for Shell Plating Table 13.2.11.2

Hull area	t_s (mm)					
	With effective protection			Without effective protection		
	PC1 to PC3	PC4 & PC5	PC6 & PC7	PC1 to PC3	PC4 & PC5	PC6 & PC7
Bow; bow intermediate ice belt	3.5	2.5	2.0	7.0	5.0	4.0
Bow intermediate lower; midbody & stern ice belt	2.5	2.0	2.0	5.0	4.0	3.0
Midbody & stern lower; bottom	2.0	2.0	2.0	4.0	3.0	2.5

13.2.11.3 Polar Class ships are to have a minimum corrosion/abrasion addition of t_s = 1.0 mm applied to all internal structures within the ice-strengthened hull areas, including plated members adjacent to the shell, as well as stiffener webs and flanges.
13.2.11.4 Steel renewal for ice strengthened structures is required when the gauged thickness is less than t_{net} + 0.5 mm.

13.2.12 Materials

13.2.12.1 Steel grades of plating for hull structures are to be not less than those given in Table 13.2.12.4 based on the as-built thickness, the Polar Class and the material class of structural members according to 13.2.12.2.

Material Classes for Structural Members **Table 13.2.12.1**

Structural Members	Material Class
Shell plating within the bow and bow intermediate ice belt hull areas (B, BI_i)	II
All weather and sea exposed SECONDARY and PRIMARY, as defined in Table 1.3.2.2(1) of PART TWO of the Rules, structural members outside 0.4 L_{UI} amidships	I
Plating materials for stem and stern frames, rudder horn, rudder, propeller nozzle, shaft brackets, ice skeg, ice knife and other appendages subject to ice impact loads	II
All inboard framing members attached to the weather and sea-exposed plating including any contiguous inboard member within 600 mm of the shell plating	I
Weather-exposed plating and attached framing in cargo holds of ships which by nature of their trade have their cargo hold hatches open during cold weather operations	I
All weather and sea exposed SPECIAL, as defined in Table 1.3.2.2(1) of PART TWO of the Rules, structural members within 0.2 L_{UI} from FP	II

13.2.12.2 Material classes specified in Table 1.3.2.2(1) of Section 3, Chapter 1 of PART TWO of the Rules are applicable to Polar Class ships regardless of the ship's length. In addition, material classes for weather and sea exposed structural members and for members attached to the weather and sea exposed shell plating of Polar Class ships are given in Table 13.2.12.1. Where the material classes in Table 13.2.12.1 and those in Table 1.3.2.2(1) of Section 3, Chapter 1 of PART TWO of the Rules differ, the higher material class is to be applied.
13.2.12.3 Steel grades for all plating and attached framing of hull structures and appendages situated below the level of 0.3 m below the lower waterline, as shown in Figure 13.2.12.3, are to be obtained from Table 1.3.2.2(6) and Table 1.3.2.2(7) of Section 3, Chapter 1 of PART TWO of the Rules based on the material class for structural members in Table 13.2.12.1 above, regardless of Polar Class.

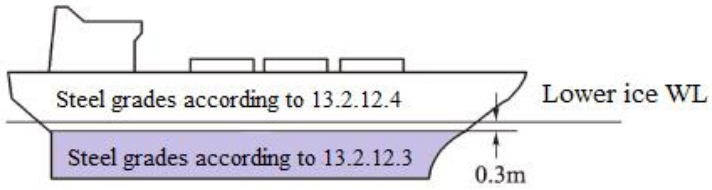


Figure 13.2.12.3
Steel Grade Requirements for Submerged and Weather Exposed Shell Plating

13.2.12.4 Steel grades for all weather exposed plating of hull structures and appendages situated above the level of 0.3 m below the lower ice waterline (LIWL), as shown in Figure 13.2.12.3, are to be not less than that given in Table 13.2.12.4.

Steel Grades for Weather Exposed Plating **Table 13.2.12.4**

Thickness t [mm]	Material Class I				Material Class II				Material Class III					
	PC1 to PC5		PC6 & PC7		PC1 to PC 5		PC6 & PC 7		PC1 to PC 3		PC4 & PC 5		PC6 & PC 7	
	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT
$t \leq 10$	B	AH	B	AH	B	AH	B	AH	E	EH	E	EH	B	AH
$10 < t \leq 15$	B	AH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$15 < t \leq 20$	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$20 < t \leq 25$	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$25 < t \leq 30$	D	DH	B	AH	E	EH(2)	D	DH	E	EH	E	EH	E	EH
$30 < t \leq 35$	D	DH	B	AH	E	EH	D	DH	E	EH	E	EH	E	EH
$35 < t \leq 40$	D	DH	D	DH	E	EH	D	DH	F	FH	E	EH	E	EH
$40 < t \leq 45$	E	EH	D	DH	E	EH	D	DH	F	FH	E	EH	E	EH

45< t ≤50	E	EH	D	DH	E	EH	D	DH	F	FH	F	FH	E	EH

Notes:
(1) Includes weather-exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0.3 m below the lowest ice waterline.
(2) Grades D, DH are allowed for a single strake of side shell plating not more than 1.8 m wide from 0.3 m below the lowest ice waterline.

13.2.12.5 Castings are to have specified properties consistent with the expected service temperature for the cast component.

13.2.13 Longitudinal strength

13.2.13.1 Application

(1) A ramming impact on the bow is the design scenario for the evaluation of the longitudinal strength of the hull.

(2) Intentional ramming is not considered as a design scenario for ships which are designed with vertical or bulbous bows, see 13.1.1.6. Hence the longitudinal strength requirements given in 13.2.13 are not to be considered for ships with stem angle γ_{stem} equal to or larger than 80°.

(3) Ice loads are only to be combined with still water loads. The combined stresses are to be compared against permissible bending and shear stresses at different locations along the ship's length. In addition, sufficient local buckling strength is also to be verified.

13.2.13.2 Design vertical ice force at the bow

(1) The design vertical ice force at the bow, F_{IB}, is to be taken as:

$$F_{IB} = \min(F_{IB,1}, F_{IB,2}) \qquad \text{MN}$$

where: $F_{IB,1} = 0.534 K_I^{0.15} [\sin(\gamma_{stem})]^{0.2} (D_{UI} \cdot K_h)^{0.5} CF_L$ MN;

$F_{IB,2} = 1.20 CF_F$ MN;

where: K_I — indentation parameter, $= K_f / K_h$;

(a) for the case of a blunt bow form:

$$K_f = \left[2CB_{UI}^{1-e_b} / (1 + e_b) \right]^{0.9} \tan(\gamma_{stem})^{-0.9(1+e_b)}$$

(b) for the case of wedge bow form ($\alpha_{stem} < 80^\circ$), $e_b = 1$ and the above simplifies to:

$$K_f = \left\{ \tan(\alpha_{stem}) / [\tan(\gamma_{stem})]^2 \right\}^{0.9};$$

$K_h = 0.01 A_{wp}$ MN/m;

CF_L — longitudinal strength class factor from Table 13.2.3.2;

e_b — bow shape exponent which best describes the waterplane (see Figures 13.2.13.2(1) and 13.2.13.2(2))
= 1.0 for a simple wedge bow form
= 0.4 to 0.6 for a spoon bow form
= 0 for a landing craft bow form;
An approximate e_b determined by a simple fit is acceptable;

γ_{stem} — stem angle, [°], to be measured between the horizontal axis and the stem tangent at the upper ice waterline (UIWL) (buttock angle as per Figure 13.2.3.2 measured on the centerline);

α_{stem} — waterline angle measured in way of the stem at the upper ice waterline (UIWL) (°) (see Figure 13.2.3.2(1));

$C = 1 / [2(L_B / B_{UI})^{e_b}]$

where: B_{UI} — moulded breadth corresponding to the upper ice waterline (UIWL), in m;

L_B — bow length used in the equation $y = (B_{UI} / 2)(x / L_B)^{e_b}$, in m, (see Figures 13.2.13.2(1) and 13.2.13.2(2));

D_{UI} — displacement as defined in 13.2.1.3, in kt, not to be taken less than 10 kt;

A_{wp} — waterplane areacorresponding to the upper ice waterline (UIWL), in m^2;

CF_F — flexural failure class factor from Table 13.2.3.2(1).

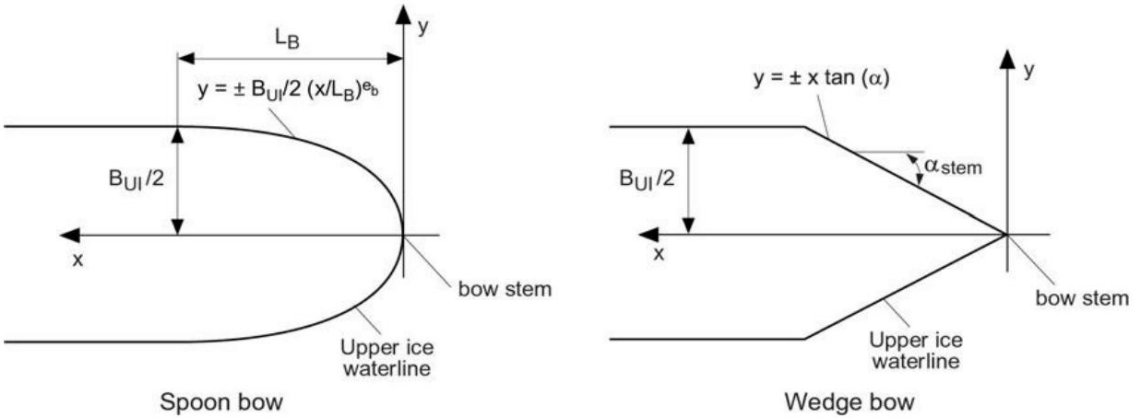


Figure 13.2.13.2(1) Bow Shape Definition

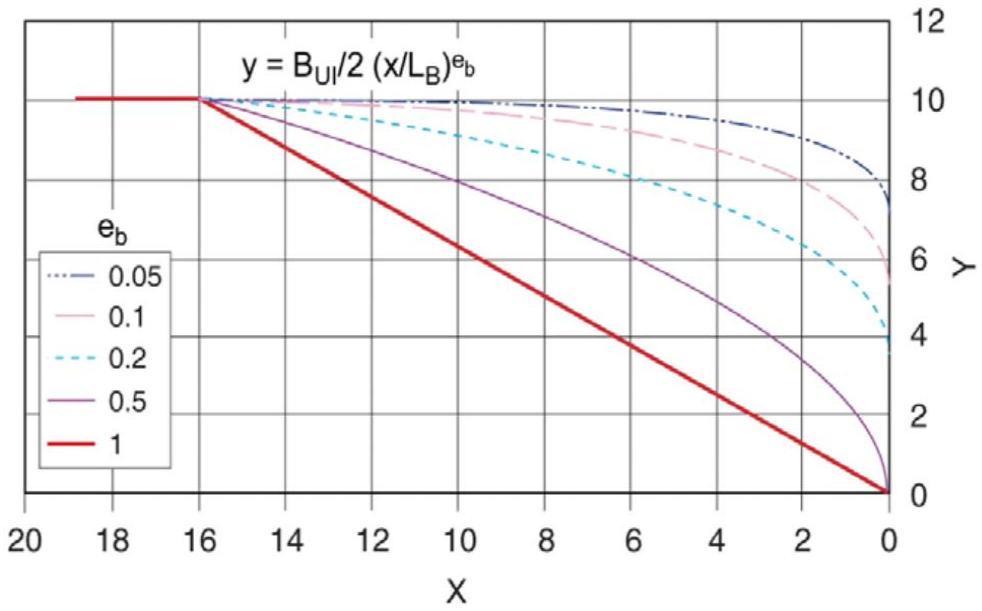


Figure 13.2.13.2 (2) Illustration of e_b Effect on the Bow Shape for B_{UI} = 20 and L_B =16

13.2.13.3 Design vertical shear force

(1) The design vertical ice shear force, F_I, along the hull girder is to be taken as:

$$F_I = C_f F_{IB} \qquad \text{MN}$$

where: C_f — longitudinal distribution factor to be taken as follows:

(a) positive shear force

C_f = 0.0 between the aft end of L_{UI} and 0.6L_{UI} from aft;

C_f = 1.0 between 0.9L_{UI} from aft and the forward end of L_{UI};

(b) negative shear force

C_f = 0.0 at the aft end of L_{UI};

C_f = –0.5 between 0.2L_{UI} and 0.6L_{UI} from aft;

C_f = 0.0 between 0.8L_{UI} from aft and the forward end of L_{UI};

intermediate values are to be determined by linear interpolation.

(2) The applied vertical shear stress, τ_a, is to be determined along the hull girder in a similar manner as in 2.2.6 of Section 2, Chapter 2 of PART TWO of the Rules by substituting the design vertical ice shear force for the design vertical wave shear force.

13.2.13.4 Design vertical ice bending moment

(1) The design vertical ice bending moment, M_I, along the hull girder is to be taken as:

$$M_I = 0.1 C_m L_{UI} [\sin(\gamma_{stem})]^{-0.2} F_{IB} \qquad \text{MN·m}$$

where: L_{UI} — length, in m, as defined in 13.2.1.2;

γ_{stem} — as given in 13.2.13.2(1);

F_{IB} — design vertical ice force at the bow, in MN;

C_m — longitudinal distribution factor for design vertical ice bending moment to be taken as follows:
C_m = 0.0 at the aft end of L_{UI};
C_m = 1.0 between $0.5L_{UI}$ and $0.7L_{UI}$ from aft;
C_m = 0.3 at $0.95L_{UI}$ from aft;
C_m = 0.0 at the forward end of L_{UI};
intermediate values are to be determined by linear interpolation.

(2) The applied vertical bending stress, σ_a, is to be determined along the hull girder in a similar manner as in 2.2.5 of Section 2, Chapter 2 of PART TWO of the Rules, by substituting the design vertical ice bending moment for the design vertical wave bending moment. The ship still water bending moment is to be taken as the permissible still water bending moment in sagging condition.

13.2.13.5 Longitudinal strength criteria

The strength criteria provided in Table 13.2.13.5 are to be satisfied. The design stress is not to exceed the permissible stress.

Longitudinal Strength Criteria **Table 13.2.13.5**

Failure mode	Applied stress	Permissible stress when $R_{eH}/\sigma_u \leq 0.7$	Permissible stress when $R_{eH}/\sigma_u > 0.7$
Tension	σ_a	ηR_{eH}	$0.41\eta\ (\sigma_u + R_{eH})$
Shear	τ_a	$\eta R_{eH} / (3)^{0.5}$	$0.41\eta\ (\sigma_u + R_{eH}) / (3)^{0.5}$
Buckling	σ_a	σ_c for plating and for web plating of stiffeners σ_c /1.1 for stiffeners	
	τ_a	τ_c	

Notes: σ_a — applied vertical bending stress, in N/mm^2;
τ_a— applied vertical shear stress, in N/mm^2;
R_{eH} — yield stress of the material, in N/mm^2;
σ_u— ultimate tensile strength of material, in N/mm^2;
σ_c— critical buckling stress in compression, according to 2.2.7 of Section 2, Chapter 2 of PART TWO of the Rules, in N/mm^2;
τ_c— critical buckling stress in compression, according to 2.2.7 of Section 2, Chapter 2 of PART TWO of the Rules, in N/mm^2;
η = 0.8;
η = 0.6 for ships which are assigned the additional notation “Icebreaker”.

13.2.14 Stem and stern frames

13.2.14.1 The stem and stern frame are to be designed according to the relevant requirements of Section 14, Chapter 2 of PART TWO of the Rules. For PC6/PC7 vessels requiring CCS ice class notations B1*/B1 equivalency, the stem and stern requirements of the ice class notations by Chapter 4, PART TWO of the Rules are to be complied with.

13.2.15 Appendages

13.2.15.1 All appendages are to be designed to withstand forces appropriate for the location of their attachment to the hull structure or their position within a hull area.

13.2.15.2 Load definition and response criteria are to be determined by practical situations.

13.2.16 Local details

13.2.16.1 For the purpose of transferring ice-induced loads to supporting structure (bending moments and shear forces), local design details are to comply with the requirements of Chapter 1, PART TWO of the Rules.

13.2.16.2 The loads carried by a member in way of cut-outs are to maintain stability. Where necessary, the structure is to be stiffened.

13.2.17 Direct calculations

13.2.17.1 Direct calculations are not to be utilized as an alternative to the analytical procedures prescribed for the shell plating and local frame requirements given in 13.2.4, 13.2.6, and 13.2.7 of this Chapter.

13.2.17.2 Direct calculations are to be used for load carrying stringers and web frames forming part of a grillage system.

13.2.17.3 Where direct calculation is used to check the strength of structural systems, the load patch specified in 13.2.3 is to be applied, without being combined with any other loads. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimized. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

13.2.17.4 The strength evaluation of web frames and stringers may be performed based on linear or non-linear analysis. Recognized structural idealization and calculation methods are to be applied. In the strength evaluation, the guidance given in 13.2.17.5 and 13.2.17.6 may generally be considered. Detailed requirements are given in CCS Guidelines for Structural Strength Direct Calculation Under Ice Loads.

13.2.17.5 If the structure is evaluated based on linear calculation methods, the following are to be considered:

(1) web plates and flange elements in compression and shear to fulfil relevant buckling criteria as specified by CCS;

(2) nominal shear stresses in member web plates to be less than $R_{eH}/\sqrt{3}$;

(3) nominal von Mises stresses in member flanges to be less than $1.15\,R_{eH}$.

13.2.17.6 If the structure is evaluated based on non-linear calculation methods, the following are to be considered:

(1) the analysis is to reliably capture buckling and plastic deformation of the structure;

(2) the acceptance criteria are to ensure a suitable margin against fracture and major buckling and yielding causing significant loss of stiffness;

(3) permanent lateral and out-of plane deformation of considered member are to be minor relative to the relevant structural dimensions;

(4) detailed acceptance criteria to be decided by CCS.

13.2.18 Welding

13.2.18.1 All welding within ice-strengthened areas is to be of the double continuous type.

13.2.18.2 Continuity of strength is to be ensured at all structural connections.

Section 3 MACHINERY INSTALLATIONS

13.3.1 General requirements

13.3.1.1 The contents of this Section apply to main propulsion, steering gear, emergency and auxiliary systems essential for the safety of the ship and the crew.

13.3.1.2 Systems subject to damage by freezing, shall be drainable.

13.3.1.3 Vessels classed PC1 to PC5 inclusive shall have means provided to ensure sufficient vessel operation in the case of propeller damage including the Controllable Pitch (CP) mechanism. Sufficient vessel operation means that the vessel should be able to reach safe haven (safe location) where repairs can be undertaken. This may be achieved either by a temporary repair at sea, or by towing, assuming assistance is available.

13.3.1.4 Means shall be provided to free a stuck propeller by turning it in reverse direction. This shall also be possible for a propulsion plant intended for unidirectional rotation.

13.3.1.5 The propeller shall be fully submerged at the ship's LIWL.

13.3.2 Drawings and particulars to be submitted

13.3.2.1 Details of the intended environmental operational conditions and the required ice strengthening for the machinery, if different from ship's ice class.

13.3.2.2 Detailed drawings and descriptions of the main propulsion, steering, emergency and auxiliary machinery and information on the essential main propulsion load control functions. The descriptions are to include operational limitations.

13.3.2.3 Description detailing where main, emergency and auxiliary systems are located and how they are protected to prevent problems from freezing, ice and snow accumulation and evidence of their capability to operate in the intended environmental conditions.

13.3.2.4 Calculations and documentation indicating compliance with the requirements of this Section.

13.3.3 Materials

13.3.3.1 Materials shall be of an approved ductile material. Ferritic nodular cast iron may be used for parts other than bolts. For nodular cast iron an averaged impact energy value of 10 J at testing temperature is regarded as equivalent to the Charpy V test requirements defined below.

13.3.3.2 Materials exposed to sea water

Materials exposed to sea water, such as propeller blades, propeller hubs and cast thruster bodies shall have an elongation not less than 15% on a test specimen according to CCS Rules for Materials and Welding.

Charpy V-notch impact testing is to be carried out for materials other than bronze and austenitic steel. The

tests shall be carried out on three specimens at minus 10 ºC, and the average energy value is to be not less than 20 J. However, Charpy V impact test requirements of CCS Rules for Materials and Welding as applicable for ships with ice class notation, shall also be applied.

13.3.3.3 Materials exposed to sea water temperature

Charpy V-notch impact testing is to be carried out for materials other than bronze and austenitic steel. The tests shall be carried out on three specimens at minus 10 ºC, and the average energy value is to be not less than 20 J. However, the Charpy V impact test requirements of CCS Rules for Materials and Welding as applicable for ships with ice class notation, shall also be applied.

This requirement applies to components such as but not limited to blade bolts, CP mechanisms, shaft bolts, propeller shaft, strut-pod connecting bolts, etc. This requirement does not apply to surface hardened components, such as bearings and gear teeth or sea water cooling lines (heat exchangers, pipes, valves, fittings etc.).

For a definition of structural boundaries exposed to sea water temperature see Figure 13.2.12.3, Section 2 of this Chapter.

13.3.3.4 Material exposed to low air temperature

Materials of exposed machinery and foundations shall be manufactured from steel or other approved ductile material. An average impact energy value of 20 J taken from three Charpy V tests is to be obtained at 10 ºC below the lowest design temperature. Charpy V impact tests are not required for bronze and austenitic steel.

This requirement does not apply to surface hardened components, such as bearings and gear teeth.

For a definition of structural boundaries exposed to air temperature see Figure 13.2.12.3, Section 2 of this Chapter.

13.3.4 Definition of main parameters and loads

13.3.4.1 The symbols, names, and units of parameters used in this Section are as follows:

c —— chord length of blade section, m;

$c_{0.7}$ —— chord length of blade section at 0.7R propeller radius, in m;

$c_{LE0.8}$ ——leading edge portion of chord length of blade section at 0.8R propeller radius, in m;

$c_{TE0.8}$ ——trailing edge portion of chord length of blade section at 0.8R propeller radius, in m;

D —— propeller diameter, in m;

d —— external diameter of propeller hub (at propeller plane), in m;

D_{pin} —— diameter of shear pin, in m;

D_{limit} —— limit value for propeller diameter, in m;

EAR —— expanded blade area ratio;

F_b —— maximum backward blade force for the ship's service life (negative sign), in kN;

F_{ex} —— ultimate blade load resulting from blade failure through plastic bending, abbreviated as blade failure load, in kN;

F_f —— maximum forward blade force for the ship's service life (positive sign), in kN;

F_{ice} —— ice load, in kN;

$(F_{ice})_{max}$—— maximum ice load for the ship's service life , in kN;

h_0 —— depth of the propeller centreline from lower ice waterline (LIWL), in m;

H_{ice} —— ice block dimension for propeller load definition, in m;

I —— equivalent mass moment of inertia of all parts on engine side of component under consideration , in kgm^2;

I_t —— equivalent mass moment of inertia of the whole propulsion system, in kgm^2;

$LIWL$ —— lower ice waterline, in m;

m —— slope for S-N curve in log/log scale;

M_{BL} —— blade bending moment, in kNm;

n —— propeller rotational speed, in r/s;

n_n —— nominal propeller rotational speed at MCR in free running condition, in r/s;

N —— number of ice load cycles;

N_{class} —— reference number of ice impacts per propeller revolution per ice class;

N_{ice} —— total number of ice load cycles on propeller blade for the ship's service life;

N_R —— reference number of ice load cycles for equivalent fatigue stress (10^8 cycles);

N_Q —— number of propeller revolutions during a milling sequence;

$P_{0.7}$ —— propeller pitch at 0.7R radius, in m;

$P_{0.7n}$ —— propeller pitch at 0.7R radius at MCR in free running condition, in m;

$P_{0.7b}$ —— propeller pitch at 0.7R radius at MCR in bollard condition, in m;

PCD —— pitch circle diameter, in m;

$Q(\varphi)$ —— torque, in kNm;

Q_{Amax} —— maximum response torque amplitude as a simulation result, in kNm;

Q_{emax} —— maximum engine torque, in kNm;

$Q_F(\varphi)$ —— Ice torque excitation for frequency domain calculations, in kNm;

Q_{fr} —— friction torque in pitching mechanism; reduction of spindle torque, in kNm;

Q_{max} —— maximum torque on the propeller resulting from propeller/ice interaction , in kNm;

Q_{motor} —— electric motor peak torque, in kNm;

Q_n —— nominal torque at MCR in free running condition, in kNm;

$Q_r(t)$ —— response torque along the propeller shaft line, in kNm;

Q_{peak} —— maximum of the response torque $Q_r(t)$, in kNm;

Q_{smax} —— maximum spindle torque of the blade for the ship's service life, in kNm;

Q_{sex} —— extreme spindle torque corresponding to the blade failure load F_{ex}, in kNm;

Q_{vib} —— Vibratory torque at considered component, taken from frequency domain open water TVC, in kNm;

r —— blade section radius, in m;

R —— propeller radius, in m;

$R_{p0.2}$ —— yield strength of the selected material (when the plastic strain is 0.2%), in MPa, to be selected according to CCS Rules for Materials and Welding;

R_m —— tensile strength of blade material, in MPa, to be selected according to CCS Rules for Materials and Welding;

S —— safety factor;

S_{fat} —— Safety factor for fatigue;

S_{ice} —— Ice strength index for blade ice force;

T —— Hydrodynamic propeller thrust in bollard condition, in kN;

T_b —— maximum backward propeller ice thrust for the ship's service life, in kN;

T_f —— maximum forward propeller ice thrust for the ship's service life, in kN;

T_n —— propeller thrust at MCR in free running condition, in kN;

T_r —— maximum response thrust along the shaft line, in kN;

T_{kmax} —— maximum torque capacity of flexible coupling, in kNm;

T_{kmax2} —— T_{kmax} at N= 1 load cycle, in kNm;

T_{kmax1} —— T_{kmax} at N= 5×10^4 load cycles, in kNm;

T_{kv} —— vibratory torque amplitude at N= 10^6 load cycles, in kNm;

ΔT_{kmax} —— maximum range of T_{kmax} at N=5×10^4 load cycles, in kNm;

t —— maximum blade section thickness, in m;

Z —— number of propeller blades;

z_{pin} —— number of shear pins;

α_i —— duration of propeller blade/ice interaction expressed in rotation angle, in ° ;

α_1 —— phase angle of the blade order excitation component for the propeller ice torque, in ° ;

α_2 —— phase angle of the blade order excitation component for the propeller ice torque, in ° ;

γ_ε —— the reduction factor for fatigue; scatter and test specimen size effect;

γ_v —— the reduction factor for fatigue; variable amplitude loading effect;

γ_m —— the reduction factor for fatigue; mean stress effect;

ρ —— a reduction factor for fatigue correlating the maximum stress amplitude to the equivalent fatigue stress for 10^8 stress cycles;

σ_{exp} —— mean fatigue strength of blade material at 10^8 cycles to failure in sea water, in MPa;

σ_{fat} —— equivalent fatigue ice load stress amplitude for 10^8 stress cycles, in MPa;

σ_{fl} —— characteristic fatigue strength for blade material, in MPa;

σ_{ref1} —— reference stress, $\sigma_{ref1} = 0.6 \cdot R_{p0.2} + 0.4 \cdot R_m$, in MPa;

σ_{ref2} —— reference stress, $\sigma_{ref2} = 0.7 \cdot R_m$ or $\sigma_{ref2} = 0.6 \cdot R_{p0.2} + 0.4 \cdot R_m$, whichever is less, in MPa;

σ_{st} —— maximum stress resulting from F_b or F_f, in MPa;

$(\sigma_{ice})_{bmax}$—— principal stress caused by the maximum backward propeller ice load, in MPa;

$(\sigma_{ice})_{fmax}$—— principal stress caused by the maximum forward propeller ice load, in MPa;

$(\sigma_{ice})_{Amax}$—— maximum ice load stress amplitude at the considered location on the blade, in MPa;

σ_{mean} —— mean stress, in MPa;

$(\sigma_{ice})_A(N)$—— blade stress amplitude distribution, in MPa.

13.3.4.2 The definition and use of loads used in this Section are given in Table 13.3.4.2:

Definition and use of loads **Table 13.3.4.2**

Load	Definition	Use of the load in design process
F_b	The maximum lifetime backward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7R chord line. Ice contact pressure at leading edge is shown with small arrows. See Figure 13.3.4.2.	Design force for strength calculation of the propeller blade.
F_f	The maximum lifetime forward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7R chord line.	Design force for calculation of strength of the propeller blade.
Q_{smax}	The maximum lifetime spindle torque on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade.	In designing the propeller strength, the spindle torque is automatically taken into account because the propeller load is acting on the blade as distributed pressure on the leading edge or tip area.
T_b	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction and the force is opposite to the hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_b can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the rules.

Load	Definition	Use of the load in design process
T_f	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction acting in the direction of hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_f can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the rules.
Q_{max}	The maximum ice-induced torque resulting from propeller/ice interaction on one propeller blade, including hydrodynamic loads on that blade.	Is used for estimation of the response torque Q_r along the propulsion shaft line and as excitation for torsional vibration calculations.
F_{ex}	Ultimate blade load resulting from blade loss through plastic bending. The force that is needed to cause total failure of the blade so that plastic hinge is caused to the root area. The force is acting on 0.8R.	Blade failure load is used to dimension the blade bolts, pitch control mechanism, propeller shaft, propeller shaft bearing and trust bearing. The objective is to guarantee that total propeller blade failure should not cause damage to other components.
Q_{sex}	Maximum spindle torque resulting from blade failure load	Is used to ensure pyramid strength principle for the pitching mechanism
Q_r	Maximum response torque along the propeller shaft line, taking into account the dynamic behaviour of the shaft line for ice excitation (torsional vibration) and hydrodynamic mean torque on propeller.	Design torque for propeller shaft line components.
T_r	Maximum response thrust along shaft line, taking into account the dynamic behaviour of the shaft line for ice excitation (axial vibration) and hydrodynamic mean thrust on propeller.	Design thrust for propeller shaft line components.

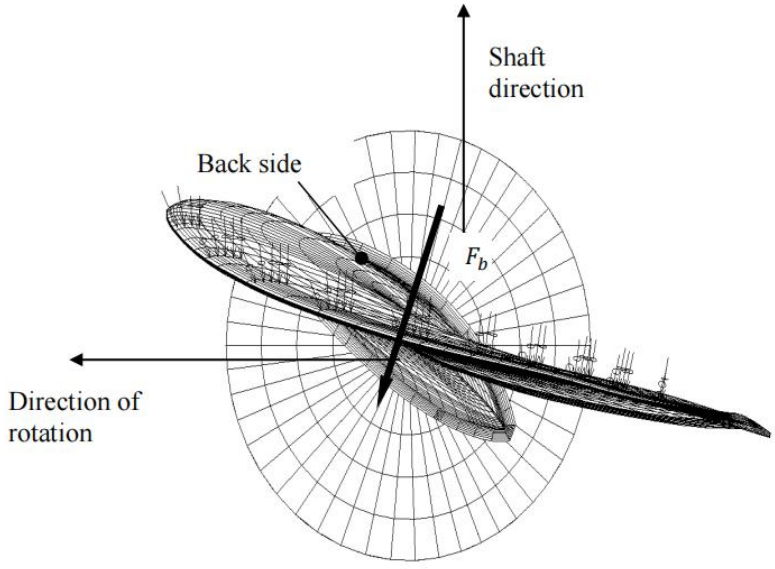


Figure 13.3.4.2 Direction of the backward blade force

13.3.5 Ice interaction loads

13.3.5.1 Propeller/ice interaction

These Rules cover open and ducted type propellers situated at the stern of a vessel having controllable pitch or fixed pitch blades. Ice loads on bow-mounted propellers shall receive special consideration. The given loads are expected, single occurrence, maximum values for the whole ship's service life for normal operational conditions, including loads resulting from directional change of rotation where applicable. These loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. These Rules also cover loads due to propeller ice interaction for azimuthing and fixed thrusters with geared transmission or an integrated electric motor ("geared and podded propulsors"). However, the load models of the regulations do not include propeller/ice interaction loads when ice enters

the propeller of a turned azimuthing thruster from the side (radially) or loads when ice blocks hit on the propeller hub of a pulling propeller. Ice loads resulting from ice impacts on the body of thrusters shall be estimated on a case by case basis, however are not included within the following section.
The loads given in section 13.3.5 are total loads including ice-induced loads and hydrodynamic loads (unless otherwise stated) during ice interaction and are to be applied separately (unless otherwise stated) and are intended for component strength calculations only.
F_b is the maximum force experienced during the lifetime of the ship that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead.
F_f is the maximum force experienced during the lifetime of the ship that bends a propeller blade forwards when the propeller mills an ice block while rotating ahead.

13.3.5.2 Ice class factors

The dimensions of the considered design ice block are $H_{ice} \times 2H_{ice} \times 3H_{ice}$. The design ice block H_{ice} and ice strength index S_{ice} used for the estimation of propeller ice loads are defined for each Ice class in Table 13.3.5.2 below.

Design ice block and ice strength index **Table 13.3.5.2**

Ice class	H_{ice}[m]	S_{ice}[−]
PC1	4.0	1.2
PC2	3.5	1.1
PC3	3.0	1.1
PC4	2.5	1.1
PC5	2.0	1.1
PC6	1.75	1
PC7	1.5	1

13.3.5.3 Design ice loads for open propellers

(1) Maximum backward blade force F_b

when $D < D_{limit}$:

$$F_b = -27 S_{ice} \left(\frac{EAR}{Z} \right)^{0.3} (nD)^{0.7} D^2 \qquad \text{kN}$$

when $D \geq D_{limit}$:

$$F_b = -23 S_{ice} \left(\frac{EAR}{Z} \right)^{0.3} (nD)^{0.7} H_{ice}^{1.4} D \qquad \text{kN}$$

where: $D_{limit} = 0.85 H_{ice}^{1.4}$;

S_{ice} and H_{ice} are selected in accordance with Table 13.3.5.2;

n —— the nominal rotational speed at MCR in the free running open water condition for CP-propellers and 85% of the nominal rotational speed (at MCR free running condition) for a FP-propeller (regardless driving engine type), in r/s.

For vessels with the additional notation Icebreaker, the above stated backward blade force F_b shall be multiplied by a factor of 1.1.

(2) Maximum forward blade force F_f

when $D < D_{limit}$:

$$F_f = 250 \frac{EAR}{Z} D^2 \qquad \text{kN}$$

when $D \geq D_{limit}$:

$$F_f = 500 \left(\frac{1}{1 - \frac{d}{D}} \right) H_{ice} \frac{EAR}{Z} D \qquad \text{kN}$$

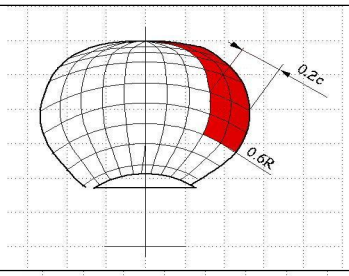
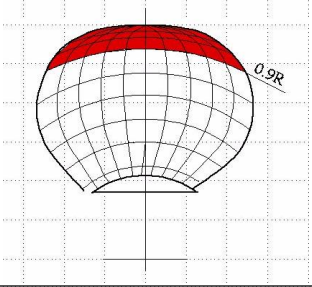
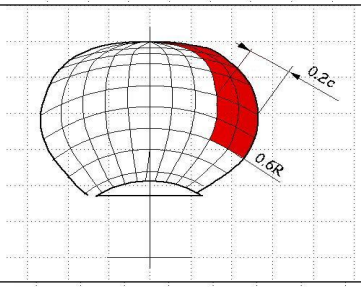
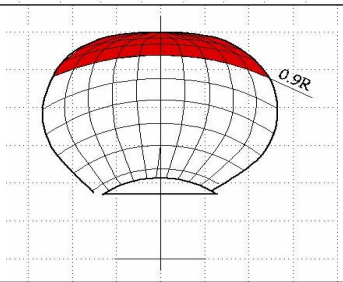
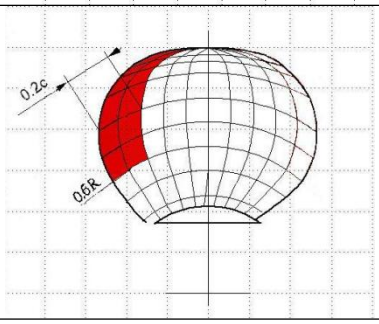
where: $D_{limit} = \left(\frac{2}{1 - \frac{d}{D}} \right) H_{ice}$, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

(3) Load cases

Load cases 1-4 shall be covered, as given in Table 13.3.5.3(3), for CP and FP propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 shall also be covered for propellers where reversing is possible.

Load cases for open propellers **Table 13.3.5.3(3)**

Load case	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length.	
Load case 2	50 % F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside 0.9R radius.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length.	
Load case 4	50%F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside 0.9R radius.	
Load case 5	60%F_f or 60%F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6R to the tip and from the trailing edge to 0.2 times the chord length	

13.3.5.4 Design ice loads for ducted propellers

(1) Maximum backward blade force F_b

when $D < D_{limit}$:

$$F_b = -9.5 S_{ice} \left(\frac{EAR}{Z} \right)^{0.3} (nD)^{0.7} D^2 \qquad \text{kN}$$

when $D \geq D_{limit}$:

$$F_b = -66 S_{ice} \left(\frac{EAR}{Z} \right)^{0.3} (nD)^{0.7} H_{ice}^{1.4} D^{0.6} \qquad \text{kN}$$

where: $D_{limit} = 4\ H_{ice}$, in m;

S_{ice} and H_{ice} are selected in accordance with Table 13.3.5.2;

n is the same as 13.3.5.3(1).

For vessels with the additional notation Icebreaker, the above stated backward blade force F_b shall be multiplied by a factor of 1.1.

(2) Maximum forward blade force F_f

when $D < D_{limit}$:

$$F_f = 250\,\frac{EAR}{Z}D^2 \qquad \text{kN}$$

when $D \geq D_{limit}$:

$$F_f = 500\left(\frac{1}{1-\frac{d}{D}}\right)H_{ice}\,\frac{EAR}{Z}D \qquad \text{kN}$$

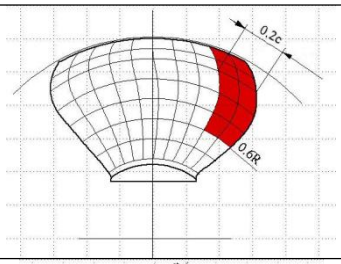
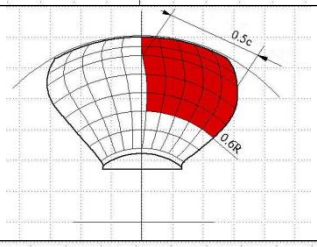
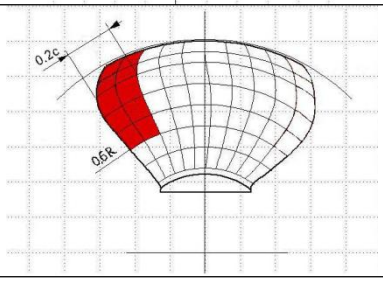
where: $D_{limit} = \left(\frac{2}{1-\frac{d}{D}}\right)H_{ice}$, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

(3) Load case

Load cases 1 and 3 shall be covered as given in Table 13.3.5.4(3) for all propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 shall also be covered for propellers, where reversing is possible.

Load cases for ducted propellers **Table 13.3.5.4(3)**

Load case	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6*R* to the tip and from the leading edge to 0.2 times the chord length.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6*R* to the tip and from the leading edge to 0.5 times the chord length.	
Load case 5	60%F_f or 60%F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6*R* to the tip and from the trailing edge to 0.2 times the chord length.	

13.3.5.5 Design ice loads for both open and ducted propellers

(1) Maximum blade spindle torque Q_{smax} for CP mechanism designing

The spindle torque Q_{smax} around the axis of the blade fitting shall be determined both for the maximum backward blade force F_b and forward blade force F_f, which are applied as per Table 13.3.5.3(3) and Table 13.3.5.4(3). If the above method gives a value which is less than the default value given by the formula below, the default value shall be used.

$$Q_{smax} = 0.25Fc_{0.7} \qquad \text{kNm}$$

where: F is taken as either F_b or F_f, whichever has the greater absolute value.

The blade failure spindle torque Q_{sex} is defined under 13.3.5.6.

(2) Load distributions (spectra) for blade loads

The Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{\max}$), as given in Figure 13.3.5.5(2) is used for the fatigue design of the blade.

$$P\left(\frac{F_{ice}}{(F_{ice})_{\max}} \geqslant \frac{F}{(F_{ice})_{\max}}\right) = e^{\left(-\left(\frac{F}{(F_{ice})_{\max}}\right)^{k} \ln(N_{ice})\right)}$$

where: k —shape parameter of the spectrum, for open propeller, k=0.75; for ducted propeller, k=1.0;

N_{ice} —number of load cycles in the spectrum, see 13.3.5.5(3);

F_{ice} —random variable for ice loads on the blade, $0 \leq F_{ice} \leq (F_{ice})_{max}$.

This results in a blade stress amplitude distribution:

$$(\sigma_{ice})_A(N) = (\sigma_{ice})_{A\max}\left\{1 - \frac{\log(N)}{\log(N_{ice})}\right\}^{\frac{1}{k}}$$

where: $(\sigma_{ice})_{A\max} = \dfrac{(\sigma_{ice})_{f\max} - (\sigma_{ice})_{b\max}}{2}$.

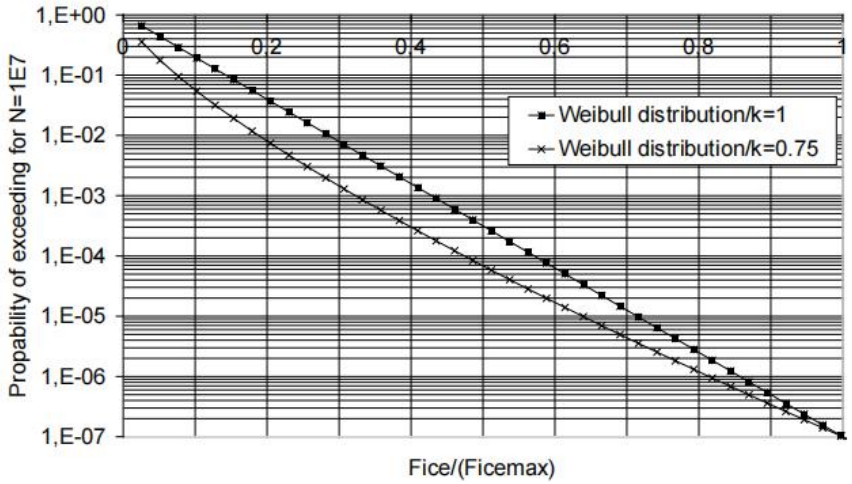


Figure 13.3.5.5(2) The Weibull-type distribution (probability of exceedance) that is used for fatigue design

(3) Number of ice loads

Number of load cycles in the load spectrum per blade is to be determined according to the formula:

$$N_{ice} = k_1 k_2 N_{class} n$$

where: N_{class} — reference number of impacts per propeller revolution for each ice class (Table 13.3.5.5(3));

k_1 — propeller position coefficient, to be taken as 1 for centre propeller; 2 for wing propeller; 3 for pulling propeller (wing and centre);

k_2 — immersion coefficient, to be determined as follows:

when $f < 0$, $k_2 = 0.8 - f$;

when $0 \leqslant f \leqslant 1$, $k_2 = 0.8 - 0.4f$;

when $1 < f \leqslant 2.5$, $k_2 = 0.6 - 0.2f$;

when $f > 2.5$, $k_2 = 0.1$;

where: $f = \dfrac{h_0 - H_{ice}}{D/2} - 1$, if h_0 is not known, h_0 may be taken as $D/2$.

k_3 — thruster type coefficient, to be taken as 1 for fixed thrusters and 1.2 for azimuthing thrusters;

For vessels with the additional notation Icebreaker, the above stated number of load cycles N_{ice} shall be multiplied by a factor of 3.

For components that are subject to loads resulting from propeller/ice interaction with all the propeller blades, the number of load cycles (N_{ice}) is to be multiplied by the number of propeller blades (Z).

Reference number of impacts **Table 13.3.5.5(3)**

Ice class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
N_{class}	21×10^6	17×10^6	15×10^6	13×10^6	11×10^6	9×10^6	6×10^6

13.3.5.6 Blade failure load for both open and ducted Propellers

(1) Bending force F_{ex}

The minimum load required resulting in blade failure through plastic bending. This shall be calculated iteratively along the radius of the blade from blade root to $0.5R$ using the equation below with the ultimate load assumed to be acting at $0.8R$ in the weakest direction.

$$F_{ex} = \frac{0.3ct^2\sigma_{ref1}}{0.8D - 2r} \times 10^3 \qquad \text{kN}$$

where:c, t and r are respectively the actual chord length, maximum thickness and radius of the cylindrical root section of the blade, which is the weakest section outside the root fillet located typically at the termination of the fillet into the blade profile.

The failure load may be calculated alternatively by means of an appropriate stress analysis reflecting the non-linear plastic material behaviour of the actual blade. A blade is regarded as having failed, if the tip is bent by more than 10% of the propeller diameter.

(2) Spindle torque Q_{sex}

The maximum spindle torque due to a blade failure load acting at 0.8R shall be determined.

The force that causes blade failure typically reduces when moving from the propeller centre towards the leading and trailing edges. At a certain distance from the blade centre of rotation the maximum spindle torque will occur. This maximum spindle torque shall be defined by an appropriate stress analysis or using equation below.

$$Q_{sex} = \max(c_{LE0.8}, 0.8c_{TE0.8}) C_{spex} F_{ex}$$

where: $C_{spex} = C_{sp} C_{fex} = 0.7\left[1 - \left(4\frac{EAR}{Z}\right)^3\right]$, to be taken not less than 0.3;

C_{sp} —non-dimensional parameter taking into account the spindle arm;

C_{fex} —non-dimensional parameter taking into account the reduction of blade failure force at the location of maximum spindle torque;

Figure 13.3.5.6(2) illustrates the spindle torque values due to blade failure loads across the whole chord length.

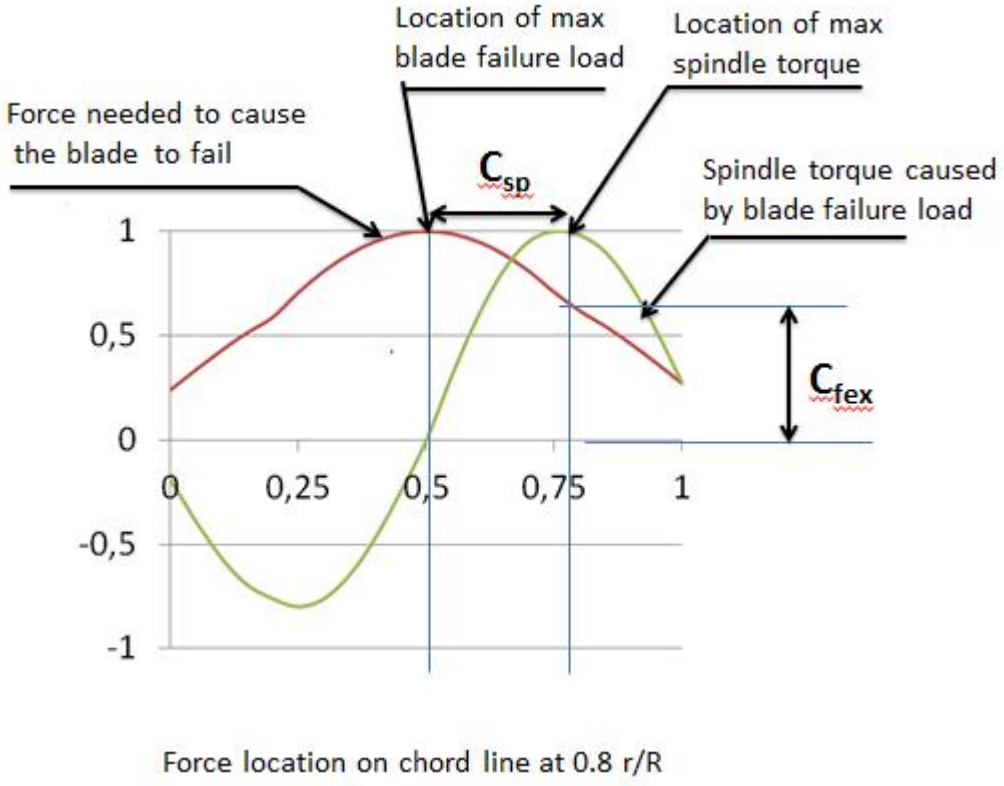


Figure 13.3.5.6(2) Schematic figure showing blade failure load and related spindle torque when the force acts at different location on the chord line at radius 0.8R

13.3.5.7 Axial design loads acting on open and ducted propellers

(1) Maximum ice thrust on propeller

Forward thrust T_f:

$$T_f = 1.1F_f \qquad \text{kN}$$

Backward thrust T_b:

$$T_b = 1.1F_b \qquad \text{kN}$$

However, the load models within this Section do not include propeller/ice interaction loads where an ice block hits the propeller hub of a pulling propeller.

(2) Design thrust along the propulsion shaft line for propellers

The design thrust along the propeller shaft line is to be calculated with the formulae below. The greater value of the forward and backward directional load shall be taken as the design load for both directions. The factors 2.2 and 1.5 take into account the dynamic magnification resulting from axial vibration.

In a forward direction:

$$T_r = T + 2.2T_f \qquad \text{kN}$$

In a backward direction:

$$T_r = 1.5T_b \qquad \text{kN}$$

If the hydrodynamic bollard thrust, T, is not known, T is to be taken as follows:

Value of *T* **Table 13.3.5.7(2)**

Propeller type	***T***
CP propellers (open)	$1.25T_n$
CP propellers (ducted)	$1.1\ T_n$
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	$0.85\ T_n$
FP propellers driven by diesel engine (ducted)	$0.75\ T_n$

Note: T_n is the nominal propeller thrust at MCR in the free running open water condition, in kN.

For pulling type propellers ice interaction loads on propeller hub must be considered in addition to the above. These will be specially considered by CCS.

13.3.5.8 Torsional design loads acting on open and ducted propellers

(1) Design ice torque on propeller for open propellers

when $D < D_{limit}$:

$$Q_{\max} = k_{open}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^3 \qquad \text{kNm}$$

when $D \geq D_{limit}$:

$$Q_{\max} = 1.9k_{open}H_{ice}^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9} \qquad \text{kNm}$$

where: $D_{limit} = 1.8\ H_{ice}$, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

k_{open} ——14.7 for PC1~PC5; 10.9 for PC6~PC7;

$P_{0.7}$ ——propeller pitch at 0.7R, in m; (For CP propellers, $P_{0.7}=P_{0.7b}$; if $P_{0.7b}$ is not known, $P_{0.7}=0.7P_{0.7n}$)

n —— the rotational propeller speed in r/s in bollard condition. If not known, n is to be taken as follows:

Value of *n* **Table 13.3.5.8(1)**

Propeller type	*n*
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propeller driven by diesel engine	$0.85n_n$

Note: n_n is the nominal propeller rotational speed at MCR in the free running open water condition, in r/s.

(2) Design ice torque on propeller for ducted propellers

when $D < D_{limit}$:

$$Q_{\max} = k_{ducted}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^3 \qquad \text{kNm}$$

when $D \geq D_{limit}$:

$$Q_{\max} = 1.9k_{ducted}H_{ice}^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9} \qquad \text{kNm}$$

where: $D_{limit} = 1.8\ H_{ice}$, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

k_{ducted} ——10.4 for PC1~PC5; 7.7 for PC6~PC7;

$P_{0.7}$ and n are selected in accordance with 13.3.5.8(1).

(3) Ice torque excitation for open and ducted propellers

The given excitations are used to estimate the maximum torque likely to be experienced once during the service life of the ship. The following load cases are intended to reflect the operational loads on the propulsion system when the propeller interacts with ice and the corresponding reaction of the complete system. The ice impact and system response cause loads in the individual shaft line components. The ice torque Q_{max} may be taken as a constant value in the complete speed range. When considerations at specific shaft speeds are performed a relevant Q_{max} may be calculated using the relevant speed.

Diesel engine plants without an elastic coupling shall be calculated at the least favourable phase angle for ice versus engine excitation, when calculated in time domain. The engine firing pulses shall be included in the calculations and their standard steady state harmonics can be used. A phase angle between ice and gas force excitation does not need to be regarded in frequency domain analysis. Misfiring does not need to be considered.

If there is a blade order resonance just above MCR speed, calculations shall cover the rotational speeds up to 105% of MCR speed.

See also Guidelines for calculations given in 13.3.5.9

① Excitation for the time domain calculation

The propeller ice torque excitation for shaft line transient dynamic analysis (time domain) is defined as a sequence of blade impacts which are of half sine shape and occur at the blade.

The torque due to a single blade ice impact as a function of the propeller rotation angle is then defined as:

when $\varphi = 0 \ldots a_i$,

$$Q(\varphi) = C_q Q_{max} sin[\varphi(180 / a_i)\ ] \qquad \text{kNm}$$

when $\varphi = a_i \ldots 360$,

$$Q(\varphi) = 0 \qquad \text{kNm}$$

where: φ is rotation angle starting when the first impact occurs.

Parameters C_q and α_i for different blade numbers are given in Table 13.3.5.8(3)①.

Ice impact magnification C_q and duration α_i factors for different blade numbers

Table 13.3.5.8(3)①

Torque excitation	Propeller/ ice interaction	C_q	α_i (°)			
			Z=3	Z=4	Z=5	Z=6
Excitation case 1	Single ice block	0.75	90	90	72	60
Excitation case 2	Single ice block	1.0	135	135	135	135
Excitation case 3	Two ice blocks （phase shift=360°/(2Z)）	0.5	45	45	36	30
Excitation case 4	Single ice block	0.5	45	45	36	30

The total ice torque is obtained by summing the torque of single blades, taking into account the phase shift 360°/Z.

At the beginning and at the end of the milling sequence (within calculated duration) linear ramp functions shall be used to increase C_q to its maximum within one propeller revolution and vice versa to decrease it to zero (see Figure 13.3.5.8(3)①).

The number of propeller revolutions during a milling sequence shall be obtained from the formula:

$$N_Q = 2H_{ice}$$

The number of impacts for blade order excitation:

$$ZN_Q$$

where: H_{ice} is selected in accordance with Table 13.3.4.2.

An illustration of all excitation cases for different blade numbers is given in Figure 13.3.5.8(3)①.

The dynamic simulation shall be performed for all excitation cases starting at MCR nominal, MCR bollard condition and just above all resonance speeds (1st engine and 1st blade harmonic), so that the resonant vibration responses can be obtained. For a fixed pitch propeller plant the dynamic simulation shall also cover bollard pull condition with a corresponding speed assuming maximum possible output of the engine.

If a speed drop occurs down to stand still of the main engine, it indicates that the engine may not be sufficiently powered for the intended service task. For the consideration of loads, the maximum occurring torque during the speed drop process shall be applied. On these cases, the excitation shall follow the shaft speed.

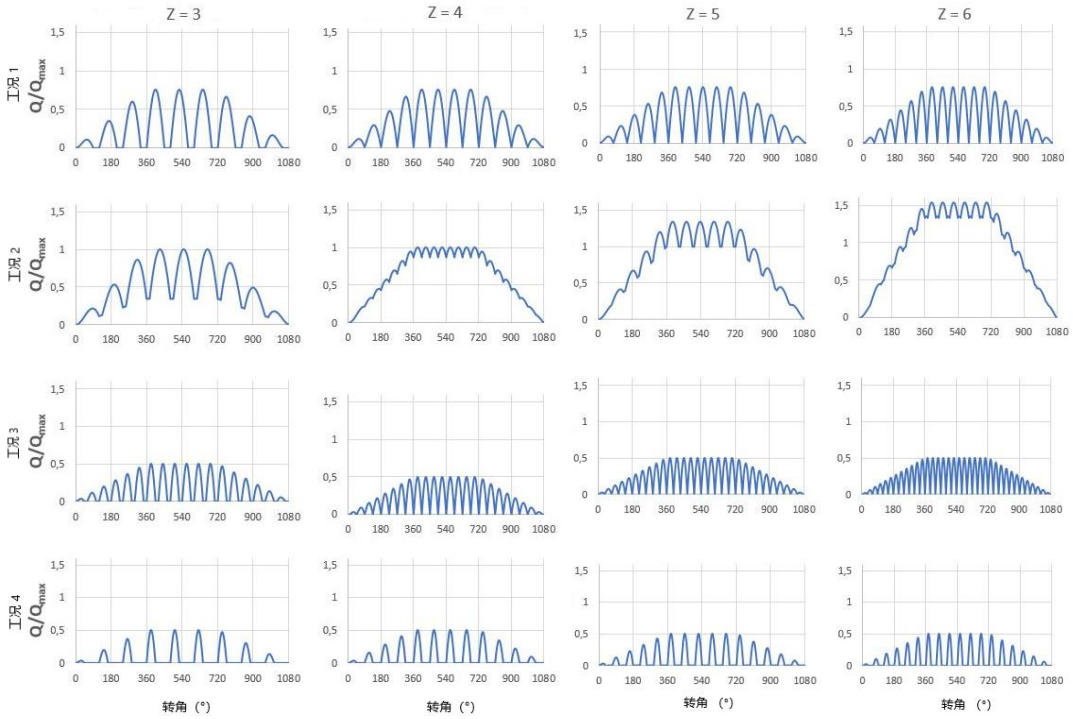


Figure 13.3.5.8(3)①　Ice block torque excitation cases for 3~6 blade propellers

② Frequency domain excitation

For frequency domain calculations the following torque excitation may be used. The excitation has been derived so that the time domain half sine impact sequences have been assumed to be continuous and the Fourier series components for blade order and twice the blade order components have been derived. The frequency domain analysis is generally considered as conservative compared to the time domain simulation provided there is a first blade order resonance in the considered speed range.

$$Q_F(\varphi) = Q_{\max} \cdot \left[C_{q0} + C_{q1} \cdot \sin\left(Z \cdot E_0 \cdot \varphi + \alpha_1\right) + C_{q2} \cdot \sin\left(2Z \cdot E_0 \cdot \varphi + \alpha_2\right) \right] \quad \text{kNm}$$

where: φ ——angle of rotation;

C_{q0} ——mean torque component;

C_{q1} ——first blade order excitation amplitude;

C_{q2} ——second blade order excitation amplitude;

E_0 ——Number of ice blocks simultaneously participating in the impact.

Coefficients for simplified excitation torque estimation are given in Table 13.3.5.8(3)②.

Coefficients for simplified excitation torque estimation Table 13.3.5.8(3)②

Torque excitation	Z=3					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0.375	0.375	-90	0	0	1
Case 2	0.7	0.33	-90	0.05	-45	1
Case 3	0.25	0.25	-90	0	0	2
Case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=4					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0.45	0.36	-90	0.06	-90	1
Case 2	0.9375	0	-90	0.0625	-90	1
Case 3	0.25	0.251	-90	0	0	2
Case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=5					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0.45	0.36	-90	0.06	-90	1
Case 2	1.19	0.17	-90	0.02	-90	1
Case 3	0.3	0.25	-90	0.048	-90	2
Case 4	0.2	0.25	0	0.05	-90	1
Torque excitation	Z=6					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0.45	0.375	-90	0.05	-90	1
Case 2	1.435	0.1	-90	0	0	1
Case 3	0.3	0.25	-90	0.048	-90	2
Case 4	0.2	0.25	0	0.05	-90	1

Torsional vibration responses shall be calculated for all excitation cases.

The results of the relevant excitation cases at the most critical rotational speeds are to be used in the following way:

The highest response torque (between the various lumped masses in the system) is in the following referred to as peak torque Q_{peak}, see Figure 13.3.5.8(3)②.

The highest torque amplitude during a sequence of impacts is to be determined as half of the range from max to min torque and is referred to as Q_{Amax}, see Figure 13.3.5.8(3)②.

Q_{Amax} can by determined by:

$$Q_{A\max} = \left[\max(Q_r(t)) - \min(Q_r(t))\right] / 2 \quad \text{kNm}$$

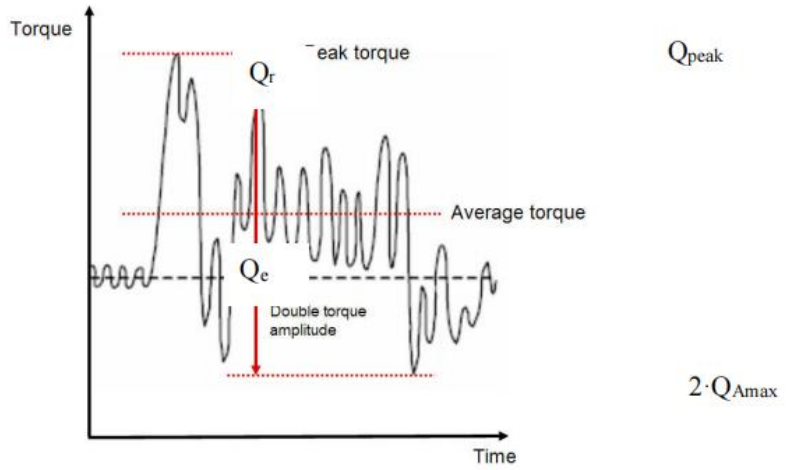


Figure 13.3.5.8(3)② Interpretation of different torques in a measured curve, as example

(4) Design torque along shaft line

① If there is no relevant first order propeller torsional resonance in the range 20% (of n_n) above and 20% below the maximum operating speed in bollard condition, the following estimation of the maximum response torque can be used to calculate the design torque along the propeller shaft line.

$$Q_r = Q_{e\max} + Q_{\text{vib}} + Q_{\max}\frac{I}{I_t} \qquad \text{kNm}$$

The above equation is to be applied for directly coupled two stroke Diesel engines without flexible coupling. For all other plants:

$$Q_r = Q_{e\max} + Q_{\max}\frac{I}{I_t} \qquad \text{kNm}$$

where: all the torques and the inertia moments shall be reduced to the rotation speed of the component being examined.

If the maximum torque $Q_{e\max}$ is not known, it shall be taken as follows:

Value of $Q_{e\max}$ **Table 13.3.5.9(1)**

Propeller type	$Q_{e\max}$
Propellers driven by electric motor	Q_{motor}
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	$0.75Q_n$

Note: Q_{motor} is the electric motor peak torque.

② If there is a first blade order torsional resonance in the range 20% (of n_n) above and 20% below the maximum operating speed (bollard condition), the design torque (Q_r) of the shaft component shall be determined by means of a dynamic torsional vibration analysis of the entire propulsion line in the time domain or alternatively in the frequency domain. It is then assumed that the plant is sufficiently designed to avoid harmful operation in barred speed range.

13.3.5.9 Torsional vibration calculation

(1) The aim of torsional vibration calculations is to estimate the torsional loads for individual shaft line components over the life time in order to determine scantlings for safe operation. The model can be taken from the normal lumped mass elastic torsional vibration model (frequency domain) including the damping. Standard harmonics may be used to consider the gas forces. The engine torque - speed curve of the actual plant shall be applied.

(2) For time domain analysis the model should include the ice excitation at propeller, the mean torques

provided by the prime mover and the hydrodynamic mean torque produced by the propeller as well as any other relevant excitations. The calculations should cover the variation of phase between the ice excitation and prime mover excitation. This is extremely relevant for propulsion lines with direct driven combustion engines.

(3) For frequency domain calculations the load should be estimated as a Fourier component analysis of the continuous sequence of half sine load peaks. The first and second order blade components should be used for excitation. The calculation should cover the whole relevant shaft speed range. The analysis of the responses at the relevant torsional vibration resonances may be performed for open water (without ice excitation) and ice excitation separately. The resulting maximum torque can be obtained for directly coupled plants by the following superposition:

$$Q_{peak} = Q_{e\max} + Q_{\text{opw}} + Q_{\text{ice}} \qquad \text{kNm}$$

where: Q_{emax} ——the maximum engine torque at considered rotational speed;

Q_{opw} ——the maximum open water response of engine excitation at considered shaft speed and determined by frequency domain analysis;

Q_{ice} ——the calculated torque using frequency domain analysis for the relevant shaft speeds, ice excitation cases 1-4, resulting in the maximum response torque due to ice excitation.

13.3.6 Design

13.3.6.1 Design principle

The propulsion line shall be designed according to the pyramid strength principle in terms of its strength. This means that the loss of the propeller blade shall not cause any significant damage to other propeller shaft line components.

The propulsion line components shall withstand maximum and fatigue operational loads with the relevant safety margin. The loads do not need to be considered for shaft alignment or other calculations of normal operational conditions.

13.3.6.2 Fatigue design in general

The design loads shall be based on the ice excitation and where necessary (shafting) dynamic analysis, described as a sequence of blade impacts (13.3.5.8(3)①). The shaft response torque shall be determined according 13.3.5.8(4).

The propulsion line components are to be designed so as to prevent accumulated fatigue failure when considering the relevant loads using the linear elastic Miner's rule as defined below.

$$D_{mds} = \frac{n_1}{N_1} + \frac{n_2}{N_2} + \cdots + \frac{n_k}{N_k} \le 1 \qquad \text{or} \qquad D_{mds} = \sum_{J=1}^{j=k} \frac{n_j}{N_j} \le 1$$

where: k —— the number of stress levels;

$N_{1\ldots k}$——the number of load cycles to failure of the individual stress level class;

$n_{1\ldots k}$——the accumulated number of load cycles of the case under consideration, per class;

D_{mds}——Miners damage sum.

The stress distribution should be divided into a frequency load spectrum having minimum 10 stress blocks (every 10 % of the load). Calculation with 5 stress blocks has been found to be too conservative. The maximum allowable load is limited by σ_{ref2} for propeller blades and yield strength for all other components. The load distribution (spectrum) should be in accordance with the Weibull distribution.

13.3.6.3 Propeller blades

(1) Calculation of blade stresses due to static loads

The blade stresses (equivalent and principal stresses) shall be calculated for the design loads given in 13.3.5.3 and 13.3.5.4. Finite element analysis (FEA) shall be used for stress analysis as part of the final approval for all propeller blades. The von Mises stresses, taken as σ_{st}, shall comply with criteria in (2).

Alternatively, the following simplified equation can be used in estimating the blade stresses for all propellers in the root area ($r/R < 0.5$) for final approval.

$$\sigma_{st} = A_1 \frac{M_{BL}}{100 \times ct^2} \qquad \text{MPa}$$

where: constant A_1 is the $\frac{actual\ stress}{stress\ obtained\ with\ beam\ equation}$. If the actual value is not available, A_1 should be taken as 1.6. $M_{BL}=\left(0.75-r/R\right)RF$, for relative radius r/R<0.5, where F is the maximum of F_b and F_f, whichever is greater.

(2) Acceptability criterion for static loads

The following criterion for calculated blade stresses shall be fulfilled:

$$\frac{\sigma_{ref2}}{\sigma_{st}} \geq 1.3$$

where:σ_{st} ——calculated stress for the design loads. If FE analysis is used in estimating the stresses, von Mises stresses shall be used.

(3) Fatigue design of propeller blade

For materials with a two slope S-N curve the fatigue calculations defined in this chapter are not required if the following criterion is fulfilled.

$$\sigma_{\exp} \geqslant B_1 \cdot \sigma_{ref2}^{B_2} \cdot \log\left(N_{ice}\right)^{B_3}$$

where: B_1, B_2 and B_3 are coefficients for propellers given in Table 13.3.6.2(3).

Value of B_1, B_2 and B_3 **Table 13.3.6.3(3)**

Coefficient	Open propeller	Ducted propeller
B_1	0.00328	0.00223
B_2	1.0076	1.0071
B_3	2.101	2.471

Where the above criterion is not fulfilled the fatigue requirements defined below shall be applied:

The fatigue design of the propeller blade is based on an estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress σ_{fat} that produces the same fatigue damage as the expected load distribution shall be calculated according to Miner's rule and the acceptability criterion for fatigue should be fulfilled as given in this section. The equivalent stress is normalised for 100 million cycles.

The blade stresses at various selected load levels for fatigue analysis are to be taken proportional to the stresses calculated for maximum loads given in section 13.3.5.

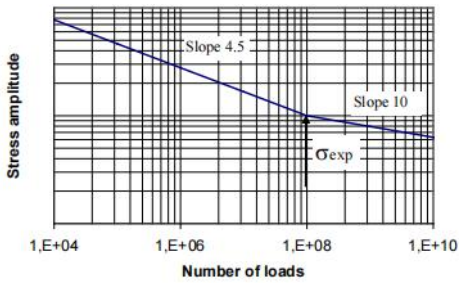
The peak principal stresses σ_f and σ_b are determined from F_f and F_b using FEA. The peak stress range $\Delta\sigma_{max}$ and the maximum stress amplitude σ_{Amax} are determined on the basis of load cases 1 and 3, 2 and 4.

$$\Delta\sigma_{\max} = 2\cdot\sigma_{A\max} = \left|\left(\sigma_{ice}\right)_{f\max}\right| + \left|\left(\sigma_{ice}\right)_{b\max}\right| \qquad \text{MPa}$$

The load spectrum for backward loads is normally expected to have a lower number of cycles than the load spectrum for forward loads. Taking this into account in a fatigue analysis introduces complications that are not justified considering all uncertainties involved.

For the calculation of equivalent stress two types of S-N curves are available. Two slope S-N curve (slopes 4.5 and 10), see Figure 13.3.6.3(3)-1. One slope S-N curve (the slope can be chosen), see Figure 13.3.6.3(3)-2.

The type of the S-N-curve shall be selected to correspond with the material properties of the blade. If the S-N-curve is not known the two slope S-N curve shall be used.



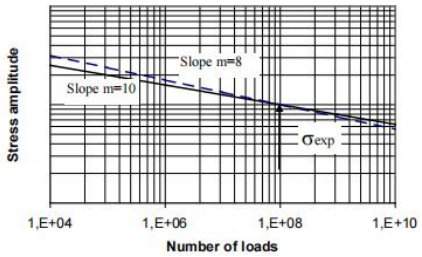


Figure 13.3.6.3(3)-1 Two-slope *S-N* curve **Figure 13.3.6.3(3)-2 Constant-slope *S-N* curve**

① Equivalent fatigue stress

A more general method of determining the equivalent fatigue stress of propeller blades is described in 13.3.6.5, where the principal stresses are considered according to 13.3.5.3 and 13.3.5.4 using the Miner's rule. For a total number of load blocks $n_{bl} > 100$, both methods deliver the same result. Therefore, they are regarded as equivalent.

The equivalent fatigue stress for 10^8 cycles which produces the same fatigue damage as the load distribution is:

$$\sigma_{fat} = \rho \cdot \left(\sigma_{ice}\right)_{\max} \quad \text{MPa}$$

where:$(\sigma_{ice})_{\max}$ —— mean value of the principal stress amplitudes resulting from design forward and backward blade forces at the location being studied, to be determined as follows:

$$\left(\sigma_{ice}\right)_{\max} = 0.5 \cdot \left(\left(\sigma_{ice}\right)_{f\max} - \left(\sigma_{ice}\right)_{b\max}\right) \quad \text{MPa}$$

where: $(\sigma_{ice})_{f\max}$ is principal stress resulting from forward load, $(\sigma_{ice})_{b\max}$ is principal stress resulting from backward load.

In the calculation of $(\sigma_{ice})_{\max}$, case 1 and case 3 or case 2 and case 4 are considered as pairs for $(\sigma_{ice})_{f\max}$ and $(\sigma_{ice})_{b\max}$. Case 5 is excluded from the fatigue analysis.

② Calculation of parameter ρ for two-slope S-N curve

When $5 \times 10^6 \le N_{ice} \le 1 \times 10^8$, the error of the following method to determine the parameter ρ is sufficiently small.

The parameter ρ relates the maximum ice load to the distribution of ice loads according to the regression formula.

$$\rho = C_1 \cdot \left(\sigma_{ice}\right)_{\max}^{C_2} \cdot \sigma_{fl}^{C_3} \cdot \log\left(N_{ice}\right)^{C_4}$$

where: $\sigma_{fl} = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$, is the blade material fatigue strength at 10^8 load cycles, see 13.3.6.3(3)④.

The coefficients C_1, C_2, C_3 and C_4 are given in Table 13.3.6.3(3)②.

Value of C_1, C_2, C_3 and C_4 **Table 13.3.6.3(3)②**

Coefficient	Open propeller	Ducted propeller
C_1	0.000747	0.000534
C_2	0.0645	0.0533
C_3	−0.0565	−0.0459
C_4	2.22	2.584

③ Calculation of parameter ρ for constant-slope S-N curve

For materials with a constant-slope S-N curve, see Figure 13.3.6.3(3)-2, the factor ρ shall be calculated from the following formula:

$$\rho = \left(G \frac{N_{ice}}{N_R}\right)^{1/m} \left[\ln(N_{ice})\right]^{-1/k}$$

where: k —— shape parameter of the Weibull distribution, k=1.0 for ducted propellers and k=0.75 for open propellers;

N_R —— reference number of load cycles (=10^8);

G —— Values for the parameter G are given in Table 13.3.6.3(3)③ below. Linear interpolation may be used to calculate the value of G for m/k ratios other than those given in the Table 13.3.6.3(3)③.

Value for the parameter *G* for different m/k ratios **Table 13.3.6.3(3)③**

m/k	G	m/k	G	m/k	G	m/k	G
3	6	5.5	287.9	8	40320	10.5	11.899E6
3.5	11.6	6	720	8.5	119292	11	39.917E6
4	24	6.5	1871	9	362880	11.5	136.843E6
4.5	52.3	7	5040	9.5	1.133E6	12	479.002E6
5	120	7.5	14034	10	3.623E6		

④ Acceptability criterion for fatigue

The equivalent fatigue stress σ_{fat} at all locations on the blade shall fulfil the following acceptability criterion:

$$\frac{\sigma_{fl}}{\sigma_{fat}} \geqslant 1.5$$

where: $\sigma_{fl} = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$, in MPa;

$\gamma_{\varepsilon 1}$—— reduction factor due to scatter (equal to one standard deviation);

$\gamma_{\varepsilon 2}$—— reduction factor for test specimen size effect;

σ_{exp} in Table 13.3.6.3(3)④ has been defined from the results of constant amplitude loading fatigue tests at 10^7 load cycles and 50% survival probability and has been extended to 10^8 load cycles. Fatigue strength values and correction factors other than those given in Table 13.3.6.3(3)④ may be used, provided the values are determined under conditions approved by CCS.

Mean fatigue strength σ_{exp} for different material types at 10^8 load cycles and stress ratio r = -1 with a survival probability of 50%

Table 13.3.6.3(3)④

Bronze and brass（a=1.0）		Stainless steel（a=0.05）	
Mn-Bronze, Cu1 (high tensile brass)	84 MPa	Ferritic (12Cr 1Ni)	144 MPa①
Mn-Ni-Bronze, Cu2 (high tensile brass)	84 MPa	Martensitic (13Cr 4Ni/13Cr 6Ni)	156 MPa
Ni-Al-Bronze, Cu3	120 MPa	Martensitic (16Cr 5Ni)	168 MPa
Mn-Al-Bronze, Cu4	113 MPa	Austenitic (19Cr 10Ni)	132 MPa

Note: ① This value may be used, provided a perfect galvanic protection is active. Otherwise a reduction of about 30 MPa shall be applied.

The S-N curve characteristics are based on two slopes, the first slope 4.5 is from 1000 to 10^8 load cycles; the second slope 10 is above 10^8 load cycles.

The maximum allowable stress for one or low number of cycles is limited to σ_{ref2}/S, with S =1.3 for static loads.

The fatigue strength σ_{fat} is the fatigue limit at 100 million load cycles.

The geometrical size factor ($\gamma_{\varepsilon 2}$) is:

$$\gamma_{\varepsilon 2} = 1 - a \cdot \ln(\frac{t}{0.025})$$

where: a —— as given in Table 13.3.6.3(3)④;

t —— the maximum blade thickness at the considered point.

The mean stress effect γ_m is:

$$\gamma_m = 1.0 - \left(\frac{1.4 \cdot \sigma_{mean}}{R_m}\right)^{0.75}$$

The following values should be used for the reduction factors if actual values are not available:

$\gamma_{\varepsilon 1}$ = 0.85, γ_v = 0.75, γ_m=0.75.

13.3.6.4 Blade bolts, propeller hub and CP mechanism

(1) General

The blade bolts, CP mechanism, propeller boss and the fitting of the propeller to the propeller shaft shall be designed to withstand the maximum static and fatigue design loads (as applicable), as defined in 13.3.5.3, 13.3.5.4, 13.3.5.5 and 13.3.6.3. The safety factor against yielding due to static loads and against fatigue shall be greater than 1.5, if not stated otherwise. The safety factor for loads, resulting from propeller blade failure as defined in 13.3.5.6 shall be greater than 1.0 against yielding.

Provided that calculated stresses duly considering local stress concentrations are less than yield strength, or maximum of 70% of tensile strength of respective materials, detailed fatigue analysis is not required. In all other cases components shall be analysed for cumulative fatigue. An approach similar to that used for shafting assessment may be applied (13.3.6.5).

(2)Blade bolts

Blade bolts shall withstand the following bending moment considered around a tangent on bolt pitch circle, or any other relevant axis for non-circular joints, parallel to considered root section:

$$M_{bolt} = S \cdot F_{ex}(0.8\frac{D}{2} - \mathrm{r}_{bolt}) \qquad \text{kNm}$$

where:r_{bolt}—— radius to the bolt plane;

S —— 1.0 safety factor.

Blade bolt pre-tension shall be sufficient to avoid separation between mating surfaces when the maximum forward and backward ice loads defined in 13.3.5.3 and 13.3.5.4 (open and ducted propellers respectively) are applied. For conventional arrangements, the following formula may be applied:

$$d_{bb} = 41 \cdot \sqrt{\frac{F_{ex}(0.8D - d) \cdot \mathrm{S} \cdot \alpha}{R_{p0.2} \cdot z_{bb} \cdot PCD}} \qquad \text{mm}$$

where:α —— 1.6 torque guided tightening; 1.3 elongation guided; 1.2 angle guided; 1.1 elongated by other additional means; other factors may be used, if evidence is demonstrated;

d_{bb}—— effective diameter of blade bolt in way of thread, in mm;

z_{bb}—— number of blade bolts;

S —— 1.0 safety factor.

(3) CP mechanism

Separate means, e.g. dowel pins, shall be provided in order to withstand the spindle torque resulting from blade failure Q_{sex} (see 13.3.5.6(2)) or ice interaction Q_{smax} (see 13.3.5.5(1)) whichever is greater. Other components of the CP mechanism shall not be damaged by the maximum spindle torques (Q_{smax}, Q_{sex}). One third of the spindle torque is assumed to be consumed by friction, if not otherwise documented trough further analysis.

The diameter of fitted pins between the blade and blade carrier can be calculated using the formula:

$$d_{fp} = 66 \cdot \sqrt{\frac{Q_s - Q_{fr}}{PCD \cdot z_{pin} \cdot R_{p0.2}}} \qquad \text{mm}$$

where:Q_s —— max($S \cdot Q_{s\max}$; $S \cdot Q_{sex}$), in kNm;

S —— 1.3 for $Q_{s\max}$, 1.0 for Q_{sex} ;

Q_{fr} —— friction between connected surfaces,= $0.33 \cdot Q_s$, in kNm. CCS may approve alternative Q_{fr} calculation according to reaction forces due to F_{ex} , or F_f , F_b whichever is relevant, utilising a friction coefficient = 0.15.

The stress in the actuating pin can be estimated by:

$$\sigma_{vMises} = \sqrt{\left(\frac{F_m \cdot \frac{h_{pin}}{2}}{\frac{\pi \cdot d_{pin}^{\ 3}}{32}}\right)^2 + 3 \cdot \left(\frac{F_m}{\frac{\pi}{4} \cdot d_{pin}^{\ 2}}\right)^2} \qquad \text{MPa}$$

where:F_m —— $\left(Q_s - Q_{fr}\right) / l_m$, in kN;

l_m —— distance pitching centre of blade – axis of pin, in m;

h_{pin}—— height of actuating pin, in mm;

d_{pin}—— diameter of actuating pin, in mm;

Q_{fr}—— friction torque in blade bearings acting on the blade palm and caused by the reaction forces

due to F_{ex} , or F_f , F_b whichever is relevant; taken to one third of spindle torque Q_s, in kNm.

The blade failure spindle torque Q_{sex} shall not lead to any consequential damage.

Fatigue strength is to be considered for parts transmitting the spindle torque from the blade to a servo system considering the ice spindle torque acting on one blade. The maximum amplitude Q_{samax} is defined as:

$$Q_{sa\max} = \frac{Q_{sb} + Q_{sf}}{2} \qquad \text{kNm}$$

where: Q_{sb} —— spindle torque due to $|F_b|$, in kNm;

Q_{sf} —— spindle torque due to $|F_f|$, in kNm.

(4) Servo pressure

The design pressure for the servo system shall be taken as the pressure caused by Q_{smax} or, Q_{sex} when not protected by relief valves on the hydraulic actuator side, reduced by relevant friction losses in bearings caused by the respective ice loads. The design pressure shall in any case not be less than relief valve set pressure.

13.3.6.5 Propulsion line components

The ultimate load resulting from total blade failure F_{ex} as defined in 13.3.5.6 shall consist of combined axial and bending load components, wherever this is significant. The minimum safety factor against yielding is to be 1.0 for all shaft line components.

The shafts and shafting components, such as bearings, couplings and flanges shall be designed to withstand the operational propeller/ice interaction loads as given in 13.3.5.

The given loads are not intended to be used for shaft alignment calculation.

Cumulative fatigue calculations shall be conducted according to the Miner's rule. A fatigue calculation is not necessary, if the maximum stress is below fatigue strength at 10^8 load cycles.

The torque and thrust amplitude distribution (spectrum) in the propulsion line is to be taken as (because Weibull exponent k = 1), with Figure 13.3.6.5-1 as an example:

$$Q_A(\mathrm{N}) = Q_{A\max} \cdot \left[1 - \frac{\log(N)}{\log(Z \cdot N_{ice})}\right]$$

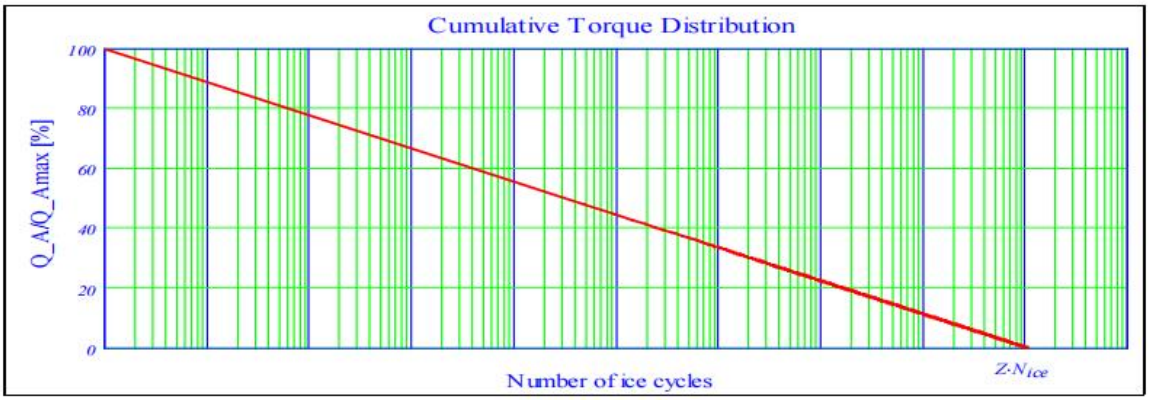


Figure 13.3.6.5-1 Cumulative torque distribution

The number of load cycles in the load spectrum is defined as $Z \cdot N_{ice}$.

The Weibull exponent should be considered as k = 1.0 for both open and ducted propeller torque and bending forces. The load distribution is an accumulated load spectrum, and the load spectrum should be divided into a minimum of ten load blocks when using the Miner summation method.

The load spectrum used counts the number of cycles for 100% load to be the number of cycles above the next step, e.g. 90 % load. This ensures that the calculation is on the conservative side. Consequently, the fewer stress blocks used the more conservative the calculated safety margin, see Figure 13.3.6.5-2.

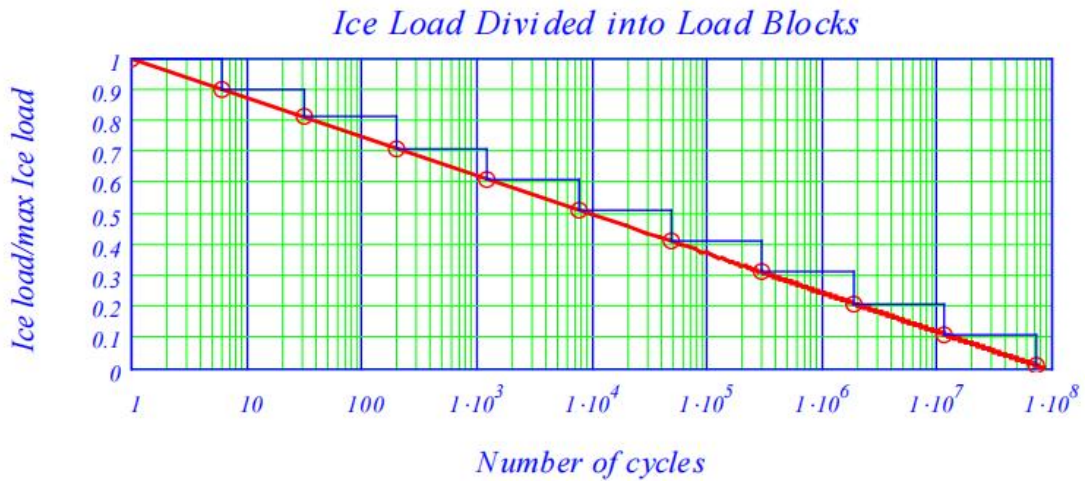


Figure 13.3.6.5-2 Example of ice load distribution (spectrum) for the shafting (k = 1)

The load spectrum is divided into n_{bl}-number of load blocks for the Miner summation method.
The following formula can be used for calculation of the number of cycles for each load block.

$$n_i = N_{ice}^{1-\left(1-\frac{i}{n_{bl}}\right)^k} - \sum_{i=1}^{i} n_{i-1}$$

where:i —— single load block, n_{bl} is the number of load blocks.

(1) Propeller fitting to the shaft

Keyless cone mounting or flange mounting may be generally used for propeller fitting to the shaft. Key mounting alone is not permitted.

① Keyless cone mounting

The friction capacity (at 0℃) shall be at least S = 2.0 times the highest peak torque Q_{peak} as determined in 13.3.5.9 without exceeding the permissible hub stresses.

The necessary surface pressure can be determined as:

$$p_{0°C} = \frac{2 \cdot S \cdot Q_{peak}}{\pi \cdot \mu \cdot D_S^2 \cdot L \cdot 10^3} \qquad \text{MPa}$$

where: μ —— 0.15 for steel-steel; 0.13 for steel-bronze;

D_S —— the shrinkage diameter at the mid-length of the taper, in m;

L —— the effective length of taper, in m.

Above friction coefficients may be increased by 0.04 if glycerine is used in wet mounting.

② Flange mounting

The flange thickness is to be at least 25% of the required aft end shaft diameter.

Any additional stress raisers such as recesses for bolt heads shall not interfere with the flange fillet unless the flange thickness is increased correspondingly.

The flange fillet radius is to be at least 10% of the required shaft diameter.

The diameter of shear pins shall be calculated according to the following equation:

$$d_{pin} = 66 \cdot \sqrt{\frac{Q_{peak} \cdot S}{PCD \cdot z_{pin} \cdot R_{p0.2}}} \qquad \text{mm}$$

where:Z_{pin}—— number of shear pins;

S —— 1.3 safety factor.

The bolts are to be designed so that the blade failure load F_{ex} (13.3.5.6) in backward direction does not cause yielding of the bolts. The following equation should be applied:

$$d_b = 41 \cdot \sqrt{\frac{F_{ex} \cdot (0.8 \cdot D / PCD + 1) \cdot \alpha}{R_{p0.2} \cdot z_b}} \qquad \text{mm}$$

where: α —— 1.6 torque guided tightening, 1.3 elongation guided, 1.2 angle guided, 1.1 elongated by other additional means, other factors may be used, if evidence is demonstrated;

d_b —— diameter flange bolt, in mm;

z_b —— number of flange bolts.

(2) Propeller shaft

The propeller shaft is to be designed to fulfil the following:

① The blade failure load F_{ex} (13.3.5.6) applied parallel to the shaft (forward or backwards) shall not cause yielding. The bending moment need not to be combined with any other loads. The diameter in way of the aft stern tube bearing shall not be less than:

$$d_p = 160 \cdot \sqrt[3]{\frac{F_{ex} \cdot D}{R_{p0.2} \cdot \left(1 - \frac{d_i^4}{d_p^4}\right)}} \quad \text{mm}$$

where:d_p —— propeller shaft diameter, in mm;

d_i —— propeller shaft inner diameter, in mm, 0 for solid shaft.

Forward from the aft stern tube bearing the shaft diameter may be reduced based on direct calculation of the actual bending moment, or by the assumption that the bending moment caused by F_{ex} is linearly reduced to 25% at the next bearing and in front of this linearly to zero at third bearing.

Bending due to maximum blade forces F_b and F_f have been disregarded since the resulting stress levels are much lower than the stresses caused by the blade failure load.

② The stresses due to the peak torque Q_{peak} shall have a minimum safety factor of S =1.5 against yielding in plain sections and S =1.0 in way of stress concentrations in order to avoid bent shafts.

Considering peak torque, the minimum shaft diameter is not to be less than that calculated from the following formulae:

Plain shaft:
$$d_p = 210 \cdot \sqrt[3]{\frac{Q_{peak} \cdot S}{R_{p0.2} \cdot \left(1 - \frac{d_i^4}{d_p^4}\right)}} \quad \text{mm}$$

Notched shaft:
$$d_p = 210 \cdot \sqrt[3]{\frac{Q_{peak} \cdot S \cdot \alpha_t}{R_{p0.2} \cdot \left(1 - \frac{d_i^4}{d_p^4}\right)}} \quad \text{mm}$$

where:α_t —— local stress concentration factor in torsion.

Notched shaft diameter shall in any case not be less than the required plain shaft diameter.

③ The torque amplitudes (13.3.5.8(4)) with the corresponding number of load cycles shall be used in an accumulated fatigue evaluation where the safety factor is S_{fat} =1.5. If the plant has high engine excited torsional vibrations (e.g. direct coupled 2-stroke engines), this shall also be considered.

④ The fatigue strengths σ_F and τ_F (3 million cycles) of shaft materials may be assessed on the basis of the material's yield or 0.2% proof strength as:

$$\sigma_F = 0.436 \cdot R_{p0.2} + 77 = \tau_F \cdot \sqrt{3} \quad \text{MPa}$$

This is valid for small polished specimens (no notch) and reversed stresses, see "VDEH 1983 Bericht Nr. ABF11 Berechnung von Wöhlerlinien für Bauteile aus Stahl".

The high cycle fatigue (HCF) is to be assessed based on the above fatigue strengths, notch factors (i.e. geometrical stress concentration factors and notch sensitivity), size factors, mean stress influence and the required safety factor of 1.6 at 3 million cycles increasing to 1.8 at 10^9 cycles.

The low cycle fatigue (LCF) representing 10^4 cycles is to be based on the smaller value of yield or 0.7 of tensile strength/√3. The criterion utilises a safety factor of 1.25.

The LCF and HCF as given above represent the upper and lower knees in a stress-cycle diagram. Since the required safety factors are included in these values, a Miner sum of unity is acceptable.

(3) Intermediate shaft

The intermediate shafts are to be designed to fulfil the requirements of 13.3.6.5(2)②~④.

(4) Shaft connections

Shaft connections are to satisfy the following requirements. Keyed connections (except for splined shaft) are not to be used.

① Shrink fit couplings (keyless)

See 13.3.6.5(1)①. A safety factor of S = 1.8 shall be applied.

② Flange mounting

The flange thickness is to be at least 20% of the required shaft diameter.

Any additional stress raisers such as recesses for bolt heads shall not interfere with the flange fillet unless the flange thickness is increased correspondingly.

The flange fillet radius is to be at least 8% of the shaft diameter.

The diameter of ream fitted (light press fit) bolts shall be chosen so that the peak torque is transmitted with a safety factor of 1.9. This accounts for a prestress. Pins shall transmit the peak torque with a safety factor of 1.5 against yielding (see the formula in 13.3.6.5(1)②) .

The bolts are to be designed so that the blade failure load F_{ex} (13.3.5.6) in backward direction does not cause yielding.

③ Splined shaft connections

Splined shaft connections can be applied where no axial or bending loads occur. A safety factor of S = 1.5 against allowable contact and shear stress resulting from peak torque shall be applied.

(5) Gear transmissions

① Shafts

Shafts in gear transmissions shall meet the same safety level as intermediate shafts, but where relevant, bending stresses and torsional stresses shall be combined (e.g. by von Mises for static loads). Maximum permissible deflection in order to maintain sufficient tooth contact pattern shall be considered for the relevant parts of the gear shafts.

② Gearing

The gearing shall fulfil following three acceptance criteria: tooth root stresses, pitting of flanks, and scuffing. In addition to above 3 criteria subsurface fatigue may need to be considered.

Common for all criteria is the influence of load distribution over the face width. All relevant parameters are to be considered, such as elastic deflections (of mesh, shafts and gear bodies), accuracy tolerances, helix modifications, and working positions in bearings (especially for multiple input single output gears).

The load spectrum (see 13.3.6.5) may be applied in such a way that the numbers of load cycles for the output wheel are multiplied by a factor of (number of pinions on the wheel / number of propeller blades Z). For pinions and wheels operating at higher speeds the numbers of load cycles are found by multiplication with the gear ratios. The peak torque (Q_{peak}) is also to be considered during calculations.

Cylindrical gears can be assessed on the basis of the international standard ISO 6336 Pt. 1-6, provided that “method B” is used. Equivalent requirements in Appendix 1, Chapter 10, PART THREE of the Rules can also be applied.

For Bevel Gears the methods or standards used or acknowledged by CCS can be applied provided that they are properly calibrated.

Tooth root safety shall be assessed against the peak torque, torque amplitudes (with the pertinent average torque) as well as the ordinary loads (open water free running) by means of accumulated fatigue analyses. The resulting factor of safety is to be at least 1.5. (Ref ISO 6336 Pt 1, 3 and 6 and Appendix 1, Chapter 10, PART THREE of the Rules)

The safety against pitting shall be assessed in the same way as tooth root stresses, but with a minimum resulting safety factor of 1.2. (Ref ISO 6336 Pt 1, 2 and 6 and Appendix 1, Chapter 10, PART THREE of the Rules)

The scuffing safety (flash temperature method – ref. ISO/TR 13989-1 and ISO/TR 13989-2) based on the peak torque shall be at least 1.2 when the FZG class of the oil is assumed one stage below specification.

The safety against subsurface fatigue of flanks for surface hardened gears (oblique fracture from active flank to opposite root) is to be assessed at the discretion of CCS. (It should be noted that high overloads can initiate subsurface fatigue cracks that may lead to a premature failure. In lieu of analyses UT inspection intervals may be used.)

③ Bearings

See 13.3.6.5(9).

④ Gear wheel shaft connections

The torque capacity shall be at least 1.8 times the highest peak torque Q_{peak} (at considered rotational speed) as determined in 6.5 without exceeding the permissible hub stresses of 80% yield.

(6) Clutches

Clutches shall have a static friction torque of at least 1.3 times the peak torque Q_{peak} and dynamic friction

torque 2/3 of the static.
Emergency operation of clutch after failure of e.g. operating pressure shall be made possible within reasonably short time. If this is arranged by bolts, it shall be on the engine side of the clutch in order to ensure access to all bolts by turning the engine.
(7) Elastic couplings
There shall be a separation margin of at least 20% between the maximum response torque and the torque where any mechanical twist limitation and/or the permissible maximum torque of the elastic coupling, valid for at least a single load cycle, is reached, expressed as follows:

$$Q_{peak} < 0.8 \cdot T_{k\max}(N=1) \qquad \text{kNm}$$

A sufficient fatigue strength shall be demonstrated at design torque level $Q_r(N=x)$ and $Q_A(N=x)$. This may be demonstrated by interpolation in a Weibull torque distribution (similar to Figure 13.3.6.5-1):

$$\frac{Q_r(N=x)}{Q_r(N=1)} = 1 - \frac{\log(x)}{\log(Z \cdot N_{ICE})} \qquad \text{and}$$

$$\frac{Q_A(N=x)}{Q_A(N=1)} = 1 - \frac{\log(x)}{\log(Z \cdot N_{ICE})}$$

where $Q_r(N=1)$ corresponds to Q_{peak} and $Q_A(N=1)$ to Q_{Amax}.

$$Q_r(\mathrm{N}=5\times10^4) \cdot S < T_{k\max}(\mathrm{N}=5\times10^4) \qquad \text{kNm}$$

$$Q_r(\mathrm{N}=1\times10^6) \cdot S < T_{kv} \qquad \text{kNm}$$

$$Q_A(\mathrm{N}=5\times10^4) \cdot S < \Delta T_{k\max}(\mathrm{N}=5\times10^4) \qquad \text{kNm}$$

where $Q_r(N=1)$ corresponds to Q_{peak} and $Q_A(N=1)$ to Q_{Amax}.
S is the general safety factor for fatigue, equal to 1.5.
See figures below when using the above formulae:

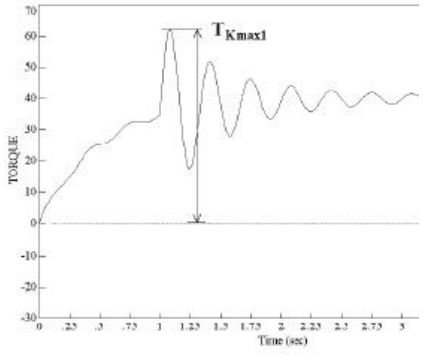


Figure 13.3.6.5(7)-1

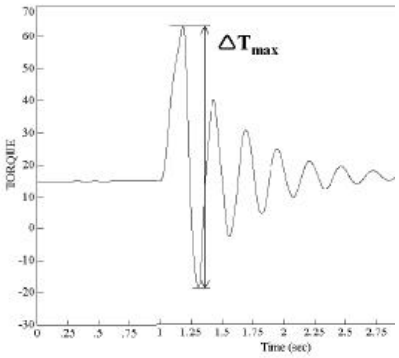


Figure 13.3.6.5(7)-2

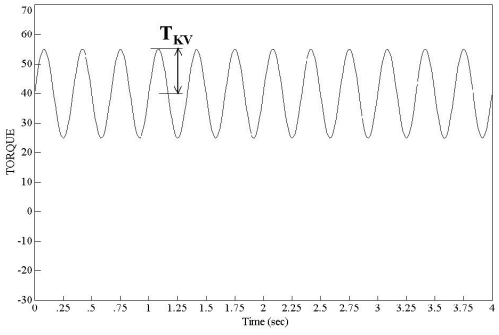


Figure 13.3.6.5(7)-3

The torque amplitude (or range Δ) shall not lead to fatigue cracking, i.e. exceeding the permissible vibratory torque. The permissible torque may be determined by interpolation in a Weibull torque distribution where T_{kmax1} respectively ΔT_{kmax} refer to 50000 cycles and T_{kv} refer to 10^6 cycles. See illustration in below Figures 13.3.6.5(7)-1, 13.3.6.5(7)-2 and 13.3.6.5(7)-3.

$$T_{k\max 1}(\mathrm{N}=5\times10^4) \geq Q_r(\mathrm{N}=5\times10^4) \qquad \text{kNm}$$

(8) Crankshafts

Special considerations apply for plants with large inertia (e.g. flywheel, tuning wheel or PTO) in the non-driving end front of the engine (opposite to main power take off).

(9) Bearings

The aft stern tube bearing as well as the next shaft line bearing are to withstand F_{ex} as given in 13.3.5.6, in such a way that the ship can maintain operational capability. Rolling bearings are to have an L_{10a} lifetime of at least 40 000 hours according to ISO 281. Thrust bearings and their housings are to be designed to withstand with the maximum response thrust specified in 13.3.5.7 and the axial force resulting from the blade failure load specified in 13.3.5.6. For the purpose of calculation, except for F_{ex}, the shafts are assumed to rotate at rated speed. For pulling propellers special consideration is to be given to loads from ice interaction on the propeller hub.

(10) Seals

Seals are to prevent egress of pollutants and be suitable for the operating temperatures. Contingency plans for preventing the egress of pollutants under failure conditions are to be documented.

Seals installed are to be suitable for the intended application. The manufacturer is to provide service experience in similar applications and/or testing results for consideration by CCS.

13.3.6.6 Azimuthing main propulsors

In addition to the above requirements, special consideration shall be given to those loading cases which are extraordinary for propulsion units when compared with conventional propellers. The estimation of load cases shall reflect the way the thrusters are intended to operate on the specific ship. In this respect, for example, the loads caused by the impacts of ice blocks on the propeller hub of a pulling propeller shall be considered. Furthermore, loads resulting from the thrusters operating at an oblique angle to the flow shall be considered. The steering mechanism, the fitting of the unit, and the body of the thruster shall be designed to withstand the loss of a blade without damage. The loss of a blade shall be considered for the propeller blade orientation which causes the maximum load on the component being studied. Typically, top-down blade orientation places the maximum bending loads on the thruster body.

Azimuth thrusters shall also be designed for estimated loads caused by thruster body/ice interaction. The thruster body shall withstand the loads obtained when the maximum ice blocks, which are given in section 13.3.5.2, strike the thruster body when the ship is at a typical ice operating speed. In addition, the design situation in which an ice sheet glides along the ship's hull and presses against the thruster body should be considered. The thickness of the sheet should be taken as the thickness of the maximum ice block entering the propeller, as defined in section 13.3.5.2.

13.3.7 Prime movers

13.3.7.1 Engines are to be capable of being started and running the propeller in bollard condition. Propulsion plants with CP propeller are to be capable being operated even when the CP system is at full pitch as limited by mechanical stoppers.

13.3.7.2 The arrangement of compressed air for mechanical starting arrangements (including capacity of air receivers and charging capacity) is to satisfy relevant requirements of 9.5.1, Chapter 9, PART THREE of the Rules. In addition, for a ship with the ice class PC1~PC6, if its propulsion engine has to be reversed for going astern, the charging time required by 9.5.1.2, Chapter 9, PART THREE of the Rules is not to exceed 0.5h.

13.3.7.3 Provisions shall be made for heating arrangements to ensure ready starting from cold of the emergency power units at an ambient temperature applicable to the Polar Class of the ship. Emergency power units shall be equipped with starting devices with a stored energy capability of at least three consecutive starts at the above mentioned temperature. The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent mean of starting is provided. A second source of energy shall be provided for an additional three starts within 30 min., unless manual starting can be demonstrated to be effective.

13.3.8 Equipment fastening loading accelerations

13.3.8.1 Essential equipment and supports shall be suitable for the accelerations as indicated in the following paragraphs. Accelerations are to be considered as acting independently.

13.3.8.2 Longitudinal Impact Accelerations, a_l

Maximum longitudinal impact acceleration at any point along the hull girder is calculated by the following formula:

$$a_l = (F_{IB} / \Delta)\ \{[1.1\ tan(\gamma + \varphi)] + [7\frac{H}{L}]\} \qquad \text{m/s}^2$$

where: φ ——maximum friction angle between steel and ice, normally taken as 10 degrees;

γ ——bow stem angle at waterline, in degrees;

Δ ——displacement, in kt;

L ——length between perpendiculars, in m;

H ——distance in meters from the water line to the point being considered, in m;

F_{IB} ——vertical impact force, defined in 13.2.13.2(1).

13.3.8.3 Vertical Accelerations, a_v

Combined vertical impact acceleration at any point along the hull girder is calculated by the following formula:

$$a_v = 2.5\ (F_{IB} / \Delta)F_X \qquad \text{m/s}^2$$

where:F_{IB} and Δ are the same as 13.3.8.2;

F_X——1.3 at FP, 0.2 at midships, 0.4 at AP, 1.3 at AP for vessels conducting ice breaking astern. Intermediate values to be interpolated linearly.

13.3.8.4 Transverse impact acceleration, a_t

Combined transverse impact acceleration at any point along hull girder is calculated by the following formula:

$$a_t = 3F_i \frac{F_X}{\Delta} \qquad \text{m/s}^2$$

where:Δ is the same as 13.3.8.2;

F_i ——total force normal to shell plating in the bow area due to oblique ice impact, defined in 13.2.3.2(2);

F_X—— 1.5 at FP, 0.25 at midships, 0.5 at FP, 1.5 at AP for vessels conducting ice breaking astern. Intermediate values to be interpolated linearly.

13.3.9 Auxiliary systems

13.3.9.1 Machinery shall be protected from the harmful effects of ingestion or accumulation of ice or snow. Where continuous operation is necessary, means should be provided to purge the system of accumulated ice or snow.

13.3.9.2 Means should be provided to prevent damage to tanks containing liquids due to freezing.

13.3.9.3 Vent pipes, intake and discharge pipes and associated systems shall be designed to prevent blockage due to freezing or ice and snow accumulation.

13.3.10 Sea Inlets and Cooling Water Systems

13.3.10.1 Cooling water systems for machinery that is essential for the propulsion and safety of the vessel, including sea chest inlets, shall be designed for the environmental conditions applicable to the ice class.

13.3.10.2 At least two sea chests are to be arranged as ice boxes (sea chests for water intake in severe ice conditions) for ice class PC1 to PC5 inclusive. The calculated volume for each of the ice boxes shall be at least $1m^3$ for every 750 kW of the totally installed power. For PC6 and PC7 there shall be at least one ice box located preferably near centre line.

13.3.10.3 Ice boxes are to be designed for an effective separation of ice and venting of air.

13.3.10.4 Sea inlet valves are to be secured directly to the ice boxes. The valve shall be a full bore type.

13.3.10.5 Ice boxes and sea bays are to have vent pipes and are to have shut off valves connected directly to the shell.

13.3.10.6 Means are to be provided to prevent freezing of sea bays, ice boxes, ship side valves and fittings above the load water line.

13.3.10.7 Efficient means are to be provided to re-circulate cooling seawater to the ice box. Total sectional area of the circulating pipes is not to be less than the area of the cooling water discharge pipe.

13.3.10.8 Detachable gratings or manholes are to be provided for ice boxes. Manholes are to be located above the deepest load line. Access is to be provided to the ice box from above.

13.3.10.9 Openings in ship sides for ice boxes are to be fitted with gratings, or holes or slots in shell plates. The net area through these openings is to be not less than 5 times the area of the inlet pipe. The diameter of holes and width of slot in shell plating is to be not less than 20 mm. Gratings of the ice boxes are to be provided with a means of clearing. The means of clearing is to be of a type using low pressure steam. Clearing pipes are to be provided with screw-down type non return valves.

13.3.11 Ballast tanks

13.3.11.1 Efficient means are to be provided to prevent freezing in fore and after peak tanks and wing

tanks located above the water line and where otherwise found necessary.

13.3.12 Ventilation systems

13.3.12.1 The air intakes for machinery and accommodation ventilation are to be located on both sides of the ship at locations where manual de-icing is possible. Anti-icing protection of the air inlets may be accepted as an equivalent solution (De-icing and anti-icing are defined in Chapter 23 of this PART) to location on both sides of the ship and manual de-icing. Notwithstanding the above, multiple air intakes are to be provided for the emergency generating set and are to be as far apart as possible.

13.3.12.2 The temperature of the inlet air shall be suitable for the safe operation of the machinery and the thermal comfort in the accommodation. Accommodation and ventilation air intakes shall be provided with means of heating, if needed.

13.3.13 Steering systems

13.3.13.1 The design ice force on rudder shall be transmitted to the rudder stops required by 13.1.5.8, Chapter 13, PART THREE of the Rules without damage to the steering system.

An ice knife shall in general be fitted to protect the rudder in centre position. The ice knife shall extend below BWL. Design forces shall be determined according to the 13.2.15 of this Chapter.

13.3.13.2 The rudder actuator is to be designed for a holding torque obtained by multiplying the open water torque (considering however a maximum speed of 18 knots), by following factors in Table 13.3.13.2:

Ice class factors of steering system **Table 13.3.13.2**

Ice class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Factor	5	5	3	3	3	1.5	1.5

13.3.13.3 The design pressure for calculations to determine the scantlings of the rudder actuator is to be at least 1.25 times the maximum working pressure corresponding to the holding torque defined above.

13.3.13.4 The rudder actuator is to be protected by torque relief arrangements, assuming the following turning speeds listed in Table 13.3.13.4 [deg/s] without an undue pressure rise (see 13.1.7.2(2), Chapter 13, PART THREE of the Rules for undue pressure rise). If the rudder and actuator design can withstand such rapid loads, this special relief arrangement is not necessary and a conventional one may be used instead (13.1.7.2, Chapter 13, PART THREE of the Rules).

Steering gear turning speeds **Table 13.3.13.4**

Ice class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Turning speeds (°/s)	10	10	7.5	7.5	7.5	6	6

13.3.13.5 Additionally for icebreakers, fast-acting torque relief arrangements are to be fitted in order to provide effective protection of the rudder actuator in case of the rudder being pushed rapidly hard over against the stops.

For hydraulically operated steering gear, the fast-acting torque relief arrangement is to be so designed that the pressure cannot exceed 115% of the set pressure of the safety valves when the rudder is being forced to move at the speed indicated in Table 13.3.13.5, also when taking into account the oil viscosity at the lowest expected ambient temperature in the steering gear compartment.

For alternative steering systems the fast-acting torque relief arrangement is to demonstrate an equivalent degree of protection to that required for hydraulically operated arrangements.

Steering gear turning speeds for icebreaker s **Table 13.3.13.5**

Ice class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Turning speeds (°/s)	40	40	20	20	20	15	15

13.3.14 Alternative design

13.3.14.1 As an alternative to this Section – a comprehensive design study may be submitted and may be requested to be validated by an agreed test programme.

CHAPTER 14 REDUNDANT PROPULSION SYSTEMS

Section 1 GENERAL PROVISIONS

14.1.1 General requirements

14.1.1.1 This Chapter applies to ships having one of the class notations specified in 14.1.3 below. Redundant propulsion systems are to comply with the provisions of this Chapter in addition to other relevant requirements of the Rules.

14.1.1.2 The system design is to ensure that at least the following functions are maintained in the event of a single failure as defined in 14.1.4.1:

(1) The propulsion system will enable the ship to maintain a full load speed not less than 7 knots while heading into BF 3 weather conditions with corresponding wave conditions. Adequate steering capability is also to be maintained at this speed.

(2) The propulsion system will enable the ship to maintain its position and heading while heading into BF 8 weather conditions with corresponding wave conditions. The results of model testing may be accepted.

(3) Availability of safety systems, including fire-fighting systems, bilge system, navigation lights, communication apparatus, life-saving appliances.

(4) Habitability conditions, including minimum lighting, ventilation, galleys, refrigerated stores, drinking water or evaporator services.

14.1.2 Definitions

14.1.2.1 For the purpose of this Section, the following definitions are applicable:

(1) Propulsion system is a system designed to provide thrust to a ship, consisting of one or more propulsion machines, one or more propulsors, one or more steering system, all necessary auxiliaries and associated control, alarm and safety systems.

(2) Propulsion machine is a device (e.g. diesel engine, turbine, electrical motor, etc.) which develops mechanical energy to drive a propulsor.

(3) Steering system is a system designed to control the direction of movement of a ship, including the rudder, steering gear, etc.

(4) Propulsor is a device (e.g. propeller, waterjet) which imparts force to a column of water in order to propel a ship, together with any equipment necessary to transmit the power from the propulsion machinery to the device (e.g. shafting, gearing, etc.).

(5) Auxiliary services system means all support systems (e.g. fuel oil system, lubricating oil system, cooling water system, compressed air and hydraulic systems, etc.) which are required to run propulsion machinery, propulsors, steering systems and generating sets.

14.1.3 Class notations

14.1.3.1 Where requested by the Owner, propulsion systems which are found to comply with the requirements specified in this Chapter may be assigned the following class notations, as appropriate.

(1) PR-1: A ship fitted with two or more propulsion machines but only a single propulsor and steering system.

(2) PR-2: A ship fitted with two or more propulsion machines and also two or more propulsors and steering systems.

(3) PR-1S: A ship fitted with only a single propulsor and steering system but having two or more propulsion machines arranged in separate compartments.

(4) PR-2S: A ship fitted with two or more propulsion machines and also two or more propulsors and steering systems, and having the propulsion machines and associated steering systems arranged in separate compartments.

14.1.4 Single failure

14.1.4.1 For the purpose of this Chapter, a single failure mainly includes but is not limited to the following:

(1) loss of a propulsion machine;

(2) any failure of a non-static component of systems which are necessary for the operation of the propulsion machine or steering gear, including prime movers, controls and monitoring of fuel oil system, lubricating oil system, cooling system, compressed air system;

(3) any failure of heat exchangers, including heat generators, necessary for propulsion (i.e. auxiliary boilers, fuel oil heaters, lubricating oil coolers, fresh water coolers, reduction gear oil coolers);
(4) any failure of any non-static component of fuel oil and lubricating oil transfer system;
(5) any failure of any of the power generating sets;
(6) any failure of any electric apparatus, including the main switchboard, electric motors, transformers, distribution switchboards, panels;
(7) any failure of the propulsor, including propeller, propeller shaft, intermediate shafts, bearings, couplings, reduction gears;
(8) any failure of any static component of the systems which are necessary for the operation of the propulsion machine or steering gear, including integrity of pipes, valves, pipe fittings, pipe supports, tanks;
(9) loss of one compartment due to fire or flooding;
(10) any failure of any component directly caused by a single failure of another component. For example, the complete loss of a main propulsion engine or of any part of the main switchboard is not to impair the proper functioning of the other machinery and equipment. Any of consequence failures are also to be considered.

14.1.4.2 A single failure concept is applied to the class notations as follows:
(1) For PR-1, the single failure concept is applied to the propulsion machines, its auxiliary service systems and its control systems. This notation does not consider failure of the propulsor or steering system, or total loss of the propulsion machinery compartment or steering gear room due to fire or flood.
(2) For PR-2, the single failure concept is applied to the propulsion system. This notation does not consider total loss of the propulsion machinery compartment or steering gear room due to fire or flood.
(3) For PR-1S, the single failure concept is applied as for PR-1**,** but total loss of one of the propulsion machinery compartments due to fire or flood is also considered.
(4) For PR-2S, the single failure concept is applied as for PR-2, but total loss of one of the propulsion machinery compartments or steering gear rooms due to fire or flood is also considered.
(5) For PR-1 and PR-2, any single failure described in 14.1.4.1(8) may not be considered.

14.1.5 Plans and documents

14.1.5.1 The following plans and documents are to be submitted for approval:
(1) Technical specifications for the redundant propulsion system, including all design details to achieve functional objectives;
(2) All plans of arrangement, piping and electrical system and calculations related to the redundant propulsion system;
(3) An Failure Mode and Effect Analysis (FMEA) report;
(4) A testing plan.

14.1.5.2 An operating manual for the redundant propulsion system is to be submitted for reference. The operating manual is to include the following, as a minimum:
(1) ship's name and CCS class number;
(2) simplified diagram and descriptions of the propulsion systems in normal condition;
(3) simplified diagram and descriptions of the propulsion redundancy features;
(4) step-by-step instructions for the use of the redundancy features;
(5) description of the communication systems;
(6) detailed instructions for local propulsion machinery control;
(7) model test and full-scale test report;
(8) propulsion capability in terms of estimated worst sea states.

14.1.5.3 The above required plans and documents, except for the FMEA report, need not be resubmitted if they have been fully covered in plans and documents submitted in compliance with other relevant requirements of the Rules.

14.1.6 Failure Mode and Effect Analysis (FMEA)

14.1.6.1 An FMEA is to be carried out in accordance with the requirements of 14.1.6.2 to 14.1.6.4 for the propulsion systems and their auxiliary service systems to demonstrate that a single failure, as specified in 14.1.4, will not cause loss of all propulsion capability, and that the redundancy design is able to achieve the functions specified in 14.1.1.2. Typical sub-systems to be analyzed include associated control and monitoring arrangements, data communications, power supplies (electrical, hydraulic or pneumatic), fuel, lubricating, cooling, etc.

14.1.6.2 Methods and procedures for the FMEA may also be referred to the relevant requirements in Appendix 4 of the International Code for the Safety of High-Speed Craft, 2000 adopted by IMO and CCS Guidelines for Application of Failure Mode and Effects Analysis.

14.1.6.3 The FMEA is to be organized in terms of system, equipment and function, and to cover main components of all relevant systems as far as possible. The failure modes and the measures in response to them are to be determined.
14.1.6.4 An FMEA report is to generally cover but not restricted to the following:
(1) description of main components of all relevant systems and functional block diagram showing interactions between them;
(2) all potential failure modes and their causes;
(3) the effects on the system of each failure mode and the severity of consequences;
(4) measures to detect failures;
(5) measures or corrective actions in response to failures; and
(6) testing procedures to verify conclusions of the FMEA, etc.

Section 2 SYSTEM ARRANGEMENT AND DESIGN

14.2.1 Propulsion machinery and propulsors

14.2.1.1 For PR-1 notation, at least two propulsion machines are to be provided. The propulsion machines and auxiliary service systems may be located in the same propulsion machinery compartment.
14.2.1.2 For PR-2 notation, at least two propulsion machines and two propulsors are to be provided. The propulsion machines, shafting, gearing and auxiliary service systems may be located in the same propulsion machinery compartment.
14.2.1.3 For PR-1S notation, at least two propulsion machines are to be provided. The propulsion machines and auxiliary service systems are to be arranged in separate compartments segregated by bulkheads of A-60 class. The gearing and shafting systems are to be separated from the propulsion machines in such a way that a fire or flood in the propulsion machinery compartment does not impair any function specified in 14.1.1.2. The bulkhead segregating gearing and propulsion machinery compartments is to be watertight with at least A-0 class.
14.2.1.4 For PR-2S notation, at least two propulsion machines and two propulsors are to be provided. The propulsion machines, shafting, gearing and auxiliary service systems are to be arranged in separate compartments segregated by watertight bulkheads of A-60 class.
14.2.1.5 For PR-1 and PR-1S notations where only two propulsion machines and one propulsor are provided, efficient means, e.g. clutches, are to be provided to disconnect propulsion machines from the propulsor.

14.2.2 Steering systems

14.2.2.1 For PR-1 and PR-1S notations, the steering system, including rudder and steering gear, only need comply with other relevant requirements of the Rules.
14.2.2.2 For PR-2 notation, at least two steering systems are to be provided. The steering gear and auxiliary service systems may be arranged in the same compartment.
14.2.2.3 For PR-2S notation, at least two steering systems are to be provided. The steering gear and auxiliary service systems are to be arranged in separate compartments segregated by bulkheads of at least A-0 class.

14.2.3 Auxiliary service systems

14.2.3.1 At least two independent auxiliary service systems, including fuel oil service tanks, are to be provided. These two systems may be designed to be completely independent, or with interconnections between them provided that effective means to disconnect or isolate the systems from each other are fitted.
14.2.3.2 For PR-1S and PR-2S notations, a fire or flood in any of the compartments is not to affect auxiliary service systems in continuously supporting the redundant propulsion.
14.2.3.3 Interconnections of auxiliary service systems arranged in separate compartments are not to compromise the fire and watertight integrity of the separating bulkhead, and effective disconnection or isolation means are to be fitted at both sides of the bulkhead. Position status of the disconnection or isolation means is to be provided at the navigation bridge and the centralized control station.

14.2.4 Electrical power systems

14.2.4.1 The power system serving the propulsion system is to be so arranged that it will not accept total black-out as the consequence of any single failure. Single failure is defined as any system or component breakdown of technical nature. For ships with PR-1S and PR-2S notations, single failure is to also include a fire or flood in any of the compartments.

14.2.4.2 Where the ship's essential equipment is fed from one main switchboard, the sections of main bus bars are to be connected with circuit breakers capable of breaking the maximum short circuit current in the system. Such breakers are to be appropriately protected. For ships with PR-1S and PR-2S notations, the sections of main bus bars are to be located in separate compartments segregated by bulkheads of A-60 class. Both ends of the lines linking the sections of main bus bars are to be fitted with appropriately protected circuit breakers.

14.2.4.3 For PR-1S and PR-2S notations, the generating sets and their auxiliary systems, the distribution systems and the power management systems are to be located in separate compartments segregated by bulkheads of A-60 class. Interconnections of systems located in separate compartments are not to compromise the fire and watertight integrity of the segregating bulkhead, and effective disconnection or isolation means are to be fitted at both sides of the bulkhead. Position status of the disconnection or isolation means is to be provided at the navigation bridge and the centralized control station.

14.2.5 Control and monitoring systems

14.2.5.1 Two independent propulsion systems are to be provided with their respective independent control and monitoring systems. If arranged with common parts, these are to be arranged with redundancy so that any single failure can be effectively isolated.

14.2.5.2 For PR-1S and PR-2S notations, the control and monitoring system for the propulsor (e.g. controllable pitch propeller control), including all associated cabling, is to be duplicated in each compartment, and fire or flooding of one compartment is not to adversely affect operation of the propulsor from the other compartment.

14.2.5.3 For PR-2S notation, the control and monitoring system for the steering system, including all associated cabling, is to be duplicated in each compartment, and fire or flooding of one compartment is not to adversely affect control and monitoring of the redundant steering system.

14.2.5.4 Uninterrupted power supply (UPS) is to be provided as backup for the control and monitoring system. For PR-1S and PR-2S notations, at least two UPSs are to be provided.

14.2.6 Interior communication systems

14.2.6.1 For PR-1S and PR-2S notations, the communication cables to each control station are to be routed through an appropriate compartment, and fire or flooding of one compartment is not to adversely affect the interior communication from the control station in another compartment.

14.2.7 Other facilities

14.2.7.1 For PR-1S and PR-2S notations, piping and cabling serving the equipment or systems, which are redundant to each other, is not to be routed through the same compartment. Where this is unavoidable, such pipes could run together in ducts of A-60 class, and such cables in cable ducts of A-60 class. Cable connection boxes are not allowed in such ducts.

14.2.7.2 For PR-1S and PR-2S notations, in case of fire or flooding in one of the compartments arranged with the propulsion system equipment, the availability of fire-fighting systems, bilge system, lighting and ventilation serving another compartment is to be maintained.

14.2.7.3 For PR-1S and PR-2S notations, in case of fire or flooding in one of the compartments arranged with the propulsion system equipment, the availability of facilities related to ship safety and habitability conditions (e.g. fire-fighting, drainage, ventilation, lighting, galleys, refrigerated stores, drinking water, navigation lights, communication apparatus and life-saving appliances) is to be maintained.

CHAPTER 15 ADDITIONAL REQUIREMENTS FOR ELECTRICALLY PROPELLED SHIPS

Section 1 GENERAL PROVISIONS

15.1.1 General requirements

15.1.1.1 The requirements of this Chapter apply to ships using electric motors as main propulsion.

15.1.1.2 In addition to this Chapter, electrically propelled ships are to comply with the applicable provisions of other PARTs and Chapters of the Rules.

15.1.1.3 Ships complying with the provisions of this Chapter are assigned with the following notation: Electrical Propulsion System

15.1.2 Definitions

15.1.2.1 The definitions in this Chapter are as follows:

(1) propulsion motor means electrical motor intended to provide propulsion power.

(2) propulsion generator means generator mainly used for power supply of the propulsion system.

Section 2 ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION INSTALLATIONS

15.2.1 General requirements

15.2.1.1 The torque available in the propulsion motors for manoeuvring is to be capable of stopping or reversing the ship in a reasonable time at the maximum service speed.

15.2.1.2 Adequate torque margin is to be provided in propulsion systems to guard against the motor from being pulled out of synchronism during rough weather or during turning in the case of multiple-screw ships, and to ensure a reliable start under all ambient conditions.

15.2.1.3 The lubrication of bearings of propulsion motors, gearing and shafting is to be effective at all normal speeds from creep speed upwards, either ahead or astern. The above shafts and bearings are not to be damaged by slow rotation caused by motor(s) or propeller(s) under all predictable oil temperature conditions.

15.2.1.4 The electric power for the propulsion system may be derived from generating sets dedicated to propulsion duty or from a common power plant which serves both propulsion and ship service loads.

15.2.1.5 Under no circumstances should a single failure of the electrical or control system cause a permanent failure of the propulsion system.

15.2.1.6 If electric propulsion is the sole means of propulsion for the ship, at least two independent propulsion motors and converters are generally to be provided. When any stator or propulsion motor fails, the remaining propulsion power is to be sufficient to maintain the efficient propulsion of the ship.

15.2.1.7 If the ship is provided with a single shaft-line propulsion system with one electric motor, a separate propulsion system is to be installed, providing power sufficient to maintain efficient propulsion of the vessel.

15.2.1.8 Propulsion systems having two or more generators, or two or more semiconductor converters, or two or more motors on one propeller shaft is to be so arranged that any unit may be taken out of service and disconnected electrically without affecting the operation of the remaining units.

15.2.1.9 The common power plant is to meet the following requirements:

(1) The control system of the plant is to ensure a safe distribution of power between propulsion and ship services, with tripping of non-essential loads and/or reduction in the propulsion power if necessary.

(2) Where one generating set is out of action, the remaining sets are to be capable of providing all essential and normal ship service loads while maintaining an effective level of propulsion power, i.e. ensuring a speed of not less than 7 knots or half of the design speed, whichever is the greater. Special consideration may be given in exceptional circumstances subject to agreement of CCS.

15.2.2 Harmonics

15.2.2.1 The electric installations are to be so designed as to prevent the harmful effects of electromagnetic interference generated by semiconductor converters.

15.2.2.2 For an electrical network fitted with semiconductor converters, single order harmonics distortion and up to 15th harmonic are not to exceed 5% of the rated voltage, and the distortion is to be reduced with the higher order and gradually reduced to 1% at 100th harmonic. The total harmonic distortion at dedicated systems (e.g. switchboard for electrical propulsion) is not to exceed 10%, otherwise documentation from the manufacturer is to be submitted indicating that the equipment is designed for operation at a higher level of distortion. This may be specially considered by CCS upon agreement among all parties to the contract.
15.2.2.3 The effects of the harmonics of currents and voltages are to be taken into consideration for the design of the propulsion motors.
15.2.2.4 Means (e.g. suitable filters) are to be provided, where necessary, to limit the effects of the rate of harmonics to the system and to other semiconductor converters.
15.2.2.5 The total harmonic distortion (THD) of the voltage waveform is the ratio of the rms value of the harmonic content to the rms value of the fundamental, expressed in per cent and may be calculated using the expression:

$$V_{THD} = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \times 100\%$$

where: V_{THD} — the total harmonic distortion;
V_h — rms amplitude of a harmonic voltage of order h;
V_1 — rms amplitude of the fundamental voltage.

15.2.3 Power management system for common power plant

15.2.3.1 For ships fitted with a common power plant, a power management system having the following functions is to be provided:
(1) automatic start-up and parallel operation of standby generators;
(2) preventing overloading the generators, by reducing the propulsion load and/or tripping non-essential loads;
(3) heavy load inquiry;
(4) ensuring even load sharing between on-line generators.

15.2.4 Prime movers

15.2.4.1 Prime movers and their governors are to comply with the requirements of Chapter 7, 8 or 9 of PART THREE of the Rules. The rated power in conjunction with the overloading and load built-up capabilities are to be adequate to supply the power needed during transitional changes under operating conditions of the electrical equipment due to manoeuvring and the heavy sea and weather conditions.
15.2.4.2 Machinery piping systems for the prime movers are to comply with all the requirements specified in Chapter 4 of PART THREE of the Rules applicable to main engines.
15.2.4.3 In the case of parallel operation of propulsion generators, the governing systems used are to permit stable operation to be maintained over the entire operational speed range of the prime movers.
15.2.4.4 During manoeuvring of the ship, the regenerated power produced by the propulsion motor is not to cause tripping due to overspeed, neither to cause dangerous overload of the system. Where necessary, braking resistors are to be provided to absorb excess amounts of regenerated energy and to reduce the speed of rotation of the propulsion motor.
15.2.4.5 The overspeed protective device is to be set to a speed in excess of the highest possible speed during the periods of power regeneration, and the generating set including prime mover is to be so designed that no damage will be raised from an overspeed equal to that at which the governor is set.

15.2.5 Propulsion generators and propulsion motors

15.2.5.1 Variable speed propulsion motors fitted with an integral fan are to be capable of operating at speeds below the rated speed with full-load torque, full-load current, full-load excitation or in similar conditions, and temperature rises are not to exceed the limits given in 3.2.3 of PART FOUR of the Rules.
15.2.5.2 The temperature of the cooling air of propulsion generators and propulsion motors provided with forced air ventilation is to be continuously monitored by means of direct reading thermometers which are readable from outside the machine and a remote audible alarm actuated by suitable temperature detectors.
15.2.5.3 For propulsion generators and propulsion motors fitted with heat exchangers in closed cooling circuits, the flow of primary and secondary coolants is to be monitored. Alternatively, monitoring of winding temperatures plus alarms may be accepted in lieu of the flow monitoring. In addition, consideration is to be given, where necessary, to the provision of devices for detecting leakage of cooling liquid in the machine enclosure and the operation of an associated alarm.

15.2.5.4 The collector rings and commutators are to be suitably arranged for easy maintenance. For purposes of inspection, repair, withdrawal and replacement of the field coils, provision is to be made for easy access to all windings and bearings.
15.2.5.5 Effective means are to be provided for the propulsion motors to prevent condensation and accumulation of moisture when they are out of service. If steam is used for heating purpose, no joints of steam pipes are permitted within the motors.
15.2.5.6 Propulsion motors are to be capable of withstanding the effects of a sudden short circuit at their terminals under all conditions without suffering damage.
15.2.5.7 Stator windings of AC machines and interpole windings of DC machines, rated above 500 kW, are to be provided with embedded temperature sensors. These sensors are to be arranged to operate an alarm if the temperature exceeds a predetermined safe value.
15.2.5.8 Stator windings of AC propulsion motors supplied by varied-frequency semiconductor converters are to be capable of withstanding the voltage variation due to action of the high-frequency switch of inverters.
15.2.5.9 Stator windings of AC propulsion motors supplied by semiconductor converters are to be provided with means to restrict generation of shaft current so as to prevent early damage of bearings.
15.2.5.10 Propulsion generators and propulsion motors are to have a protection degree of at least IP 23. High voltage propulsion generators and propulsion motors are to have a protection degree of at least IP 44.
15.2.5.11 Propulsion generators and propulsion motors with semiconductor converters are to be designed for the expected harmonics of the system. A sufficient reserve is to be considered for the temperature rise due to total harmonic distortion.

15.2.6 Excitation

15.2.6.1 The output current and voltage of exciters and their supply are to be suitable for the output required during manoeuvring and overcurrent conditions including short circuit as well as stalling condition. For this reason, attention is to be paid to the strength of shafts and couplings of rotating sets and to the power of their driving machines.
15.2.6.2 Any single fault in the propulsion generators and propulsion motors excitation system is not to result in a total loss of propulsion power.
15.2.6.3 Field circuits are to be provided with means for suppressing voltage rise when a field switch is opened.
15.2.6.4 For Ward-Leonard systems, arrangements for generator and motor excitation are to be such that if the motor excitation circuit is opened by a switch or contactor, the generator excitation circuit is simultaneously interrupted, or the generator voltage is immediately reduced to zero.
15.2.6.5 In constant voltage systems with two or more independently controlled motors in parallel on the same generator(s), the armature circuit-breaker is to be tripped when an excitation circuit is opened by a switch or contactor.
15.2.6.6 If the protection device of the excitation system trips, the respective circuit breaker of the propulsion generator or motor is also to trip and is to be alarmed.
15.2.6.7 Where fuses are used for excitation circuit protection, it is essential that they do not interrupt the field discharge resistor circuit upon rupturing.

15.2.7 Propulsion control

15.2.7.1 Main and local controls are to be provided, independent of any remote or automatic system, to permit effective control of the propulsion equipment. Should the remote control system fail, local operation is to be possible within a reasonably short time and is to have the highest priority.
15.2.7.2 Either manual operation or operation with the aid of power or a combination of both may be used. All manoeuvring switches, field-regulators and controllers are to be operable effortlessly. If failure of the power supply occurs in systems with power-aided control (e.g. with electrical, pneumatic or hydraulic aid), the control of any such device is to be capable of being restored by other suitable means in a short time.
15.2.7.3 When two or more control stations are provided, a selector switch or other means is to be provided for transferring the manoeuvring controls to the designated station. Simultaneous control from more than one control station is not to be possible. Provision is to be made to prevent malfunction due to the transferring of the control stations. In addition, indication is to be located at each control station to indicate which station is in control.
15.2.7.4 Levers for operating contactors, line switches, field switches and similar devices of ahead and astern circuits are to be interlocked to prevent their improper operation causing ahead and astern circuits being energized simultaneously.

15.2.7.5 The reference value transmitters in the control stations and the control equipment are to be so designed that any defect in the desired value transmitters or in the cables between the control station and the propulsion system will not cause a substantial increase in the propeller speed.
15.2.7.6 Measures are to be taken that the control of the propulsion system can be activated only when the designated control lever is in zero position and the system is ready for operation.
15.2.7.7 Each control station is to have an emergency stop device which is independent of the control lever. The emergency stops are to be independent of the normal stop, and separate for each propulsion line. The emergency stop device is to be monitored against wire break and short circuit. The emergency stop device is to be protected against inadvertent action.
15.2.7.8 The control system is to limit the propulsion power if the power available from the generator(s) is not sufficient to supply the demand level of propulsion power. In the event of a power limitation, there is to be a visual indication at the control stations.
15.2.7.9 Propulsion control systems are to be stable throughout their normal operating range and arranged to attenuate any effects of cyclic propeller load fluctuations caused by wave action. The control system is to ensure that there is no dangerous overspeed of propulsion motors upon loss of load.
15.2.7.10 Failure of an automatic control system is not to result in the following consequences:
(1) substantial change in the propeller speed and propulsion direction;
(2) total breakdown of power supply system (i.e. blackout);
(3) changes in available power, that is, no start or stop of generators is to occur.

15.2.8 Cables

15.2.8.1 The conductors of cables external to the components of the propulsion plant, other than cables and interconnecting wiring for computers, data loggers or other automation equipment requiring currents of very small value, are to consist of not less than seven strands and have a cross-sectional area of not less than 1.5 mm^2.
15.2.8.2 Propulsion cables are not to have splices or joints, except terminal joints, and all cable terminals of the propulsion system are to be sealed.
15.2.8.3 For determination of current rating of main cables (cables connecting generators to semiconductor converters and cables connecting semiconductor converters to propulsion motors) of the propulsion system, the additional heating effects due to harmonics in the system are to be taken into account.

15.2.9 Protection

15.2.9.1 Over-current protective devices, if fitted in the main circuits, are to be set sufficiently high so that there is no possibility of their action due to the over-current caused by manoeuvring or normal operation in heavy seas, or in floating pack ice.
15.2.9.2 For DC systems in which overspeed of the propulsion motors may occur (due to light loads or loss of propeller, etc.), suitable overspeed protection is to be provided.
15.2.9.3 Where separately driven DC generators are connected electrically in series, means is to be provided to prevent rotation reversal of a generator upon failure of the driving power of its prime-mover.
15.2.9.4 In excitation circuits, there is to be no overload protection causing the opening of the circuit, except for excitation circuits with semiconductor converters.
15.2.9.5 Means are to be provided for discriminative tripping or rapid reduction of the magnetic fluxes of generators or motors to ensure that over-currents do not reach the value which may endanger the propulsion plant.
15.2.9.6 Means for earth leakage detection is to be provided for the main propulsion circuit and be arranged to operate an alarm upon the occurrence of an earth fault. Where fault current flowing is liable to cause damage, arrangements for opening the main propulsion circuit are also to be provided. If the neutral is earthed, it is to be through an arrangement which will limit the current not to exceed approximately 20 A upon a fault to earth in the propulsion system.
15.2.9.7 Means are to be provided for earth leakage detection in excitation circuits of propulsion machines, but may be omitted in circuits of brushless excitation systems and of motors rated up to 500 kW.
15.2.9.8 Upon detection of a failure in the generators' excitation systems, an alarm is to be given on the navigation bridge and in the engine control room and actions to bring the system into a safe operational mode are to be automatically executed.
15.2.9.9 In the design of DC machines and their protective systems, consideration is to be given to measures necessary to minimize any damage in the event of short circuit.
15.2.9.10 Direct-current propulsion circuits are not to have fuses. Each circuit is to be protected by overload relays to open the field circuits or by remote-controlled main-circuit interrupting devices.

15.2.9.11 If there is a possibility of blocking the propeller (e.g. during ice-breaking operation), a protection against damage to the propulsion plant is to be provided.
15.2.9.12 Fuses may be provided for filter circuits. Visual and audible alarms are to be provided at the control station for tripping of the fuse.
15.2.9.13 Differential protection or similar protection against internal short-circuit is to be provided for propulsion motors with an output of 1,500 kW or above.
15.2.9.14 The following protection of semiconductor converters is to be provided:
(1) protection against overvoltage in the supply systems to which converters are connected;
(2) protection against over-currents in semiconductor elements during normal operation;
(3) short-circuit protection.
15.2.9.15 Each propulsion transformer is to be protected against primary and secondary side short-circuit. If the primary side of transformers is protected for short-circuit only, overcurrent protection is to be arranged on the secondary side.

15.2.10 Monitoring instrumentation and alarms

15.2.10.1 Alarms and displays associated with the electrical propulsion system are given in Table 15.2.10.1. These alarms and displays are to be located in the centralized control station of the engine room (in the local station if without the centralized control station). Alarms and displays equivalent to those given in the Table may be accepted subject to agreement of CCS. Alarms for safety actions and group alarms for propulsion generators, motors and semiconductor converters are to be provided in the bridge.

Electric propulsion system monitoring, alarm and safety action item list Table 15.2.10.1

System	Monitored parameter	Without class notations			BRC, MCC & AUT-0 notations			Remark
		Alarm	Display	Auto shut-down	Alarm	Display	Auto shut-down	
Propulsion generator (AC & DC)	Bearing lub. oil inlet pressure – low or bearing temperature – high	√	√	√	√	√	√	Prime mover automatic shutdown
	Voltage – off-limits (high/low)		√		√	√		To read all phases
	Frequency – off-limits (high/low)		√		√	√		For AC propulsion generators only
	Current		√			√		To read all phases
	Power		√			√		To indicate power consumed and power available for propulsion in bridge and centralized control station
	Stator windings temperature – high	√	√		√	√		To read all phases; for generators > 500 kW
	Main generator circuit breakers – open/close					√		
	Generator running		√			√		
	Failure of on-line generator				√			
	Transfer of standby generator				√			
	Generator cooling medium temperature – high	√			√	√		If applicable
	Failure of generator cooling pump or fan motor				√			If applicable
	Field voltage and current		√			√		Applicable to electrical excitation system where provided
	Interpole windings temperature – high	√	√		√	√		For DC generators

System	Monitored parameter	Without class notations			BRC, MCC & AUT-0 notations			Remark
		Alarm	Display	Auto shut-down	Alarm	Display	Auto shut-down	
Propulsion Motor (AC & DC)	Bearing lub. oil inlet pressure – low or bearing temperature – high	√	√	√	√	√	√	
	Voltage – off-limits (high/low)		√		√	√		To read all phases.
	Field voltage					√		
	Frequency – off-limits (high/low)				√	√		For AC propulsion motors only. For propulsion motor controlled by frequency converter, the monitoring of the output of frequency converter may be taken as an alternative
	Armature current		√			√		To read all phases
	Field current		√			√		For synchronous motors
	Stator windings temperature – high	√			√	√		To read all phases; for AC motors > 500 kW only
	Motor circuit breakers – open/close					√		
	Motor running		√			√		
	Motor overspeed	√	√	√	√	√	√	For DC propulsion motors
	Failure of on-line motor				√			
	Transfer of standby motor				√			
	Motor cooling medium temperature – high	√			√	√		If applicable
	Failure of cooling pump or fan motor				√			If applicable
	Interpole current		√			√		For DC propulsion motors only
	Differential protection or similar protection	√			√			For motors ≥ 1500 kW
Propulsion Semiconductor converter	Voltage (input)		√			√		
	Current (input)		√			√		
	Overload (high current)	√			√			Alarms before protective device is activated
	Open/close position for assignment switches					√		
	Converter cooling medium temperature – high	√	√		√	√		If applicable
	Failure of converter cooling pump or fan motor	√			√			If applicable
	Inter-phase reactor temperature – high				√	√		
	Tripping of filter circuit fuse	√			√			
Propulsion Transformer	Transformer windings temperature – high	√	√		√	√		

System	Monitored parameter	Without class notations			BRC, MCC & AUT-0 notations			Remark
		Alarm	Display	Auto shut-down	Alarm	Display	Auto shut-down	
Others	Field circuit earth fault	√			√			May be omitted in circuits of brushless excitation systems and of motors rated up to 500 kW
	Main propulsion circuit earth fault		√			√		

15.2.10.2 Ships having machinery notation(s) are to comply with the automatic control and monitoring requirements applicable to diesel engines and gas turbines of propulsion generating sets as well as main boilers and auxiliary steam turbines, as specified in PART SEVEN of the Rules. Where two or more propulsion generating sets are provided and 100% design speed is still achieved upon the shutdown of any of them, only the automatic control and monitoring requirements of PART SEVEN of the Rules for auxiliary diesel engines, auxiliary gas turbines and auxiliary steam turbines are to be complied with.

15.2.11 Special requirements for podded propulsion system

15.2.11.1 Where a ship is fitted with one or more podded propulsion units, the unit used as steering manoeuvring system is to be supplied and controlled in compliance with the requirements of 13.1.8, PART THREE of the Rules.

15.2.11.2 Where the electric motor is supplied by a slip ring, the following checks and tests on the ring are to be considered:

(1) check of the IP protection degree, in accordance with the location of the slip ring;

(2) check of clearances and creepage distances;

(3) check of contact resistance of the slip ring;

(4) endurance test: After the contact pressure and rated current are set, the slip ring is subjected to a rotation test. The number of rotations is evaluated taking into consideration the ship operation and rotation speed control system. The possibility of turning the pod 180° to proceed astern and 360° to return to the original position is to be considered. The ring may be submitted to cycles comprising full or partial rotation in relation to the use of the pod as steering gear. The voltage drops and current are to be recorded. An overload test is to be carried out (minimum 150%, 15s);

(5) check of the behaviour of the slip ring when subjected to the vibration described in IEC Publication 60068-2-6;

(6) check of the behaviour of the slip ring, after damp heat test, as described in IEC Publication 60068-2-30;

(7) after the damp heat test, an insulation resistance test is to be carried out;

(8) dielectric strength test.

15.2.11.3 All system failure alarms are to be displayed in the bridge. Alarms are to be arranged for the pod under the following circumstances:

(1) overload of propulsion motors;

(2) power failure of propulsion motors;

(3) low pressure of hydraulic oil system;

(4) low pressure of lubricating oil supply;

(5) high temperature of lubricating oil;

(6) low level of lubricating oil tank for motor bearings;

(7) high temperature of motor cooling air inlet;

(8) high temperature of motor cooling air outlet;

(9) abnormal operation of bilge pump;

(10) high level of pod bilge.

15.2.11.4 Sensors for control, monitoring and alarm systems located within the pod are to be duplicated, one acting as a standby for the other.

15.2.11.5 An effective cooling system is to be provided for the propulsion motor within the pod, and a standby cooling arrangement is to be provided and available for immediate use.

15.2.11.6 Two independent means of automatic bilge drainage are to be provided for the pod. The number and location of bilge level detectors are to be such that accumulation of liquids will be detected at all design angles of heel and trim.

15.2.11.7 The pod connecting bolts and slewing ring bearings are to comply with recognized standards, as applicable.

15.2.12 Cooling and ventilation

15.2.12.1 Loss of ventilation to compartments with forced air cooling is not to cause loss of propulsion. To this end, two sets of ventilation fans are to be provided, one acting as a standby unit for the other.

15.2.12.2 If semiconductor converters are separately cooled, the plant is to be capable of continuing operation at reduced power level if the cooling system fails. Means to contain any leakage of cooling liquid are to be provided so that the liquid does not cause a failure of the converter or any other electrical equipment located near the converter.

Section 3 STRUCTURAL REQUIREMENTS FOR PODDED PROPULSION UNITS

15.3.1 General requirements

15.3.1.1 Members of the hull support structure for a podded propulsion unit comprise a pedestal girder and its face plate (if fitted) that support the strut, and an orthotropic grillage of webs and floors that are connected to or surround the pedestal girder, as shown in Figure 15.3.1.1. This grillage may be of single or double bottom construction, but normally of double bottom in way of the podded propulsion unit.

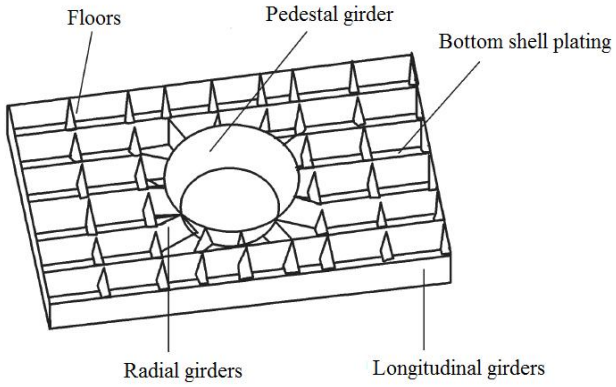


Figure 15.3.1.1

15.3.1.2 The outer ends of radial girders are generally to be connected to bottom longitudinal girders and floors and aligned with them both longitudinally and transversely, transferring the supported load to the hull structure. If the spacing of radial girders is too great, consideration is to be given to arranging supporting brackets between the slewing bearing outer races and pedestal girder to increase the rigidity of outer races. The thickness of the pedestal girder and its surrounding girders is not to be less than the minimum Rule thickness of solid floors or girders at the same positions. Where abutting plates are of dissimilar thickness, the applicable taper requirements of Chapter 2, PART TWO of the Rules are to be complied with.

15.3.1.3 In general, full penetration welding is to be applied in way of connections of the pedestal girder to the bottom shell plating and to the inner bottom plating or top outer races, and in way of the end connections between the radial girders and the pedestal girder. Radial girder webs are to be welded to the underside of the outer races at the top of the pedestal girder and its face plate, if fitted, is to be welded to the outer side of such outer races. Elsewhere, for primary members, double continuous fillet welding is to be applied using a minimum weld factor of 0.34.

15.3.1.4 The hull support structure is to be able to withstand the maximum loads transferred from the strut of podded propulsion unit and is to be sufficiently stiff that any deformation as a consequence of the maximum loads will not exceed the limits required for slewing bearing operation. The limits are to be based on the operational requirements for the pod.

15.3.1.5 The arrangement of the hull support structure and scantlings of its primary members are subject to direct strength analysis according to the following requirements:

(1) The support structure is to be modelled (e.g. elements and mesh size, etc.) by regular means of hull structure direct calculation, and the boundary conditions are to be obtained on the principle that response consequences of the members for assessment are not affected.

(2) Loads are to be provided by the pod manufacturer/designer, generally taking into consideration normal and ultimate conditions of the podded propulsion unit (see Note ① of Table 15.3.1.5).

(3) The calculated stress of the structural member is not to be greater than the permissible value. The permissible stress value is obtained by the material yield strength divided by the corresponding safety factor given in Table 15.3.1.5.

Safety Factor **Table 15.3.1.5**

Condition / Stress type	Normal condition	Ultimate condition
Normal stress	1.67	1.50
Shear stress	2.50	2.25
Equivalent Von Mises stress of plate elements	1.43	1.33

Notes:

① Normal condition means the normal operation condition, in which the structure does not fail while the ship is in normal service; ultimate condition means the most critical condition, in which the structure is subject to the maximum load expected due to accident.

② For check of the equivalent Von Mises stress of plate elements, only the equivalent stresses at the mid plane (membrane) at the element centroid are to be considered. However, high stress due to poor-shape elements may not be considered.

③ The safety factor for a plate element directly connected to the pedestal and located at the corner of a three-dimensional intersection may be appropriately reduced, but not to be less than 1.1. Where refined mesh analysis is applied here, the stress value of the element may be deducted by 5%.

15.3.1.6 In addition, scantlings of primary members are not to be less than those required for the stern structure in PART TWO of the Rules, as applicable.

CHAPTER 16 MEASUREMENT OF VIBRATION AND NOISE

Section 1 GENERAL PROVISIONS

16.1.1 General requirements

16.1.1.1 This Chapter applies to ships of 65 m or over in length applying for the class notations G-ECO,G-ECO VIBx and Gd-ECO NOIx specified in CCS Rules for Green Eco-Ships.

Section 2 NOISE

16.2.1 General requirements

16.2.1.1 Noise is to meet the requirements of Chapter 2, 2.2.1.1(3), 2.5.2 and Chapter 4, 4.3.2 of CCS Rules for Green Eco-Ships. Noise measurements are to be carried out in accordance with CCS Guidelines for Control and Measurement of Noises for Ships and Marine Products.

Section 3 VIBRATION

16.3.1 General requirements

16.3.1.1 Vibration is to meet the requirements of Chapter 2,2.5.1 and Chapter 4, 4.3.1 of CCS Rules for Green Eco-Ships. Vibration measurements are to be carried out in accordance with the requirements of Section 4.

Section 4 MEASUREMENTS AND REPORTS

16.4.1 General requirements

16.4.1.1 The measurements of noise and vibration may be undertaken by CCS or an organization accepted by CCS. The measurements are to be witnessed by a CCS Surveyor.

16.4.2 Instrumentation

16.4.2.1 The vibration measurement and calibration equipment is to comply with ISO 6954:2000 and ISO 8041, and the instrumentation is to include at least a transducer with an appropriate amplifier, and a FFT analyser.

16.4.2.2 The instrumentation used is to be within a calibration validity period specified by the calibration authority, and copies of relevant documents are to be provided prior to measurements and together with the measurement report.

16.4.3 Test conditions for measurements

16.4.3.1 Prior to measurements, a measurement procedure is to be submitted to CCS for approval. This procedure is at least to contain details of the arrangement of measuring points, loading condition, weather condition, machinery operating condition, and measuring equipment. CCS may require additional measurements at the measuring points or locations.

16.4.3.2 Possible deviation from the required conditions may be accepted by CCS and this is to be clearly mentioned in the report.

16.4.3.3 Tests are to be conducted when the ship is fully outfitted and all systems contributing to noise and vibration levels are operational.

16.4.3.4 Generally the main engine is to operate with the power output corresponding to the designed normal seagoing condition, or at least 80% of the maximum continuous power available. All machineries and equipment that may operate simultaneously under normal operation conditions are to be run simultaneously.

16.4.3.5 In general, the tests are to be conducted in deep water, with a water depth not less than 5 times the mean draft and a distance from shore not less than 25 times the ship breadth. For ships usually

operating in shallow waters, the tests are to be performed with conditions corresponding to normal service conditions.

16.4.3.6 The tests are to be conducted in sea conditions not greater than sea state 3 on the WMO sea state code, with the wind force being not greater than 4 on the Beaufort scale.

16.4.3.7 Tests may generally be conducted in sea trial conditions. For cargo ships which may be operated over a large range of drafts, if the designed normal seagoing condition is different from the test conditions, additional measurements may be required.

16.4.3.8 Ship course is to be kept constant as far as possible, with rudder angle variations being within the range of ±2 degrees portside or starboard, for the duration of the measurement.

16.4.3.9 For offshore service ships to be operated at DP, measurements are to be carried out with the side thrusters in an operating condition corresponding to contractual conditions or with at least 40% power on the thrusters.

16.4.4 Vibration measurements

16.4.4.1 Vibration measurements are to be conducted in accordance with ISO 6954:2000 and ISO 20283-2.

16.4.4.2 Measurement locations are to be chosen so that the assessment represents the overall vibration environment on board the ship. In cabins, vibration readings are to be taken in the centre of the floor area. In large spaces, such as restaurants, sufficient measurements are required to define the vibration profile.

16.4.4.3 The vibration measurement report is to comply with ISO 6954:2000 and ISO 20283-2, containing measurement positions and directions indicated on a general arrangement plan, tabulated vibration levels, ship and machinery details, test conditions, and copies of the relevant instrument calibration certificates.

CHAPTER 17 ADDITIONAL REQUIREMENTS FOR GEOTEXTILES LAYERS

Section 1 GENERAL PROVISIONS

17.1.1 Application

17.1.1.1 This Chapter applies to ships provided with special equipment for laying geotextiles.

17.1.1.2 Geotextiles layers are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of CCS Rules for Materials and Welding and of the flag State Administration, if any.

17.1.2 Notation

17.1.2.1 Ships complying with the provisions of this Chapter may be assigned the notation: Geotextiles Layer.

17.1.3 Definition

17.1.3.1 Geotextiles layers mean ships provided with special equipment for laying geotextiles, which are engaged in operations of laying soft mattress related to construction of cofferdams on land and floating structure projects under different environmental conditions such as coastal shoals and deep-water harbors.

17.1.4 Plans and documents

17.1.4.1 In addition to the plans and documents required in the relevant PARTs and Chapters of the Rules, the following plans and documents are to be submitted to CCS for approval (where applicable):

(1) Plan of reinforcement structure of geotextiles laying turning plate equipment;

(2) Plan of reinforcement structure of geotextiles laying positioning equipment.

17.1.4.2 The following plans and documents are to be submitted to CCS for information (where applicable):

(1) Information related to geotextiles laying equipment (such as turning plate, guide beam, coil drum and crane, etc.);

(2) Strength calculations of reinforcement structure of geotextiles laying equipment;

(3) Arrangement plan of positioning equipment of geotextiles laying operation;

(4) Strength calculations of reinforcement structure of geotextiles laying operation.

For special structures and arrangement, expansion of the submission scope of plans and documents may be required if deemed necessary by CCS.

Section 2 HULL STRUCTURE AND ARRANGEMENT

17.2.1 Hull structure

17.2.1.1 For hull structural strength, consideration is to be given to necessary reinforcement of the support structure of the equipment used in geotextiles laying operation.

17.2.2 Requirements for the support structure of geotextiles laying equipment

17.2.2.1 The strength of support and reinforcement structure of geotextiles laying equipment and geotextiles laying operation positioning equipment is to be checked by referring to the relevant requirements of Section 7, Chapter 3, PART TWO of the Rules.

17.2.3 Bunker

17.2.3.1 The bunker cannot be directly positioned under the working deck, unless a void hold or ballast tank etc. is arranged between the working deck and the bunker.

17.2.4 Hold arrangement

17.2.4.1 The working deck is to be distant from the engine room air inlet and outlet as far as possible.

Section 3 EQUIPMENT

17.3.1 General provisions

17.3.1.1 Geotextiles layers are to be capable of anchor mooring positioning or dynamic positioning.

17.3.2 Wheel house

17.3.2.1 A geotextiles layer is to be provided with a wheel house with good vision or a 360° video system for the whole ship, and communication by means of hardwired connection between the wheel house and the remote control station is to be provided.

CHAPTER 18 ADDITIONAL REQUIREMENTS FOR HEAVY EQUIPMENT CARRIER

Section 1 GENERAL PROVISIONS

18.1.1 Application

18.1.1.1 This Chapter applies to the carriers having larger deck areas and specially engaged in loading/unloading on decks and long-distance transporting the complete sets of heavy equipment and project facilities with the larger dimension/weight such as bridge cranes and heavy equipment at sea (hereinafter called the heavy equipment carriers).

18.1.1.2 The designer is to carry out the calculation and verification for longitudinal strength and the strength of deck and supporting structure below according to the heavy equipment intended to carry and submit the calculation information to CCS for information.

18.1.1.3 Besides the applicable requirements in this Chapter and the other Parts of the Rules as well as the CCS Rules for Materials and Welding, the heavy equipment carriers are to comply with the relevant provisions of the Administrations of flag States.

18.1.1.4 Where it complies with the requirements of this Chapter, the heavy equipment carrier may be assigned to the class notation of:

Bridge Crane and Heavy Equipment Carrier

Section 2 OUTFITTINGS

18.2.1 Equipment number

18.2.1.1 The equipment number for heavy equipment carriers is to comply with the requirements of 3.2.1 in Chapter 3 of PART TWO of the Rules, the total lateral windward area of the designed maximum complete sets of heavy equipment and project facilities is to be taken into consideration in the calculation of equipment number. Where such lateral windward area of the heavy equipment and project facilities can not be provided, the equipment number may be taken by increasing two grades.

18.2.2 Securing

18.2.2.1 The securing for the heavy equipment carriers carrying complete sets of heavy equipment and project facilities is to meet the requirements of CCS Guidelines for the Preparation of the Cargo Securing Manual. It may be acceptable that the ship’s dynamic load is obtained by the seakeeping characteristics analysis and quasi-static force analysis under the worst sea conditions occurred possibly through the recognized software.

Section 3 INTACT STABILITY

18.3.1 Intact stability

18.3.1.1 The intact stability of heavy equipment carriers is to meet the requirements for dry cargo ships of the flag State Administrations.

18.3.1.2 The streamlined reduction is not to be considered when the wind area of complete sets of heavy equipment and project facilities is calculated, however, the lateral overlapping area may be deducted.

Section 4 SPECIAL REQUIREMENTS FOR EXTRA BALLAST OPERATION

18.4.1 General requirements

18.4.1.1 Extra ballast operation for heavy equipment carrier means:

(1) an operational condition for a ship with the draft not exceeding operational draft mark during the ballasting operation in order to load/unload the complete sets of heavy equipment and project facilities at port; and
(2) ship shifting at port with restrictions such as passing through bridge, etc., under the ballast condition of (1).
18.4.1.2 The extra ballast operation may be carried out provided that the heavy equipment carrier meets the requirements of this Section. The implementation of extra ballast operation is to be in compliance with the requirements of Extra Ballast Operational Procedure Manual in Section 5 of this Chapter.
18.4.1.3 During the extra ballast operation, the heavy equipment carrier is also to be in accordance with the following restricted meteorological/sea conditions:
(1) Beaufort scale not exceeding 5 for the extra ballast operation mentioned in 18.4.1.1(1);
(2) Beaufort scale not exceeding 4 and at the normal calm sea area (significant wave height less than 0.3 m) for the extra ballast operation mentioned in 18.4.1.1(2).
18.4.1.4 In order to ensure the ship draft and floating condition meet the relevant requirements during its extra ballast operation, ship draft meter is to be provided onboard and capable of indicating the forward draft, aft draft and amidship draft in the bridge.

18.4.2 Operational draft mark

18.4.2.1 Where the ship is ballasted to the maximum draft, the ratio between reserve buoyancy under freeboard deck and displacement at the draft is not to be less than 15%.
18.4.2.2 The maximum draft waterline mark which is allowable under extra ballast operation is to be assigned at the ship's both sides, refer to Figure 18.5.2.5 in Section 5 of this Chapter. The maximum extra ballast waterline mark is a horizontal line 400 mm in length and 25 mm in breadth. The upper edge of the line is to be in line with the maximum draft waterline and marked the letters of EB of 115 mm in height and 75 mm in width to indicate the extra ballast operational draft at both ends above the line.
18.4.2.3 Before the maximum draft waterline mark of extra ballast operation for heavy equipment carrier is assigned, it is to be verified that the requirements of reserve buoyancy, stability and strength of this Section have been met and marked in the Extra Ballast Operational Procedure Manual.

18.4.3 Intact stability and floating condition

18.4.3.1 The maximum angle of heel during the loading/unloading of complete set of heavy equipment and project facilities is not to exceed the following:
(1) where the ship affects the action of beam wind evenly with the load of 0.22 kPa (speed of 18 m/s), the angle of heel is not to exceed the emerging angle of freeboard deck edge, the level of wind moment is to be measured to the half draft from the centroid of wind area, for calculation, the wind area of complete set of heavy equipment and project facilities is to be in accordance with the requirement of 18.3.1.2 of this Chapter;
(2) 12°, whichever is the less.
18.4.3.2 The elements of each ballasting step under ship's extra ballast condition as corrected for free surface are to comply with the following:
(1) where the ship affects the action of beam wind evenly with the load of 0.22 kPa (speed of 18 m/s), the angle of heel is not to exceed the emerging angle of freeboard deck edge, the level of wind moment is to be measured to the half draft from the centroid of wind area, for calculation, the wind area of complete set of heavy equipment and project facilities is to be in accordance with the requirement of 18.3.1.2 of this Chapter;
(2) the initial metacentric height (GM) is not to be less than 0.5 m;
(3) the positive range of righting lever (GZ) curve is not to be less than 15°;
(4) the area under the righting lever (GZ) curve up to the angle of maximum GZ is not to be less than 0.035 m·rad.

18.4.4 Structural strength

18.4.4.1 The hull longitudinal strength under extra ballast condition is to meet the requirements of Longitudinal Strength in Section 2 of Chapter 2, PART TWO of the Rules, in which the wave load of hull beam is to be determined by direct calculation, or is obtained as 40% of the value calculated according to the formula in 2.2.3 of Section 2 in Chapter 2, PART TWO of the Rules.
18.4.4.2 The local strength of hull structure under extra ballast condition is to be verified.

Section 5 EXTRA BALLAST OPERATIONAL PROCEDURE MANUAL

18.5.1 General requirements

18.5.1.1 The purpose of Extra Ballast Operational Procedure Manual is to indicate that the ship meets with the requirements of extra ballast operation types and operational draft mark, stability and strength and provide the operational procedure and specification which the implementation for extra ballast operation – filling and discharging the ballast water is to be complied with to the master.

18.5.1.2 The Extra Ballast Operational Procedure Manual is to be submitted to CCS for approval.

18.5.2 Contents of the Extra Ballast Operational Procedure Manual

18.5.2.1 The initial condition of ship before extra ballast operation includes:

(1) loading conditions of complete sets of heavy equipment and project facilities, including the datum such as quantity, location, weight and center of gravity;

(2) datum such as quantity, location, weight and center of gravity of consumables carried onboard the ship;

(3) datum such as quantity, location, weight and center of gravity of ballast water loaded onboard the ship.

18.5.2.2 Steps for ballast operation such as filling of ballast water under full-loaded arrival condition are as follows:

Initial condition:

(1) loading condition of complete sets of heavy equipment and project facilities……

(2) condition of consumables carried onboard the ship……

(3) loading condition of ballast water……

Each steps of extra ballast operation:

(1) Step 1……

Filling the following ballast tanks with ballast water to the completely full capacity:

……

(2) Step 2……

Filling the following ballast tanks with ballast water to the completely full capacity:

……

(3) Step 3……

Filling the following ballast tanks with ballast water to the completely full capacity:

……

18.5.2.3 The stability and strength calculation for steps specified in 18.5.2.2 of this Section for each operation mentioned in 18.5.1.1 of this Section is to be given as Tables 18.5.2.3(1) and 18.5.2.3(2):

Stability and Strength Calculation for Each Step of Extra Ballast Operation during Loading/Unloading of Complete Sets of Heavy Equipment and Project Facilities at Port

Table 18.5.2.3(1)

Loading Condition ID	Exps 0	Exps 1	Exps 2	Exps 3	……
Ballast steps	Step 0	Step 1	Step 2	Step 3	……
Displacement (t)					……
MAX. BM (kN·m)					……
Location of MAX. BM					……
MAX. SF (kN)					……
Location of MAX. SF					……
Draft at LCF (m)					……
Draft at AP (m)					……
Draft at FP (m)					……
Mean draft (m)					……
Trim (m)					……
VCG (m)					……
Corrected GM (m)	(> 0.5)	(> 0.5)	(> 0.5)	(> 0.5)	(> 0.5)
MAX. GZ (m)					
Heel at MAX. GZ (deg)					
Area under GZ curve up to heel at MAX. GZ (m·rad)	(> 0.002)	(> 0.002)	(> 0.002)	(> 0.002)	(> 0.002)
Reserve Buoyancy (%)	(> 15)	(> 15)	(> 15)	(> 15)	(> 15)
Positive stability range (deg)	(> 10)	(> 10)	(> 10)	(> 10)	(> 10)

Stability and Strength Calculation for Each Steps of Extra Ballast Operation during Shifting of Ship Carried with Complete Sets of Heavy Equipment and Project Facilities

Table 18.5.2.3(2)

Loading Condition ID	Bdg 0	Bdg 1	Bdg 2	Bdg 3	……
Ballast steps	Step 0	Step 1	Step 2	Step 3	……
Displacement (t)					……
MAX. BM (kN·m)					……
Location of MAX. BM					……
MAX. SF (kN)					……
Location of MAX. SF					……
Draft at LCF (m)					……
Draft at AP (m)					……
Draft at FP (m)					……
Mean draft (m)					……
Trim (m)					……
VCG (m)					……
Corrected GM (m)	(> 0.5)	(> 0.5)	(> 0.5)	(> 0.5)	(> 0.5)
MAX. GZ (m)					
Heel at MAX. GZ (deg)					
Area under GZ curve up to heel at MAX.GZ (m·rad)	(> 0.002)	(> 0.002)	(> 0.002)	(> 0.002)	(> 0.002)
Reserve Buoyancy (%)	(> 15)	(> 15)	(> 15)	(> 15)	(> 15)
Positive stability range (deg)	(> 10)	(> 10)	(> 10)	(> 10)	(> 10)

18.5.2.4 The format table of capacity of ballast tank is given in Table 18.5.2.4:

Table of Capacity of Ballast Tank **Table 18.5.2.4**

No.	Compartment	Frame No.	Capacity (m^3)	LCG (m)	TCG (m)	VCG (m)	F.S.I. (m^4)
1							
…							

18.5.2.5 The sketch of maximum draft waterline mark (starboard) is given in Figure 18.5.2.5:

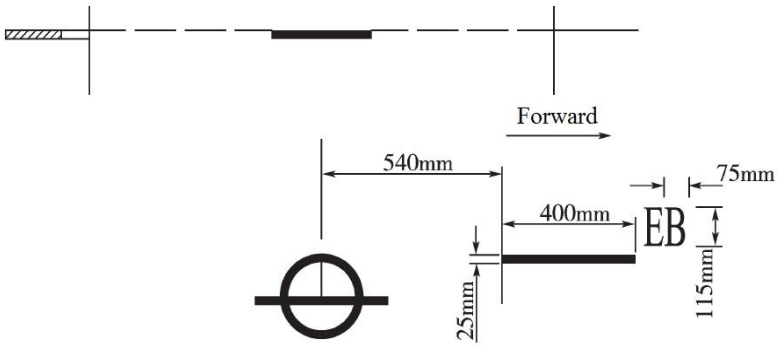


Figure 18.5.2.5 The Sketch of Maximum Draft Waterline Mark (starboard)

where: EB means the extra ballast.

CHAPTER 19 AC SHORE CONNECTION SYSTEMS

Section 1 GENERAL PROVISIONS

19.1.1 General requirements

19.1.1.1 This Chapter applies to AC shore connection systems with rated voltages (voltage between phases) of 15 kV or less for power supply to ships in port. Such systems are capable of transferring load between the shore supply and the ship's electrical power via blackout or temporary parallel running.

19.1.1.2 Guidelines for operations of shore connection are to be developed for ships to ensure operational safety for shore connection.

19.1.1.3 Where an HVSC system is arranged otherwise than specified in this Chapter, consideration may be given by CCS to acceptance of such arrangement, provided that it achieves an equivalent safety level.

19.1.1.4 During shore supply, proper measures are to be taken to avoid and minimize any harm to the safety of the ship and its personnel due to loss of electrical power.

19.1.1.5 The shipside installations fitted in areas where flammable gas or vapour and/or combustible dust may be present are to be certified safe type as suitable for the flammable gas or vapour and/or combustible dust encountered, otherwise they are to be prohibited from being used.

19.1.1.6 A compatibility assessment is to be performed to verify the possibility to connect the ship to shore supply prior to the first arrival at a terminal, taking into account the compatibility of voltage, frequency, capacity and short-circuit current of the shore supply.

19.1.2 Class notation and product certificate

19.1.2.1 Ships fitted with shipside installations for HVSC systems and complying with the requirements of this Chapter may be, upon request, approval of drawings, survey and testing, assigned by CCS the following class notation: AMPS. The maintenance, suspension, cancellation and reinstatement of the class notation are to be in compliance with Section 9, Chapter, PART ONE of the Rules.

19.1.2.2 Shipside installations for HVSC systems will be, upon survey, issued by CCS appropriate product certificates.

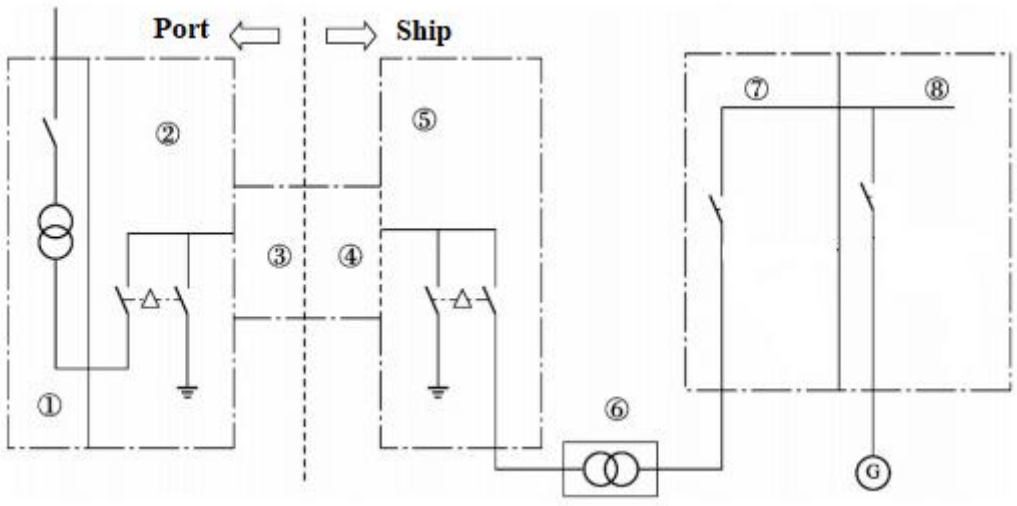
19.1.3 Definitions and terms

19.1.3.1 For the purpose of this Chapter, the following definitions apply:

(1) An **AC shore connection system** is the equipment used for power supply to ships in port, consisting of shipside and shore installations.

(2) An **AC low voltage shore connection system** is an AC shore connection system with rated voltages (voltage between phases) of 1 kV or less for power supply from port (shore supply) to ship's power distribution system.

(3) An **AC high voltage shore connection system** is an AC shore connection system with rated voltages (voltage between phases) of shore supply to ship's distribution system from 1 kV up to and including 15 kV. A typical AC HVSC system is shown in Figure 19.1.3.1(3).



① HV shore supply system (including transformers); ② HV shore distribution box; ③ Shore connection socket box; ④ Cable management system and cables (with plugs); ⑤ Shore connection switchboard; ⑥ Transformer; ⑦ Shore receiving control panel; ⑧ Generator panel of main switchboard

Figure 19.1.3.1(3) Diagram of a Typical AC High Voltage Shore Connection System

(4) **Shipside installations** are the equipment fitted on the ship for connection to shore supply, generally consisting of plugs/sockets, shore connection switchboards, transformers, shore receiving control panel (usually integrated into the main switchboard), shore connection cables and a cable management system.
(5) **Shore installations** are the equipment fitted at a terminal or port and used for power supply to ships, generally consisting of an HV shore distribution box, transformers, frequency converters (if applicable) and a shore connection socket box.
(6) A typical **cable management system** consists of cable winches, automatic controls of cable length or tension together with associated instrumentation. The ship's shore connection cables are picked and laid through the cable management system for connection to shore supply.
(7) **Equipotential bonding** provides electric connections between conductive parts, intended to achieve equipotentiality.

19.1.4 Drawings and information

19.1.4.1 Drawings and information specified in 19.1.4.2 and 19.1.4.3 of this Chapter are to be submitted to CCS for approval.
19.1.4.2 The following drawings and information for ship system are to be submitted for approval:
(1) Estimation of loads under shore connection;
(2) Evaluation of short-circuit currents under shore connection (applicable to ships provided with AC high voltage shore connection systems, and ships provided with AC low voltage shore connection systems for which short circuit current calculations are submitted in accordance with requirements of 1.1.3.1(2) of PART FOUR of the Rules);
(3) Drawing of the electrical system of shipside installations;
(4) Arrangement of shipside installations;
(5) Mooring test program for HVSC system (to be submitted to the CCS attending surveyor for review).
19.1.4.3 The following drawings and information for marine products of shipside installations of HVSC system are to be submitted for approval:
(1) Technical specifications of the system;
(2) Switchboards (including shore connection switchboard, transformer cabinet (if fitted), shore receiving control panel):
① electrical schematic diagram;
② list of components;
③ structural drawing (including external size, housing material, housing structure, coating, layout of faceplate, internal arrangement, rating plate, nameplate);
(3) Details of plugs/sockets;
(4) Details of shore connection cables;

(5) Details of cable management system;
(6) Test programs for the above equipment.
19.1.4.4 The following information are to be submitted to CCS for reference:
(1) Technical instructions of the system (for drawing approval of both ship and marine products);
(2) Instructions for fitting, using and maintenance (for drawing approval of marine products);
(3) List of system equipment (for drawing approval of marine products).

Section 2 SYSTEM DESIGN

19.2.1 General requirements

19.2.1.1 The AC shore connection system is to have a capacity sufficient for ensuring expected services (including emergency services) normally required for the ship while in port.
19.2.1.2 An equipotential bonding between the ship and the shore is to be established, and this bonding is not to change the earthing principle of the ship's power distribution system.
19.2.1.3 During shore supply, at least one of the ship's main generators or harbour generators is to be standby and, upon blackout of the shore supply, automatically started and connected to the main switchboard.

19.2.2 Emergency shutdown

19.2.2.1 Emergency shutdown facilities are to be provided to ensure instantaneously opening shore connection circuit breakers on shore and on board the ship. The emergency shutdown facilities are to be designed according to the fail-safe principle and so arranged as to prevent inadvertent activation.
19.2.2.2 The emergency shutdown facilities are to be activated automatically in any of the following cases:
(1) loss of equipotential bonding (applicable to AC high voltage shore connection system);
(2) alarm signal from the cable management system (mechanical stress of cable is too high, or remaining cable length is too short);
(3) loss of any control and monitoring circuits of HVSC system;
(4) disengaging of power plugs from any socket while the connection is live.
19.2.2.3 Emergency stop buttons that activate emergency shutdown facilities are to be provided at least at:
(1) the location of the shore connection switchboard;
(2) the position of operation of the cable management system;
(3) the location of the shore receiving control panel.
19.2.2.4 Activation of the emergency shutdown is to result in an audible and visual alarm at a manned location① of the ship in port.
19.2.2.5 Following the emergency shutdown, the circuit breaker is not to be closed until reset manually.

19.2.3 Safety interlocking

19.2.3.1 For the AC high voltage shore connection system, an earthing switch complying with the requirements of 5.3 of IEC 62271-200 is to be provided at the end of shore connection cable on board. While the shore connection circuit breakers are in the open position, the conductors of the cables are to be kept earthed by the earthing switch.
19.2.3.2 Arrangements are to be provided so that the shore connection circuit breaker (fitted in the shore connection switchboard) cannot be closed or automatically opened from its closed position in any of the following cases:
(1) equipotential bonding is not established (applicable to AC high voltage shore connection system);
(2) the pilot contact circuit of shore connection plugs/sockets is not established②;
(3) emergency shutdown facilities are activated;
(4) loss of any control and monitoring circuits of HVSC system;
(5) alarm signal from the cable management system (tension level of cable is too high, or remaining cable length is too short);
(6) earth fault on the ship's distribution system (applicable to AC high voltage shore connection system);
(7) the shore supply is not present.

---

① The location of the on-duty operator of shore connection as specified in the Guidelines for operations of shore connection.
② The connection is established by proper contact of the pilot contactors embedded in the plug and socket.

19.2.4 Cable management system

19.2.4.1 A cable management system is to be provided for shore connection cables to ensure that:
(1) the mechanical tension applied to the cables will not exceed the designed permissible value;
(2) the possibility of transmitting mechanical stresses to cables or terminals is excluded;
(3) the shore connection circuit breaker will be instantaneously opened where cables are excessively extended.

19.2.5 Load transfer

19.2.5.1 Load transfer between the shore supply and the shipstantaneously opened where cabcuted via blackout or temporary parallel running.
19.2.5.2 Where load transfer is executed via blackout, means are to be provided to prevent simultaneous supply from the ship's generators (including emergency ones) and the shore supply.
19.2.5.3 Where load transfer is executed via temporary parallel running of the shipboard generator and the shore supply, compliance of voltage and frequency variations with the requirements of 1.2.2, Chapter 1, PART FOUR of the Rules is to be ensured.
19.2.5.4 The temporary running in parallel is also to comply with the following requirements:
(1) Means are to be provided for automatic synchronization of the shipboard generator and the shore supply.
(2) Load transfer is to be automatic.
(3) The duration of the temporary parallel running is to be as short a period as practicable allowing for the safe transfer of the load.
(4) If the defined transfer time limit for load transfer is exceeded, the transfer is to be stopped, shore connection circuit breakers are to be opened, and an audible and visual alarm is to be activated at a manned location.

19.2.6 Short-circuit protection

19.2.6.1 Where only the shore supply is used, the short-circuit current calculation is to be referred to CCS guidance document GD021-1999 Calculation of Short-Circuit Current Fed through AC Shore Power System or other methods acceptable to CCS. For temporary parallel running of the shore supply and the ship's electrical power, the short-circuit current calculation is to be referred to IEC 60909 publications or other methods acceptable to CCS.
19.2.6.2 During shore supply, the prospective short-circuit current level at any point in the ship's power distribution system is not to exceed the short-circuit breaking and making capacities of circuit breakers installed onboard.
19.2.6.3 For assessment of short-circuit currents, the prospective short-circuit current level for both the shore supply and the ship's electrical power are to be taken into account. Consideration may be given to the following measures for restricting prospective short-circuit currents during connection to shore supplies:
(1) preventing parallel connection of shore supplies with the ship's sources of electrical power; or
(2) restricting the number of the ship's generating sets operating during parallel connection to transfer load; and/or
(3) restricting the short-circuit current level from shore supply to the ship's power distribution system.

Section 3 ELECTRICAL EQUIPMENT

19.3.1 General requirements

19.3.1.1 In addition to the requirements of this Chapter, shipside installations of the AC high voltage shore connection system are to comply with the requirements of 2.14.2.3, 2.14.2.4, 2.14.4, 2.14.6 and 2.14.7 of Chapter 2, PART FOUR of the Rules.
19.3.1.2 Equipment with voltage above 1 kV is not to be installed in the same enclosure with low voltage equipment, unless segregation or other suitable means are provided to ensure that access to low voltage equipment is obtained without danger.
19.3.1.3 In addition, shipside installations are to be arranged to prevent interference with the ship's mooring and cargo handling operations.
19.3.1.4 The degrees of protection provided by enclosures for components of shipside installations are to be appropriate to the location where they are situated, and comply with the requirements of 1.3.2.2 of Chapter 1 and 2.14.2.2 of Chapter 2, PART FOUR of the Rules.

19.3.2 Shore connection switchboard

19.3.2.1 The shore connection switchboard of the AC high voltage shore connection system is to be in accordance with the publication IEC 62271-200, service continuity LSC1.
19.3.2.2 The shore connection switchboard is to be located as close as possible to shore connection cables on board.
19.3.2.3 The switchboard is to include a circuit-breaker for protection against undervoltage, overvoltage and short-circuit current.
19.3.2.4 The shore connection switchboard is to be fitted with the following instruments, indicators and alarms:
(1) one voltmeter: all three phases;
(2) one ammeter: all three phases;
(3) one frequency meter;
(4) one kilowatt-hour meter (optional);
(5) shore power indicator: power connected;
(6) circuit breaker tripping with alarm;
(7) earth-fault alarm (applicable to AC high voltage shore connection system);
(8) phase rotation indicator.
19.3.2.5 Where measures for restricting short-circuit currents are taken as required in 19.2.6.3(3), a corresponding device is to be provided in the shore connection switchboard.

19.3.3 Shore receiving control panel

19.3.3.1 The shore receiving control panel is to be in accordance with the applicable requirements in Section 3, Chapter 3, PART FOUR of the Rules.
19.3.3.2 The shore receiving control panel is in general to be a component of the main switchboard, which is to be provided with isolation switches or circuit breakers.
19.3.3.3 The shore receiving control panel is to be fitted with the following instruments:
(1) two voltmeters[①]: 1 for measuring the voltage in each phase of the shore supply, 1 for measuring the busbar voltage;
(2) one ammeter: all three phases of the shore supply;
(3) two frequency meters[①]: 1 for measuring the frequency of the shore supply, 1 for measuring the bus-bar frequency;
(4) phase rotation indicator;
(5) synchronizing device.

19.3.4 Transformers

19.3.4.1 Transformers are to be of the separate winding type for primary and secondary sides and comply with the applicable requirements of the series publications IEC 60076.

19.3.5 Cables

19.3.5.1 High voltage shore connection cables are to comply with the requirements of Annex A of the publication IEC 80005-1 or other acceptable standards. Low voltage shore connection cables are to comply with the requirements of Annex A of the publication IEC80005-3 or other acceptable standards.
19.3.5.2 Fixed high voltage cables on board are to comply with the requirements of publications IEC 60092-353 and IEC 60092-354 or other equivalent standards.

19.3.6 Plugs and socket outlets

19.3.6.1 The ship may be connected to the shore supply via suitable means or plugs and socket outlets. Plugs and socket outlets are to be designed so that an incorrect connection cannot be made and that plugs cannot be inserted or withdrawn while live. Plugs and socket outlets are to be in accordance with international[②] and/or national standards.

---

① Where the shore supply is connected to the bus bar and the voltage and frequency of the bus bar are easy to observe for the operator, only one voltmeter and one frequency meter may be fitted.

② For the standards for AC high voltage shore connection systems, refer to IEC 62613-1, Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC systems) – Part 1: General Requirements and IEC 62613-2, Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC systems) – Part 2: Dimensional compatibility and interchangeability requirements for accessories to be used by various types of ships. For the standards for AC low voltage shore connection systems, refer to IEC 60309-1, Plugs, socket-outlets and couplers for industrial purposes – Part 1: General Requirements, IEC 60309-2, Plugs, socket-outlets and couplers for industrial purposes – Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories and IEC 60309-5, Plugs, socket-outlets

Section 4 SURVEY AND TESTING

19.4.1 Inspections and tests of products

19.4.1.1 Shipside installations and their components are to be certified by CCS in accordance with Chapter 3, PART ONE of the Rules.

19.4.1.2 Components of shipside installations are to be inspected and tested according to approved drawings and relevant standards.

19.4.2 Ship surveys

19.4.2.1 The first survey of shipside installations after fitting onboard new ships or ships in service is to be carried out in accordance with 19.4.2.2 of this Chapter, and the subsequent surveys are to be carried out in accordance with 19.4.2.3 and 19.4.2.4 of this Chapter.

19.4.2.2 Initial survey

(1) Check of product certificates of shipside installations.

(2) Check of compliance of the arrangement and fitting of shipside installations with approved drawings.

(3) The installations are to be subjected to the following inspections and tests:

① visual examination;

② test of insulation resistance to earth;

③ voltage withstand test of high voltage cable installation (applicable to AC high voltage shore connection systems, refer to 2.14.7.2(6) of Chapter 2, PART FOUR of the Rules;

④ functional tests, including overcurrent protection test of the connected breakers, test of phase rotation, test of emergency shutdown facilities, test of safety interlocking, test of load transfer in parallel (if applicable);

⑤ measurement of insulation resistance in hot condition;

⑥ functional test of cable management system.

19.4.2.3 Annual survey

(1) Shipside installations are to be subjected to the following tests:

① visual examination;

② test of insulation resistance to earth;

③ if practicable, the connection to shore supply may be tested for shore-to-ship power supply. Where such test is impracticable, the availability of the equipment is to be confirmed by examining the records of shore supplies and/or the records of maintenance of shipside installations.

19.4.2.4 The requirements for intermediate survey are the same as those for annual surveys.

19.4.2.5 Special surveys include, in addition to the annual survey items, functional tests as required in 19.4.2.2(3)④ of this Section and functional test of cable management system as required in 19.4.2.2(3)⑥ of this Section.

---

and couplers for industrial purposes – Part 5: Dimensional compatibility and interchangeability requirements for plugs, socket-outlets, ship connectors and ship inlets for low-voltage shore connection systems (LVSC).

CHAPTER 20 ADDITIONAL REQUIREMENTS FOR ANCHOR HANDLING

Section 1 GENERAL PROVISIONS

20.1.1 Application

20.1.1.1 The requirements of this Chapter apply to anchor-handling ships.

20.1.2 Class notation

20.1.2.1 Ships complying with the requirements of this Chapter will be assigned the following class notation:

(1) Anchor Handling.

20.1.3 Plans and documents

20.1.3.1 The following plans are to be submitted for approval:

(1) Foundation and supporting structure of anchor handling winch;

(2) Stern rollers, towing pins, shark jaws and their supporting structures;

(3) Stability booklet (additional requirements for anchor handling);

(4) Construction profile and shell expansion.

20.1.3.2 The following plans or documents are also to be submitted for information:

(1) Arrangement of anchor handling equipment;

(2) Type and rated parameters of the anchor handling winch.

Section 2 HULL STRUCTURE

20.2.1 General requirements

20.2.1.1 Where not provided in this Chapter, the hull structure of anchor-handling ships is to comply with the relevant requirements of Chapter 2, PART TWO of the Rules.

20.2.2 Shell plating

20.2.2.1 The side shell in way of the stern rollers immediately adjacent to high duty mooring bollards and in other high load areas is to be suitably reinforced. Where an anchor-handling ship is not provided with any fender, the thickness of shell plating is not to be less than that required in Section 3, Chapter 2, PART TWO of the Rules and not to be less than 11 mm.

20.2.3 Deck plating

20.2.3.1 The deck plating near the stern and that subject to concentrated loads are to be suitably increased in thickness. Where an anchor handling ship is an offshore supply ship, the increased thickness of deck plating is not to be less than 2 times that required by 11.3.2.1, Section 3, Chapter 11, PART TWO of the Rules.

20.2.3.2 Where the anchor and chain are kept on the deck, effective means (e.g. wooden sheathing) are to be provided to uniformly distribute their weight on the deck.

Section 3 ANCHOR HANDLING EQUIPMENT AND SUPPORTING STRUCTURES

20.3.1 Anchor handling arrangement

20.3.1.1 The following equipment is to be provided on anchor-handling ships:

(1) anchor handling winches;

(2) stern rollers;

(3) shark jaws;

(4) towing pins.

20.3.1.2 Anchor handling winches are to be designed in such a way as to allow an emergency release in

all operating conditions, and this is to be operable from the navigation bridge. After an emergency release, the braking of winches is to be capable of being restored to normal function immediately.

20.3.2 Equipment and supporting structures

20.3.2.1 The anchor handling winch and associated accessories are to be capable of sustaining the maximum load from the hoisting, rendering and braking including any dynamic loads as applicable without permanent deformation.

20.3.2.2 The foundation and supporting structures of anchor handling winches are to be capable of sustaining the maximum braking load or 1.5 times the maximum hoisting load, whichever is greater. The considered stress is not to be greater than the following permissible values:

normal stress $[\sigma] = 0.9R_{eH}$;

shear stress $[\tau] = 0.5R_{eH}$;

equivalent stress $[\sigma_e] = 1.0R_{eH}$;

where: R_{eH} is yield stress of material, in N/mm^2.

20.3.2.3 Stern rollers, shark jaws and towing pins are to be sized such that they, together with their supporting structures, are capable of sustaining 2 times the maximum static working load in all conditions of their arrangement, and the permissible stress under consideration is to be in accordance with 20.3.2.2 of this Section.

CHAPTER 21 HULL MONITORING SYSTEMS

Section 1 GENERAL PROVISIONS

21.1.1 General requirements

21.1.1.1 This Chapter applies to hull monitoring systems installed voluntarily on board ships.

21.1.1.2 The ships provided with hull monitoring systems in accordance with this Chapter may apply for a corresponding class notation.

21.1.1.3 The hull monitoring system may be used to collect and monitor hull stress, wave and operational parameters. The system is to give warning when changes of these data approach levels that require action.

21.1.1.4 For ships not complying with the requirements of this Chapter, other arrangements achieving safety level to the same extent as that specified by this Chapter may be used, subject to agreement of CCS.

21.1.1.5 In no case is the hull monitoring system (including sensors) to be installed to damage the hull structure and impair the performance of ship, or give rise to any potential safety hazard. The system is not intended as a substitute for correct judgment and responsibility of crew members.

21.1.2 Class notations

21.1.2.1 Upon request of the owner and in accordance with different sensors/components of the hull monitoring system, the following class notations may be assigned:

(1) HMS(×): Sensors monitoring the global longitudinal stress amidships are installed in the hull monitoring system, and also sensors/components monitoring other parameters may be selected, where within the brackets there will be letters specifying the selected sensors/components and multiple letters are separated by comma ","[①] and arranged in alphabetical order indicated in the table.

The following sensors/components in Table 21.1.2.1 may be selected for the hull monitoring system:

Letters Specifying Selected Sensors/Components Table 21.1.2.1

Letter	Description
Gn	Sensor monitoring the global hull strain
Dn	Sensor monitoring the local hull strain
On	Sensor monitoring the propulsion shaft(s) output
An	Sensor monitoring the axial acceleration
Mn	Device for monitoring of hull rigid body motions (six degrees of freedom)
Pn	Sensor monitoring the transient sea pressure acting on the hull (slamming)
Sn	Sensor monitoring the liquid motion pressures in tanks (sloshing)
Tn	Sensor monitoring the temperature
Bn	Device for monitoring the wave
Wn	Wind sensor
Nn	Navigation sensors
Ln	Backed up statistics and triggered time series to be sent to CCS periodically
Cn	Online link to loading instrument that is continuously up-dating the loading condition

Note: n denotes the number of sensors or devices.

(2) HMS-HSC (×): applicable to high speed craft and the sensors/components installed in the hull monitoring system are to comply with Table 21.4.3.2.

21.1.2.2 The class notations specified in 21.1.2.1 are to be assigned on the basis of approved drawings, certification of equipment and onboard survey.

21.1.2.3 The hull monitoring system (including sensors) is to be furnished with a type approval certificate of CCS or other equivalent documents acceptable to CCS.

21.1.3 Plans and documents

21.1.3.1 Documents containing the following information are to be submitted for approval:

---

① For example, a bulk carrier equipped with sensors monitoring the global longitudinal stress amidships and also sensors monitoring the axial acceleration and local hull strain may be assigned the class notation HMS (Gn, Dn, An) upon request of the owner.

(1) arrangement of sensors (including the information on each sensor);
(2) diagrams of power systems of the hull monitoring system.
21.1.3.2 The following documents are to be submitted for information:
(1) explanation on relevant software (including data processing unit);
(2) instruction manuals of the hull monitoring system.

21.1.4 Documents to be kept on board

21.1.4.1 Instruction manuals are to be kept on board. The manuals are at least to contain the following instructions on:
(1) operation;
(2) setting and calibration of sensors and system;
(3) identification of faults;
(4) repairs;
(5) systematic maintenance and function testing (showing how components and systems are to be tested and what is to be observed during the tests);
(6) interpretation of measuring results.
21.1.4.2 A log for maintenance and calibration of the hull monitoring system is to be kept on board.

Section 2 SYSTEM DESIGN

21.2.1 System composition and components

21.2.1.1 The hull monitoring system generally consists of a computer system (upper layer) and sensors installed in appropriate spaces (lower layer). Relevant information monitored by each sensor is transferred to the computer system. Upon receipt of such information, processing, display, alarm and storage are carried out by the computer system.
21.2.1.2 Sensors are to be so selected as to ensure that they are suitable for use in the marine environment and their type and accuracy are also suitable for use of the signal.
21.2.1.3 In the case that the ship already has installed a sensor for monitoring of a certain parameter, installation of a separate sensor for the hull monitoring system is not required.
21.2.1.4 Wave sensors may be used to monitor the wave condition, which produces a two dimensional spectrum (wave frequency and relative direction between wave and ship heading). Based on the spectrum, significant wave height, main wave direction and main wave period may be derived.
21.2.1.5 An anemometer giving speed and dominant direction of the wind may be used.
21.2.1.6 The speed of the ship may be taken from the GPS system or the speed log.
21.2.1.7 The course of the ship may be taken from the GPS system or the gyro compass.

21.2.2 System requirements

21.2.2.1 The hull monitoring system is to have functions of processing and display, and provide relevant information to ship’s operators.
21.2.2.2 The system is to include a computer with sufficient capacity to perform the tasks required, e.g. process the sensor signals, display the information required on a screen, give alarms and store the data.
21.2.2.3 All electrical components that are exclusively used in the hull monitoring system, i.e. not sensors included in the navigation system, are to be powered through an UPS (un-interruptible power supply). In case of main power failure, the UPS is to have sufficient capacity to maintain normal operation of the hull monitoring system for at least 10 minutes.
21.2.2.4 The hull monitoring system is to automatically re-start for normal operation at return of main power.
21.2.2.5 In the case that the ship is equipped with a loading instrument, the still water shear forces and bending moments are to be transferred to the hull monitoring system. These data can be entered manually, read from a disk or transferred through an electronic link. The system may use this information to calculate the bending stress at the global strain positions.
21.2.2.6 The system is to be designed to give visual and audible alarm for at least the following incidents:
(1) power failure;
(2) sensor failure;
(3) signal from a sensor exceeding the alarm threshold value.
21.2.2.7 The programs and data held in the data recording system are to be protected from corruption by loss of power.
21.2.2.8 The user interface (display, keyboard and alarms) is at least to be installed on the bridge.

21.2.2.9 A data storage device suitable for saving time series and statistical information is to be used.
21.2.2.10 The system is to have minimum data storage capacity and functionality as specified in 21.3.9.
21.2.2.11 The hull monitoring system is to be configurable. The configuration is to include all settings that are relevant for a specific installation. Such settings will typically be calibration factors, sensors threshold values, filter cut-off frequencies, statistical calculations that are selected for the different sensors, etc.
21.2.2.12 The system is to have output port for providing Voyage Data Recorder with all IMO mandatory information (IMO resolution MSC.333(90) as amended by IMO resolution MSC.494 (104)) from the system. The port is to be compliant with IEC 61162.
21.2.2.13 Information on how to interpolate the vertical hull girder bending moment values from the loading instrument to the strain gauge positions is to be included in the computer programme of the system so that the loading instrument readings can be used for setting and checking the system.
21.2.2.14 Each strain gauge is initially to be set to a stress calculated in an agreed loading condition. This calculated stress is to be compatible with the output of the loading instrument and calculations made using the loading manual. The set-up is not to be carried out when dynamic stresses are present and is to be made when temperature effects are minimized and in absence of large gradients. The initial reading of the global strain gauge is to be checked against an agreed loading condition in calm water. In the event that the difference is greater than 5% of the approved value or 5 N/mm^2 occurs, whichever is the greater, the setup and subsequent checking are to be repeated.

21.2.3 System installation
21.2.3.1 The position of the strain gauges is to take account of the structural configuration of the ship and its mode of operation.
21.2.3.2 Deck-mounted strain gauges are to be protected from green seas on deck by appropriate siting or by using breakwaters or similar means. Strain gauges installed in other positions are to be suitably protected against external damages.
21.2.3.3 Motion sensors to measure motions are to be placed in positions where their functioning will not be affected by vibrations. Accelerometers and motion monitoring devices are to be mounted on a structural point where local structural vibration will be minimal. If resilient mounts are used, it is to be demonstrated that they have frequency characteristics that do not affect the signal in the frequency range of interest.
21.2.3.4 The rigid body motions are to be referred to the center of gravity in loaded condition.

21.2.4 Loads due to transient sea pressure (slamming)
21.2.4.1 Loads due to transient sea pressure (slamming) are preferably to be measured in terms of normal stress (strain) at the structure on which the pressure is acting, e.g. the pressure loads are to be measured as normal stress on longitudinal(s) or plating.
21.2.4.2 The loads may alternatively be measured using pressure transducer(s) mounted through the hull.
21.2.4.3 An accelerometer in the bow area may be used as an indicator of slamming incidents.

21.2.5 Loads due to liquid motions in tanks (sloshing)
21.2.5.1 Loads due to liquid motions in tanks (sloshing) are preferably to be measured in terms of stress (strain) in the structure on which the loads are acting.
21.2.5.2 The loads may alternatively be measured in terms of pressure using a pressure transducers mounted through the tank wall.

21.2.6 Structural temperature
21.2.6.1 Temperature sensors installed on the supporting structure① of cargo tanks containing cooled or heated cargo, are at least to have an operational range that covers the temperature of the cargo and the temperature in the structure when the cargo hold is empty.

Section 3 DATA PROCESSING AND STORAGE

21.3.1 General requirements
21.3.1.1 The parameters given in 21.4.3 are to be processed and made available for the hull monitoring

① For liquid tanks provided with the independent tank, the supporting structure means the saddle supporting the liquid tank; for the integral tank, the supporting structure mainly means the inner side of bulkhead.

display.
21.3.1.2 The measured signals are to be split into given time intervals for data processing. The results from the data processing for each time interval are to be stored. The time interval selected is to be set during the initial configuration of the software.
21.3.1.3 The type of processing each individual sensor's signal is to be defined during the initial configuration of the system. The configured information document can be accessed and consulted.

21.3.2 Data filtering

21.3.2.1 The software is to include high-pass and low-pass time domain digital filters. The cut-off frequency of the filters is to be configurable through the software.
21.3.2.2 The filters are to be designed to have a stop-band attenuation of at least 40 dB.
21.3.2.3 The filters are to be initiated at the start-up of the hull monitoring software, and be continuously active as long as the software is running during normal operation. The part of the filtered signal that is corrupted by the settling of the filter during start-up is not to be used in the subsequent data analyses.
21.3.2.4 The system is to have the capability to simultaneously perform filtering on all the measured time series of hull responses. The time series subjected to filtering are to be configurable through the software.
21.3.2.5 The system is to be able to put the time signal from all sensors measuring the ship responses through the following filtering processes, giving four different time series:
(1) no filtering (static value and both wave and vibrations responses are maintained);
(2) high-pass filtering (static value and low cycle temperature fluctuation are removed, the wave response and vibration responses of the signal are maintained);
(3) low-pass filtering (static value and the wave response is maintained);
(4) high-pass filtering (only the vibration response is maintained).
21.3.2.6 The software is to be able to display each of the four different time series described in 21.3.2.5.
21.3.2.7 The software is to be able to perform the data analyses described in 21.3.3 through 21.3.6 on each of the four different time series described in 21.3.2.5.

21.3.3 Statistical calculations

21.3.3.1 The software is to be able to perform the statistical calculations on the time series described in 21.3.1.2 and 21.3.2.5. The sensors selected for statistical calculations and statistical operation to be performed are to be configurable in the initial set-up of the software.
21.3.3.2 The following statistical parameters are to be calculated for each of the selected ship response parameters:
(1) maximum value;
(2) minimum value;
(3) mean value;
(4) standard deviation;
(5) skewness;
(6) kurtosis;
(7) mean zero crossing period.
21.3.3.3 For each of the ship responses, a histogram of all the peaks in the time history is to be established. The amplitude for each response is to be divided into pre-set intervals, and the number of peaks within each interval is to be counted. Hence, the histogram will contain the number of peak occurrences within each interval. The intervals are to be set during configuration of the software.
21.3.3.4 Similar histograms of the ship responses as described for the peaks in 21.3.3.3 are also to be established for the troughs.
21.3.3.5 For transient phenomena, such as liquid impacts (slamming and sloshing), the integrated energy of each impact is to be calculated.
21.3.3.6 For transient phenomena, such as liquid impacts (slamming and sloshing), the rise time of each impact is to be calculated. The limits for the calculation are to be configurable.
21.3.3.7 Based on assumptions of statistical distribution of the parameters derived in 21.3.3.2 to 21.3.3.5, a curve for the probability of exceeding a certain value within a given time period is to be estimated. The time period is to be configurable through the software.
21.3.3.8 Based on the probability curve, the probability of exceeding a predefined threshold value is to be found. The threshold value is to be configurable through the software.

21.3.4 Fatigue life estimation

21.3.4.1 The fatigue life of the structural elements equipped with strain sensors is to be estimated based on the measured time history.

21.3.4.2 The stress response histograms are to be established for each strain sensor using a type of cycle count method.

21.3.5 Loads due to transient sea pressure (slamming)

21.3.5.1 The number of transient peaks recorded by the sensor installed for the recording of slamming incidents exceeding the threshold level, is to be counted. The number count for a pre-defined time period is to be made available for the display. The threshold value and the time period are to be configurable through the software.

21.3.6 Hull stress

21.3.6.1 The hull girder strain (stress) may often be influenced by strain induced by temperature differences in the hull structure. This strain may be caused by temperature differences between the cargo and the environments or by partial heating of the hull structure due to sunshine. These effects may be reflected as low cycle variations of the measured strain. The strain due to these temperature differences is normally not to be included in the analyses performed by the hull monitoring system. The hull monitoring system is to have the capability to optionally remove the strain due to temperature differences in the hull girder.

21.3.6.2 The hull monitoring system is to have the capability to read the still water bending/torsion moments calculated by the loading instrument (if applicable). This information could either be typed manually into the hull monitoring system or be transferred electronically by disk or data link. Based on this information, the hull monitoring system is to be capable of computing the strain (stress) due to the still water bending moments at each position where a sensor measuring global hull strain (stress) is positioned. In the case when the sensor position does not correspond to a section for where the still water bending moments are computed, a linear interpolation between the moments on each side of the sensor position may be applied.

21.3.6.3 The hull monitoring system is to have the following three options for each individual strain sensor, to be selected independently, for input to the statistical analyses and the alarm handler. The option is to be selected during the initial installation of the hull monitoring system, with explanations given in the configuration file.

(1) measured strain as recorded (including possible effects due to temperature differences in the hull structure);

(2) measured strain high-passed filtered in order to remove low cycle temperature effects;

(3) measured strain high-passed filtered in order to remove low cycle temperature effects, and then have a strain offset added to the filtered strain signal, corresponding to the strain due to still water loading at each sensor position.

21.3.7 Threshold values and alarms

21.3.7.1 The hull monitoring software is to be designed to allow input of a minimum and a maximum threshold value for each sensor.

21.3.7.2 The measured values are to be compared to the given threshold values for each sensor. In the case that the computed value exceeds 80% of a threshold value, an alarm is to be given.

21.3.7.3 The cause of the alarm is to be automatically written to an alarm log that is to be stored on an electronic device.

21.3.8 Trend predictions

21.3.8.1 The results from the calculations for each time interval are to be arranged in such way that a sequence of the latest data from each individual sensor can be displayed as a trend.

21.3.8.2 A 4-hour data sequence from each individual sensors is to form the basis for a forecast trend prediction of the expected response from each individual sensor for at least the next hour. The measured and the predicted data is to be made available for the display.

21.3.8.3 When the signal from an individual sensor exceeds 80% of the specified threshold value for that sensor, the expected time to reach the threshold value is to be predicted based on trend analyses. The measured and the predicted data is to be made available for the display.

21.3.9 Data storage

21.3.9.1 The system is to have capacity to store at least one year of statistical data and 24 h of time series from all sensors. For sensors dedicated to slamming and sloshing measurements, it is sufficient to store the time sequences where the transients are exceeding a given threshold value.

21.3.9.2 The system is to have the capability to back-up the recorded data on a medium suitable to be

read on a personal computer (PC).
21.3.9.3 The data back-up files are to include all the recorded data presented on a suitable text format. The files are to include sufficient information to clearly describe the content of the files.
21.3.9.4 For each time interval, the system is to store the results from all the calculations for all the individual parameters recorded. The data is to be labelled with a time stamp (date and time) corresponding to the beginning of the time interval.
21.3.9.5 The system is to automatically store time series for all the measured parameters for a number of time intervals corresponding to at least a period of the last 4 h of recording. Time series older than this period is to automatically be deleted from the storage device.
21.3.9.6 The system is to have the functionality to permanently store the data specified in 21.3.9.5. The system is to have the storage capacity to permanently store at least 12 such periods.

Section 4 DISPLAY AND MONITORING

21.4.1 Display

21.4.1.1 The hull monitoring system is to have a display suitable for presentation of screen images.
21.4.1.2 The system is to have at least screens that display the following information:
(1) clearly visualize the position of each individual sensor;
(2) the status of each individual sensor, i.e. whether the sensor is operational or faulty;
(3) real time information of the measured time series of each individual sensor;
(4) signal level from each individual sensor compared to the threshold values;
(5) trends of the statistical parameters for each individual sensor, including forecast predictions;
(6) alarm status.

21.4.2 Manual input

21.4.2.1 The system is to be provided with means for manual input.

21.4.3 Extent of monitoring

21.4.3.1 For the class notation HMS(×), in addition to sensors monitoring the global longitudinal stress amidships which are installed port and starboard, other parameters may also be monitored. Recommended parameters to be monitored for the various types of ships and available sensors/components are given in Table 21.4.3.1.

Recommended Parameters to be Monitored for Types of Ships and Available Sensors/Components Table 21.4.3.1

No.	Parameter	Applicable ship type	Available sensors/ components	Remark
1	Vertical accelerations at forward perpendicular ($0.01L$[①]) at centerline	a, b, c, d	A	① L is length of ship as defined in 1.1.2.1, Chapter 1, PART TWO of the Rules
2	Transverse acceleration in the $0.4L$ mid ship area	b, c, d	A	To monitor inertia loading on sensitive cargo. Sudden change in response may indicate irregular situations such as ingress of water in holds or at vehicle decks
3	Global longitudinal stress at the quarter length $L/4$ from mid ship (port and starboard)	a[②], b[②], c[②], d[③]	G	② For ships with length L>180 m ③ For ships with hull girder sectional modulus < $1.5W_{rule}$ and with length L>180 m
4	Longitudinal stress close to bottom ($L/2$) amidships (port and starboard)	b[④], c[⑤]	G	④ Longitudinal stresses ($L/2$) amidships below the neutral axis, e.g. at bilge area. Only for ships with large openings in deck ⑤ Longitudinal stresses ($L/2$) amidships below the neutral axis, e.g. at bilge area
5	Double bottom bending	b[⑥]	D	⑥ For Bulk Carriers with class notation BC-B and BC-A, one strain sensor in inner bottom of each hold
6	Bending/shear stress in pillar bulkheads	c[⑦]	D	⑦ For ships with operational limits with respect to draught with empty holds
7	Lateral loads at bottom near forward perpendicular	a, b, c, d	P	
8	Lateral loads at side	a, b, c, d	P	

No.	Parameter	Applicable ship type	Available sensors/ components	Remark
9	Lateral loads at the bow door	d⑧	P	⑧ For Ro-Ro Ships only
10	Loading instrument	a, b, c, d	C	Ship provided with a loading instrument may choose whether to establish an online link to the hull monitoring system
11	Position, speed/course	a, b, c, d	N	
12	Power output and revolutions of propulsor (s)	a, b, c, d	O	
13	Wave condition	a, b, c, d	B	
14	Wind condition	a, b, c, d	W	
15	Structural temperature	a	T	
16	Sloshing response of liquid in tanks	a	S	
17	Ship's attitude	a, b, c, d	M	
In the Table, a: oil tankers, petroleum asphalt tankers, chemical tanker, liquefied gas carriers; b: bulk carriers and ore carriers; c: container ships; d: general cargo ships, ro-ro ships, passenger ships and other ships.				

21.4.3.2 For the class notation HMS-HSC (×), the parameters to be monitored and corresponding types of sensors are given in Table 21.4.3.2.

Parameters to be Monitored for High Speed Craft and Corresponding Types of Sensors

Table 21.4.3.2

No.	Parameter	Available sensors	Remark
1	Vertical, transverse and longitudinal acceleration at the centerline of each hull in the fore body (fore of forward perpendicular)	A	Must be installed
2	Vertical, transverse and longitudinal acceleration at the longitudinal center of gravity (LCG)	A	Must be installed
3	Vertical, transverse and longitudinal acceleration at the centerline of each hull aft body (aft of aft perpendicular)	A	Must be installed
4	Global longitudinal stress amidships	G	Recommended to be installed
5	Global transverse stress in wet deck in center between each hull	D	Recommended to be installed (for multi-hull ships with length L>50 m)
6	Lateral loads at bottom near forward perpendicular	P	Recommended to be installed

Section 5 COMPONENT REQUIREMENTS

21.5.1 General requirements

21.5.1.1 All components are to be replaceable and designed for easy maintenance.

21.5.1.2 Electrical equipment and installation in hazardous areas are to be in accordance with PART FOUR of the Rules.

21.5.1.3 All equipment located at the navigation bridge is to be fitted with dimmers and has displays which do not interfere undue with the night vision of the officer of the watch.

21.5.2 Sensors

21.5.2.1 Strain sensors are to be designed in such way that the measured value is not influenced by changes in temperature.

21.5.2.2 Sensors for measuring global hull strain are to be mounted in such way that influence of local strain is minimized.

21.5.2.3 Sensors that are part of other systems, can be utilized in the hull monitoring system. Connections to such sensors are to be made in such way that they do not influence performance of the other systems. Failure of the hull monitoring system is not to influence the performance of other systems.

21.5.2.4 Accelerations are to be measured over a range of -20 m/s^2 to +20 m/s^2. The measurement uncertainty of the acceleration is to be less than 2% of the measured value, or 0.10 m/s^2, whichever is the greater.

21.5.2.5 The rigid body ship motions is to be measured by a device with integrated sensors, giving the 6º of freedom (3 translations and 3 rotations). The translations (accelerations) are to be measured over a range of -20 m/s^2 to +20 m/s^2. The angles are to be measured over a range of -90º to +90º, -45º to +45º and -180º to +180º, for the roll, pitch and yaw motions respectively. The measurement uncertainty is to be less than 2% of the measured value, or 0.10 m/s^2 for translations and 0.5º for angles, whichever is the greater.

21.5.2.6 The sea pressure acting on the hull is to be measured over a range of 0 – 2 MPa. The measurement uncertainty of the pressure is to be less than 2% of the measured value, or 0.01 MPa, whichever is the greater.

21.5.2.7 The liquid motion pressures in tanks (sloshing) is to be measured over a range of 0 – 4 MPa. The measurement uncertainty of the pressure is to be less than 4% of the measured value, or 0.02 MPa, whichever is the greater.

21.5.2.8 The structural strain is to be measured in a range related to the yielding strain of the material. The measurement uncertainty is to be less than 3% of the measured value or 20 micro strain, whichever is the greater. For ships made of steel or aluminium, a range from -2 000 micro strain to +2 000 micro strain can be assumed. For ships constructed using special material qualities or different types of materials, i.e. composite materials, the strain range is to be specially considered by CCS.

21.5.2.9 The sensors installations designed for low frequency responses, i. e. motions and wave loading are to record the physical quantities within the specified uncertainties within the frequency range 0.01 – 3 Hz. Installations designed to measure slamming responses are to record the physical quantity within the specified uncertainties in the frequency range 5 – 100 Hz. Installations designed to measure sloshing responses are to record the physical quantity within the specified uncertainties in the frequency range 30 – 1200 Hz. For the physical quantity recorded above, the uncertainty is to be within the specified range.

21.5.2.10 The data processing unit is to be capable of handling information supplied by all sensors including navigational instruments at the actual transfer rate.

21.5.2.11 The information from the sea-state parameters is at least to be updated and submitted every 10 minutes.

21.5.3 Signal conditioning units

21.5.3.1 The signal conditioning units are to be matched to the connected sensor.

21.5.3.2 The signals from analogue sensors are to be low-pass filtered prior to digitising to avoid signal noise. The filters are to be matched to the frequency range for the different sensors.

21.5.3.3 The sensors installations designed for low frequency responses, i.e. motions and wave loading are to be digitised with at least 20 Hz. Installations designed to measure slamming responses are to be digitised with at least 500 Hz. Installations designed to measure sloshing responses in tanks are to be digitised with at least 3 kHz.

CHAPTER 22 ADDITIONAL REQUIREMENTS FOR ERGONOMIC CONTAINER LASHING

Section 1 GENERAL PROVISIONS

22.1.1 Application

22.1.1.1 The provisions of this Chapter are voluntary and the aim of this Chapter is to ensure that persons engaged in carrying out container securing operations on deck have safe working conditions. This Chapter applies to container ships and ships which are specifically designed and fitted for the purpose of carrying containers on deck.

22.1.2 Class notation

22.1.2.1 The following class notation may be assigned to those complying with the requirements specified in this Chapter:
(1) Ergonomic Container Lashing: ECL

22.1.3 Definitions

22.1.3.1 Fencing is a generic term for guardrails, safety rails, safety barriers and similar structures that provide protection against the falls of persons.
22.1.3.2 Lashing positions include positions:
(1) in between container stows on hatch covers;
(2) at the end of hatches;
(3) on outboard lashing stanchions/pedestals;
(4) outboard lashing positions on hatch covers; and
(5) any other position where people work with container securing.
22.1.3.3 Stringers are the uprights or sides of a ladder.
22.1.3.4 Turnbuckles and lashing rods specified in this Chapter include similar cargo securing devices.

22.1.4 Plans and information

22.1.4.1 The following information is to be submitted:
(1) Details of container stowage arrangements;
(2) Details of working areas including means of access, fall protection arrangements and anti-slip surfaces;
(3) Details of lashing bridges including stowage arrangements for lashing bars, means of access and fall protection arrangements;
(4) Details of walkways and transit areas including fall protection and anti-slip surfaces;
(5) Details of access openings, ramps, ladders, steps, hatchways and coamings;
(6) Details of container securing fittings including fixed and loose fittings;
(7) Details of deck lighting;
(8) Details of reefer power outlets.

Section 2 SAFE ACCESS DESIGN

22.2.1 General provisions

22.2.1.1 The minimum clearance for transit areas is to be at least 2 m high and 600 mm wide. See dimensions "B" in Figure 22.2.1, "J" in Figure 22.2.4, "K_1" in Figure 22.2.2 and Table 22.2.1.
22.2.1.2 All relevant deck surfaces used for movement about the ship and all passageways and stairs are to have non-slip surfaces.
22.2.1.3 Where necessary for safety, walkways on deck are to be delineated by painted lines or otherwise marked by pictorial signs.
22.2.1.4 All protrusions in access ways, such as cleats, ribs and brackets that may give rise to a trip hazard are to be highlighted in a contrasting colour.

22.2.2 Lashing position design (platforms, bridges and other lashing positions)

22.2.2.1 Lashing positions are to be designed to eliminate the use of three high lashing bars and be positioned in close proximity to lashing equipment stowage areas. Lashing positions are to be designed to provide a clear work area which is unencumbered by deck piping and other obstructions and take into consideration:
(1) the need for containers to be stowed within safe reach of the personnel using the lashing position so that the horizontal operating distance from the securing point to the container does not exceed 1,100 mm and not less than 220 mm for lashing bridges and 130 mm for other positions, see dimensions "C_1" and "C_2" in Figure 22.2.2, "C_3" in Figure 22.2.1 and Table 22.2.1;
(2) the size of the working area and the movement of lashing personnel; and
(3) the length and weight of lashing gear and securing components used.
22.2.2.2 The width of the lashing positions is preferably to be 1,000 mm, but not less than 750 mm. See dimensions "*A*" in Figure 22.2.1, "*GL*" and "*GT*" in Figure 22.2.3, "*I*" in Figure 22.2.4, "*K*" in Figure 22.2.2 and Table 22.2.1.
22.2.2.3 The width of permanent lashing bridges is to be:
(1) 750 mm between top rails of fencing, see dimension "*F*" in Figure 22.2.2 and Table 22.2.1; and
(2) a clear minimum of 600 mm between storage racks, lashing cleats and any other obstruction, see dimension "F_1" in Figure 22.2.2 and Table 22.2.1.
22.2.2.4 Platforms on the end of hatches and outboard lashing stations are preferably to be at the same level as the top of the hatch covers.
22.2.2.5 Toe boards (or kick plates) are to be provided around the sides of elevated lashing bridges and platforms to prevent securing equipment from falling and injuring people. Toe boards are preferably to be 150 mm high, however, where this is not possible they are to be at least 100 mm high.
22.2.2.6 Any openings in the lashing positions through which people can fall are to be possible to be closed.
22.2.2.7 Lashing positions are not to contain obstructions, such as storage bins or guides to reposition hatch covers.
22.2.2.8 Lashing positions which contain removable sections are to be capable of being temporarily secured.

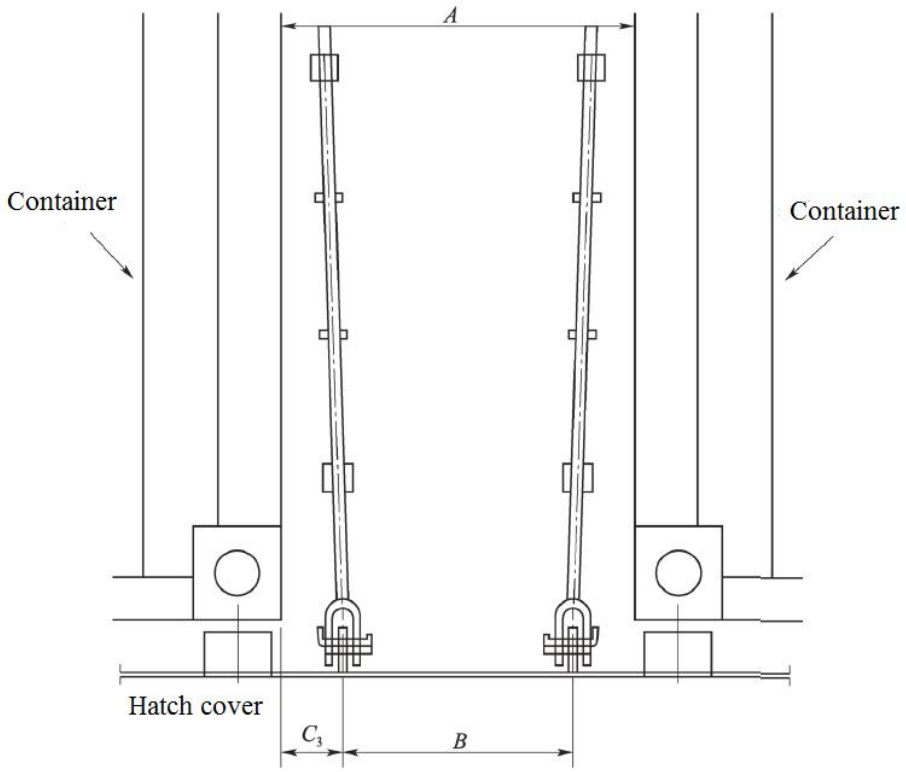


Figure 22.2.1

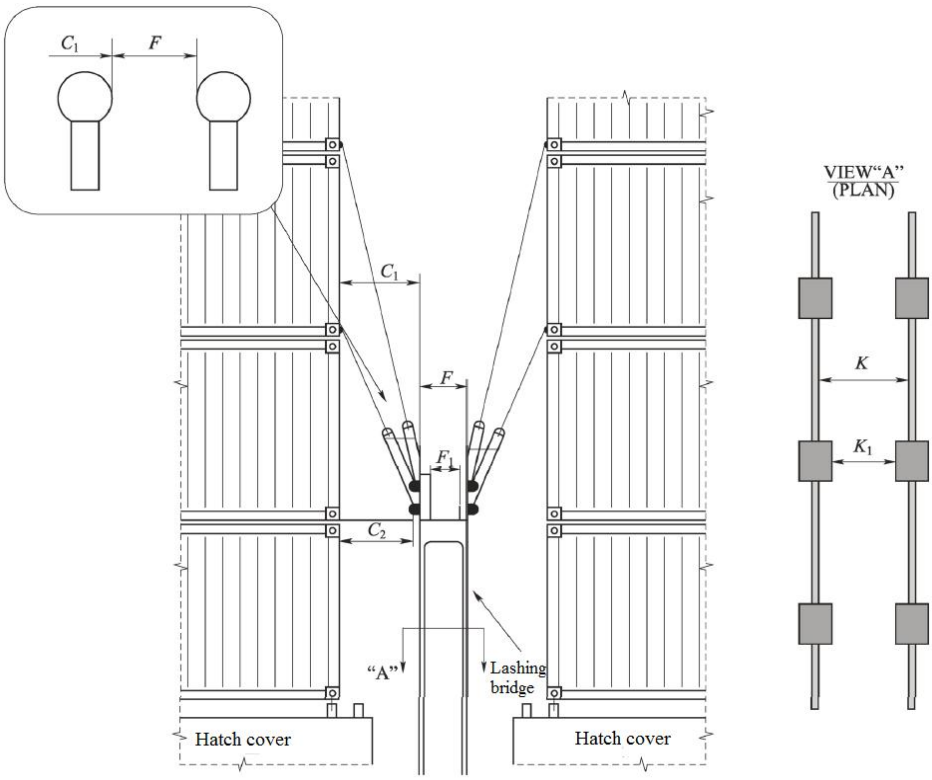


Figure 22.2.2

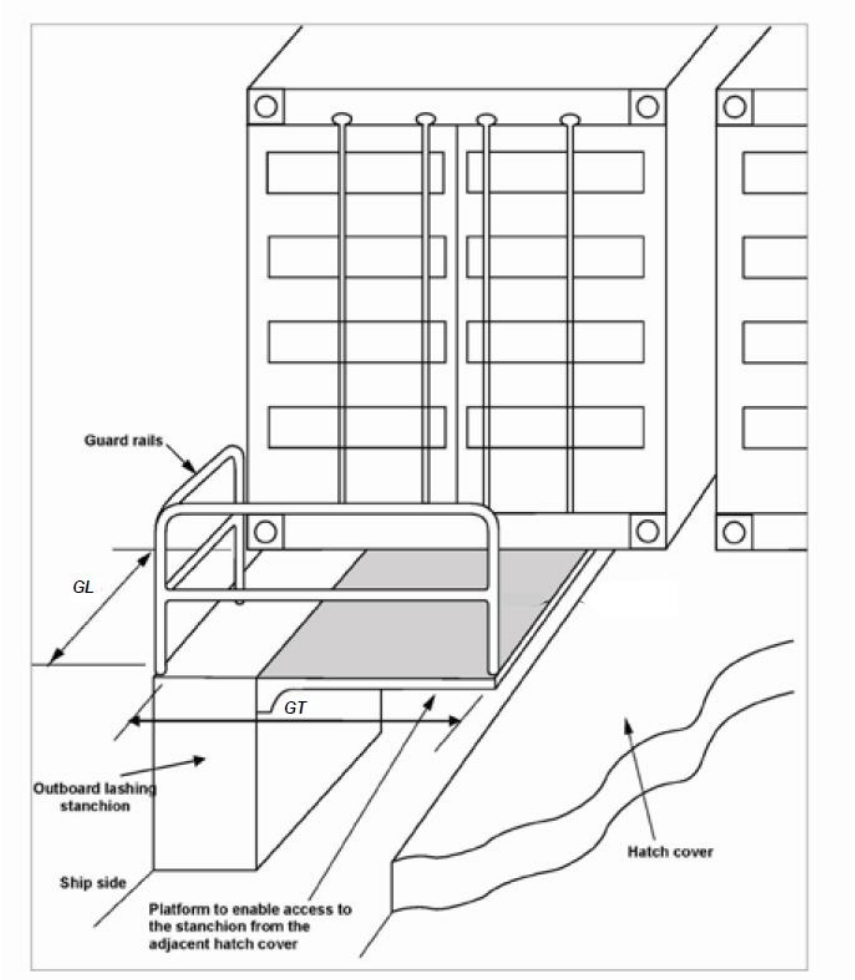


Figure 22.2.3

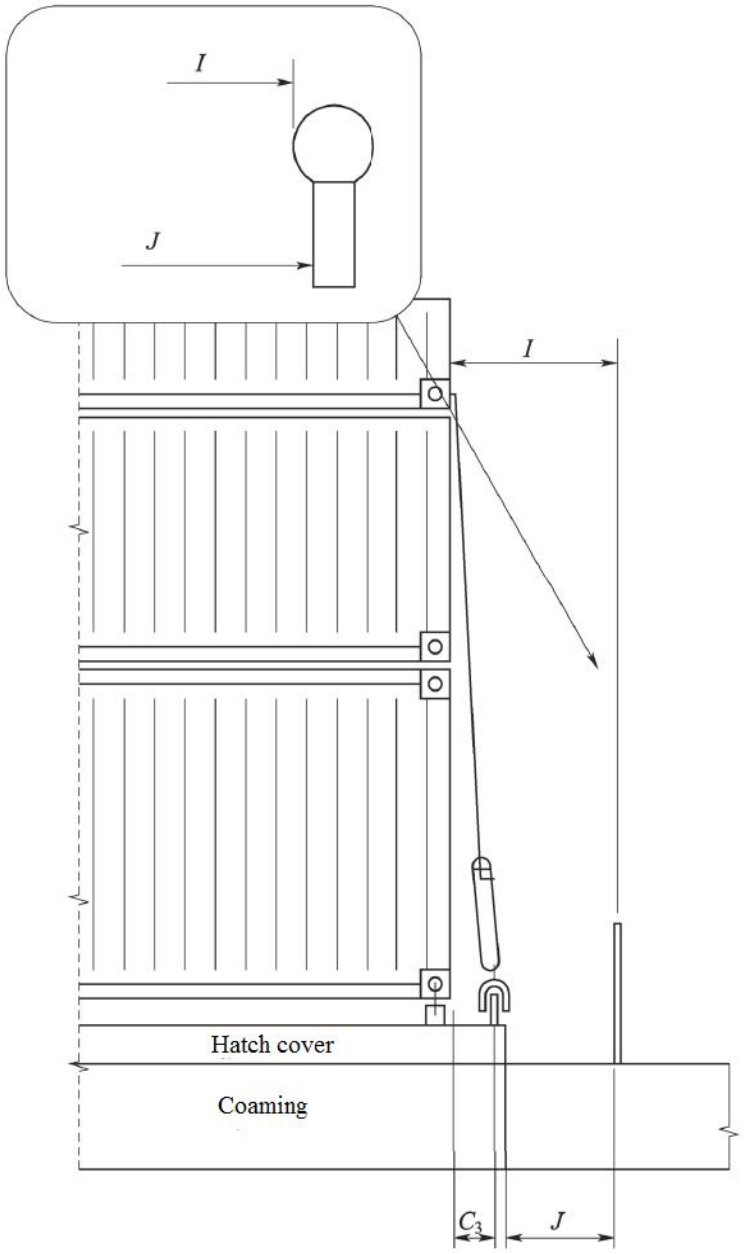


Figure 22.2.4

Container securing dimensions as shown in Figures 22.2.1 to 22.2.4 are listed in Table 22.2.1:

Table 22.2.1

Dimension	Description	Requirement (mm)
A	Width of work area between container stacks	750 minimum
B	Distance between lashing plates on deck or on hatch covers	600 minimum
C_1	Distance from lashing bridge fencing to container stack	1100 maximum
C_2	Distance from lashing plate to container stack (lashing bridge)	220 minimum
C_3	Distance from lashing plate to container stack (elsewhere)	130 minimum
F	Width of lashing bridge between top rails of fencing	750 minimum
F_1	Width of lashing bridge between storage racks, lashing cleats and any other obstruction	600 minimum
GL	Width of working platform for outboard lashing – fore/aft	750 minimum
GT	Width of working platform for outboard lashing – transverse	750 minimum
I	Width of work platform at end of hatch cover or adjacent to superstructure	750 minimum
J	Distance from edge of hatch cover to fencing	600 minimum
K	Width of lashing bridge between top rails of fencing	750 minimum
K_1	Width of lashing bridge between the pillars of the lashing bridge	600 minimum
Notes:		

B — Measured between the centres of the lashing plates. C_1 — Measured from inside of fencing. C_2, C_3 — Measured from centre of lashing plate to end of container. *F*, *K* — Measured to inside of fencing. *GL* — Measured from end of container to inside of fencing. *GT* — Measured to inside of fencing. *I* — Measured to inside of fencing. *J* — Measured to inside of fencing.

22.2.3 Fencing design

22.2.3.1 Bridges and platforms, where appropriate, are to be fenced. As a minimum, fencing design is to take into consideration:

(1) the strength and height of the rails are to be designed to prevent workers from falling;

(2) flexibility in positioning the fencing of gaps. A horizontal unfenced gap is not to be greater than 300 mm;

(3) provisions for locking and removal of fencing as operational situations change based on stowage anticipated for that area;

(4) damage to fencing and how to prevent failure due to that damage; and

(5) adequate strength of any temporary fittings. These are to be capable of being safely and securely installed.

22.2.3.2 The top rail of fencing is to be 1 m high from the base, with two intermediate rails. The opening below the lowest course of the guard rails is not to exceed 230 mm. The other courses are to be not more than 380 mm apart.

22.2.3.3 Where possible fences and handrails are to be highlighted with a contrasting colour to the background.

22.2.3.4 Athwartships cargo securing walkways are to be protected by adequate fencing if an unguarded edge exists when the hatch cover is removed.

22.2.4 Ladder and manhole design

22.2.4.1 Where a fixed ladder gives access to the outside of a lashing position, the stringers are to be connected at their extremities to the guardrails of the lashing position, irrespective of whether the ladder is sloping or vertical.

22.2.4.2 Where a fixed ladder gives access to a lashing position through an opening in the platform, the opening shall be protected with either a fixed grate with a lock back mechanism, which can be closed after access, or fencing. Grabrails are to be provided to ensure safe access through the opening.

22.2.4.3 Where a fixed ladder gives access to a lashing position from the outside of the platform, the stringers of the ladder are to be opened above the platform level to give a clear width of 700 to 750 mm to enable a person to pass through the stringers.

22.2.4.4 A fixed ladder is not to slope at an angle greater than 25° from the vertical. Where the slope of a ladder exceeds 15° from the vertical, the ladder is to be provided with suitable handrails not less than 540 mm apart, measured horizontally.

22.2.4.5 A fixed vertical ladder of a height exceeding 3 m, and any fixed vertical ladder, from which a person may fall into a hold, is to be fitted with guard hoops, which are to be constructed in accordance with paragraphs 22.2.4.6 and 22.2.4.7.

22.2.4.6 The ladder hoops are to be uniformly spaced at intervals not exceeding 900 mm and are to have a clearance of 750 mm from the rung to the back of the hoop and be connected by longitudinal strips secured to the inside of the hoops, each equally spaced round the circumference of the hoop.

22.2.4.7 The stringers are to be carried above the floor level of the platform by at least 1 m and the ends of the stringers are to be given lateral support and the top step or rung is to be level with the floor of the platform unless the steps or rungs are fitted to the ends of the stringers.

22.2.4.8 As far as practicable, access ladders and walkways, and work platforms are to be designed so that workers do not have to climb over piping or work in areas with permanent obstructions.

22.2.4.9 There are to be no unprotected openings in any part of the workplace. Access opening must be protected with handrails or access covers that can be locked back during access.

22.2.4.10 As far as practicable, manholes are not to be situated in transit areas, however, if they are, proper fencing is to protect them.

22.2.4.11 Access ladders and manholes are to be large enough for persons to safely enter and leave.

22.2.4.12 A foothold at least 150 mm deep is to be provided.

22.2.4.13 Handholds are to be provided at the top of the ladder to enable safe access to the platform to be gained.

22.2.4.14 Manhole openings that may present a fall hazard are to be highlighted in contrasting colour around the rim of the opening.
22.2.4.15 Manhole openings at different levels of the lashing bridge are not to be located directly below one another, as far as practicable.

Section 3 LASHING SYSTEMS

22.3.1 General provisions

Lashing systems, including tensioning devices, are to:
(1) conform to international standards (ISO 3874), where applicable;
(2) be compatible with the planned container stowages;
(3) be compatible with the physical ability of persons to safely hold, deploy and use such equipment;
(4) be uniform and compatible, e.g. twistlocks and lashing rod heads are not to interfere with each other;
(5) be subject to a periodic inspection and maintenance regime. Non-conforming items are to be segregated for repair or disposal; and
(6) be according to the CSM.

22.3.2 Twistlock design

22.3.2.1 Shipowners are to ensure that the number of different types of twistlocks provided for cargo securing is kept to a minimum and clear instructions are provided for their operation. The use of too many different types of twistlocks may lead to confusion as to whether the twistlocks are locked.
22.3.2.2 The design of twistlocks is to ensure the following:
(1) positive locking with easy up and down side identification;
(2) dislodging from corner fitting is not possible even when grazing a surface;
(3) access and visibility of the unlocking device is effective in operational situations;
(4) unlocked positions are easily identifiable and do not relock inadvertently due to jolting or vibration; and
(5) unlocking poles are as light as possible, of a simple design for ease of use.
22.3.2.3 Where it is not feasible to entirely eliminate working on the tops of container stows, the twistlock designs used are to minimize the need for such working, e.g. use of SATLs, fully automatic twistlocks or similar design.

22.3.3 Lashing rod design

22.3.3.1 The design of containership securing systems is to take into account the practical abilities of the workers to lift, reach, hold, control and connect the components called for in all situations anticipated in the cargo securing plan.
22.3.3.2 The maximum length of a lashing rod is to be sufficient to reach the bottom corner fitting of a container on top of two high cube containers and be used in accordance with the instructions provided by the manufacturers.
22.3.3.3 The weight of lashing rods is to be minimized as low as possible consistent with the necessary mechanical strength.
22.3.3.4 The head of the lashing rod that is inserted in the corner fitting is to be designed with a pivot/hinge or other appropriate device so that the rod does not come out of the corner fitting accidentally.
22.3.3.5 The rod's length in conjunction with the length and design of the turnbuckle is to be such that the need of extensions is eliminated when lashing high cube (9'6") containers.
22.3.3.6 Lightweight rods are to be provided where special tools are needed to lash high cube containers.

22.3.4 Turnbuckle design

22.3.4.1 Turnbuckle end fittings are to be designed to harmonize with the design of lashing rods.
22.3.4.2 Turnbuckles are to be designed to minimize the work in operating them.
22.3.4.3 Anchor points for turnbuckles are to be positioned to provide safe handling and to prevent the bending of rods.
22.3.4.4 To prevent hand injury during tightening or loosening motions, there is to be a minimum distance of 70 mm between turnbuckles.
22.3.4.5 The turnbuckle is to incorporate a locking mechanism which will ensure that the lashing does not work loose during the voyage.
22.3.4.6 The weight of turnbuckles is to be minimized as low as possible consistent with the necessary mechanical strength.

22.3.5 Storage bins and lashing equipment stowage design

22.3.5.1 Bins or stowage places for lashing materials are to be provided.

22.3.5.2 All lashing gear are to be stowed as close to its intended place of use as possible.

22.3.5.3 The stowage of securing devices is to be arranged so they can easily be retrieved from their stowage location.

22.3.5.4 Bins for faulty or damaged gear are also to be provided and appropriately marked.

22.3.5.5 Bins are to be of sufficient strength.

22.3.5.6 Bins and their carriers are to be designed to be lifted off the vessel and restowed.

Section 4 LIGHTING DESIGN

22.4.1 A lighting plan is to be developed to provide for:

22.4.1.1 the proper illumination of access ways, not less than 10 lux (1 foot candle), taking into account the shadows created by containers that may be stowed in the area to be lit, for example different length containers in or over the work area;

22.4.1.2 a separate fixed or temporary (where necessary) lighting system for each working space between the container bays, which is bright enough, not less than 50 lux (5 foot candle), for the work to be done, but minimizes glare to the deck workers;

22.4.1.3 such illumination is, where possible, to be designed as a permanent installation and adequately guarded against breakage; and

22.4.1.4 the illumination intensity is to take into consideration the distance to the uppermost reaches where cargo securing equipment is utilized.

Section 5 SPECIALIZED CONTAINER SAFETY DESIGN

22.5.1 Temperature controlled unit power outlets are to provide a safe, watertight electrical connection.

22.5.2 Temperature controlled unit power outlets are to feature a heavy duty, interlocked and circuit breaker protected electrical power outlet. This is to ensure the outlet can not be switched "live" until a plug is fully engaged and the actuator rod is pushed to the "ON" position. Pulling the actuator rod to the "OFF" position is to manually de-energize the circuit.

22.5.3 The temperature controlled unit power circuit is to de-energize automatically if the plug is accidentally withdrawn while in the "ON" position. Also, the interlock mechanism is to break the circuit while the pin and sleeve contacts are still engaged. This provides total operator safety and protection against shock hazard while eliminating arcing damage to the plug and receptacle.

22.5.4 Temperature controlled unit power outlets are to be designed to ensure that the worker is not standing directly in front of the socket when switching takes place.

22.5.5 The positioning of the temperature controlled unit feed outlets is not to be such that the flexible cabling needs to be laid out in such a way as to cause a tripping hazard.

22.5.6 Stevedores or ship's crew who are required to handle temperature controlled unit cables and/or connect and disconnect reefer units are to be given training in recognizing defective wires and plugs.

22.5.7 Means or provisions are to be provided to lay the temperature controlled unit cables in and protect them from lashing equipment falling on them during lashing operations.

22.5.8 Defective or inoperative temperature controlled unit plugs/electrical banks are to be identified and confirmed as "locked out/tagged out" by the vessel.

CHAPTER 23 ADDITIONAL REQUIREMENTS FOR SHIPS OPERATING IN LOW AIR TEMPERATURE ENVIRONMENTS

Section 1 GENERAL PROVISIONS

23.1.1 General requirements

23.1.1.1 This Chapter applies for ships intended to operate in low air temperature environments and in addition, for ships operating in areas and during periods where more severe ice and snow accretion are likely to occur.

23.1.1.2 Ships applying for CCS Anti-Cold Climate notation are to comply with the requirements of this Chapter in addition to the requirements of other Chapters of the Rules, as applicable.

23.1.1.3 Low air temperature environments may affect hull structure, function of equipment and systems, human performance and safety of the ships' operation. To remove or mitigate adverse impacts of low air temperatures and take anti-cold climate measures reasonably and effectively, the following risks, but not limited to, are to be taken into account:

(1) loss of material properties;
(2) reduced efficiency or failure of machinery/equipment;
(3) freezing of cargo;
(4) freezing of ballast water;
(5) reduced habitability;
(6) reduced human performance;
(7) frostbite;
(8) ice accretion of the ship above the waterline.

23.1.1.4 Where the design and construction of ship are different from the provisions of this Chapter, a risk analysis method may be used to evaluate the ships and their equipment, so as to ensure the achievement of goals and functional requirements of this Chapter or develop operational limitations. The operational limitations are to be indicated in relevant design information.

23.1.2 Definitions

23.1.2.1 For the purpose of this Chapter:

(1) Mean Daily Low Temperature (MDLT) means the mean value of the daily low temperature for each day of the year over a minimum 10 year period. A data set acceptable to the Administration may be used if 10 years of data is not available. (Refer to Figure 23.1.2.1 for MDLT)

(2) Low air temperature environment means water areas with the lowest MDLT (LMDLT) lower than -10℃, such as the Arctic Ocean, the Antarctic Ocean, Gulf of St. Laurence, the northern Baltic Sea, Sea of Okhotsk, the Bohai Sea and the northern Huanghai Sea, etc. In general, waters of this type are covered by regional sea ice in the winter. (Refer to Figure 23.1.2.1 for LMDLT)

(3) Design Service Temperature (DST) means a temperature indicator set for the ship measuring the service performance of materials, equipment and systems in low air temperature environments in the design. The temperature is determined by the shipowner in accordance with the purpose and service condition of the ship and is in general to be set at least 10℃ below the LMDLT for the intended area and season of operation.

(4) Minimum Anticipated Temperature (MAT) means the lowest ambient temperature that may be anticipated in the intended navigation areas of the ship during the voyage. If accurate historical statistical data is not available, MAT is in general to be taken as at least 20℃ lower than LMDLT.

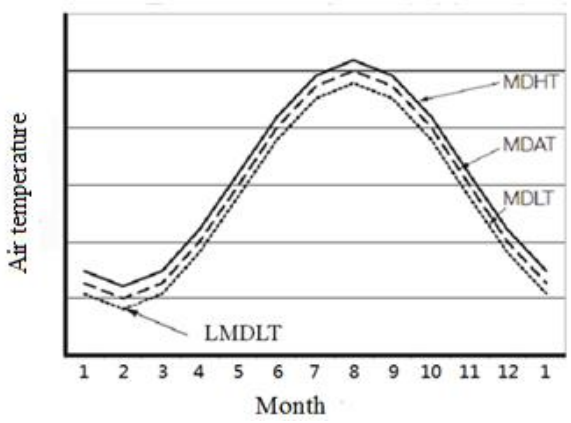
(5) Positive temperature spaces mean spaces that are maintained constantly above 0℃ by lagging heat insulating materials or installing air conditioning systems thus making freezing unlikely.

(6) Low temperature spaces mean spaces where the ambient temperature is constantly below 0℃ thus making freezing likely.

(7) Anti-icing means preventing the exposed areas and facility surfaces from accumulation and freezing of ice and snow (i.e. ice and snow accretion) by means of covering, heating or other measures which are generally applied to areas such as superstructures, deck passageways, railings and handholds, cargo decks and helicopter platforms as well as equipment for navigation, mooring, life-saving and fire-fighting.

(8) De-icing means removing ice and snow accretion in the exposed areas and facility surfaces by using tools.

(9) Anti-freezing means keeping the liquid inside tanks, equipment and pipelines exposed to low air temperature environments from freezing by excitation, circulation, insulation and heating, etc.



Notes:

MDHT – Mean Daily High Temperature
MDAT – Mean Daily Average Temperature
MDLT – Mean Daily Low Temperature
LMDLT – Lowest Mean Daily Low Temperature

Figure 23.1.2.1 General Temperature Definitions

23.1.3 Class notations

23.1.3.1 The following Anti-Cold Climate notations may be assigned upon application of the shipowner subject to compliance of the ship with the provisions of this Chapter:

(1) ACC (DST): Ships that are plan approved and surveyed by CCS and found compliant with the requirements of this Chapter may be assigned with the class notation, i.e. the basic Anti-Cold Climate notation.

(2) ACC-POLAR (DST): Ships that are plan approved and surveyed by CCS and found compliant with the requirements of this Chapter and that are anticipated to operate in polar waters may be assigned with the class notation, i.e. the polar Anti-Cold Climate notation.

(3) H (DST): Ships that are plan approved and surveyed by CCS and the materials used for hull structures of which comply with the relevant requirements in Sections 2 and 10 of this Chapter may be assigned with the class notation, i.e. the hull Anti-Cold Climate notation.

(4) DE-ICE: Ships that are plan approved and surveyed by CCS and found compliant with the requirements in Section 11 of this Chapter may be assigned with the class notation, i.e. the DE-ICE notation.

23.1.4 Plans and documents

23.1.4.1 For H (DST) notation, the relevant structural plans to be submitted for approval as required by other Chapters of the Rules are to contain steel grades of the materials.

23.1.4.2 In addition to 23.1.4.1 above, for ACC (DST), ACC-POLAR (DST) notations, anti-cold climate design plans and documents as follows are to be submitted for approval:

(1) General arrangement highlighting anti-cold climate features and design service temperatures;

(2) List of anti-cold climate equipment and systems;

(3) Details of main/auxiliary engines arrangements (including anti-cold climate features such as heating arrangement);

(4) Details of materials specification/heating arrangements for exposed pipes/components;

(5) Details of anchoring lifting appliance anti-cold arrangements;

(6) Details of materials specification/heating arrangements for exposed cabling/components;

(7) Details of anti-cold climate for fire-fighting appliances;

(8) Details of anti-cold climate for life-saving appliances;

(9) Details of heating arrangements for cabins;

(10) Details of cabin and escape route arrangements;

(11) Details of anti-freezing arrangements for tanks;

(12) Inventory and locations of de-icing measures;

(13) Calculations of ice accretion stability;

(14) Details of anti-freezing arrangements for emergency towing (applicable to tankers);

(15) Anti-freezing arrangements for crew's working passageways;

(16) Structural strength calculation of the cargo maintenance system (additional ice accretion load,

applicable to liquefied gas carriers);
(17) Diagram of the environmental control system (dew-point temperature control, applicable to liquefied gas carriers);
(18) Anti-cold climate arrangements for the rescue area (applicable to offshore supply vessels);
(19) Anti-cold climate arrangements for cargo securing equipment (applicable to container ships);
(20) Anti-cold climate arrangements for the helicopter deck or hovering area.

23.1.4.3 For ACC (DST), ACC-POLAR (DST) notations, the following plans and documents are to be submitted for information:
(1) anti-cold climate design instructions;
(2) anti-cold climate operational and maintenance procedures, for example:
① continuous circulation of fluids and/or heating media;
② use of heating arrangements in low air temperature environments;
③ application of lubricants in exposed and low temperature spaces;
④ applicable locations and application procedures of antifreeze;
⑤ use of oil fuel for emergency generators and lifeboat/rescue boat engines in low air temperature environments;
⑥ applicable antifreeze and cleaning solutions for bridge windows;
⑦ draining and/or drying of pipelines prone to freezing;
⑧ characteristics and application procedures of de-icing tools.

23.1.4.4 For DE-ICE notation, refer to 23.11.3 for the requirements for submittal of plans and documents.

23.1.4.5 Anti-cold climate design diagrams and anti-cold climate operational and maintenance procedures are always to be kept on board ships.

Section 2 MATERIALS AND WELDING

23.2.1 General requirements

23.2.1.1 For ships intended to operate in low air temperature environments, the materials used for hull structures and machinery and equipment are to satisfy the normal usage demands at the design service temperature.

23.2.1.2 Material grades are to be selected based on design service temperature, material class and thickness.

23.2.1.3 Materials and welding are to comply with the relevant requirements of PART TWO of the Rules in addition to the requirements of this Section.

23.2.2 Materials of hull structural members

23.2.2.1 Steels for hull structures exposed to low air temperature environments are not to be of lower grade than those specified in Table 23.2.2.2(1) and the material grade is to be selected in accordance with Tables 23.2.2.2(2), 23.2.2.2(3) and 23.2.2.2(4).

23.2.2.2 As a special product, the steels for anchor chain cables and offshore mooring chains are to be in accordance with the requirements of Section 12, Chapter 3, PART ONE of CCS Rules for Materials and Welding, except that the use of grade 1 chain cables is not permitted. The highest temperature for the impact test is -20℃.

23.2.2.3 The materials for hatch coamings, hatch covers, foundations of cranes and windlasses are at least to be of class II. The material grade is to be selected in compliance with the requirements for material class and thickness as given in Tables 23.2.2.2(2), 23.2.2.2(3) and 23.2.2.2(4) respectively.

Material Class in Low Air Temperature Environments **Table 23.2.2.2(1)**

Structural member category	Structural member	Material class	
		Within 0.4*L* amidships	Outside 0.4*L* amidships
Secondary	Deck plating exposed to weather in general, side plating above CWL⑤, transverse bulkheads above CWL⑥	I	I
Primary	Strength deck plating① Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings	II	I

Structural member category	Structural member	Material class	
		Within 0.4*L* amidships	Outside 0.4*L* amidships
	Longitudinal bulkhead above CWL⑥ Top wing tank bulkhead above CWL⑥		
Special	Sheer strake at strength deck; stringer plate in strength deck②; deck strake at longitudinal bulkhead③; continuous longitudinal hatch coamings④	III	II

Notes: ① Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.

② Not to be less than grade E/EH within 0.4*L* amidships in ships with length exceeding 250 m.

③ In ships with breadth exceeding 70 m at least three deck strakes are to be class III.

④ Not to be less than grade D/DH.

⑤ The Cold Waterline (CWL) is to be taken as 300 mm below the minimum design Ballast Waterline (BWL).

⑥ Applicable to platings attached to shell plating exposed to low air temperature environments. At least one strake is to be considered as the exposed plating which is to be at least 600 mm in width.

Material Grade Requirements for Class I in Low Air Temperature Environments

Table 23.2.2.2(2)

Plate thickness (mm)	Design service temperature (℃)											
	-23~-27℃		-28~-32℃		-33~-38℃		-39~-48℃		-49~-58℃		-59~-68℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	A	AH	A	AH	B①	AH	B	AH	D	DH	D	DH
$10 < t \leq 15$	A	AH	A	AH	B	AH	D	DH	D	DH	D	DH
$15 < t \leq 20$	B	AH	B	AH	B	AH	D	DH	D	DH	E	EH
$20 < t \leq 25$	B	AH	B	AH	D	DH	D	DH	D	DH	E	EH
$25 < t \leq 30$	B	AH	D	DH	D	DH	D	DH	E	EH	E	EH
$30 < t \leq 35$	D	DH	D	DH	D	DH	D	DH	E	EH	E	EH
$35 < t \leq 45$	D	DH	D	DH	D	DH	E	EH	E	EH	–	FH
$45 < t \leq 50$	D	DH	D	DH	E	EH	E	EH	–	FH	–	FH

Note: ① If fully killed, grade A steel is also acceptable.

Material Grade Requirements for Class II in Low Air Temperature Environments

Table 23.2.2.2(3)

Plate thickness (mm)	Design service temperature (℃)											
	-23~-27℃		-28~-32℃		-33~-38℃		-39~-48℃		-49~-58℃		-59~-68℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	A	AH	A	AH	B	AH	D	DH	D	DH	E	EH
$10 < t \leq 20$	B	AH	B	AH	D	DH	D	DH	E	EH	E	EH
$20 < t \leq 30$	B	AH	D	DH	D	DH	E	EH	E	EH	–	FH
$30 < t \leq 40$	D	DH	D	DH	E	EH	E	EH	–	FH	–	FH
$40 < t \leq 45$	D	DH	D	DH	E	EH	–	FH	–	FH	–	–
$45 < t \leq 50$	E	EH	E	EH	E	EH	–	FH	–	FH	–	–

Material Grade Requirements for Class III in Low Air Temperature Environments

Table 23.2.2.2(4)

Plate thickness (mm)	Design service temperature (℃)											
	-23~-27℃		-28~-32℃		-33~-38℃		-39~-48℃		-49~-58℃		-59~-68℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	B	AH	B	AH	D	DH	D	DH	E	EH	E	EH
$10 < t \leq 20$	B	AH	D	DH	D	DH	E	EH	E	EH	–	FH
$20 < t \leq 25$	D	DH	D	DH	E	EH	E	EH	E	FH	–	FH
$25 < t \leq 30$	D	DH	E	EH	E	EH	E	EH	–	FH	–	FH
$30 < t \leq 35$	E	EH	E	EH	E	EH	–	FH	–	FH	–	–
$35 < t \leq 40$	E	EH	E	EH	E	EH	–	FH	–	FH	–	–
$40 < t \leq 50$	E	EH	E	EH	–	FH	–	FH	–	–	–	–

23.2.3 Machinery materials

23.2.3.1 Deck machinery materials are to comply with the requirements for steels for machinery structures in Section 6, Chapter 3, PART ONE of CCS Rules for Materials and Welding. The materials for lifting appliances are to be in accordance with CCS Rules for Lifting Appliances of Ships and Offshore Installations, and the materials not covered in that Rules are to comply with the requirements of 23.2.3.2 below.

23.2.3.2 The material classes of members/components of machinery installations exposed to low air temperature environments are to be in accordance with Table 23.2.3.2; the plates are to comply with the requirements of 23.2.2.1 and castings and forgings are to comply with the requirements of 23.2.3.6 and 23.2.3.7 respectively.

Material Classes for Equipment and Members/Components Table 23.2.3.2

Main component	Sub-component	Class
Deck machinery and equipment		
Windlass	Cable lifter, gear wheel, shaft	II
	Foundation bolt, brake system, stripper bar	II
	Casing	I
Mooring winches	Gear wheel, shaft, foundation bolt	II
	Casing	I
Winch hydraulic motors		II
Winch controls	Hydraulics	II
Bollards		III
Fairleads/bits		II
Anchor	Crown/head, shackle and shank	II
	Crown/head pin and shackle/swivel pin	I
Anchor lashing		II
Chain stopper		II
Emergency towing system①		II
Exposed weight-bearing structures and machinery components, cargo securing arrangements		II
Lifting appliances, boat davits/boat hooks		II
Others		
Ventilator, small hatch cover, manhole cover		I

Note: ① When emergency towing arrangements are used as bollards, the material is to be class III.

23.2.3.3 Charpy V-notch impact tests for materials of the piping systems (including pipes, valves and fittings) for machinery equipment and systems exposed to low air temperature environments are to be in accordance with the requirements as given in Tables 23.2.3.3(1) to 23.2.3.3(3).

23.2.3.4 The material classes specified in Tables 23.2.3.3(1) to 23.2.3.3(3) are opposite to the classes of piping in Section 1, Chapter 2, PART THREE of the Rules, i.e. for class I piping, the material class of the piping is to be class III.

23.2.3.5 In general, the Charpy V-notch impact energy of piping materials exposed to low air temperature environments is not to be less than 27 J.

Impact Testing Temperature Requirements for Class I in Low Air Temperature Environments

Table 23.2.3.3(1)

Wall thickness (mm)	Design service temperature (℃)					
	-23~-27℃	-28~-32℃	-33~-38℃	-39~-48℃	-49~-58℃	-59~-68℃
t≤10	+20	+20	+20	0	-20	-20
10<t≤15	+20	+20	0	-20	-20	-20
15<t≤20	0	0	0	-20	-20	-40
20<t≤25	0	0	-20	-20	-20	-40
25<t≤30	0	-20	-20	-20	-40	-40
30<t≤35	-20	-20	-20	-20	-40	-40
35<t≤45	-20	-20	-20	-40	-40	-40
45<t≤50	-20	-20	-40	-40	-60	-60

Impact Testing Temperature Requirements for Class II in Low Air Temperature Environments

Table 23.2.3.3(2)

Wall thickness (mm)	Design service temperature (℃)					
	-23~-27℃	-28~-32℃	-33~-38℃	-39~-48℃	-49~-58℃	-59~-68℃
t≤10	+20	+20	0	-20	-20	-40
10<t≤20	0	0	-20	-20	-40	-40
20<t≤30	0	-20	-20	-40	-40	-60
30<t≤40	-20	-20	-40	-40	-60	-60
40<t≤45	-20	-20	-40	-60	-60	–
45<t≤50	-40	-40	-40	-60	-60	–

Impact Testing Temperature Requirements for Class III in Low Air Temperature Environments

Table 23.2.3.3(3)

Wall thickness (mm)	Design service temperature (℃)					
	-23~-27℃	-28~-32℃	-33~-38℃	-39~-48℃	-49~-58℃	-59~-68℃
t≤10	0	0	-20	-20	-40	-40
10<t≤20	0	-20	-20	-40	-40	-60
20<t≤25	-20	-20	-40	-40	-60	-60
25<t≤30	-20	-40	-40	-40	-60	-60
30<t≤35	-40	-40	-40	-60	-60	–
35<t≤40	-40	-40	-40	-60	-60	–
40<t≤45	-40	-40	-60	-60	-60	–
45<t≤50	-40	-40	-60	-60	–	–

23.2.3.6 Steel forgings and castings used for exposed machinery and system components are to be made of killed steel and to comply with the relevant requirements of Chapters 5 and 6, PART ONE of CCS Rules for Materials and Welding.

23.2.3.7 The impact testing temperature for steel forgings and castings is given in Table 23.2.3.7. For steel the yield strength of which is less than 305 N/mm^2, the minimum average impact energy is to be 27 J; for steel the yield strength of which is equal to or greater than 305 N/mm^2, the minimum average impact energy is to be 34 J.

Impact Testing Temperature Requirements for Steel Forgings and Castings in Low Air Temperature Environments **Table 23.2.3.7**

Class	Design service temperature (℃)			
	-23~-27℃	-28~-32℃	-33~-38℃	≤-39℃
Class I or II	-20	-20	-40	Specially considered
Class III	-20	-40	-40	
Note: For manufacturing and installation of non-welded members, the testing temperature may increase by 20℃, but not more than 0℃.				

23.2.4 Welding

23.2.4.1 The welding technical requirements for hull structural members and machinery structural members/components are to be referred to in Section 2, Chapter 5, PART THREE of CCS Rules for Materials and Welding.

23.2.4.2 The selection of welding consumables are to satisfy the performance requirements of the pieces to be welded. For welding of high strength quenched and tempered steel, low hydrogen welding consumables are to be used.

23.2.4.3 The finished welds are to comply with the rules requirements.

Section 3 SHIP ARRANGEMENTS

23.3.1 General requirements

23.3.1.1 Equipment and areas that require anti-icing/anti-freezing measures are as far as possible to be situated in protected locations, such as enclosed spaces, semi-enclosed spaces or covered by curtains.

23.3.1.2 For structures, equipment and pipes, the heating capacity for anti-icing and anti-freezing arrangements is to be sufficient to prevent icing or freezing in low air temperature environments, the arrangements are to be able to maintain a surface temperature of at least 3 ℃ under the minimum anticipated temperature.

23.3.1.3 In anti-icing and anti-freezing arrangements using heating, special attention is to be paid to the heat transfer from the heating cables or pipes to the equipment or structure to be heated. The spacing and fastening of heating cables or pipes are to be appropriate for efficient heating to keep the equipment or structure ice-free under the minimum anticipated temperature.

23.3.1.4 For anti-icing and de-icing arrangements applying heating by fluids in pipes, the installation is to ensure that the heating fluid maintains its heating effectiveness under the minimum anticipated temperature.

23.3.2 Accommodation

23.3.2.1 Accommodation heating systems are to be capable of maintaining a reasonable internal temperature in all spaces normally occupied when the ship is at sea. Supplementary heaters may also be used in accommodation and other manned spaces in addition to the air conditioning heating system specified in 23.6.4.12.

23.3.2.2 Heating arrangements are to be provided for the following spaces, but not limited to, containing machinery and equipment for essential or emergency services to satisfy the service demands of such spaces:

(1) navigation bridge;
(2) radio room;
(3) hospital room (including sick bay);
(4) battery room;
(5) mooring rope stores (including the bosun's store);
(6) observation/security cabins (where fitted);
(7) enclosed forecastle/sheltered deck (where fitted);
(8) under-deck passageways (where fitted);
(9) main engine and auxiliary machinery space(s) (including individually arranged main generator room);
(10) azimuth thruster space(s) (including pods);
(11) boiler room;
(12) workshop room and store(s);
(13) engine control room;
(14) switchboard room;
(15) steering gear room;

(16) bow thruster(s) room;
(17) emergency generator room;
(18) fire control station(s);
(19) fire-fighting appliances stores;
(20) stores for de-icing, anti-freezing measures (where fitted);
(21) emergency fire pump-room.
In general, fixed heating arrangements are to be used. For items (6), (7), (10) to (13) above, when the design service temperature is not lower than -25℃, portable heating arrangements may be accepted.
23.3.2.3 Accommodation requiring heating arrangements to maintain a reasonable internal temperature is to be provided with a fixed thermometer.

23.3.3 Tanks
23.3.3.1 The ship is to have an appropriate arrangement to prevent the surfaces in ballast tanks, fresh water tanks and other relevant tanks from freezing over considering the minimum anticipated temperature.
23.3.3.2 Tank arrangements are to be such that fuel oil tanks are to be maintained 10℃ above the fuel's pour point and water tanks are to be maintained not lower than 2℃ under the minimum anticipated temperature.
23.3.3.3 Different anti-freezing measures are to be used depending on conditions, such as continuous circulation, bubble turbulence or convection-inducing systems, etc.; where the design service temperature is below -40℃, convection-inducing measures are to be used, such as a vertical heating coil.
23.3.3.4 Level gauging arrangements of the tank is to function under the minimum anticipated temperature.
23.3.3.5 Where the ballast tank is fully below the light service waterline or lower ice waterline, whichever is lower, and where the fresh water tank is not adjacent to the shell or deck and is located in the heated area, anti-freezing measures may not be provided, unless specified otherwise.

23.3.4 Superstructures and deckhouses
23.3.4.1 For ships operating in polar waters, the bridge wings are to be enclosed and both sides are to be visible without opening the bridge doors and windows. Additional conning positions, if any, are to be enclosed.
23.3.4.2 Bridge windows are to be fitted with heating and cleaning systems and are to function under the minimum anticipated temperature. Where the water flushing system is fitted, measures are to be taken to prevent pipelines and fittings from freezing and thus becoming inoperable.
23.3.4.3 Navigation bridge doors and the adjacent deck areas are to be so arranged as to prevent ice and snow accretion.
23.3.4.4 Cargo control room sidescuttles (including window wipers) are to be heated as required and external access for cleaning is to be provided.
23.3.4.5 At least one of the Master's cabin windows is to have a heating arrangement for a view over the cargo deck where necessary.
23.3.4.6 Windows in accommodation spaces are generally to be double-glazed except for those on ships operating in low air temperature environments occasionally or for a short period.
23.3.4.7 Exterior stairs and railings not forming the escape routes are to be provided with anti-icing or de-icing protection.

23.3.5 Helicopter decks
23.3.5.1 Helicopter decks or hovering areas, if provided, are to be provided with de-icing measures.

Section 4 STABILITY

23.4.1 General requirements
23.4.1.1 Ships operating in low temperature environments① are to have sufficient stability when subject to ice accretion under the minimum anticipated temperature.
23.4.1.2 Ships operating in low temperature environments are to be:
(1) designed to minimize the accretion of ice;

① Low temperature environments mean environments where ice accretion is possible when the air temperature is below 0℃.

(2) equipped with such means for removing ice; for example, electrical and pneumatic devices, and/or special tools such as axes or wooden clubs for removing ice from bulwarks, rails and erections;
(3) monitored for ice accretion during operation and appropriate measures are to be taken to ensure that ice accretion allowance does not exceed the value specified in the Stability Manuel.

23.4.2 Intact stability

23.4.2.1 Intact stability of ships when subject to ice accretion is to comply with the relevant requirements in Section 9, Chapter 1, PART TWO of the Rules.

23.4.2.2 For ships operating in low air temperature environments, the following icing allowances are to be considered in the stability calculation:
(1) 30 kg/m^2 on exposed decks and gangways;
(2) 7.5 kg/m^2 for projected lateral area of each side of the vessel above the water plane; and
(3) the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging of vessels having no sails and the projected lateral area of other small objects are to be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.

23.4.2.3 The Stability Manuel is to contain the information on ice accretion allowance in the stability calculation.

Section 5 WATERTIGHT AND WEATHERTIGHT INTEGRITY

23.5.1 General requirements

23.5.1.1 For ships operating in low temperature environments, all closing appliances and doors related to watertight and weathertight integrity onboard are to be operable.

23.5.2 Hatches, side doors and cargo loading doors

23.5.2.1 For ships intended to operate in low air temperature environments (except for those navigating in the cold areas occasionally or for a short period), the following requirements are also to be complied with:
(1) If the hatches or doors are hydraulically operated, measures are to be taken to prevent liquid from freezing or excessive viscosity.
(2) Watertight and weathertight doors, hatches and closing devices not in habitable environments but required for use while at sea are to be so designed as being operable by persons wearing heavy winter clothes and thick mittens.

23.5.2.2 Ramp doors and side doors are to be provided with means to remove ice accretion around hatches and doors.

23.5.3 Freeing ports, scuppers, discharges and inlets

23.5.3.1 For ships intended to operate in low air temperature environments, freeing ports, scuppers, discharges and inlets are to be kept clear.

23.5.3.2 Freeing ports are to comply with the following requirements:
(1) freeing ports are to be fitted with anti-icing protection;
(2) if a shutter is fitted on the freeing port, it is to be provided with heating sufficient for maintaining its opening ability;
(3) increasing the freeing port area by 30% is accepted as an alternative to heating.

23.5.3.3 For decks, passageways and muster areas that are required to be kept ice-free, the scuppers and discharges in such spaces are to be provided with anti-freezing protection.

Section 6 MACHINERY INSTALLATIONS

23.6.1 General requirements

23.6.1.1 All machinery, equipment and systems, including pipes and cabling, are to be located inside spaces as far as practicable to minimize exposure to low air temperature environments where ice and snow accretion are likely to occur.

23.6.1.2 Main and auxiliary machinery and exposed essential machinery equipment are to be capable of operating satisfactorily under the minimum anticipated temperature.

23.6.1.3 Each machinery and system on board ships are to be provided with the following appropriate protection methods to prevent effects of low temperatures and ice accretion:
(1) heating (for space and/or dedicated arrangements for equipment/systems);
(2) de-icing equipment;
(3) covers (where PVC covers or other water resistant materials are used, they are to be fixed firmly to prevent unintended removal in severe weather conditions);
(4) drainage;
(5) insulation;
(6) selection of materials;
(7) selection of lubricants, oils, hydraulics and greases, etc.
23.6.1.4 Where heating arrangements are provided, they are to be fitted with the following:
(1) means for ascertaining the temperature;
(2) for systems where heating arrangements could result in excessively high temperatures or pressures being generated, that may cause damage, malfunction or braking of equipment, there are to be arrangements provided for cutting off the heating;
(3) appropriate control arrangements;
(4) indication of the system(s) operation;
(5) where failure of a heating arrangement could result in a hazardous situation, an alarm is to be activated.

23.6.2 Main and auxiliary machinery

23.6.2.1 To ensure the starting capacity of ships from the dead-ship condition, due consideration is to be given to the impacts of the minimum anticipated temperature on the relevant machinery and electrical equipment.
23.6.2.2 The combustion air system of the prime mover is to be suitable for the minimum anticipated temperature.
(1) The arrangements for air supply to main propulsion, main generators and emergency generators are to ensure that the engine manufacturer's specification for air intake temperature is complied with.
(2) Turbochargers and the associated combustion air system for internal combustion engines are to be so designed as to obtain surge-free operation throughout the range of ambient air temperatures in which the ship is expected to operate.
(3) For ships operating in polar waters all year round, where the design service temperature is below -40℃, the combustion air is to be led directly from the weather to the engines having a rated power of 100 kW and over by way of ducting or other suitable means.
(4) The combustion air intakes are to be located on both sides of the ship and so arranged as to prevent the recirculation of engine exhaust gases into the combustion air intakes, ice/snow accretion and blockage of the duct.
(5) Combustion air for other internal combustion engines used as prime movers is to be provided in accordance with the manufacturer’s recommendations. The details and arrangements will be subject to special consideration of CCS.
23.6.2.3 The lubricating oil of the engine is to be maintained at the proper minimum temperature in accordance with the manufacturer’s recommendations to allow equipment start-up. The use of steam heating coils within prime mover sump tanks is not permitted.
23.6.2.4 Under the anticipated seawater temperature condition, oil-lubricated bearings are to be provided with means to heat the lubricating oil to maintain viscosity in accordance with the bearing manufacturer’s requirements; water-lubricated bearings are to be suitable for continuous operation in low temperatures.
23.6.2.5 Steering gear components are to be provided with greases or lubricating oils suitable for low temperature unless they are arranged in positive temperature spaces.
23.6.2.6 Azimuth propulsion systems as well as ship steering systems (such as pods) are to be provided with suitable provisions to prevent freezing, including heating arrangements, suitable lubricating oils, hydraulic oils and antifreeze.
23.6.2.7 Where an auxiliary boiler serves anti-cold climate arrangements simultaneously, its capacity is to satisfy the demand under the minimum anticipated temperature; for ships operating in polar waters all year round, where the design service temperature is below -40 ℃, at least two auxiliary boilers are to be provided, either of which is to satisfy the demand of the ship.

23.6.3 Deck machinery

23.6.3.1 Exposed control panels of deck machinery are to be provided with protective covers or heating arrangements for anti-freezing protection.

23.6.3.2 Where ice accretion occurs to cranes on deck in low air temperature environments, the cranes are to be able to withstand ice accretion allowance in the stowed and operating conditions as applicable. Crane foundations and supporting structures are also to be able to support a crane with the ice accretion allowance under consideration above.
23.6.3.3 Means are to be provided for habitable working conditions in exposed crane cabs, where fitted, by providing internal space heating arrangements. Cab windows are to be provided with heating arrangements to prevent icing.
23.6.3.4 Suitable provisions for cold start at the design service temperature of exposed deck cranes are to be provided. Suitable lubricating oils and greases, circulation facilities for hydraulic oils and a flushing system for the hydraulic oil are to be provided.
23.6.3.5 The anchor windlass and exposed windlass controls are to be provided with appropriate covers or heating arrangements for anti-icing protection. Alternatively, they are to be arranged in enclosed or semi-enclosed deck areas. Anchor chains are to be capable of being de-iced manually.
23.6.3.6 The hawse pipes are to be provided with anti-freezing protection or de-icing protection by steam or hot water.
23.6.3.7 Hawse pipe wash lines are to be provided with continuous circulation or heating arrangements for anti-freezing protection of water in the pipes.
23.6.3.8 Mooring winches are to be provided with suitable covers or heating arrangements for anti-icing protection. De-icing measures are to be arranged in the vicinity of mooring winches.
23.6.3.9 The foundations of anchor windlass and mooring winches may be cast by epoxy resin, the minimum anticipated temperature is to be taken into account for selection of the epoxy resin.

23.6.4 Piping systems
23.6.4.1 Piping systems are to be so designed as to minimize exposure of crew to low air temperature environments during normal operation and routine maintenance.
23.6.4.2 The possibility of ingress of ice/snow and the adverse impacts of low air temperature and ice accretion are to be taken into account for piping systems located in exposed or low temperature spaces. Exposed piping systems are to be suitable for the minimum anticipated temperature.
(1) Hoses in low air temperature environments are to maintain their flexibility and tightness.
(2) Exposed valves are to avoid freezing of fluids on either side of the valve and to prevent the accumulation of snow and spray ice.
(3) Piping components located in exposed or low temperature spaces, such as valve control units, manifolds, vents, gasket seals, and thermal instruments such as indicators, sensors and other fittings, are to be provided with anti-icing, anti-freezing protection or other means to provide for continued functionality.
(4) Pipes in which fluids are liable to freezing are to be so arranged as to be drained effectively, otherwise means are to be provided for anti-freezing protection.
(5) Overboard discharge outlets are normally to be arranged below the waterline.
(6) Overboard discharge valves arranged in low temperature spaces or above the waterline are to be provided with low pressure steam connections for clearing purposes, unless other anti-freezing measures are provided.
(7) Due consideration is to be given to the thermal expansion and cold contraction impacts on pipes due to temperature difference for piping arrangements in exposed and low temperature spaces.
23.6.4.3 Vent piping systems and sounding pipes are to maintain functionality in low air temperature environments.
(1) For air pipes and pipe heads arranged in exposed or low temperature spaces, measures are to be taken to prevent blockage due to internal humidity freezing.
(2) Exposed air vent pipe heads are to be provided with anti-icing measures against blockage, such as heat tracing or protective cover; where protective covers are provided against icing, the covers are not to interfere with the free flow of air through the vent openings.
(3) Sounding pipes of tanks are to be provided with anti-freezing measures for ready availability.
(4) Where the tank is provided with heating arrangements, anti-freezing measures may be exempted for the vent piping system and sounding pipe upon calculation.
23.6.4.4 Ballast water piping systems are to maintain functionality in low air temperature environments.
(1) The use of gray cast iron material for piping, valves and fittings is prohibited.
(2) Where local freezing of ballast tanks is unavoidable, GRP piping and other system components in the tanks likely to be damaged by fallen ice hitting are to be suitably protected.
(3) Where sea chests are provided for ballast water piping system separately, direct steam connections to the sea chests are to be provided for de-icing purposes; alternatively, a sea bay and heating arrangements may be used.

(4) Sea inlet valves are to be provided with low pressure steam connection for clearing purposes.
(5) Overboard discharge outlets are generally not to be above the waterline; where they must be above the waterline, suitable heating arrangements are to be provided for ballast water discharge pipes.
(6) Where the design service temperature is below -40℃, suitable heating arrangements are to be provided for ballast water discharge pipes.
23.6.4.5 Fresh water piping systems in low air temperature environments are to be provided with suitable anti-freezing arrangements.
(1) Fresh water pipes are to be arranged in positive temperature spaces as far as practicable and are to be thermally insulated or heat traced when running through low temperature spaces.
(2) Exposed sections of fresh water lines are to be fitted with an isolating valve located inside a positive temperature space such that the exposed length can be drained, and in general a dry air blow connection is to be provided at the most forward end.
(3) Fresh water generation systems' inlet water temperatures are to comply with the manufacturer's requirements.
23.6.4.6 Drainage piping systems are to maintain functionality in low air temperature environments.
(1) Drainage pipes are to be arranged in positive temperature spaces as far as practicable or heat traced.
23.6.4.7 Fuel oil piping systems are to maintain functionality in low air temperature environments.
(1) In addition to adding additives to fuel oil, where necessary, fuel oil tanks for engines and boilers are to be provided with heating coils to ensure continuous supply of fuel oil in the minimum anticipated temperature.
(2) Where ships need to be filled with fuel oil in low air temperature environments, fuel oil filling stations are to be located in an area sheltered from the weather and easy for access and operation. For fuel oil filling pipes located on the deck, alternative arrangements to protect the filling pipes are to be provided such as a removable or hinged cover may be installed.
(3) Where the design service temperature is below -25℃, fuel oil filling pipes and transfer pipes arranged in exposed and low temperature spaces are to be heat traced and thermally insulated.
23.6.4.8 Seawater cooling piping systems are to ensure normal seawater supply in the anticipated environments.
(1) At least one sea chest is arranged as such to prevent the blockage of seawater inlet gratings and seawater pipe inlets by floating ice.
(2) Sea chest valves are to be provided with low pressure steam connection for clearing purposes.
(3) Where the design service temperature is below -40℃, cooling water discharge pipes are to be provided with suitable heating arrangements.
(4) As an alternative to (1), (2) and (3) above, ballast water may be circulated as cooling water for main and auxiliary engines, and relevant heat balance calculations are to be submitted.
23.6.4.9 Compressed air piping systems are to ensure supply of sufficiently dry compressed air to essential systems in low air temperature environments.
(1) Compressed air for low temperature spaces is to have a dew point not higher than the design service temperature, but at least as low as -25℃.
(2) Compressed air supplying control air to exposed facilities is to have a dew point not higher than the minimum anticipated temperature.
(3) Where the design service temperature is not lower than -25℃, heating arrangements may be used as an alternative to (1) and (2) above; where the design service temperature is lower than -25℃, heating arrangements are to be provided for control air.
(4) Compressed air pipes arranged on exposed decks are to be provided with drainage valves at the lowest position.
23.6.4.10 Hydraulic piping systems are to maintain functionality in low air temperature environments.
(1) Hydraulic oil is to either be of a type that maintains an acceptable viscosity, or the hydraulic system is to have heating or circulation arrangements to keep fluids at an appropriate temperature to ensure the operability of the essential systems they serve.
(2) As far as practicable, hydraulic oil power packs are to be sited in positive temperature spaces. Where this is not practicable, the hydraulic oil and piping system are to be suitable for operation under the minimum anticipated temperature.
(3) Exposed control stand valves for hydraulic oil lines used for remote control are to be provided with heating arrangements for anti-freezing protection of the mechanism.
(4) Where the design service temperature is lower than -25℃, heating arrangements are to be provided under the bottom of hydraulic oil tank in low temperature spaces; where the design service temperature is lower than -40℃, hydraulic pipes in low temperature spaces are also to be thermally insulated or heated.

23.6.4.11 Steam piping systems are to maintain functionality in low air temperature environments.
(1) Means are to be provided for anti-freezing protection of condensate in exposed steam pipes, by thermal insulation or by compressed air blow when not in use.
23.6.4.12 HVAC systems are to operate effectively under the anticipated design service temperature.
(1) Accommodation spaces are to be heated at least to 18 ℃ under the anticipated design service temperature and maintained at this temperature.
(2) The maximum fresh air ratio in accommodation spaces is to be 0.5.
(3) The relative humidity of spaces fitted with HVAC systems is to be maintained in the range between 30% and 70%.
(4) Condensate on the inner bulkheads of accommodation spaces is to be kept at a minimum and effective condensate drainage systems are to be provided.
(5) Condensate on observation windows of the navigation bridge and cargo control room are to be kept at a minimum.
(6) Closing appliances for ventilation inlets and outlets are to be suitably arranged to prevent disturbance by snow and ice accretion and to maintain the effectiveness of air circulation.

23.6.5 Electrical equipment
23.6.5.1 In addition to complying with the requirements of Section 1, Chapter 2, PART FOUR of the Rules, the capacity of the main power source is to be sufficient to supply the air-conditioning system and heating arrangements provided to keep spaces at positive temperatures.
23.6.5.2 In addition to complying with the requirements of Section 2, Chapter 2, PART FOUR of the Rules, the emergency power source is to supply the following equipment and ensure 18 h for cargo ships and 36 h for passenger ships:
(1) power to the heating arrangements in the following spaces:
① navigation bridge;
② radio room;
③ engine room centralized control room;
④ workshop;
⑤ cargo control room;
⑥ fire control room;
⑦ hospital room;
⑧ at least one public space of cargo ships (such as crew mess room and recreation room), one or several public spaces of passenger ships sufficient to hold all passengers and crew;
⑨ battery room;
⑩ emergency generator room;
⑪ emergency fire pump room;
(2) heat tracing for any piping associated with the emergency consumer;
(3) auxiliary boiler, if provided, with the control, monitoring and safety system.
23.6.5.3 Generators and electric motors installed on exposed decks and in low temperature spaces are to be provided with condensation-proof arrangements as well as lubricating oil suitable for the design service temperature if the bearings require forced lubrication or pre-lubrication.
23.6.5.4 Distribution boxes, switchboards and controllers on exposed decks and in low temperature spaces are to be provided with condensation-proof arrangements.
23.6.5.5 Electric cables on exposed decks and in low temperature spaces are to be type approved according to the design service temperature. Electric cables on exposed decks are to be protected by metallic pipes or lines or sheaths.
23.6.5.6 Where electrical equipment is used to heat battery rooms, the explosion group and temperature class of equipment is not to be lower than IIC T1.
23.6.5.7 Illumination lights and navigation lights installed on exposed decks are to be suitable for the design service temperature. Where lights mentioned above cannot generate sufficient heat to keep the light fixture ice-free, they are to be readily accessible and suitable for manual de-icing, or heating arrangements are to be provided.
23.6.5.8 Where closed circuit television systems are fitted on exposed decks, these are to be provided with heating arrangements or covers, to prevent the equipment from damages or abnormal operation due to freezing.

Section 7 FIRE FIGHTING

23.7.1 General requirements

23.7.1.1 Fire-fighting systems and appliances are to be readily available at the design service temperature.

23.7.1.2 Fire mains and fire-fighting system piping are to be provided with the following anti-freezing protection, but not limited to:

(1) located in a heated passageway; or

(2) provided with heat tracing; or

(3) arranged as a dry system.

23.7.1.3 Where piping is arranged as a dry system, it is to be drained after use. Drains are to be located at the lowest points in the system, and connection means of compressed air vent pipe are to be provided at the end of the pipe other than the end where the drains are located in order to maintain the line drying. The piping layout is to ensure that all water will drain to them without being trapped in U-bends, low points or dead-ends.

23.7.1.4 For the fire-fighting system, isolating valves are to be provided between pipelines on exposed deck and those in the heated spaces. The isolating valves in exposed locations are to be provided with anti-icing protection and located in areas where it is easily accessible.

23.7.1.5 Fire extinguishing agents (foams, powders, gases) are to be rated for operation at the design service temperature.

23.7.1.6 Hydrants are to be provided with anti-icing and anti-freezing protection. The stowage positions for fire hoses and nozzles are to be provided with anti-icing and anti-freezing protection, the hoses and nozzles are to be dried immediately after use.

23.7.1.7 Portable extinguishers located in exposed and low temperature spaces are to be rated for operation at the design service temperature. The storage facilities of the portable extinguishers are to be provided with anti-icing protection and readily accessible.

23.7.1.8 All two-way portable radiocommunication equipment are to be operable at the design service temperature.

23.7.2 Fire pumps

23.7.2.1 All fire pumps, including emergency fire pumps, are to be installed in positive temperature spaces to ensure the ship's normal operation of the fire-fighting system under the minimum anticipated temperature.

23.7.2.2 Main fire pumps, if provided with separate sea chests, are arranged as such to prevent the blockage of seawater inlet gratings and seawater pipe inlets by floating ice.

23.7.2.3 Sea chests of emergency fire pumps are to be provided with means for heating, insulation or low pressure steam connection to prevent the blockage by floating ice.

23.7.3 Fire-fighter's outfits

23.7.3.1 Fire-fighter's outfits are to be stowed in easily accessible positive temperature spaces.

23.7.4 Escape routes

23.7.4.1 Essential emergency routes, such as escape routes, muster areas, lifeboat embarkation areas, are to be provided with anti-icing protection. Where exposed decks of the ship have no anti-icing requirements, de-icing tools to remove ice and snow accretion are to be provided to ensure the safety of persons onboard. Gangways and ramps are to be provided with de-icing arrangements.

23.7.4.2 Overhead structures are to be provided with de-icing or other arrangements to prevent injuries to persons or damages to essential safety equipment/structures by fallen ice.

23.7.4.3 Escape routes are to be provided with anti-icing protection to ensure that the escape routes are ice-free or providing a minimum ice-free width of 700 mm, enabling the use of at least one railing. Railings that are important as hand-holds (stairs, escape ways) are to have anti-icing protection. Railings that function only as barriers, but are not intended as handholds, may be provided with de-icing arrangements only.

23.7.4.4 External handrails on routes, stairways and ladders, if provided with heating arrangements for anti-icing protection, are to be fitted with arrangements to cut off automatically in the event of excessively high temperatures to prevent injuries to persons when in contact.

23.7.4.5 Escape routes are to be so dimensioned as not to hinder passage for persons wearing polar clothing.

23.7.4.6 Exits forming escape routes are to be provided with anti-icing measures and door seals are to be suitable for the design service temperature.

Section 8 LIFE-SAVING APPLIANCES AND ARRANGEMENTS

23.8.1 General requirements

23.8.1.1 The performance standards of life-saving appliances and arrangements are to comply with the requirements of this Section in addition to the provisions of the International Life-Saving Appliance (LSA) Code.

23.8.1.2 Life-saving appliances and arrangements are to be fully functional at the design service temperature (DST).

23.8.1.3 For ships operating in polar waters, life-saving appliances and arrangements are to be fully operable at the design service temperature (DST) during the maximum expected rescue time.

23.8.1.4 For ships the design service temperature (DST) of which is below -30℃, the muster station is to be located inside space.

23.8.1.5 The bridge and exposed deck life-buoys are to be provided with anti-icing protection and be arranged such that it is immediately deployable by the crew.

23.8.2 Lifeboats

23.8.2.1 Lifeboats are to be of totally enclosed type. The capacity of the lifeboats is to be sized for persons dressed in heat-insulated immersion suits or anti-cold climate clothing.

23.8.2.2 Lifeboat engines are to start within 2 min at the design service temperature (DST). Two separate power sources are to be provided for the start-up of lifeboat engines. Lifeboat engine batteries are to be suitable for low temperature conditions.

23.8.2.3 The cooling system for lifeboat engines is to ensure that the engines are operable at the design service temperature (DST).

23.8.2.4 Cooling water, fuel and lubricating oils for engines are to be suitable for engine operation at the design service temperature (DST).

23.8.2.5 Heating arrangements are to be provided in way of the lifeboat doors.

23.8.2.6 Heating arrangements are to be provided for lifeboat windows at the operating position, and measures are to be taken to maintain clear field of vision.

23.8.2.7 Consideration is to be given to the capacity of drinking water containers to be suitable to allow for expansion due to freezing.

23.8.2.8 Additional rations, equaling to at least 30% of the amount specified in the LSA Code, are to be provided for ships usually operating in low air temperature environments.

23.8.2.9 The release mechanism of lifeboats is to be provided with heating or other arrangements to ensure safe release at the design service temperature (DST).

23.8.2.10 Suitable de-icing tools are to be provided in the vicinity of the stowage positions for lifeboats.

23.8.3 Rescue boats

23.8.3.1 Rescue boats provided onboard are to be rigid rescue boats.

23.8.3.2 Cooling water, fuel and lubricating oils for engines are to be suitable for engine operation at the design service temperature (DST).

23.8.4 Liferafts

23.8.4.1 Where the design service temperature (DST) is blow -30℃, the inflation of inflatable liferafts is to be completed within a period of 3 min.

23.8.4.2 Where the design service temperature (DST) is below -30℃, the container and hydrostatic release mechanism for liferafts are to be provided with heating or other arrangements to ensure easy launching, inflation and release of the liferafts at the design service temperature (DST).

23.8.4.3 Where manual inflation pumps for inflatable liferafts are provided onboard, the pumps are to be stowed in positive temperature spaces in the vicinity of the inflatable liferafts.

23.8.4.4 Additional rations, equaling to at least 30% of the amount specified in the LSA Code, are to be provided for ships usually operating in low air temperature environments.

23.8.4.5 Suitable de-icing tools are to be provided in the vicinity of the stowage positions for lifeboats.

23.8.5 Launching appliances for survival craft and rescue boats

23.8.5.1 Hydraulic oil and lubricating oil for launching and embarkation appliances are to be suitable for operation at the design service temperature (DST). Greases suitable for operation in low temperatures are to be provided for davits and release hooks.
23.8.5.2 Electric motors, winches and automatic release hooks are to have moveable covers; where the design service temperature (DST) is below -40℃, heating arrangements are to be provided.
23.8.5.3 Electric motors, hydraulic units, winches, brakes and other components of launching appliance are to be operable at the design service temperature (DST). Appropriate tests are to be carried out to verify their operability.
23.8.5.4 Other members of launching appliances, such as winches, sheaves, winch brakes, etc. are to be provided with heating or other arrangements to ensure safe launching of survival craft and rescue boats at the design service temperature (DST).
23.8.5.5 The stowage positions for embarkation ladders are to be provided with covers or heating arrangements to prevent ice accretion.

23.8.6 Communication
23.8.6.1 Fixed two-way VHF radio installations onboard lifeboats are to be capable of operation at the design service temperature (DST).
23.8.6.2 For ships operating in polar waters, signal appliances fitted on all survival craft and rescue boats are to be operable at the design service temperature (DST).

Section 9 NAVIGATIONAL SAFETY

23.9.1 General requirements
23.9.1.1 Radio installations and navigational equipment installed on exposed decks are to be type tested according to the design service temperature.
23.9.1.2 Arrangements are to be made to prevent damage to antennae due to accumulation of ice and snow except for whip type antennae. Antennae may be heated or placed in heated domes, or in a place easily accessible for manual de-icing.
23.9.1.3 The movement of rotating antennae (e.g., radar, Inmarsat B and F) is not to be inhibited by snow or ice.

23.9.2 Navigational equipment
23.9.2.1 Ships operating in polar waters are to be provided with two searchlights that can rotate 360° horizontally and be remotely operated from the wheelhouse. Searchlight housing is to use heated glass or be provided with covers to prevent accumulation of ice and snow. The rotation mechanism is to be provided with anti-icing protection.
23.9.2.2 Magnetic compasses installed on exposed decks are to be provided with protective covers.

Section 10 SHIP TYPE SPECIFIC ADDITIONAL REQUIREMENTS

23.10.1 General requirements
23.10.1.1 The requirements of this Section apply respectively to different ship types, including oil tanker/chemical tanker, liquefied gas carrier, bulk carrier/ore carrier, offshore supply vessel and other special ship types.
23.10.1.2 The above-mentioned ship types are to comply with the following specific requirements in addition to the applicable requirements in Sections 1 to 9.

23.10.2 Bulk carrier/Ore carrier
23.10.2.1 Bulk carriers and ore carriers applying for Anti-Cold Climate notations are to comply with the following requirements.
23.10.2.2 Ballast tanks and piping are to comply with the following additional requirements:
(1) If fitted, piping connecting the upper wing tanks and lower wing tanks is to have anti-freezing protection. If a steam heating coil is fitted on the surface of this connecting pipe, it is to be protected so as to avoid being damaged due to cargo loading and unloading operations.

(2) For double bottom tanks and lower wing tanks that may be exposed to the design service temperature, ballast water inside such tanks is to be prevented from freezing. Water ingress alarms of cargo holds and bilge piping are to take the impacts of low temperature into account.
(3) If an air bubble system or heating coil system is provided in the lower wing tank for anti-freezing protection, no additional anti-freezing protection will be required for the upper wing tank and connecting pipe.
23.10.2.3 Where cargo loading and unloading operations will be carried out in low air temperature environments for long duration, the low-temperature performance of materials of inner bottom plating of double bottom tanks and sloping bottom plating of lower wing tanks is to be considered in the design.

23.10.3 Oil tanker/Chemical tanker
23.10.3.1 Oil tankers and chemical tankers applying for Anti-Cold Climate notations are to comply with the following requirements.
23.10.3.2 In addition to the provisions of 23.3.2.2, compartments requiring additional heating arrangements are to include cargo control rooms, cargo pump rooms, oil discharge monitoring equipment rooms (where fitted) as well as compressor rooms, motor rooms and cargo transfer observation stations that may be fitted. For cargo control rooms and cargo transfer observation stations, where the design service temperature is not lower than -25℃, portable heating arrangements may be accepted.
23.10.3.3 The emergency towing arrangements are to be provided with either anti-icing or de-icing protection. The pre-rigged emergency towing arrangement is to have suitable cover or heating arrangements for anti-icing protection, or be located in an enclosed or semi-enclosed deck area to be readily available.
23.10.3.4 Piping systems arranged on exposed decks are to comply with the following additional requirements:
(1) For exposed cargo piping and piping supports installed on the main deck, including vent piping, the design loads are to include the expected ice/snow accretion allowance.
(2) The supports for cargo piping systems on exposed deck are to be so arranged that free expansion and contraction of the pipes during cargo operations cannot be blocked by ice/snow accretion.
(3) Means are to be provided for anti-freezing protection of cargo fluids within exposed pipes, particularly for small bore pipes such as cargo drain and pressure gauge lines. When the design service temperature is below -25℃, the cargo and stripping lines on exposed deck are to be provided with suitable heat tracing and thermal insulation.
(4) Exposed inert gas systems and relevant equipment are to comply with the following requirements:
① the inert gas system scrubber is to be located in a compartment not affected by the weather. The cooling water system for inert gas scrubber is to be provided with suitable means of anti-freezing protection;
② means for the deck water seal are to be provided to ensure the added fluid to be free from freezing. Proper application of antifreeze or provision of heating arrangements may be used;
③ the exposed water supply and discharge lines to the deck water seal are to be provided with heating arrangements or thermal insulation with continuous circulation;
④ the non-return valve for the deck water seal is to be provided with suitable drainage and a set of control handles for testing;
⑤ the pressure/vacuum breakers are to be suitable for the minimum anticipated temperature. Proper application of antifreeze or provision of heating arrangements may be used;
⑥ drainage lines are to be thermally insulated;
⑦ equipment requiring de-icing maintenance are to be grouped together as far as practicable and readily accessible.
(5) Pressure/vacuum valves are to be provided with suitable anti-icing protection and de-icing measures so as to keep the valves readily operable.
(6) De-icing arrangements with steam or hot water are to be provided in areas designated for control of cargo loading and unloading (including gangways), with a fixed pipeline on the deck and connection valves for hoses.
23.10.3.5 The safe access to bow gangway is to either be provided with anti-icing protection, or it is to be made of a grating with raised non-skid points that will give safe footing in the presence of minor sea spray icing.
23.10.3.6 Monitoring systems are to comply with the following requirements:
(1) Heat tracing systems are to be provided with the temperature monitoring function so that any system failure or temperature exceeding limits will result in an alarm at the manned control station.

(2) The following instruments and equipment, when exposed to the low air temperature environments, are to be provided with heat tracing systems:

① level indicators for cargo tanks;

② overflow control;

③ pressure gauges;

④ temperature-indicating devices;

⑤ instrumentation for gas detection systems.

23.10.4 Liquefied gas carrier (LPG/LNG)

23.10.4.1 LPG and LNG carriers applying for Anti-Cold Climate notations are to comply with the following requirements.

23.10.4.2 For cargo containment system or any cover for the containment system exposed outside the hull, the requirements of 4.3.4 in Chapter 4, PART THREE of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk are to be complied with, taking into account the following ice and snow loads on the system or the cover in low air temperature environments:

(1) static load of ice and snow;

(2) dynamic load from sliding or dropped ice.

23.10.4.3 In addition to the provisions of 23.3.2.2, compartments requiring additional heating arrangements are to include cargo control rooms, cargo pump rooms, nitrogen storage rooms as well as compressor rooms, motor rooms and cargo transfer observation stations that may be fitted. For cargo control rooms and cargo transfer observation stations, where the design service temperature is not lower than -25℃, portable heating arrangements may be accepted.

23.10.4.4 The emergency towing arrangements are to be provided with either anti-icing or de-icing protection. The pre-rigged emergency towing arrangement is to have suitable cover or heating arrangements for anti-icing protection, or be located in an enclosed or semi-enclosed deck area to be readily available.

23.10.4.5 Exposed cargo related systems are to function properly in low air temperature environments and under ice/snow accretion conditions:

(1) For exposed cargo piping and piping supports installed on the main deck, including vent piping, the design loads are to include the expected ice/snow accretion allowance.

(2) The supports for cargo piping systems on exposed deck are to be so arranged that free expansion and contraction of the pipes during cargo operations cannot be blocked by ice/snow accretion.

(3) Where LNG carriers utilize cargo boil-off as fuel for propulsion power, particularly operating in the "gas only mode", the normal rate of boil-off (NBOR) is to take into account the minimum anticipated temperature, and the provisions for forced boil-off are to be adequate.

(4) Exposed safety relief valves and other valves are to be arranged in such a way as to provide their local and remote activation under all circumstances. De-icing and heat tracing arrangements are to be provided for the valves. Valve actuators with local position indicators are to be of the enclosed type.

(5) Emergency shutdown (ESD) valves are to be provided with anti-icing protection.

(6) All piping and pressure/vacuum protection systems (including valves) are to be provided with heat tracing arrangements so as to keep them readily operable.

(7) The maximum temperature of heating media within the cargo area is to be controlled within safe and controllable limits, taking into account the auto ignition temperature of the cargoes being carried.

(8) Equipment used for the environmental control of the cargo spaces, inter-barrier spaces and other spaces are to be designed to maintain a dew point below the lesser of the design service temperature or -30℃.

(9) Spaces required to be ventilated before entering are to be equipped with suitable means of pre-heating the ventilation systems to provide for their proper functioning at the design service temperature.

(10) If the cargo manifold and cargo vapor areas and associated valves are enclosed from the weather, the enclosures are to be arranged in such a way as to provide for sufficient ventilation of the space during cargo loading and unloading. Where mechanical ventilation is provided, the number of air changes is to be at least 30 per hour based on the gross volume of the space. In addition, gas detectors are to be provided.

(11) The vent mast head is to be designed to prevent blockage by ice accretion. Drip pans for the purpose of collecting moisture in the vent mast are to be provided. Drip pans with associated drain pipes inside the vent mast head and foot are to be provided with heat tracing.

(12) A steam-operated vapor heater for the purpose of preventing vapor descending to the deck is to be installed in the vapor line before the vent riser used for controlled venting.

(13) Insulation of the boil-off gas piping is required in way of areas exposed or subject to the design service temperature.

(14) The air intakes and exhaust louvres for cargo control rooms, cargo pump rooms, compressor rooms and motor rooms (where fitted) are to be provided with anti-icing protection by de-icing measures or heating arrangements.
(15) De-icing arrangements with steam or hot water are to be provided in areas designated for control of cargo loading and unloading (including gangways), with a fixed pipeline on the deck and connection valves for hoses.
(16) The piping system providing water curtain for the cargo loading and unloading area is to be provided with anti-freezing arrangements. Seawater for the water curtain may be preheated to avoid excessive ice accretion at the side shell plating.
23.10.4.6 A water spray system installed on exposed deck is to be equipped with heating arrangements for anti-freezing protection, and to be dried immediately after use.
23.10.4.7 Dry chemical powder systems are to be so arranged as to prevent clogging of the nozzles, and being capable of releasing the medium at the design service temperature.
23.10.4.8 The safe access to bow gangway is to either be provided with anti-icing protection, or it is to be made of a grating with raised non-skid points that will give safe footing in the presence of minor sea spray icing.
23.10.4.9 Monitoring systems are to comply with the following requirements:
(1) Heat tracing systems are to be provided with the temperature monitoring function so that any system failure or temperature exceeding limits will result in an alarm at the manned control station.
(2) The following instruments and equipment, when exposed to the low air temperature environments, are to be provided with heat tracing systems:

① level indicators for cargo tanks;
② overflow control;
③ pressure gauges;
④ temperature-indicating devices;
⑤ instrumentation for gas detection systems.

23.10.5 Offshore supply vessel

23.10.5.1 Offshore supply vessels applying for Anti-Cold Climate notations are to comply with the following requirements.
23.10.5.2 Piping systems arranged on exposed decks are to comply with the following additional requirements:
(1) Drilling muds and other specialized bulk cargoes carried by offshore support vessels may be particularly susceptible to freezing and may flow less freely in low air temperature environments. This fact is to be taken into account in the design. Valves and control stations are to be suitably located so as to be protected from cold and ice/snow accretion, as practicable.
(2) Where the transfer of fuel, drilling muds and other specialized bulk cargoes to drill ships at sea is anticipated, all equipment associated with the transfer such as, hoses, valves, fittings, etc. are to be suitable for operation under the minimum anticipated temperature.
23.10.5.3 For vessels with a rescue zone, suitable arrangements are to be provided for anti-icing protection:
(1) on a cross-deck area between the rescue zones port and starboard;
(2) the railings and handrails in the rescue zone; and
(3) routes to the accommodation/treatment areas.

23.10.6 Other ship types

23.10.6.1 Other ship types applying for Anti-Cold Climate notations are to comply with the following requirements.
23.10.6.2 For container ships, the exposed cargo securing arrangements are to be prevented from freezing, the material of which are to be suitable for the design service temperature, and are to be provided with grease suitable for use in low air temperature environments and with de-icing measures.
23.10.6.3 For container ships, where five layers or more of containers are stowed on exposed deck, the stowage positions for portable fire-extinguishing monitors are to be provided with anti-icing and anti-freezing protection, and the monitors are to be dried immediately after use.
23.10.6.4 For standby ships/rescue ships, the rescue facilities, if provided, are to be provided with anti-icing protection.

23.10.6.5 For standby ships/rescue ships, helicopter decks or hovering areas, if provided, are to be provided with de-icing measures, to ensure normal operation of the deck/area at the design environmental conditions for a period of one hour.
23.10.6.6 External fire-extinguishing appliances of fire-fighting ships are to be provided with anti-icing and anti-freezing protection.

Section 11 ANTI-ICING AND DE-ICING MEASURES

23.11.1 Application
23.11.1.1 This Section applies for ships operating occasionally in low air temperature environments and also for ships operating in areas and during periods where more severe ice and snow accretion are likely to occur but not in low air temperature environments.
23.11.1.2 The anti-icing and/or de-icing measures complying with this Section are to be taken by the above-mentioned ships.

23.11.2 Class notation
23.11.2.1 Ships complying with the provisions of this Section are to be assigned with the following notation:
(1) winterization de-icing notation: DE-ICE.

23.11.3 Plans and documents
23.11.3.1 The following plans and documents are to be submitted for approval:
(1) Arrangement of anti-icing and de-icing equipment, indicating heating capacity;
(2) Single line diagram of heating cables, if provided;
(3) Piping diagram of steam or heating fluids, if provided;
(4) Stability calculations in which ice accretion is considered.
23.11.3.2 The following plans and documents are to be submitted for information:
(1) Anti-icing and de-icing procedures manual.
23.11.3.3 Anti-icing and de-icing procedures manual is always to be kept on board ships.

23.11.4 Main methods for anti-icing/de-icing
23.11.4.1 Main methods for anti-icing are:
(1) heating by steam, hot fluids or heating cables;
(2) using permanent or removable protective covers.
23.11.4.2 Main methods for de-icing are:
(1) flushing by hot water or steam;
(2) de-icing by mechanical means manually;
(3) using hot air or chemical substances.

23.11.5 Technical requirements
23.11.5.1 The anti-icing and de-icing arrangements of ships are to comply with the requirements given in Table 23.11.5.1.

Anti-icing and De-icing Arrangements **Table 23.11.5.1**

Area or equipment	Anti-icing and de-icing requirements	Reference No.
Ship arrangements		
Tanks	The ship is to have an appropriate arrangement to prevent the surface of ballast tanks, fresh water tanks and other relevant tanks from freezing over considering the minimum anticipated temperature.	23.3.3.1
Superstructures and decks		
Bridge windows	Bridge windows are to be fitted with heating and cleaning systems and are to function under the minimum anticipated temperature. Where the water flushing system is fitted, measures are to be taken to prevent pipelines and fittings from freezing and thus becoming inoperable.	23.3.4.2
Bridge doors	Navigation bridge doors and the adjacent deck areas are to be so arranged as to prevent ice and snow accretion.	23.3.4.3
Master's cabin windows	At least one of the Master's cabin windows is to have a heating arrangement for a view over the cargo deck where necessary.	23.3.4.5
Exterior stairs and	Exterior stairs and railings not forming the escape routes are to be provided	23.3.4.7

Area or equipment	Anti-icing and de-icing requirements	Reference No.
railings	with anti-icing or de-icing protection.	
Helicopter decks or hovering areas	Helicopter decks or hovering areas, if provided, are to be provided with de-icing measures.	23.3.5.1
Stability		
Means for removing ice	Equipped with such means for removing ice; for example, electrical and pneumatic devices, and/or special tools such as axes or wooden clubs for removing ice from bulwarks, rails and erections.	23.4.1.2(2)
Ice accretion monitoring	Monitored for ice accretion during operation and appropriate measures are to be taken to ensure that ice accretion allowance does not exceed the value specified in the Stability Manuel.	23.4.1.2(3)
Watertight and weathertight integrity		
Ramp doors and side doors	Ramp doors and side doors are to be provided with means to remove ice accretion around hatches and doors.	23.5.2.2
Freeing ports	Freeing ports are to be fitted with anti-icing protection.	23.5.3.2(1)
Scuppers and discharges	For decks, passageways and muster areas that are required to be kept ice-free, the scuppers and discharges in such spaces are to be provided with anti-freezing protection.	23.5.3.3
Main and auxiliary machinery		
Combustion air intakes	The combustion air intakes are to be located on both sides of the ship and so arranged as to prevent the recirculation of engine exhaust gases into the combustion air intakes, ice/snow accretion and blockage of the duct.	23.6.2.2(4)
Piping		
Exposed valves	Exposed valves are to prevent the accumulation of snow and spray ice.	23.6.4.2(2)
Piping components located in exposed or low temperature spaces	Piping components located in exposed or low temperature spaces, such as valve control units, manifolds, vents, gasket seals, and thermal instruments such as indicators, sensors and other fittings, are to be provided with anti-icing, anti-freezing protection or other means to provide for continued functionality.	23.6.4.2(3)
Exposed air vent pipe heads	Exposed air vent pipe heads are to be provided with anti-icing measures against blockage, such as electric heat tracing or protective cover; where protective covers are provided against icing, the covers are not to interfere with the free flow of air through the vent openings.	23.6.4.3(2)
Sea chests	At least one sea chest is arranged as such to prevent the blockage of seawater inlet gratings and seawater pipe inlets by floating ice.	23.6.4.8(1)
Exposed control stand valves	Exposed control stand valves for hydraulic oil lines used for remote control are to be provided with heating arrangements for anti-freezing protection of the mechanism.	23.6.4.10(3)
Electrical installations		
Generators and electric motors installed on exposed decks and in low temperature spaces	Generators and electric motors installed on exposed decks and in low temperature spaces are to be provided with condensation-proof arrangements.	23.6.5.3
Distribution boxes, switchboards and controllers on exposed decks and in low temperature spaces	Distribution boxes, switchboards and controllers on exposed decks and in low temperature spaces are to be provided with condensation-proof arrangements.	23.6.5.4
Illumination lights and navigation lights installed on exposed decks	If illumination lights and navigation lights installed on exposed decks cannot generate sufficient heat to keep the light fixture ice-free, they are to be readily accessible and suitable for manual de-icing, or heating arrangements are to be provided.	23.6.5.7
Deck machinery		
Exposed control panels of deck machinery	Exposed control panels of deck machinery are to be provided with protective covers or heating arrangements for anti-freezing protection.	23.6.3.1
Cab windows of cranes	Cab windows are to be provided with heating arrangements to prevent icing.	23.6.3.3
Anchor windlass and its control	The anchor windlass and exposed windlass controls are to be provided with appropriate covers or heating arrangements for anti-icing protection. Alternatively, they are to be arranged in enclosed or semi-enclosed deck areas.	23.6.3.5
Anchor chains	Anchor chains are to be capable of being de-iced manually.	23.6.3.5
Hawse pipes	The hawse pipes are to be provided anti-icing protection or de-icing	23.6.3.6

Area or equipment	Anti-icing and de-icing requirements	Reference No.
	protection by steam or hot water.	
Hawse pipe wash lines	Hawse pipe wash lines are to be provided with continuous circulation or heating arrangements for anti-freezing protection of water in the pipes.	23.6.3.7
Mooring winches	Mooring winches are to be provided with suitable covers or heating arrangements for anti-icing protection. De-icing measures are to be arranged in the vicinity of mooring winches.	23.6.3.8
Fire fighting		
Isolating valves	The isolating valves in exposed locations are to be provided with anti-icing protection and located in areas where it is easily accessible.	23.7.1.4
Hydrants	Hydrants are to be provided with anti-icing and anti-freezing protection. The stowage positions for fire hoses and nozzles are to be provided with anti-icing and anti-freezing protection, the hoses and nozzles are to be dried immediately after use.	23.7.1.6
Portable extinguishers	The storage facilities for portable extinguishers are to be provided with anti-icing protection and readily accessible.	23.7.1.7
Sea chests of emergency fire pumps	Sea chests of emergency fire pumps are to be provided with means for heating, insulation or low pressure steam connection to prevent the blockage by floating ice.	23.7.2.3
Emergency routes	Essential emergency routes, such as escape routes, muster areas, lifeboat embarkation areas, are to be provided with anti-icing protection. Where exposed decks of the ship have no anti-icing requirements, de-icing tools to remove ice and snow accretion are to be provided to ensure the safety of persons onboard. Gangways and ramps are to be provided with de-icing arrangements.	23.7.4.1
Overhead structures	Overhead structures are to be provided with de-icing or other arrangements to prevent injuries to persons or damages to essential safety equipment/structures by fallen ice.	23.7.4.2
Escape routes	Escape routes are to be provided with anti-icing protection to ensure that the escape routes are ice-free or providing a minimum ice-free width of 700 mm, enabling the use of at least one railing. Railings that are important as hand-holds (stairs, escape ways) are to have anti-icing protection. Railings that function only as barriers, but are not intended as handholds, may be provided with de-icing arrangements only.	23.7.4.3
Exits forming escape routes	Exits forming escape routes are to be provided with anti-icing and de-icing measures.	23.7.4.6
Life-saving appliances		
Life-buoys	The bridge and exposed deck life-buoys are to be provided anti-icing protection and be arranged such that it is immediately deployable by the crew.	23.8.1.5
Release mechanism of lifeboats	The release mechanism of lifeboats is to be provided with heating or other arrangements to ensure safe release.	23.8.2.9
Vicinity of lifeboats	Suitable de-icing tools are to be provided in the vicinity of the stowage positions for lifeboats.	23.8.2.10
Launching appliances of survival craft and rescue boats	Electric motors, winches and automatic release hooks of survival craft and rescue boats are to have moveable covers.	23.8.5.2
Launching appliances of survival craft and rescue boats	Other members of launching appliances, such as winches, sheaves, winch brakes, etc. are to be provided with heating or other arrangements to ensure safe launching of survival craft and rescue boats.	23.8.5.4
Embarkation ladders	The stowage positions for embarkation ladders are to be provided with covers or heating arrangements to prevent ice accretion.	23.8.5.5
Navigational equipment		
Antennae	Arrangements are to be made to prevent damage to antennae due to accumulation of ice and snow except for whip type antennae. Antennae may be heated or placed in heated domes, or in a place easily accessible for manual de-icing.	23.9.1.2
Searchlight housing	Searchlight housing is to use heated glass or be provided with covers to prevent accumulation of ice and snow. The rotation mechanism is to be provided with anti-icing protection.	23.9.2.1
Magnetic compasses	Magnetic compasses installed on exposed decks are to be provided with protective covers.	23.9.2.2

23.11.5.2 Anti-icing and de-icing arrangements specific to ship types are also to comply with the requirements given in Table 23.11.5.2.

Anti-icing and De-icing Arrangements Specific to Ship Types **Table 23.11.5.2**

Area or equipment	Anti-icing and de-icing requirements	Reference No.
Oil tanker/Chemical tanker		
Emergency towing arrangements	The emergency towing arrangements are to be arranged with either anti-icing or de-icing protection. The pre-rigged emergency towing arrangement is to have suitable cover or heating arrangements for anti-icing protection, or be located in an enclosed or semi-enclosed deck area to be readily available.	23.10.3.3
Cargo piping	① For exposed cargo piping and piping supports installed on the main deck, including vent piping, the design loads are to include the expected ice/snow accretion allowance. ② The supports for cargo piping systems on exposed deck are to be so arranged that free expansion and contraction of the pipes during cargo operations cannot be blocked by ice/snow accretion.	23.10.3.4(1) 23.10.3.4(2)
Inert gas systems and related equipment	① Means for the deck water seal are to be provided to ensure the added fluid to be free from freezing. Proper application of antifreeze or provision of heating arrangements may be used. ② The pressure/vacuum breakers are to be suitable for the minimum anticipated temperature. Proper application of antifreeze or provision of heating arrangements may be used. ③ Equipment requiring de-icing maintenance are to be grouped together as far as practicable and readily accessible.	23.10.3.4(4)② 23.10.3.4(4)⑤ 23.10.3.4(4)⑦
Pressure/vacuum valves	Pressure/vacuum valves are to be provided with suitable anti-icing protection and de-icing measures so as to keep the valves readily operable.	23.10.3.4(5)
Areas designated for control of cargo loading and unloading	De-icing arrangements with steam or hot water are to be provided in areas designated for control of cargo loading and unloading (including gangways), with a fixed pipeline on the deck and connection valves for hoses.	23.10.3.4(6)
Safe access	The safe access to bow gangway is to either be provided with anti-icing protection, or it is to be made of a grating with raised non-skid points that will give safe footing in the presence of minor sea spray icing.	23.10.3.5
Liquefied gas carriers		
Cargo containment system or any cover for the containment system	For cargo containment system or any cover for the containment system exposed outside the hull, special consideration is to be given to ice and snow loads on the system or the cover.	23.10.4.2
Emergency towing arrangements	The emergency towing arrangements are to be provided with either anti-icing or de-icing protection. The pre-rigged emergency towing arrangement is to have suitable cover or heating arrangements for anti-icing protection, or be located in an enclosed or semi-enclosed deck area to be readily available.	23.10.4.4
Cargo piping	① For exposed cargo piping and piping supports installed on the main deck, including vent piping, the design loads are to include the expected ice/snow accretion allowance. ② The supports for cargo piping systems on exposed deck are to be so arranged that free expansion and contraction of the pipes during cargo operations cannot be blocked by ice/snow accretion.	23.10.4.5(1) 23.10.4.5(2)
Safety relief valves and other valves	Exposed cargo related safety relief valves and other valves are to be provided with de-icing and heat tracing arrangements.	23.10.4.5(4)
Emergency shutdown valves	Emergency shutdown (ESD) valves are to be provided with anti-icing protection.	23.10.4.5(5)
Vent masts	The vent mast head is to be designed to prevent blockage by ice accretion.	23.10.4.5(11)
Air intakes and exhaust louvres	The air intakes and exhaust louvres for cargo control rooms, cargo pump rooms, compressor rooms and motor rooms (where fitted) are to be provided with anti-icing protection by de-icing measures.	23.10.4.5(14)
Areas designated for control of cargo loading and unloading	De-icing arrangements with steam or hot water are to be provided in areas designated for control of cargo loading and unloading (including gangways), with a fixed pipeline on the deck and connection valves for hoses.	23.10.4.5(15)
Water spray systems	A water spray system installed on exposed deck is to be equipped with heating arrangements for anti-freezing protection, and to be dried immediately after use.	23.10.4.6
Safe access	The safe access to bow gangway is to either be provided with anti-icing protection, or it is to be made of a grating with raised non-skid points that will give safe footing in the presence of minor sea spray icing.	23.10.4.8

Area or equipment	Anti-icing and de-icing requirements	Reference No.
Offshore supply vessels		
Piping for drilling muds and other specialized bulk cargoes	The valves and control stations of piping for drilling muds and other specialized bulk cargoes are to be suitably located so as to be protected from cold and ice/snow accretion, as practicable.	23.10.5.2(1)
Rescue zones	For vessels with a rescue zone, suitable arrangements are to be provided for anti-freezing protection: (1) on a cross-deck area between the rescue zones port and starboard; (2) the railings and handrails in the rescue zone; and (3) routes to the accommodation/treatment areas.	23.10.5.3
Container ships		
Cargo securing arrangements of container ships	For container ships, the exposed cargo securing arrangements are to be prevented from freezing, and are to be provided with grease suitable for use in low air temperature environments and with de-icing measures.	23.10.6.2
Portable fire-extinguishing monitors of container ships	For container ships, where five layers or more of containers are stowed on exposed deck, the stowage positions for portable fire-extinguishing monitors are to be provided with anti-icing and anti-freezing protection, and the monitors are to be dried immediately after use.	23.10.6.3
Standby ships and rescue ships		
Rescue facilities	For standby ships and rescue ships, the rescue facilities, if provided, are to be provided with anti-icing protection.	23.10.6.4
Helicopter decks or hovering areas	For standby ships and rescue ships, helicopter decks or hovering areas, if provided, are to be provided with de-icing measures, to ensure normal operation of the deck/area at the design environmental conditions for a period of one hour.	23.10.6.5
Fire-fighting ships		
External fire-extinguishing appliances of fire-fighting ships	External fire-extinguishing appliances of fire-fighting ships are to be provided with anti-icing and anti-freezing protection.	23.10.6.6

Section 12 SURVEY REQUIREMENTS FOR ANTI-COLD CLIMATE NOTATIONS

23.12.1 General requirements

23.12.1.1 This Section applies to plan approval and survey of ships to be assigned with Anti-Cold Climate notations in accordance with the requirements of this Chapter, to verify anti-cold climate measures are suitable for ship's operation in anticipated low air temperature environments.

23.12.1.2 In plan approval, installation and testing according to the requirements of this Section, the requirements of the flag State Administration and/or the Administration of the ship's intended operational areas, and of the relevant international conventions are to be taken into account for anti-cold climate measures; if applicable, it is to be ensured that they are not contradictory to the statutory requirements and to be confirmed that anti-cold climate measures will not impair or weaken the normal operation of the relevant equipment and systems.

23.12.1.3 For equipment, systems and components exposed to low air temperature environments, the design service temperature is to be specified. All relevant purchase orders and plans are to indicate the temperature to ensure it complies with the appropriate approval and the requirements of the impact strength test at low temperature. Such equipment, systems and components are to be confirmed that there is the evidence of the design service temperature performance, which may include the marine product certificate issued by CCS, or statement of the manufacturer, or statement of experience at similar ambient temperature.

23.12.1.4 If the design service temperature of structural materials of the ship (DST_1) is lower than the design service temperature of equipment and system anti-cold climate measures (DST_2), H(DST_1) notation may be assigned individually. In this case, the polar service temperature (PST) of the polar ships is to be taken as DST_2.

23.12.2 Initial survey

23.12.2.1 In the process of plan approval, a design evaluation of anti-cold climate measures is to be carried out based on plans and documents submitted according to 23.1.4 of this Chapter, to confirm their

compliance with the rules requirements and their adequacy and suitability being verified, but not to confirm technical details of the specific anti-cold climate measures.

23.12.2.2 The hull and machinery arrangements are to be surveyed to confirm their compliance with the rules requirements and approved plans. The installation and testing of structures, equipment, systems and outfittings according to the agreed plan are to be conducted to the satisfaction of the Surveyor, of which the start-up and operation are to be verified, but their performance at the design service temperature are not necessarily confirmed.

23.12.3 Survey after construction

23.12.3.1 Survey to maintain class notations is to be carried out within 3 months before or after the anniversary date of assigning the Anti-Cold Climate notations except for the H(DST) notation.

23.12.3.2 During an annual survey, the Surveyor is to confirm that the arrangements and equipment comply with the rules and to verify as far as practicable the functions of the installed equipment and related controls and alarm systems according to the anti-cold climate measures listed in 23.1.4.2 and/or 23.11.3. The survey is to include but not limited to the following applicable items:

(1) Hull:

① anti-freezing arrangements for tanks;

② anti-icing/de-icing arrangements for passageways and openings;

③ heating arrangements for essential spaces;

④ heating and cleaning systems for bridge windows;

⑤ anti-cold climate measures for life-saving appliances and fire-fighting systems.

(2) Machinery, equipment and systems:

① For all ships:

a. pre-heating and introduction of combustion air for internal combustion engines and other prime movers;

b. anti-cold climate measures for deck machinery;

c. de-icing and anti-freezing arrangements for exposed piping;

d. anti-cold climate measures for navigational equipment;

e. emergency heating system for specified spaces, and tests are to be carried out where necessary.

② For bulk carriers and ore carriers:

a. anti-freezing arrangements connecting the upper and lower wing tanks.

③ For oil tankers and chemical tankers:

a. anti-freezing arrangements for the related equipment of the inert gas system, if fitted;

b. inspecting heat-tracing of additional fire-fighting and safety systems;

④ For liquefied gas carriers:

a. ventilation and gas detectors of enclosed cargo areas, if fitted;

b. inspecting heat-tracing of additional fire-fighting and safety systems provided according to CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gas in Bulk.

⑤ For offshore supply vessels:

a. for vessels with a rescue zone, anti-icing arrangements of the following positions are to be inspected:

(a) on a cross-deck area between the rescue zones port and starboard;

(b) the railings and handrails in the rescue zone; and

(c) routes to the accommodation/treatment areas.

23.12.4 Products inspection

23.12.4.1 Products for ships assigned with the Anti-Cold Climate notations are to specify the conditions for use in the relevant plans, purchase documents, survey notices or applications, including installation positions, minimum ambient temperature, anti-cold climate measures, etc.

23.12.4.2 Exposed equipment and systems are to consider the low temperature impacts in the following aspects, as appropriate, to verify their functionality at the design service temperature:

(1) materials and welding of structures and components, including low temperature resistant brittle materials and low temperature welding procedures;

(2) seal materials, with low temperature resistant performance;

(3) lubricating medium, using grease with low temperature performance;

(4) warm-keeping measures, including heat tracing (power), cover;

(5) de-icing methods, including limitations and requirements of de-icing methods;

(6) moving components, low temperature impacts;

(7) working medium, using hydraulic oil with low temperature performance;
(8) drives: hydraulic motor, electric motor, hydraulic pump, etc. involving the measures above;
(9) control box: low temperature impacts.

23.12.4.3 Where necessary, the marine product certificate is to indicate the design service temperature.

CHAPTER 24 ADDITIONAL REQUIREMENTS FOR STAND-BY SHIPS AND RESCUE SHIPS

Section 1 GENERAL PROVISIONS

24.1.1 Application

24.1.1.1 Unless expressly provided otherwise, this Chapter applies to stand-by ships and rescue ships.

24.1.1.2 Stand-by ships and rescue ships are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of CCS Rules for Materials and Welding and of the flag State Administration, if any.

24.1.2 Notation

24.1.2.1 Stand-by ships complying with the provisions of this Chapter may be assigned the notation: Stand-by Ship.

24.1.2.2 Rescue ships complying with the provisions of this Chapter may be assigned the notation: Rescue Ship.

24.1.3 Definitions

24.1.3.1 Stand-by ship means ships providing safety stand-by and conventional rescue for offshore installations or ships in operation, capable of receiving personnel evacuated from offshore engineering installations and offshore structures or from other ships on account of an emergency, or of rescuing personnel from sea.

24.1.3.2 Rescue ship means ships engaged in rescue operations at sea for ships and crew in distress.

24.1.3.3 Survivors mean personnel evacuated from offshore engineering installations and offshore structures or from other ships on account of an emergency, or rescued from sea.

24.1.4 Plans and documents

24.1.4.1 In addition to those required in the relevant PARTs and Chapters of the Rules, the following plans and documents are to be submitted to CCS for approval. For special structures and arrangements, the scope of plans and documents to be submitted for approval may be expanded if deemed necessary by CCS:

(1) Arrangement of safety and rescue equipment;

(2) System diagram and arrangement of searchlights;

(3) System diagram of aviation frequency two-way VHF radiotelephone apparatus.

24.1.4.2 The following plans and documents are to be submitted to CCS site surveyors:

(1) Operation manual, in working language, available onboard for the crew. The operation manual is to include:

① safety stand-by and rescue information and training details provided by the ship owner or operator;

② maintenance and operation of safety and rescue equipment, including the arrangement and information on the use of radio apparatus onboard provided as required;

③ safety and rescue procedures, to guide the evacuation of personnel from offshore engineering installations and offshore structures or from other ships, or the rescue of personnel from sea;

④ operation details of safety and rescue;

⑤ dynamic capability analysis (ship's mooring, heading keeping capability, speed, etc., under the specified sea conditions).

Section 2 CONSTRUCTION AND ARRANGEMENT

24.2.1 Superstructures and deckhouses

24.2.1.1 The structure is to comply with the relevant requirements of Chapter 11, PART TWO of the Rules.

24.2.1.2 Windows are to comply with the relevant requirements of Chapter 11, PART TWO of the Rules.

24.2.1.3 Navigation bridge

(1) The navigation bridge is to be so arranged that there is an unobstructed view all around. Clear view at the navigation bridge is to be ensured during safe rescue operations.

(2) Windows are to be installed from the outside except for those on the aft bulkhead.

24.2.2 Rescue zone

24.2.2.1 A rescue zone with a length of not less than 5 m is to be established and extended as far as possible on each side of the ship.

24.2.2.2 The rescue zone is to be located well clear of the propellers and as close to midships as practicable, with a clear deck area portside to starboard to permit the boarding of survivors and to carry on rescue operations.

24.2.2.3 Handrails in the rescue zone are to be provided with doors or chains which are readily openable, or removable stanchions are to be used. Bulwarks in the rescue zone are to be provided with doors, openings or other means of embarkation. Such means of embarkation are to be arranged to facilitate the hanging and use of boarding nets.

24.2.2.4 The rescue zone is to be provided with boarding nets fitted with lifelines.

24.2.2.5 The rescue zone is to be free of hull fittings and projections and overboard discharges which would impede rescue operations.

24.2.2.6 The rescue zone is to be provided with lighting required by 24.4.5.

24.2.2.7 The rescue zone is to be marked so as to be readily identified from seaward.

Section 3 ACCOMMODATION SPACES FOR SURVIVORS

24.3.1 Provision requirements for the spaces

24.3.1.1 General requirements

(1) Spaces provided for shelter of the survivors are to be enclosed from the weather and provided with heating, lighting and ventilation facilities.

(2) In emergency, the survivors may be lodged in the accommodation spaces other than the following spaces: sanitary area, galley, the master's cabin, radio room, navigation bridge and main passages that are to be kept unblocked.

(3) The dimension of the shelter spaces for the survivors is to be indicated on the general arrangement plan.

24.3.1.2 The area of the shelters is to be determined as 0.75 m^2 for every assigned survivors, including free spaces and floors for movable furniture, fixed seating and fixed beds; other fixed furniture, toilets and bathrooms are not to be included.

24.3.1.3 Sanitary facilities

(1) Dedicated sanitary facilities are to be provided for the survivors. One set of fixtures comprising a toilet, a washing basin and shower, is to be provided for every 50 survivors.

(2) Fresh water tanks and potable water tanks of sufficient quantity are to be provided for the survivors onboard.

24.3.1.4 Treatment area

(1) The treatment area is to be readily accessible for the survivors from the rescue zone and is to be effectively isolated from the crew's accommodation area.

(2) Given the situation when the survivors are transferred to the helicopter winching area, the arrangement of the treatment area is to make transfer passage easily accessible and unobstructed.

(3) Corridors and doors leading to the rescue zone are to be sufficient in width to allow the passage of stretchers transferring survivors.

Section 4 RESCUE AND SAFETY EQUIPMENT

24.4.1 Rescue boats

24.4.1.1 A rescue boat is to be provided on a stand-by ship.

24.4.1.2 A readily available fast rescue boat is to be provided on a rescue ship.

(1) The rescue boat and its launching appliances are to comply with the requirements of Chapters V and VI of the International Life-saving Appliance (LSA) Code.

(2) Where davits for rescue boats have to rely on electricity for operation, they are to be power supplied by emergency switchboard.

24.4.2 Rescue nets

24.4.2.1 Rescue nets are not to be less than 5 m in width with the center of gravity at bottom.

24.4.2.2 The length of the rescue nets is to extend at least 1 m below the waterline at lightest draught.

24.4.3 Searchlights

24.4.3.1 Two searchlights capable of rotating 360° horizontally are to be provided. The searchlights are remotely controllable at the navigation bridge.

24.4.3.2 The searchlights are to provide at least 50 lux illumination at a distance of 250 m.

24.4.4 Water spray fire extinguishing systems

24.4.4.1 The water spray fire extinguishing system is to be provided on a rescue ship to protect the rescue operation area on the open deck against the heat and fire in the boundary of the rescue zone.

24.4.4.2 The nozzles of the water spray fire extinguishing system are to be arranged to give an even distribution of waterspray over the whole rescue operation area on the open deck.

24.4.4.3 The water spray fire extinguishing system is to ensure even distribution of water spray in the rescue operation area.

24.4.4.4 The water spray fire extinguishing system is to have a capacity of at least 5 *l*/min per m^2 of the protected area which is internally insulated to A-60 class and at least 10 *l*/min per m^2 of other protected areas.

24.4.4.5 The pumping capacity is to be sufficient to supply simultaneously at the required pressure the sections which serve the maximum area of the rescue zone. Where the main fire pumps are used for this purpose, they are to be capable of operating this system, the water monitors and the hose stations simultaneously at the required pressure. A connection with a shut-off valve is to be fitted between the piping system for the water monitors and the supply line for the water spray fire extinguishing system.

24.4.4.6 Means are to be taken to ensure that necessary visibility from the navigation bridge and the remote-control station can be maintained during the water spray operations.

24.4.5 Deck illumination

24.4.5.1 Main lighting and emergency lighting are to be provided in the following areas:

(1) rescue boat stowage locations, launching appliances, reception and rescue areas;

(2) to provide floodlighting of the sea in way of the rescue zone and rescue boat launch and recovery area;

(3) the helicopter winching deck area and access routes leading to and from the reception area.

24.4.6 Treatment facilities

24.4.6.1 Treatment facilities, including stretchers, blankets or coverings, bandages and dressing, splints, thermal insulation blankets and insulation materials, etc. are to be provided.

24.4.6.2 The treatment facilities are to be readily available.

24.4.6.3 The treatment facilities are to be appropriately wrapped, labeled, stored and marked.

24.4.7 Towing

24.4.7.1 Means to tow rescue boats, lifeboats or liferafts are to be provided.

24.4.8 Other life-saving appliances

24.4.8.1 The relevant life-saving appliances are to be provided according to Table 24.4.8.1.

Other Life-Saving Appliances **Table 24.4.8.1**

Appliance	Quantity
Fall protection equipment (e.g. safety harness and safety line with hook)	3
Throw lines	4
Diver ladders	2
Lifejackets	Assigned number of survivors
Long handle hooks	2
Lifebuoys with self-igniting lights and ropes (not less than 30 m in length)	4

24.4.9 Helicopter winching deck area

24.4.9.1 Helicopter winching deck area is to be provided. The area is to be unobstructed and well-illuminated.

Section 5 NAVIGATION AND COMMUNICATION EQUIPMENT

24. 5.1 Navigation equipment

24.5.1.1 Regardless of its dimension, shipborne navigation equipment required to be provided for cargo ships of 500 gross tonnage and above according to the Administration is to be provided.

24.5.2 Radiocommunications

24.5.2.1 One two-way VHF radiotelephone using aviation frequency (121.5 MHz and 123.1 MHz) is to be provided, in addition to the radio equipment required by the Administration.

CHAPTER 25 ADDITIONAL REQUIREMENTS FOR DIVING SUPPORT VESSELS

Section 1 GENERAL PROVISIONS

25.1.1 Application

25.1.1.1 This Chapter applies to vessels supporting diving operations or unmanned remotely operated vehicles operations.

25.1.1.2 Diving support vessels are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of CCS Rules for Materials and Welding and of the flag State Administration, if any.

25.1.2 Notations

25.1.2.1 The following notations may be assigned to vessels complying with the requirements of this Chapter[①]:

Diving Support Vessel[②] is assigned to vessels permanently supporting diving system and complying with the relevant requirements of this Chapter.

DSV-Air is assigned to vessels supporting conventional air diving systems and complying with the relevant requirements of this Chapter.

DSV-Sat is assigned to vessels supporting saturation diving systems and complying with the relevant requirements of this Chapter.

Types of Diving **Table 25.1.2.1**

	Type of diving	
Parameter	DSV-Air	DSV-Sat
Designed diving depth	≤58 MSW	≤457 MSW
Diving duration	≤8 hours	No restriction
Breathing air medium	compressed air	Heliox or equivalent
MSW = Metres Sea Water		

25.1.2.2 Vessels complying with the requirements of Section 6 of this Chapter may be assigned the notation ROVS.

25.1.3 Definitions

25.1.3.1 Diving support vessels are mother vessels supporting diving operations or submersible system operations.

25.1.4 Plans and documents

25.1.4.1 In addition to those required in the relevant PARTs and Chapters of the Rules, the following plans and documents are to be submitted to CCS for approval. For special structures and arrangements, the scope of plans and documents to be submitted for approval may be expanded if deemed necessary by CCS:

(1) Arrangement of the diving system;

(2) Details of hull supporting structure for submersible and its handling system;

(3) Electrical loading evaluation of diving system operation conditions during the operation of the diving system;

(4) Power system diagram and electrical equipment arrangement of the diving system;

(5) Piping schematics for the diving support vessel's piping systems supplying diving systems;

(6) Arrangement and details of communication systems between the diving support vessel and diving systems.

25.1.4.2 The following plans and documents are to be submitted to CCS for information:

(1) Design details of foundation for submersible and its handling system;

(2) Calculations of supporting structure for submersible and its handling system.

---

① DSV-Air, DSV-Sat may be assigned together with the notation Diving Support Vessel or separately as special performance notations.

② The DSV-Sat notation must be obtained for granting the Diving Support Vessel notation

25.1.4.3 The following plans and documents are to be submitted to CCS site surveyors:
(1) Operation manual.

Section 2 SEA KEEPING OF VESSEL'S POSITION

25.2.1 General requirements

25.2.1.1 During the operation of the diving system, the diving support vessel is to be capable of withstanding wind and wave in order to maintain its position at sea.
25.2.1.2 The means to maintain position may be a mooring system with anchors or a dynamic positioning system.

25.2.2 Dynamic positioning systems

25.2.2.1 Where the diving support vessel uses the dynamic positioning system to maintain its position, such dynamic positioning system is to comply with the relevant provisions for DP-2 or DP-3 in Chapter 11 of this PART.

Section 3 ARRANGEMENT OF DIVING SYSTEMS

25.3.1 Installation location of diving systems

25.3.1.1 The diving system is to be installed in the non-hazardous area of the diving support vessel (IEC 60079-1). Special consideration is to be given as appropriate if the system is installed in the hazardous area.
25.3.1.2 Diving systems and breathing gas storage facilities are not to be installed in machinery spaces, except for equipment not used for operating the diving system.
25.3.1.3 Diving systems are not to be installed in the vicinity of exhausts/ventilation outlets from machinery spaces and galleys.
25.3.1.4 The diving system is to be located so that the diving operations are not affected by propellers, thrusters or anchors of the diving support vessel.
25.3.1.5 The diving system is to be so arranged that diving operations are conducted as far away as practicable from the vessel's overboard discharge outlets/suction inlets.
25.3.1.6 Where an impressed current cathodic protection system is fitted, the system is to be switched off during the diving operations.
25.3.1.7 Where pressure vessels serving divers are fitted, such as the deck pressurized tank, it is recommended that the pressure vessels are arranged longitudinally along the diving support vessel so as to reduce the impact of rolling on divers.
25.3.1.8 Diving systems are to be installed in spaces or locations that are adequately ventilated and provided with suitable lighting on the diving support vessel.
25.3.1.9 Where any part of the diving system is located on the open deck, reasonable protection is to be provided so as to prevent damages caused by wave, ice or other activities onboard.
25.3.1.10 In order to minimize deflections and to obtain satisfactory transfer of heavy loads through the deck foundations, it is recommended that diving systems be installed in-line with the supporting deck structure.

25.3.2 Storage room for breathing gas cylinders of the diving system

25.3.2.1 Breathing gas cylinders for diving systems are to be stored on the open deck or in well ventilated enclosed spaces, and away from flammable substances and sources of ignition.
25.3.2.2 Where breathing gas cylinders are stored on the open deck area, weathertight shelters against wave and heat radiation and effective protection against mechanical damages are to be provided for the cylinders.
25.3.2.3 The boundaries between the enclosed spaces storing breathing gas cylinders and other enclosed spaces are to be gastight. The doors of the enclosed spaces are to open outward.
25.3.2.4 The storage area or space for breathing gas cylinders is to be provided with appropriate draining arrangements.
25.3.2.5 The outlets of relief valves or bursting discs are to be piped-outside the enclosed spaces to the open deck and away from sources of ignition.
25.3.2.6 The enclosed spaces storing breathing gas cylinders are to be provided with an independent ventilation system, the outlets of which are in safe areas. The ventilation capacity of the forced ventilation

system is to be such as to provide for at least eight air changes per hour, based on the gross volume of the enclosed spaces.
25.3.2.7 The air of the ventilation system is to be drawn from safe areas.
25.3.2.8 The fans of the ventilation system are to be of non-sparking construction.
25.3.2.9 Breathing gas mixtures containing more than 25% oxygen by volume are to be treated and handled as pure oxygen.
25.3.2.10 Pure oxygen breathing gas cylinders are to be stored on the open deck, but not to be stored in the spaces or areas below the deck.
25.3.2.11 When breathing gas mixtures containing less than 25% oxygen by volume are stored in enclosed spaces, the following requirements are to be complied with:
(1) at least two oxygen analyzers fitted with audible and visual alarms are to be provided, one of which is used to monitor the upper levels of the enclosed spaces and the other of which is used to monitor the lower levels of the enclosed spaces;
(2) the enclosed spaces for storage of the breathing gas cylinders are to be kept clean, i.e. free of grease or other debris.
25.3.2.12 Where the diving support vessel is also used for fire-fighting operations, means are to be provided to protect the oxygen cylinders from heat that may radiate from the fire that is being extinguished.

25.3.3 Diving system control station

25.3.3.1 Where the diving support vessel is permanently provided with the diving system, the diving system control station is to comply with the requirements of this Chapter.
25.3.3.2 The diving system control station is to be securely fastened at a location close to and in sight of the diving location.
25.3.3.3 The position of the diving system control station is to allow the operations control personnel an overview of the diving system, including all activities related to the submersible operations.
25.3.3.4 The diving system control station is not to be located in the hazardous area.
25.3.3.5 When selecting the location of the diving system control station, ship's motion or support structure vibrations are to be considered.
25.3.3.6 A direct two-way direct communication systems are to be provided between the diving system control station and the following spaces or persons as applicable:
(1) diver in the water;
(2) diving bell;
(3) each chamber of the deck decompression chambers;
(4) operating space of the handling system and the emergency control station;
(5) dynamic positioning control station;
(6) navigation bridge.
25.3.3.7 Emergency communication means are to be provided between the control station of a diving system and divers in its deck decompression chamber and diving bell.
25.3.3.8 Where more than one control station are provided onboard for the diving system, direct communication is to be provided between these stations.

25.3.4 Power supply and illumination of the diving system

25.3.4.1 Electrical installations essential to safe completion of the diving operations are to be supplied from the main and emergency power sources.
25.3.4.2 The main power source of the diving support vessel may be used to supply normal power to diving systems, provided that the main power source of the vessel has sufficient capacity simultaneously supply the vessel's electrical loads as well as the electrical loads of the diving systems. The main power source of the diving system can also be supplied by the dedicated self-contained power source.
25.3.4.3 In the event of failure of the main source of electrical power to the diving system, an independent emergency source of electrical power is to be available for the safe termination of the diving operation. The emergency power source can be dedicated self-contained power source (provided by the vessel or fitted on the submersible), or the emergency power source mentioned in 25.3.4.4.
25.3.4.4 The emergency generator of the diving support vessel can be used as the emergency power source mentioned in 25.3.4.3, provided that the emergency power generator has sufficient capacity to supply the emergency electrical loading of the diving support vessel and of the diving system simultaneously.
25.3.4.5 The power supply extent and duration of the emergency power source of the diving system are to comply with 10.2.1.9 and 10.2.1.10, Chapter 10 of CCS Rules for the Construction and Classification of Diving Systems and Submersibles.

25.3.4.6 The emergency power source of the diving system is to be installed outside the engine room of the diving support vessel and be as far apart as practicable from the main power generator.
25.3.4.7 Appropriate illumination is to be provided at the interface between the diving system and the diving support vessel. The critical handling area of the diving system is to be provided with illumination supplied by the main and emergency power source.

Section 4 STRUCTURAL REQUIREMENTS

25.4.1 Deck foundations, fastening arrangements and hull supporting structures
25.4.1.1 Deck foundations and fastening arrangements are to permit relative movement of manned pressure vessels and large gas storage cylinders due to internal pressure variations that may cause them to expand/contract.
25.4.1.2 For manned pressure vessels and large gas storage cylinders installed on the diving support vessel, the relevant requirements for the installation of independent tanks (independent pressure vessels) onboard may be referred to.
25.4.1.3 For the submersible and its handling system, the strength of the supporting structure is to be checked. For the calculation and modelling methods, the relevant requirements of Chapter 1, PART TWO of the Rules may be referred to, where: inertia force of the foundation and fastening arrangements of the submersible may be calculated according to Section 5, Chapter 1, PART TWO of the Rules; ② the design load of the handling system of the submersible is to comply with the requirements of Appendix B of CCS Rules for the Construction and Classification of Diving Systems and Submersibles.
25.4.1.4 The calculation stress of the hull supporting structure of the submersible is not to be greater than the permissible value in Table 3.7.4.12, Chapter 3, PART TWO of the Rules. The calculation stress of the hull supporting structure under the foundation of the handling system of the submersible is to satisfy the requirements in 3.10.7, Chapter 3 of CCS Rules for the Construction and Classification of Diving Systems and Submersibles.

25.4.2 Moon pools
25.4.2.1 Moon pools, where provided for diving operations are to meet the following requirements:
(1) Openings are to be a suitable distance from the deck edge, from cargo hatch covers, from superstructure breaks and from other area of structure discontinuity.
(2) The side structure of moon pools are to be designed for impact loads from diving equipment that may be guided through the moon pools.
(3) The plating thickness of the moon pool side structures is not to be inferior to the requirements for shell plating in Section 3, Chapter 2, PART TWO of the Rules.
(4) The corner radius of the moon pool opening is to comply with the requirements of 2.4.4, PART TWO of the Rules.
(5) Free edges of the moon pool opening are to be suitably rounded in order to protect diving system umbilicals from sharp edges.
(6) Means of protection are to be provided around the moon pool opening, such as guardrails, to prevent personnel from falling into the moon pool.

Section 5 FIRE-FIGHTING

25.5.1 Structural protection
25.5.1.1 Diving systems installed in enclosed spaces
(1) Enclosed spaces on diving support vessels housing diving systems are to be separated from adjacent spaces by means of A-60 class bulkheads or decks. All doors between these enclosed spaces and adjacent enclosed spaces are to be of the self-closing type. The enclosed spaces of the diving system are not to be connected to the machinery spaces of category A.
(2) Pipes and cables passing through the bulkheads and decks of the enclosed spaces are to be of A-60 class mechanical penetrations or electrical penetrations.
(3) The enclosed spaces of the diving system are to be provided with independent forced ventilation. The outlets of the ventilation system are to be in the safe areas. The ventilation capacity of the forced ventilation system is to be such as to provide for at least eight air changes per hour, based on the gross volume of the enclosed spaces.

25.5.1.2 Diving systems installed on the open deck

(1) The diving system may be installed on the open deck or similar structures directly adjacent to the machinery spaces of category A.

(2) Where the diving system is installed in areas directly adjacent to the machinery spaces of category A, the bulkheads and decks are to be of A-60 class division.

25.5.2 Fire-extinguishing systems and means of cooling

25.5.2.1 Diving systems installed in enclosed spaces

(1) Fixed fire extinguishing systems installed in enclosed spaces are to be:

① fixed pressure water spray fire-extinguishing systems suitable for machinery spaces of category A according to the requirements of the FSS Code; or

② fixed gas fire-extinguishing systems suitable for machinery spaces of category A according to the requirements of the FSS Code; or

③ equivalent fire-extinguishing systems deemed by the Administration to provide an equivalent level of protection.

(2) Portable fire extinguishers of sufficient number are to be provided in the enclosed spaces storing the diving system, one of which is to be placed near the access to the enclosed spaces. Spare charges are to be provided for 100% of the first ten extinguishers and 50% of the remaining fire extinguishers in the enclosed spaces.

(3) Where fixed gas fire-extinguishing systems are used, the selection of the fire-extinguishing medium is to be such that when the medium is applied in its entirety in the enclosed spaces, the concentration③ of the toxic gas will not impair human body.

25.5.2.2 Diving systems installed on the open deck

(1) Decks or similar hull structure areas storing diving systems are to be provided with appropriate fire-extinguishing systems.

(2) Fire hoses on the diving support vessel connecting to the fire mains are to be protected as appropriate.

25.5.2.3 Means of cooling

(1) For windows, observation windows or other windows fitted on the manned pressure vessels in the enclosed spaces, means of cooling are to be provided.

(2) Enclosed spaces storing breathing gas cylinders or pressure vessels are to be provided with manually-actuated water spray systems so as to cool the breathing gas cylinders or pressure vessels in case of fire. The application rate on the projected horizontal area is at least $10L/m^2$ per minute. Water mist fire-extinguishing systems may be provided in the enclosed spaces as an alternative, the application rate of which is at least $5L/m^2$ per minute.

25.5.3 Fire detection and alarm systems of the diving system

25.5.3.1 The control panel of the fire detection and alarm system of the diving support vessel is to be installed in the dynamic positioning control station or mooring control station, and repeaters are to be provided in the diving control station and engine room centralized control room.

25.5.3.2 When diving systems are installed in enclosed spaces, the following requirements are to be complied with:

(1) automatic fire detection and alarm systems complying with the FSS Code are to be provided in the enclosed spaces;

(2) the loop or group of the fire detection and alarm systems of the enclosed spaces is to be independent of those of other spaces.

25.5.3.3 When diving systems are installed on the open deck, the following requirements are to be complied with:

(1) the open deck and similar structures of the diving support vessel is to be provided with suitable automatic fire detection and alarm systems;

(2) visual and audible monitoring systems continuously monitored by personnel at the control station may substitute the automatic fire detection and alarm systems on the open deck of the diving support vessel.

25.5.4 Piping systems

25.5.4.1 Piping systems carrying breathing gases under high pressure are not to be arranged inside accommodation spaces, engine rooms or similar compartments.

---

③ The concentration of fire-extinguishing medium is to be lower than the No Observed Adverse Effect Level (NOAEL) as defined in amendments to MSC/Circ.848 (MSC.1/Circ.1267).

25.5.4.2 Piping systems carrying breathing gases are to run as far as practicable apart from electrical cable conduits.
25.5.4.3 Piping systems containing flammable fluids are not to run through enclosed spaces or open deck areas housing breathing gas cylinders.

Section 6 UNMANNED REMOTELY OPERATED VEHICLE SUPPORT

25.6.1 General requirements

25.6.1.1 An unmanned underwater vehicle which can only be operated with remote controls. Such vehicles are divided into, according to the pattern of control, tethered ones operated through umbilical and non-tethered ones operated through sound wave.
25.6.1.2 Unmanned remotely operated vehicles and their relevant supporting systems (the handling system, control station, etc.), if complying with the requirements of this Section, may be assigned the notation ROVS upon request of the ship owner and ship operator.

25.6.2 Handling systems

25.6.2.1 Handling systems of unmanned remotely operated vehicles are to comply with the relevant requirements of CCS Rules for the Construction and Classification of Diving Systems and Submersibles.
25.6.2.2 Handling systems of unmanned remotely operated vehicles are to be so arranged as to minimize the possibility of any interference with propellers, thrusters or anchors of the support vessel.
25.6.2.3 Safe storage location with fastening arrangements is to be provided for remotely operated vehicle being securely stowed on the support vessel while they are not in operation.
25.6.2.4 The relevant hull structure strengthening of the unmanned remotely operated vehicle as well as the hull structure strengthening beneath the handling system foundation are to comply with the requirements of 25.4.1 of this Chapter.

25.6.3 Control stations

25.6.3.1 The control station for the unmanned remotely operated vehicle is to be securely fastened at a location close to and in sight of the launch and recovery location.
25.6.3.2 The control station for the unmanned remotely operated vehicle is to provide direct communication to the following positions:
(1) the vessel’s control station;
(2) the control station of any other underwater vehicle;
(3) the control station for subsea equipment on the offshore engineering support vessel, such as the control station for oil well accident handling.

Section 7 SURVEY, INSPECTION AND TESTING

25.7.1 General requirements

25.7.1.1 The installation of the diving system and/or ROV system on the diving support vessel is to be to the satisfaction of the attending surveyor.
25.7.1.2 The diving system and/or ROV system on the diving support vessel is to be approved by CCS or other IACS members.
25.7.1.3 Upon installation, the diving system and/or ROV system and their support vessel interfaces as well as the interfaces between the diving systems and/or ROV systems installed on the support vessel are to be functionally tested to the satisfaction of the attending surveyor.

CHAPTER 26 ADDITIONAL REQUIREMENTS FOR INSTALLATION OF BALLAST WATER MANAGEMENT SYSTEMS

Section 1 GENERAL PROVISIONS

26.1.1 Application

26.1.1.1 Unless provided otherwise, this Chapter applies to :

(1) existing ships where an application for approval of BWMS is made on or after 1 July 2022;

(2) a ballast water management system which is installed in ships contracted for construction on or after 1 July 2022.

26.1.1.2 In addition to the requirements contained in International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (hereinafter referred to as the BWM Convention), the requirements of this Chapter for the installation of ballast water management systems above are to be complied with.

26.1.1.3 Ballast Water Management System is also to meet the additional requirements for fire safety measures as specified in appendix 1 to this Chapter.

26.1.2 Definitions

26.1.2.1 For the purpose of this Chapter:

(1) Ballast water management system (hereinafter referred to as 'BWMS') means any system which processes ballast water such that it meets or exceeds the ballast water performance standard in regulation D-2 of the BWM Convention. The BWMS includes ballast water equipment, all associated piping arrangements as specified by the manufacturer, control and monitoring equipment and sampling facilities. The categorization of BWMS technologies is given in Table 26.1.2.1 of this Chapter. Applicability of the requirements for each BWMS technology is in accordance with Table 26.1.2.2 of this Chapter.

(2) Cargo area of tankers is defined in:

① for tankers to which regulation 1.6.1 of SOLAS Chapter II-2 as amended by IMO resolutions up to MSC.421(98) (hereinafter the same) applies, regulation 3.6 of SOLAS Chapter II-2;

② for chemical tankers, Paragraph 1.3.6 of the IBC Code as amended by IMO resolutions up to MSC.460(101);

③ for gas carriers, Paragraph 1.2.7 of the IGC Code as amended by IMO resolutions up to MSC.441(99); and

④ for offshore support vessels, Paragraph 1.3.1 of the IMO Resolution A.673(16) as amended by Resolution MSC.236(82) or Paragraph 1.2.7 of the IMO Resolution A.1122(30), as applicable.

(3) Dangerous gas means any gas which may develop an atmosphere being hazardous to the crew and/or the ship due to flammability, explosivity, toxicity, asphyxiation,corrosivity or reactivity and for which due consideration of the hazards is required, e.g. hydrogen (H_2), hydrocarbon gas, oxygen (O2), carbon dioxide (CO2), carbon monoxide (CO), ozone (O_3), chlorine (Cl_2) and chlorine dioxide (ClO_2), etc.

(4) Hazardous area is defined in IEC 60092-502 and means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus. When a gas atmosphere is present, the following hazards may also be present: toxicity, asphyxiation, corrosivity and reactivity.

(5) Dangerous liquid means any liquid that is identified as hazardous in the Material Safety Data Sheet or other documentation relating to this liquid.

(6) Non-hazardous area means an area which is not a hazardous area as defined in above (4).

Categorization of BWMS technologies **Table 26.1.2.1**

BWMS's Technology category*		1	2	3a	3b	3c	4	5	6	7a	7b	8
Characteristics		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N from a N Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side stream electrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank	In-tank pasteurization and de-oxygenation with N2 generator
Des-infection when ballasting	Making use of active substance		x			In-tank technology: No treatment when ballasting or de-ballasting	x	x	x	x	x	In-tank technology: No treatment when ballasting or de-ballasting
	Full flow of ballast water is passing through the BWMS	x	x	x	x		x				x	
	Only a small part of ballast water is passing through the BWMS to generate the active substance							x				
After-treatment when deballasting	Full flow of ballast water is passing through the BWMS	x									x	
	Injection of neutralizer						x	x	x	x	x	
	Not required by the Type Approval Certificate issued by the Administration		x	x								
Examples of dangerous gas as defined in 26.1.2.1(3)			(1)	O_2 N_2	CO_2 CO		H_2 Cl_2	H_2 Cl_2	(1)	O_2 O_3 N_2		O_2 N_2

Note:
(1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.
(2) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting)

Footnote: *Taking into consideration future developments of BWMS technologies, some additional technologies may be considered in this Table 1 by identifying their characteristics in the same manner as for the above BWMS categories 1, 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8.

Applicability of the requirements for each BWMS technology **Table 26.1.2.2**

BWMS's Technology category*→	1	2	3a	3b	3c	4	5	6	7a	7b	8
Requirements of this Chapter ↓	In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N from a N Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side stream electrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge water treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank	In-tank pasteurization and de-oxygenation with N2 generator
26.1.1and 26.1.2	x	x	x	x	x	x	x	x	x	x	x
26.2.1.1 to 26.2.1.4	x	x	x	x	x	x	x	x	x	x	x
26.2.1.5			x	x	x						x
26.2.1.6	x	x	x	x	x	x	x	x	x	x	x
26.2.1.7			x	x	x						x
26.2.1.8				x						x	
26.2.1.9	x	x	x	x	x	x	x	x	x	x	x
26.2.2.1（1）				x	x				x	x	
26.2.2.1（2）						x	x	x			
26.2.2.2	x	x	x	x		x	x	x	x	x	
26.2.2.3	x	x	x	x	x	x	x	x	x	x	x
26.2.2.4	x	x	x	x		x	x	x	x	x	
26.2.3.1（1）		x	x			x	x	x	x	x	x
26.2.3.1（2）			x	x	x				x	x	x
26.2.3.1（3）									x	x	
26.2.3.1（4）						x	x	x	x	x	
26.2.3.1（5）						x	x	x			
26.2.3.1（6）			x	x	x				x	x	x
26.2.3.2（1）to（4）		x	x	x	x	x	x	x	x	x	x
26.2.3.2（5）			x			x	x	x	x	x	x
26.2.3.2（6）			x			x	x	x	x	x	x
26.2.3.2（7）			x						x	x	x
26.2.3.2（8）			x			x	x	x	x	x	x
26.2.3.3		x				x	x	x	x	x	
26.2.3.4						x	x	x	x	x	

Section 2 INSTALLATION

26.2.1 General requirements

26.2.1.1 All valves, piping fittings and flanges are to comply with the relevant requirements of Chapter 2, PART THREE of the Rules. In addition, special consideration can be given to the material used for this service with the agreement of CCS.

26.2.1.2 The BWMS is to be provided with by-pass or override arrangement to effectively isolate it from any essential ship system to which it is connected. For new installation or retrofit to existing ships, under normal operating conditions of ballasting and de-ballasting given in the Ballast Water Management Plan (BWMP) the adequacy of the generating plant capacity installed on the vessel is to be demonstrated by an electrical load analysis.

For retrofit installation to exiting ships, a revised electrical load analysis with preferential trips of non-essential services can be accepted.

26.2.1.3 The BWMS is to be operated in accordance with the requirements specified in the type approval certificate (TAC) issued by the flag Administration or a recognized organization authorized by it. BWMS is to be operated within its Treatment Rated Capacity (TRC) as per the TAC. This may require limiting of ship's ballast pump flowrates.

The arrangement of the bypasses or overrides of the BWMS is to be consistent with the approved Operation Maintenance and Safety Manual by the Flag Administration's Type Approval.

In case the maximum capacity of the ballast pump(s) exceeds the maximum treatment rated Capacity (TRC) of the BWMS specified in the TAC issued by the Flag Administration, there is to be a limitation on the BWMP giving a maximum allowable flow rate for operating the ballast pump(s) that is not to exceed the maximum TRC of the BWMS.

26.2.1.4 BWMS should be subject to design review by CCS to verify the compliance of the BWMS's manufacturer package with CCS Rules.

Manufacturers of the BWMS may apply for this design review at the type approval process.

In general, monitoring functions of BWMS belongs to system category I under the application of 2.6.3 of Chapter 2, PART SEVEN of the Rules. However, in case a by-pass valve is integrated in the valve remote control system, the by-pass valve belongs to the system category II Ballast transfer remote control system.

The BWMS's components are required to be inspected and certified by CCS at the manufactory including pressure vessels, piping class I or II, filters, switchboards, etc.

26.2.1.5 Where a vacuum or overpressure may occur in the ballast piping or in the ballast tanks due to the height difference or injection of inert gas or nitrogen (N_2), a suitable protection device is to be provided, e.g. P/V valves, P/V breakers, breather valves or pressure safety relief valve or high/low pressure alarms.

The pressure and vacuum settings of the protection device should not exceed the design pressure of the ballast piping (BWMS categories 3a and 3b) or ballast tank (BWMS categories 3a, 3b and 3c), as relevant.

For BWMS categories 3a, 3b and 3c, the inert gas or nitrogen product enriched air from the inert gas system and from the protection devices installed on the ballast tanks (i.e. P/V valves, P/V breakers or P/V breather valves) are to be discharged to a safe location[①②] on the open deck.

Safe location needs to address the specific types of discharges separately.

Signboards or similar warnings at the discharge areas are to be provided.

① inert gas or nitrogen product enriched air from:

a in-line (categories 3a and 3b) and in-tank (categories 3c and 8) de-oxygenation BWMS: the protection devices installed on the ballast tanks, nitrogen or inert gas generators, nitrogen buffer tank (if any); or

b in-line ozone injection BWMS (categories 7a and 7b): the oxygen generator;

safe locations on the open deck are:

a not within 3 m of areas traversed by personnel; and

b not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

② oxygen-enriched air from:

a in-line and in-tank de-oxygenation BWMS (categories 3a and 8): the nitrogen generator; or

b in-line ozone injection BWMS (categories 7a and 7b): the protection devices or vents from oxygen generator, compressed oxygen vessel, the ozone generator and ozone destructor devices;

safe locations on the open deck are:

a outside of hazardous area;

b not within 3 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker

openings, and equipment which may constitute an ignition hazard;

c not within 3 m of areas traversed by personnel; and

When the concerned ballast tanks are hazardous areas, an extension of hazardous area is to be considered at the outlet of the protection devices: with reference to IEC 60092-502 §4.2.2.9 the areas on open deck, or semi-enclosed spaces on open deck, within 1.5 m of their outlets are to be categorized hazardous zone 1 and with reference to IEC 60092- 502 §4.2.3.1, an additional 1.5 m surrounding the 1.5 m hazardous zone 1 is to be categorized hazardous zone 2. Any source of ignition such as anchor windlass or opening into chain locker should be located outside the hazardous areas.

Where products covered by IEC 60092-502 are stored on-board or generated during operation of the BWMS, the requirements of this standard are to be followed in order to:

① Define hazardous areas and acceptable electrical equipment, and

② Design ventilation systems.

26.2.1.6 Electric and electronic components are not to be installed in a hazardous area unless they are of certified safe type for use in the area. Cable penetrations of decks and bulkheads are to be sealed when a pressure difference between the areas is to be maintained.

26.2.1.7 Inert gas systems installed for de-oxygenation BWMS (categories 3a, 3b, 3c and 8) are to be designed in accordance with the following requirements:

(1) FSS Code Ch 15 requirements

① 2.1.2, 2.1.3;

② 2.2.1.3, 2.2.1.4, 2.2.2.1, 2.2.2.2, 2.2.2.3, 2.2.2.6, 2.2.4.1, 2.2.4.2, 2.2.4.3, 2.2.4.4, 2.2.4.5 except 2.2.4.5.1.3 and 2.2.4.5.3;

③ 2.3.1.1.2, 2.3.1.2, 2.3.1.4.2, 2.3.1.5, 2.3.1.6, 2.3.2 except 2.3.2.2.1;

④ 2.4.1.3, 2.4.1.4 and 2.4.2;

⑤ For inert gas systems installed for in-tank de-oxygenation BWMS (category 8): 2.2.3.1, 2.2.3.2 except 2.2.3.2.6, 2.2.3.2.7 and 2.2.3.2.10.

In general, when applying FSS Code Ch.15 requirements to inert-gas based BWMS, the following modifications are to be considered:

① The terms "cargo tank" and "cargo piping" are to be replaced by "ballast water tank" or "ballast water piping" as relevant.

② The term "cargo control room" is to be replaced by "BWMS control station" as relevant.

③ Requirements for slop tanks on combination carriers are to be disregarded.

④ When applying FSS Code / 15.2.2.4.5.1.1, the acceptable oxygen content is to be specified by the manufacturer, 5% oxygen content need not necessarily be applied.

(2) 4.1.1.2, 4.2.2.1, 4.2.2.3, 4.2.2.7, 4.2.2.8, 4.2.3.4, 4.2.3.5 and 4.2.3.6 of Chapter 4, PART SIX of the Rules. In applying 4.2.3.6, the terms “cargo tanks” and “cargo piping” are to be understood as “ballast tanks” and “ballast piping” respectively. For de-oxygenation BWMS (categories 3a, 3b, 3c and 8), the requirements in (1) prevail.

26.2.1.8 When cavitation is the BWMS treatment process (for example by use of pressure vacuum reactor working in combination with a vertical ballast water drop line) or part of the BWMS treatment process (for example by use of “smart pipe” or “special pipe” in BWMS category 7b or by use of “venturi pipe” in BWMS technology 3b) or by use other means, the design and the wall thickness or grade of materials or inside coating or surface treatment of the part of the piping where the cavitation is taking place is to be specifically considered.

26.2.1.9 When it is required to have an automatic shutdown of the BWMS for safety reasons, this must be initiated by a safety system independent of the BWM control system.

26.2.2 Additional requirements for tankers

26.2.2.1 Hazardous area classification is to be in accordance with IEC 60092-502 with due consideration of IACS UI SC274.

(1) BWMS using ozone generators (categories 7a and 7b) and de-oxygenation BWMS using inert gas generator by treated flue gas from main or auxiliary boilers or gas from an oil or gas-fired gas generator (categories 3b and 3c) are to be located outside the cargo area in accordance with FSS Code Ch 15 §2.3.1.1.2.

Note: this requirement does not apply to inert gas generators for which FSS Code Ch 15/2.4.1 and 4.2.2 and 4.2.3 of Chapter 4, PART SIX of the Rules apply.

(2) In-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6) can be located inside the hazardous areas with due consideration of the requirement of 26.2.1.6 but are not to be located inside the

---

d not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

cargo pump room unless it is demonstrated by the BWMS manufacturer that the additional hazards that could be expected from dangerous liquids and dangerous gases stored or evolved from the BWMS (for example H_2 generation):

① do not lead to an upgrade of the hazardous area categorization of the cargo pump room,

② are not reactive with the cargo vapours expected to be present in the cargo pump room,

③ are not reactive with the fire-extinguishing medium provided inside the cargo pump room,

④ are not impacting the performance of the existing fire-fighting systems provided inside the cargo pump room, and

⑤ are not introducing additional hazards inside the cargo pump room such as toxicity hazards that would not have been prior addressed by suitable counter measures.

Notes:

① In-line full flow electrolysis BWMS (category 4) could be accepted in cargo compressor rooms of liquefied gas carriers and inside cargo pump rooms of oil tankers or chemical tankers if that cargo pump room is located above the cargo tank deck.

② For submerged cargo pumps, the room containing the hydraulic power unit or electric motors is not to be considered as the "cargo pump room".

③ Ballast pump rooms and other pump rooms not containing the cargo pumps are not to be considered as the "cargo pump room".

26.2.2.2 In general, two independent BWMS should be required i.e. one for ballast tanks located within the cargo area and the other one for ballast tanks located outside cargo area. Specific arrangements where only one single In-line BWMS (categories 1, 2, 3a, 3b, 5, 6, 7a and 7b) could be accepted are given in appendix 2.

Note: When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with 3.4.14 of Chapter 3, PART SIX of the Rules, the ballast water of the Fore Peak tank is to be processed by the BWMS processing the ballast water of the other ballast tanks within the cargo area.

26.2.2.3 Isolation between ballast piping serving the ballast tanks inside and outside of the cargo area is to be in accordance with the following requirements:

(1) Means of appropriate isolation are as follows: Interconnection in between the ballast piping serving the ballast tanks located within the cargo area and the ballast piping serving the ballast tanks located outside the cargo area may be accepted if appropriate isolation arrangement is provided in accordance with appendix 2 is applied.

Notes:

① The means of appropriate isolation is necessary for the interconnection specified above regardless of the diameter of the piping.

② As indicated in appendix 2, the means of appropriate isolation is necessary for the interconnection specified in said Paragraph in the case of the active substance piping such as N2 gas piping, inert gas piping, neutralizer piping, fresh water piping for filter cleaning, compressed air piping for remaining water purge and sea water piping for adjusting the salinity etc. At the discretion of the Classification Society and for active substance piping and neutralizer piping (both not exceeding 50.8 mm) only, alternative isolation arrangements, provided preferably on the open deck, offering enhanced safety and gastightness may be considered for penetration of the bulkhead separating the non-hazardous machinery space from a hazardous area (such as the cargo pump room) at as high an elevation in the machinery space as possible, preferably, just below the main deck. The arrangements are to provide suitable protection measures in addressing the pollution hazards and safety concerns due to the potential migration of hydrocarbon or flammable or toxic liquids or vapours from the hazardous areas.

③ The means of appropriate isolation described above for the interconnection specified in said Paragraph need not be applied to the sampling lines described in Paragraph 26.2.2.4.

① two non-return valves with positive means of closing in series with a spool piece (also mentioned "means of dis-connection" in appendix 2), as indicated in Figure 26.2.2.3(1):

Note: As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the spool piece.

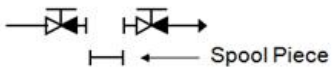


Figure 26.2.2.3(1)
Two Non-return Valves with Positive Means of Closing in Series with a Spool Piece

or:

② two non-return valves with positive means of closing in series with a liquid seal at least 1.5 m in depth, as indicated in Figure 26.2.2.3(2):

Note a: As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the liquid seal.
Note b: For ships operating in cold weather conditions, freeze protection should be provided in the water seal. A portable heating system can be accepted for this purpose.

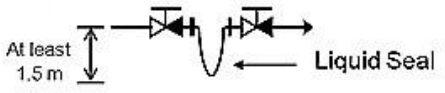


Figure 26.2.2.3(2)
Two Non-return Valves with Positive Means of Closing in Series with a Liquid Seal At Least 1.5 m in Depth

or:

③ automatic double block and bleed valves and a non-return valve with positive means of closing, as indicated in Figure 26.2.2.3(3):

Note: As an alternative to positive means of closure, an additional valve having such means of closure may be provided after the non-return valve.

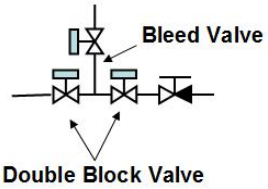


Figure 26.2.2.3(3)
Automatic Double Block and Bleed Valves and a Non-return Valve with Positive Means of Closing

(2) The above-mentioned means of appropriate isolation is to be provided on the open deck in the cargo area.

Note: When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with 3.4.14 of Chapter 3, PART SIX of the Rules, the means of appropriate isolation described in Paragraphs (1) and (2) is not required in between the Fore Peak Tank and the common ballast water piping serving the other ballast water tanks within the cargo area.

26.2.2.4 Sampling lines which are connected to the ballast water piping system serving the tanks in the cargo area and provided for the purpose of the following:

① for any BWMS: ballast water sampling required by the G2 Guideline of the BWM Convention, or

② for BWMS technologies categories 4, 5, 6, 7a and 7b: total residual oxidant (TRO) analysis in closed loop system;

are not to be led into a non-hazardous enclosed space outside the cargo area.

However, the sampling lines may lead into a non-hazardous enclosed space outside the cargo area provided the following requirements are fulfilled:

(1) The sampling facility (for BWMS monitoring/control) is to be located within a gas tight enclosure (hereinafter, referred to as a 'cabinet'), and the following ① through ④) are to be complied.

① In the cabinet, a stop valve is to be installed on each sampling line.

② Gas detection equipment is to be installed in the cabinet and the valves specified in ① above are be automatically closed upon activation of the gas detection equipment.

③ Audible and visual alarm signals are to be activated both locally and at the BWMS control station when the concentration of explosive gases reaches a pre-set value, which is not to be higher than 30% of the lower flammable limit (LFL). Upon an activation of the alarm, all electrical power to the cabinet is to be automatically disconnected.

Note: when the electrical equipment is of a certified safety type, the automatic disconnection of power supply is not required.

④ The cabinet is to be vented to a safe location in non-hazardous area on open deck and the vent is to be fitted with a flame arrester.

(2) The standard internal diameter of sampling pipes is to be the minimum necessary in order to achieve the functional requirements of the sampling system.

(3) The cabinet is to be installed as close as possible to the bulkhead facing the cargo area, and the sampling lines located outside the cargo area are to be routed on their shortest ways.

(4) Stop valves are to be located in the non-hazardous enclosed space outside the cargo area, in both the suction and return lines close to the penetrations through the bulkhead facing the cargo area. A warning plate stating "Keep valve closed when not performing measurements" is to be posted near the valves.

Furthermore, in order to prevent backflow, a water seal or equivalent arrangement is to be installed on the hazardous area side of the return pipe.
(5) A stop valve is to be installed on the cargo area for each sampling line (i.e. both the suction and return lines).
(6) The samples which are extracted from the ballast water piping system serving the tanks within the cargo area are not to be discharged to a tank located outside the cargo area and not to discharge to a piping line supplying the spaces located outside the cargo area.

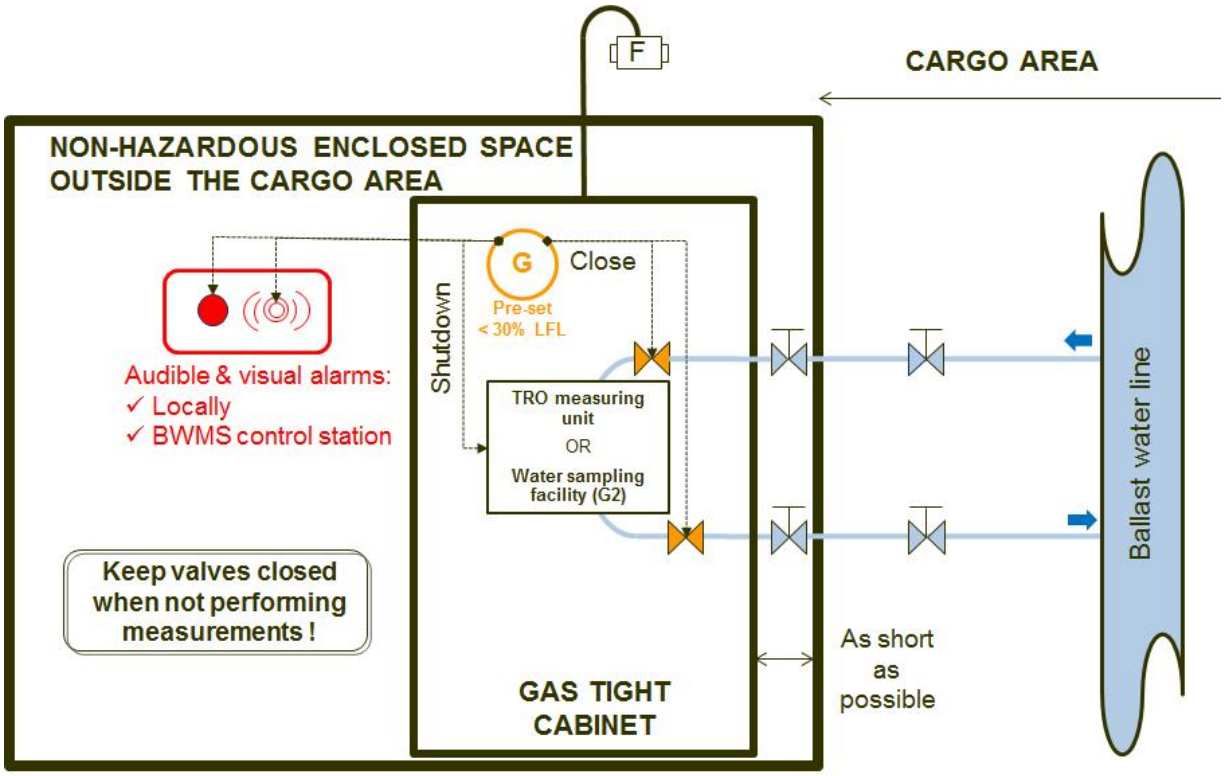


Figure 26.2.2.4 Arrangement of sampling lines led to outside the cargo area

26.2.3 Special requirements for BWMS categories 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8 generating dangerous gas or dealing with dangerous liquids

26.2.3.1 Where the operating principle of the BWMS involves the generation of a dangerous gas, the following requirements are to be satisfied:
(1) Gas detection equipment is to be fitted in the spaces where dangerous gas could be present, and an audible and visual alarm is to be activated both locally and at the BWMS control station in the event of leakage.
The gas detectors should be located as close as possible to the BWMS components where the dangerous gas may accumulate.
For flammable gases and explosive atmosphere including but not limited to H_2, the construction, testing and performance of the gas detection devices is to be in accordance with IEC 60079-29-1, IEC 60079-29-2, IEC 60079-29-3 and/or IEC 60079-29-4, as applicable.
Where other hazards are considered like toxicity, asphyxiation, corrosive and reactivity hazards, a recognized standard acceptable to CCS is to be selected with due consideration of the specific gases to be detected and due consideration of the performance of the detection device with regards to the specific atmosphere where it is used.
(2) In spaces where inert gas generator systems are fitted (BWMS categories 3b and 3c) or nitrogen generators are fitted (BWMS categories 3a and 8), at least two oxygen sensors are to be positioned at appropriate locations (as required by Paragraph 2.2.4.5.4 of Chapter 15 of the FSS Code as amended by IMO resolutions up to MSC.410(97)) to alarm when the oxygen level falls below 19%. The alarms are to be both audible and visual and are to be activated:
① inside the space;

② at the entry into the space; and

③ inside the BWMS control station.

For BWMS categories 7a and 7b, at least two oxygen sensors are to be positioned at appropriate locations in the following spaces:

① spaces where ozone generators are fitted, or

② spaces where ozone destructors are fitted, or

③ spaces where ozone piping is routed;

to alarm when the oxygen level raises above 23 %. The alarms are to be both audible and visual and are to be activated at the following locations:

① inside the space; and

② at the entry into the space; and

③ inside the BWMS control station.

Automatic shut-down of the BWMS is to be arranged when the oxygen level raises above 25%. Audible and visual alarms independent from those specified in the preceding paragraph are to be activated prior to this shut-down.

(3) For BWMS categories 7a and 7b, at least one ozone sensor is to be provided at the vicinity of the discharge outlet to the open deck from the ozone destructors addressed in 26.2.3.2(3) to alarm when the ozone concentration level raises above 0.1 ppm. The alarms are to be both audible and visual and are to be activated in the BWMS control room. In addition, at least two ozone sensors are to be positioned at appropriate location in the following spaces:

① spaces where ozone generators are fitted, or

② spaces where ozone destructors are fitted, or

③ spaces where ozone piping is routed

to alarm when the ozone concentration level raises above 0.1 ppm. The alarms are to be both audible and visual and are to be activated at the following locations:

① inside the space;

② at the entry into the space; and

③ inside the BWMS control station.

Automatic shut-down of the BWMS is to be arranged when the ozone concentration measured from one of the two sensors inside the space raises above 0.2 ppm.

(4) Inside double walled spaces or pipe ducts constructed for the purpose of 26.2.3.2 (1) Note ①, sensors are to be provided for the detection of H_2 leakages (BWMS categories 4, 5 and 6 when relevant) or O_2 leakages (BWMS categories 7a and 7b) or O_3 leakages (BWMS categories 7a and 7b). The sensors are to activate an alarm at the high level settings and automatic shut-down of the BWMS at the high-high level settings described in above (1) and (3).

Note: As an alternative to the sensor for the gas detection, monitored under-pressurization inside the double walled spaces or pipe ducts could be provided with an automatic alarm and shut-down of the BWMS in case of loss of the under-pressurization. The monitoring can be achieved either by monitoring the pressure inside the double walled spaces or pipe ducts or by monitoring the exhaust fan.

(5) For in-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6): the hydrogen de-gas arrangement (when provided) is to be provided with redundant ventilation fans and redundant monitoring of the ventilation system.

In addition the ventilation fan shall be certified explosion proof and have spark arrestor to avoid ignition sources to enter the ventilation systems whereas remaining H_2 gas may be present in dangerous concentrations.

Audible and visual alarms and automatic shut-down of the BWMS are to be arranged for respectively high and high-high levels of H_2 concentration. The open end of the hydrogen by-product enriched gas relieving device is to be led to a safe location[③] on open deck.

(6) The open end of inert gas or nitrogen gas enriched air (BWMS categories 3a, 3b, 3c and 8) or oxygen-enriched air (BWMS categories 3a, 7a, 7b and 8) are to be led to a safe location[①②] on open deck.

26.2.3.2 Where the piping is conveying active substances, by-products or neutralizers that are containing dangerous gas or dangerous liquids as defined respectively in 26.1.2.1(3) and (5), the following requirements are to be satisfied:

---

①② For safe location, refer to requirements of paragraph 26.2.1.5.

③ For safe location, refer to requirements of paragraph 26.2.3.2(3).

Notes:

① This requirement is applicable to the injection lines conveying the dangerous gas or dangerous liquids but not applicable to the ballast water lines where the dangerous gas or dangerous liquids are diluted.

② The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used for assessing the hazards that could be expected from the media conveyed by the BWMS piping.

(1) Irrespective of design pressure and temperature, the piping is to be either of Class I (without special safeguard) or Class II (with special safeguard) as required by Table 2.1.5.1 of Chapter 2, PART THREE of the Rules. The selected materials, the testing of the material, the welding, the non-destructive tests of the welding, the type of connections, the hydrostatic tests and the pressure tests after assembly on-board are to be as required in Chapter 2, PART THREE of the Rules. Mechanical joints, where allowed, are to be selected in accordance with Table 2.5.3.1(3) of Chapter 2, PART THREE of the Rules.

Notes:

① For piping class II with special safeguards conveying dangerous gas like hydrogen (H_2), oxygen (O_2) or ozone (O_3), the special safeguards are to be either double walled pipes or pipe duct.

② For piping class II with special safeguards conveying dangerous liquids, other special safeguards could be considered like shielding, screening, etc.

③ Plastic pipes may be accepted after due assessment of the dangerous gas or dangerous liquids conveyed inside. When plastic pipes are accepted, the requirements of Appendix 1to Chapter 2, PART THREE of the Rules apply.

(2) The length of pipe and the number of connections are to be minimised.

(3) Inside double walled space or pipe ducts constructed as the special safeguard for the purpose of 26.2.3.2(1) Note ① are to be equipped with mechanical exhaust ventilation leading to a safe location[①②] on open deck.

(4) The routing of the piping system is to be kept away from any source of heating, ignition and any other source that could react hazardously with the dangerous gas or liquid conveyed inside. The pipes are to be suitably supported and protected from mechanical damage.

(5) Pipes carrying acids are to be arranged so as to avoid any projection on crew in case of a leakage.

(6) H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) or O_3 piping (BWMS categories 7a and 7b) are not to be routed through accommodation spaces, services spaces and control stations.

(7) O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) are not to be routed through hazardous areas unless it is arranged inside double walled pipes or pipe ducts constructed as the special safeguard for the purpose of 26.2.3.2(1) Note ① and provided with suitable gas detection as described in 26.2.3.1(4) and mechanical exhaust ventilation as described in 26.2.3.2(3).

(8) The routing of H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) is to be as short and as straight as possible. When necessary, horizontal portions may be arranged with a minimum slope in accordance with the manufacturer's recommendation.

26.2.3.3 For BWMS using chemical substances or dangerous gas which are stored on-board for either:

① storage or preparation of the active substances (BWMS categories 2 and 6), or

---

① hydrogen by-product enriched gas from:

- in-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6): the hydrogen de-gas arrangement (when provided);

safe locations on the open deck are:

- not within 5 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard;
- not within 3 m of areas traversed by personnel; and
- not within 5 m of air intakes from non-hazardous enclosed spaces.

The areas on open deck, or semi-enclosed spaces on open deck, within 3 m of the outlets are to be categorized hazardous zone 1 plus an additional 1,5 m surrounding the 3 m hazardous zone 1 is to be categorized hazardous zone 2.

Electrical apparatus located in the above hazardous areas zone 1 and zone 2 is to be suitable for at least IIC T1.

② For in-line ozone injection BWMS (categories 7a and 7b), vent outlet from O_3 destructor device (ODS) can be considered as oxygen-enriched air provided that:

- the ODS are duplicated; and
- the manufacturer justified that the quantity of consumable (activated carbon) used by the ODS is sufficient for the considered life cycle of the BWMS; and - ozone detection is arranged in the vicinity of the discharge outlet from the vent outlet of the ODS to alarm the crew in case the ODS is not working.

If one of the above 3 conditions is not fulfilled, the safe location from ODS on open deck are:

- outside of hazardous area;
- not within 3 m of any source of ignition;
- not within 6 m of areas traversed by personnel; and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

② storage or preparation of the neutralizers (BWMS categories 4, 5, 6, 7a and 7b), or
③ recycling the wastes produced by the BWMS (BWMS category 2),
procedures are to be in accordance with the Material Safety Data Sheet and BWM.2/Circ.20 “Guidance to ensure safe handling and storage of chemicals and preparations used to treat ballast water and the development of safety procedures for risks to the ship and crew resulting from the treatment process”, and the following measures are to be taken as appropriate:
(1) The materials, inside coating used for the chemical storage tanks, piping and fittings are to be resistant to such chemicals substances.
(2) Chemical substances (even if they are not defined as dangerous liquid in the sense of 26.1.2.1(4)) and gas storage tanks are to be designed, constructed, tested, inspected, certified and maintained in accordance with:

① for independent tanks permanently fixed onboard containing dangerous liquids (e.g. sulfuric acid H_2SO_4) or dangerous gas (e.g. oxygen O_2): Chapter 6, PART THREE of the Rules as applicable to pressure vessels;
② for independent tanks permanently fixed onboard not containing dangerous liquid (e.g. sodium sulphite, sodium biosulphite or sodium thiosulfphate neutralizers) and not containing dangerous gas (eg. nitrogen N_2): Chapter 6, PART THREE of the Rules as applicable to pressure vessels or other industry standard recognized by CCS.

(3) When the chemical substances are stored inside integral tanks, the ship's shell plating is not to form any boundary of the tank.
(4) Dangerous liquids and dangerous gas storage tank air pipes are to be led to a safe location[1&2] on open deck.
(5) An operation manual containing chemical injection procedures, alarm systems, measures in case of emergency, etc. is to be kept onboard.
(6) Dangerous liquid storage tanks and their associated components like pumps and filters, are to be provided with spill trays or secondary containment system of sufficient volume to contain potential leakages from tank openings, gauge glasses, pumps, filters and piping fittings.
Further to the safety and/or pollution assessment of the concerned chemical substances, consideration should be provided for segregation of the drains from such spill trays (or secondary containment system) or piping systems from engine room bilge system or from cargo pump room bilge system, as applicable. When necessary, arrangement should be provided within the spill trays (or within the secondary containment system) for the detection of dangerous liquid or dangerous gas as defined respectively in 26.1.2.1(3) and (5).
Note: The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used for this assessment.
26.2.3.4 A risk assessment is to be conducted in a generic manner during the design review mentioned in 26.2.1.4 and submitted to CCS for approval for the following BWMS categories:
- BWMS category 4: in all cases;
- BWMS category 5: in all cases;
- BWMS category 6: when one of the MSDS indicates that the chemical substance stored on-board is either flammable, toxic, corrosive or reactive;
- BWMS category 7a and 7b: in all cases.

Note: The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used as a reference for this assessment.
(1) The recommended risk assessment techniques for BWMS and other guidances are listed below but not limited to:
- FMEA, FMECA, HAZID, HAZOP, etc.
- ISO 31010 – Risk Assessment Techniques
- IACS Recommendation Rec. 146
- Rules of the Classification Society for risk assessment techniques

(2) The risk assessment should ensure that the package supplied by the BWMS’s manufacturer is intrinsically safe and/or provides mitigation measures to the hazards created by the BWMS which have been identified during the design review mentioned in 26.2.1.4 but that need to be implemented during the installation on-board.

Appendix 1 ADDITIONAL FIRE SAFETY MEASURES RELATED TO THE INSTALLATION OF BALLAST WATER MANAGEMENT SYSTEMS

Section 1 GENERAL REQUIREMENTS①

1.1 Application

1.1.1 This Appendix details fire safety measures, in addition to that required by SOLAS II-2, related to the installation of Ballast Water Management Systems onboard any ship. This section is to be read in conjunction with this Chapter.

1.1.2 The requirements of this Appendix apply for BWMS technologies as listed in Table 26.1.2.1. BWMS with alternative technologies are to be specially considered.

1.2 Definitions

1.2.1 Airlock

An airlock is a space enclosed by gastight steel bulkheads with two gastight doors spaced not more than 2.5 m apart. The doors are to be self-closing without any holding back arrangements. Air locks are to have mechanical ventilation and are not to be used for other purposes. An audible and visual alarm system to give a warning on both sides of the air lock is to be provided to indicate if more than one door is moved from the closed position. The air lock space is to be monitored for dangerous gas as defined in 26.1.2.1(3) of this Chapter.

1.2.2 Ballast Water Management System (BWMS)

Ballast Water Management System means any system defined in paragraph 26.1.2.1 of this Chapter.

---

① This Section is to be uniformly implemented for:

i) existing ships, where the application for approval for the [installation] plans of BWMS is dated on or after 1 July 2022; or

ii) BWMS installed on the new ships contracted for construction on or after 1 July 2022.

1.2.3 Ballast Water Management Room (BWMR)
A Ballast Water Management Room is any space containing equipment belonging to the Ballast Water Management System. A space containing remote controls for the BWMS or a space dedicated to the storage of liquid or solid chemicals for BWMS need not be considered as a BWMR for the purposes of this Section.
1.2.4 BWMS storing, introducing or generating chemicals.
In general, BWMS storing, introducing or generating chemicals refer to:
(1) In-line flocculation (cat.2 as per Table 26.1.2.1),
(2) Chemical injection (cat.6 as per Table 26.1.2.1) and
(3) BWM technologies using neutralizers injection (cat.4, 5, 6 and 7 as per Table 26.1.2.1)
BWMS that do not store, introduce or generate toxic or flammable chemicals may be specially considered as detailed in Table 1.1.2.1 below.

Requirements that may be reduced for BWMS storing, introducing or generating chemicals depending on the chemicals

Table 1.1.2.1

Requirement	Conditions to be met before reducing the requirement
2.3.4	The stored chemicals are neither toxic nor flammable
3.1.1	The BWMS does not use any flammable or toxic chemical substances
3.3.1	No dangerous gas as defined in 26.1.2.1(3) will be generated by the BWMS
6.1.1	No toxic chemical is stored and no toxic gas will be generated by the BWMS
7.1.1 7.1.3 7.1.6	No toxic chemical is used or will be generated by the BWMS

The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guidelines) and “safety hazard’’ as listed in Ch.17 of IMO IBC code are to be considered for this purpose.
Note: Chemicals include additives for BWMS.

Section 2 FIRE CATEGORIZATION

2.1 General
2.1.1 BWMR shall be classified as follows for the purpose of applying the requirements of SOLAS Chapter II-2:
(1) BWMR containing oil-fired inert gas generators (i.e. BWMS cat.3b and 3c as per Table 1.1.2.1) is to be treated as machinery spaces of category A;
(2) Other BWMR shall be considered as other machinery spaces and shall be categorized, depending on the ship type (10) or (11) according to SOLAS II-2/9.2.2.3 or (7) according to SOLAS II-2/9.2.2.4, II-2/9.2.3 and II-2/9.2.4.

2.2 BWMS located in the cargo area of tankers
2.2.1 Notwithstanding the above, where a BWMS is located in the cargo area of a tanker as allowed by Chapter 26, PART EIGHT of the Rules, the BWMR shall be categorized as (8), a cargo pump-room, according to SOLAS II-2/9.2.4.2.2 for determining the extent of fire protection to be provided.
Note: The cargo area of a tanker is defined in para 26.1.2.1(2) of Chapter 26 of this PART.

2.3 Storage of chemicals
2.3.1 Spaces where the storage of liquid or solid chemicals for BWMS is intended shall be categorized as store-rooms for the purpose of applying the requirements of SOLAS Chapter II-2, i.e.:
(1) On passenger ships carrying more than 36 passengers:
① “Other spaces in which flammable liquids are stowed” as defined in SOLAS II-2/9.2.2.3.2.2(14), if flammable products are stored;
② “Store-rooms, workshops, pantries, etc.” as defined in SOLAS II-2/9.2.2.3.2.2(13) otherwise.
(2) On other ships:
① “Cargo pump-rooms” as defined in SOLAS II-2/9.2.4.2.2.2(8) if located in the cargo area of a tanker;

② “Service spaces (low risk)” as defined in SOLAS II-2/9.2.2.4.2.2(5), SOLAS II-2/9.2.3.3.2.2(5) or II-2/9.2.4.2.2.2(5) if the surface area is less than 4m2 and if no flammable products are stored;

③ “Service spaces (high risk)” as defined in SOLAS II-2/9.2.2.4.2.2(9), SOLAS II-2/9.2.3.3.2.2(9) or II-2/9.2.4.2.2.2(9) otherwise.

Note: It is understood that only chemical injection (cat.6 as per Table 26.1.2.1), in-line flocculation (cat.2 as per Table 26.1.2.1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Table 26.1.2.1) will require chemical or additive storage.

2.3.2 Where the storage of chemicals is foreseen in the same room as the ballast water management machinery, this room shall be considered both as a store-room and as a machinery space in line with 2.1.

2.3.3 When the chemical substances are stored inside integral tanks, the ship's shell plating shall not form any boundary of the tank.

2.3.4 Tanks containing chemicals shall be segregated from accommodation, service spaces, control stations, machinery spaces not related to the BWMS and from drinking water and stores for human consumption by means of a cofferdam, void space, cargo pump-room, empty tank, oil fuel storage tank, BWMR or other similar space. On-deck stowage of permanently attached deck tanks or installation of independent tanks in otherwise empty hold spaces should be considered as satisfying this provision.

Section 3 BWMR LOCATION AND BOUNDARIES

3.1 BWMS using chemical substances

3.1.1 For BWMS storing, introducing or generating chemicals, the BWMR and chemical substance storage rooms are not to be located in the accommodation area. Any ventilation exhaust or other openings from these rooms are to be located not less than 3m from entrances, air inlets and openings to accommodation spaces. This requirement need not apply in case the BWMS is located in the engine room.

3.2 Ozone-based BWMS

3.2.1 Ozone-based BWMS – i.e. cat.7a and 7b - shall be located in dedicated compartment, separated from any other space by gastight boundaries. Access to the BWMR from any other enclosed space is to be through airlock only, except if the only access to that space is from the open deck.

Access to the ozone based BWMR may be provided through the engine room only provided:

(1) Access from the engine room to the BWMR is through airlock and,

(2) An alarm repeater is provided in the BWMR, which will repeat any alarm activated in the engine room.

3.2.2 A sign shall be affixed on the door providing personnel with a warning that ozone may be present and with the necessary instructions to be followed before entering the room.

3.3 General

3.3.1 BWMR containing equipment for BWMS of the following types shall be equipped with tested gastight and self-closing doors without any holding back arrangements:

(1) BWMS storing, introducing or generating chemical substances

(2) De-oxygenation based on inert gas generator

(3) Electrolysis

(4) Ozone injection

Doors leading to the open deck need however not to be self-closing.

Section 4 FIRE FIGHTING

4.1 Fixed fire-extinguishing system

4.1.1 Where fitted, fixed fire extinguishing systems shall comply with the relevant provisions of the Fire Safety Systems Code.

4.1.2 Ozone-based BWMS

BWMR containing equipment related to ozone-based BWMS shall be provided with a fixed fire extinguishing system suitable for category A machinery spaces and capable of manual release.

4.1.3 Where a fixed fire-extinguishing system is provided in the BWMR, it should be compatible with the BWMS and the chemical products that are used, produced or stored in the BWMR. Specific attention shall be paid to potential chemical reactions between the fire extinguishing medium and chemical products used for water treatment. Especially, water-based fire-extinguishing systems should be avoided in case of sulfuric acid storage.

4.1.4 Foam fixed fire-extinguishing system
For all kinds of BWMS, in case a foam fire extinguishing system is installed in the BWMR, its efficiency shall not be impaired by chemicals used by the BWMS where relevant.
4.1.5 Where a fixed fire-extinguishing system is installed in the BWMR, automatic shutdown of the BWMS upon release of the fixed fire extinguishing system shall be arranged. Any need for cooldown necessary for safe shutdown to be considered in the shutdown sequence.
4.1.6 Where BWMS that includes air or O_2 storage is located in a room covered by a fixed gas fire-extinguishing system, air or O_2 storage shall be taken into account for the gas capacity calculation, unless the discharge pipe from safety valves for air or O_2 storage are led directly to outside the room.

4.2 Portable fire-fighting equipment
4.2.1 There shall be at least one portable fire extinguisher that complies with the provisions of the Fire Safety Systems Code and suitable for electrical fires in the BWMR containing UV type BWMS.

Section 5 FIRE PREVENTION

5.1 Equipment protection
5.1.1 Overcurrent or overvoltage protection is to be installed to protect UV type BWMS.
5.1.2 Electrolysis reactors are to be provided with at least with two independent means of monitoring operation. The monitoring system shall initiate audible and visual alarms and automatic shutdown of the BWMS in the event that an anomaly is detected. Requirements for shutdown arrangement are clarified in 26.2.1.9 of Chapter 26 of this PART.
Note: If a pressure relief valve is also provided, the vent of this valve is to be led to a safe location on the open deck, as clarified in Chapter 26 of this PART. The valve should be positioned to optimally remove gas from the electrolysis reactor.

5.2 Fire detection
5.2.1 A fixed fire detection and fire alarm system complying with the provisions of the Fire Safety Systems Code shall be installed in spaces containing an inert gas generator or an ozone generator.
5.2.2 A section of fire detectors which covers a control station, a service space or an accommodation space is not to include a BWMR containing equipment related to ozone based BWMS.

Section 6 VENTILATION

6.1 Ventilation arrangement
6.1.1 The ventilation systems for BWMR containing BWMS of the following types shall be independent of the ventilation systems serving any other spaces:
(1) BWMS storing, introducing or generating chemical substances;
(2) De-oxygenation, including pasteurization and de-oxygenation (cat.3 and cat.8 as per Table 26.1.2.1);
(3) Electrolysis;
(4) Ozone injection.
6.1.2 The ventilation exhaust for BWMR containing a nitrogen generator shall be located in the lower part of the room in order to efficiently evacuate dangerous gases – as defined in 26.1.2.1(3) of Chapter 26 of this PART - heavier than air.
6.1.3 The ventilation exhaust for BWMR containing electrolysis systems shall be located so as to be able to efficiently evacuate dangerous gases – as defined in 26.1.2.1(3) of Chapter 26 of this PART - that could be generated during the electrolysis process. Due regard is to be paid to the expected quantity and density of such gases when designing the ventilation exhaust.
6.1.4 The following requirements apply to ventilation ducts serving BWMR for ozone-based BWMS:
(1) The part of the ducts located outside of the BWMR shall be made of steel having a thickness of at least 3 mm for ducts with a free cross-sectional area of less than 0.075 m^2, at least 4 mm for ducts with a free cross-sectional area of between 0.075 m^2 and 0.45 m^2, and at least 5 mm for ducts with a free cross-sectional area of over 0.45 m^2; and
(2) The ducts shall be suitably supported and stiffened;
(3) The outside openings of the ducts shall be fitted with protective screens of not more than 13 mm square mesh.

6.1.5 The ventilation system for BWMR containing ozone-based BWMS or ventilation system for hydrogen de gas arrangement as required by 26.2.3.1(5) of Chapter 26 of this PART shall be interlocked with the BWMS such that:
(1) In case of loss of ventilation (primary and secondary), a visual and audible alarm shall be triggered both inside and outside the BWMR and at a place where a responsible member of the crew is on duty. If the ventilation is not restored after a pre-set time, the BWMS shall then be automatically shut down. Any need for cooldown necessary for safe shutdown is to be considered in the shutdown sequence.
(2) It shall not be possible to start the BWMS without the ventilation running.
6.1.6 For ventilation systems serving BWMR and containing or conveying a dangerous gas, relevant requirements in 26.2.3.1 of Chapter 26 of this PART are to be satisfied.

6.2 Ventilation rate

6.2.1 An adequate power ventilation system shall be provided in enclosed BWMR.
6.2.2 The ventilation capacity shall be at least 30 air changes per hour where explosive or toxic gases may be generated during operation of the BWMS. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guidelines) and "safety hazard'' as listed in Ch.17 of IBC code are to be used as references for identifying those cases.
6.2.3 The ventilation capacity may be reduced as follows:

(1) Flocculation-type BWMS	6 air changes per hour
(2) De-oxygenation, incl. pasteurization and de-oxygenation (cat.3 and cat.8 as per Table 26.1.2.1)	6 air changes per hour
(3) Full flow electrolysis	6 air changes per hour
(4) Side-stream electrolysis	20 air changes per hour
(5) Ozone injection	20 air changes per hour
(6) Chemical injection	6 air changes per hour

Note: More stringent ventilation capacity requirements may arise from other regulations e.g. IBC Code requirements for spaces located in the cargo area.

Section 7 PERSONAL EQUIPMENT

7.1 General Requirement

7.1.1 Suitable protection equipment shall be available onboard for the protection of the crew members who are engaged in the servicing, maintenance and repair of BWMS storing, introducing or generating chemicals, as recommended by the product manufacturers. The protection equipment shall consist of large aprons, special gloves with long sleeves, suitable footwear, coveralls of chemical-resistant materials, and tight fitting goggles or face shields or both. The protective clothing and equipment shall cover all skin so that no part of the body is unprotected. This protection equipment is to be provided separately without taking into account equipment required by other mandatory requirements.
7.1.2 Work clothes and protective equipment shall be kept in easily accessible places and in special lockers. Such equipment shall not be kept within accommodation spaces, with the exception of new, unused equipment and equipment which has not been used since undergoing a thorough cleaning process. Notwithstanding the above, storage rooms for such equipment within accommodation spaces if adequately segregated from living spaces such as cabins, passageways, dining rooms, bathrooms, etc.
7.1.3 When a BWMS storing, introducing or generating chemicals is installed on board, suitably marked decontamination showers and an eyewash are to be available in a convenient location in close proximately to the BWMS and the chemical store room(s).
7.1.4 An emergency escape breathing apparatus (EEBD) is to be provided in the BWMR. This emergency escape breathing apparatus may be one of the EEBDs provided in accordance with the requirements of SOLAS II-2/13.
An EEBD need not be required for BWMS of cat.1 as per Table 26.1.2.1.
7.1.5 A personal ozone detector, calibrated as per the manufacturer's specifications, shall be provided for each person engaged in the servicing, maintenance and repair of BWMS utilizing ozone.
7.1.6 A two-way portable radiotelephone apparatus dedicated for the BWMS service, maintenance and repair shall be provided, in addition to those required by SOLAS for firefighting purposes. This two-way radiotelephone apparatus is to be properly identified in order to avoid mix-up with the apparatus intended for fire-fighting operations. Where the BWMS may release explosive gases, this two-way radiotelephone apparatus is to be of a certified safe type suitable for use in zone 1 hazardous areas, as defined in IEC

Publication 60079.Where the BWMS stores, utilizes or introduces chemicals, the apparatus is to undergo deep cleaning or de-contamination after use.
A two-way portable radiotelephone apparatus need not be required for BWMS of cat.1 as per Table 26.1.2.1.

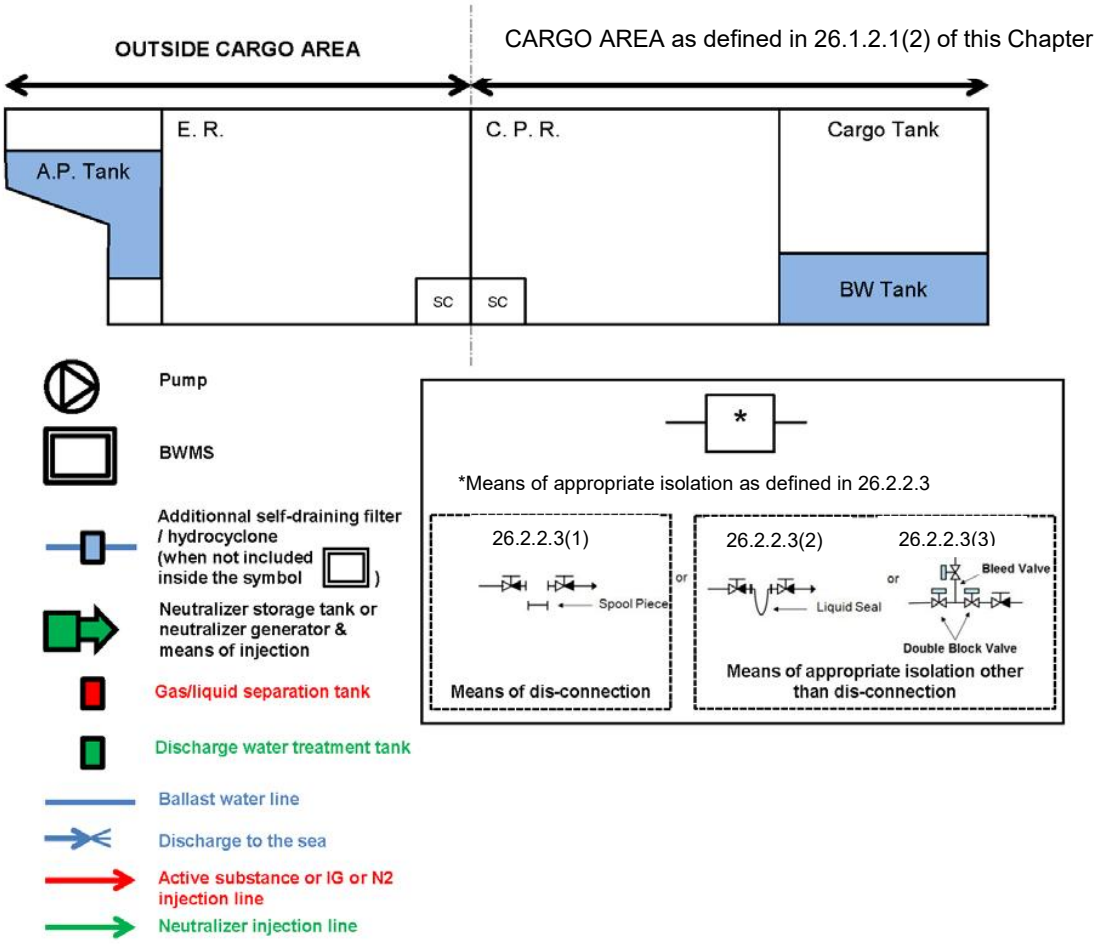
Appendix 2 INSTALLATION OF ONE SINGLE BWMS ON TANKERS

BWMS's Technologies Categorization **Table 1.1**

BWMS's Technology category* →		1	2	3a	3b	4	5	6	7a	7b
Characteristics↓		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO2 or UV + Plasma	In-line Flocculation	In-line membrane separation and deoxygenation (injection of N2 from a N2 Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-line full flow electrolysis	In-line side stream electrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank
Des-infection when ballasting	Making use of active substance		x			x	x	x	x	x
	Full flow of ballast water is passing through the BWMS	x	x	x	x	x				x
	Only a small part of ballast water is passing through the BWMS to generate the active substance						x			
After-treatment when deballasting	Full flow of ballast water is passing through the BWMS	x								x
	Injection of neutralizer					x	x	x	x	x
	Not required by the Type Approval Certificate issued by the Administration		x	x						
Examples of dangerous gas as defined in 26.1.2.1(3) of Chapter 26 of this PART			(1)	O_2 N_2	CO_2 CO	H_2 Cl_2	H_2 Cl_2	(1)	O_2,O_3,N_2	
Arrangement of one single BWMS	BWMS is located in the outside the cargo area	Not Acceptable	Case 1.2 （2）	Case 1.3a（2）	Case 1.3b	Case 1.4（2）	Case 1.5	Case 1.6	Case 1.7a	Case 1.7b(2)

Notes:
(1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.
(2) Only Means of dis-connection as described in 26.2.2.3 are to be applied.
(3) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or deballasting).

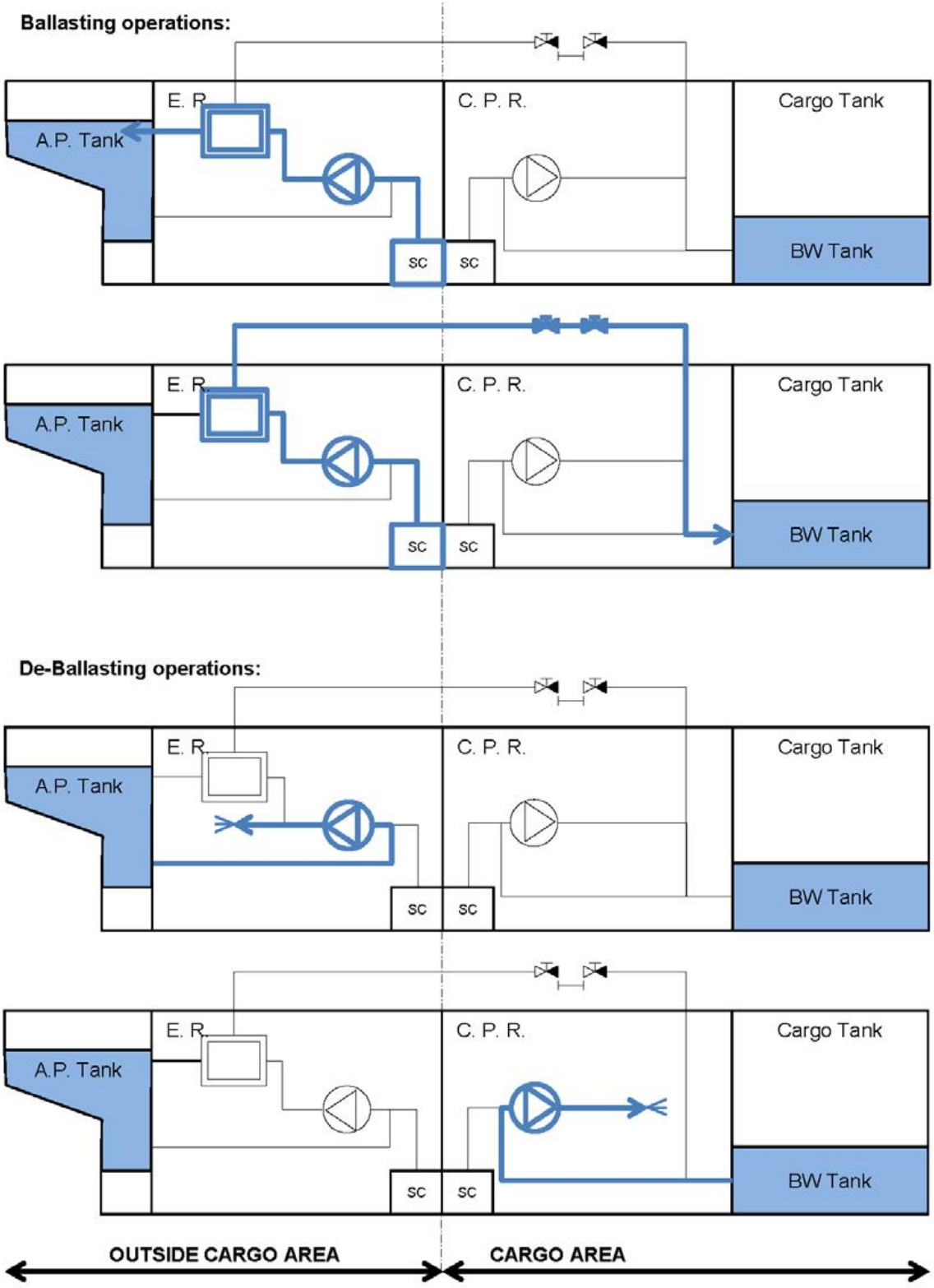
Note: This Appendix does not cover In-tank technologies categories 3c and 8.


OUTSIDE CARGO AREA
CARGO AREA as defined in 26.1.2.1(2) of this Chapter
E. R.
C. P. R.
Cargo Tank
A.P. Tank
SC
SC
BW Tank
Pump
BWMS
Additionnal self-draining filter / hydrocyclone (when not included inside the symbol)
Neutralizer storage tank or neutralizer generator & means of injection
Gas/liquid separation tank
Discharge water treatment tank
Ballast water line
Discharge to the sea
Active substance or IG or N2 injection line
Neutralizer injection line
*
*Means of appropriate isolation as defined in 26.2.2.3
26.2.2.3(1)
Spool Piece
or
26.2.2.3(2)
Liquid Seal
or
26.2.2.3(3)
Bleed Valve
Double Block Valve
Means of dis-connection
Means of appropriate isolation other than dis-connection

BWMS installed outside the cargo area

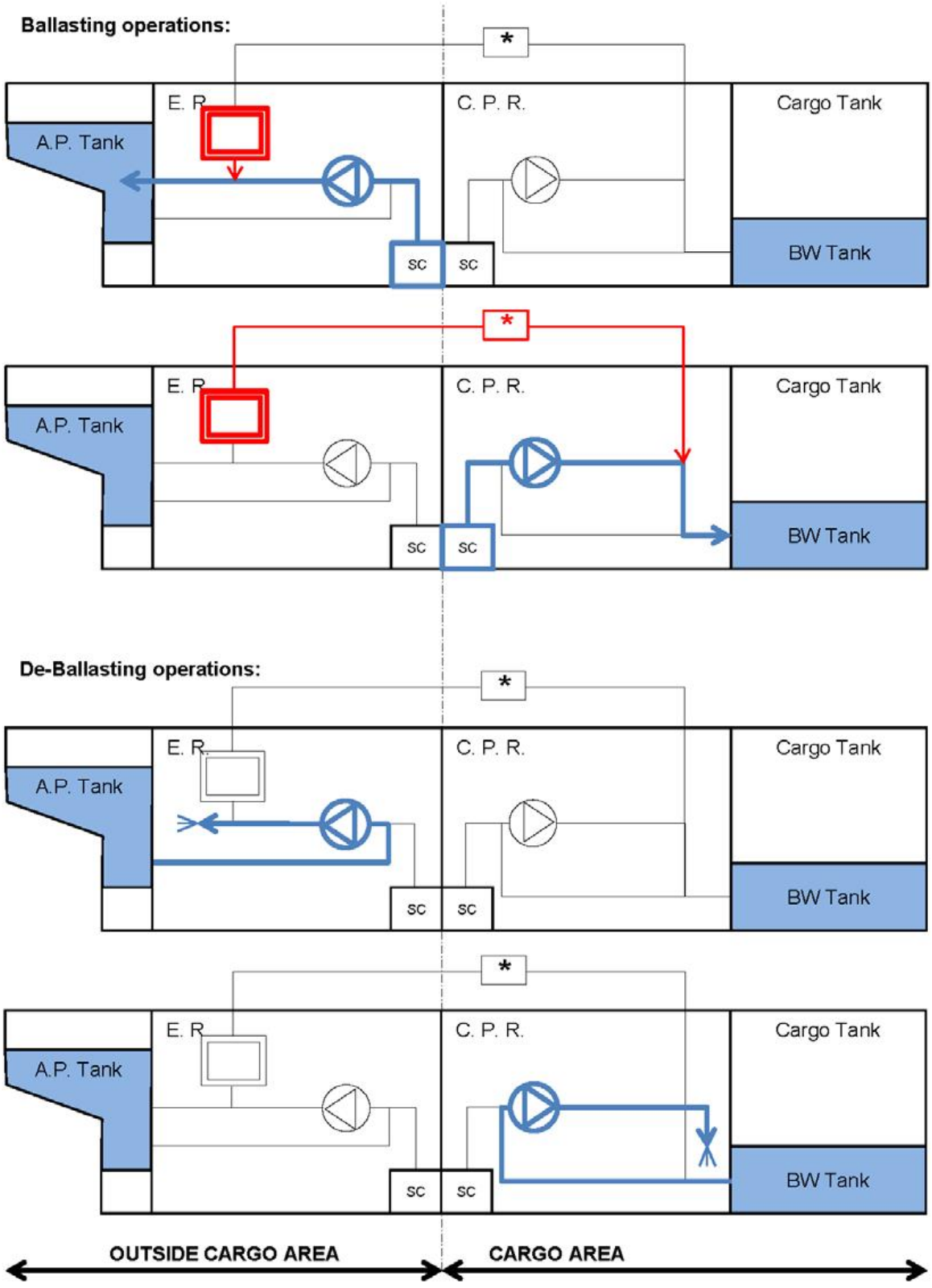
Case 1.2 (Technology category 2, Flocculation); and

Case 1.3a (Technology category 3a De-oxygenation with N2 Generator)



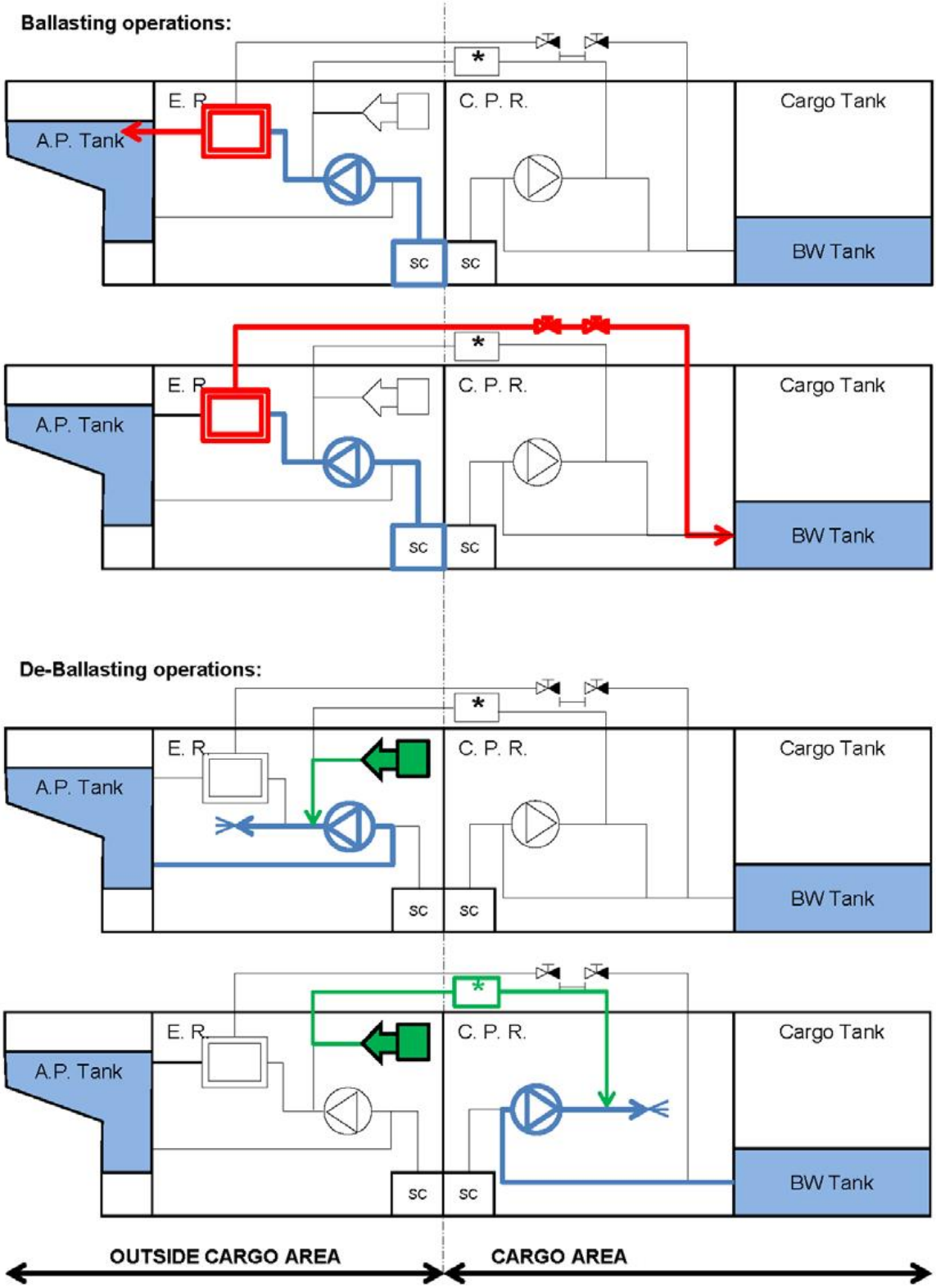
BWMS installed outside the cargo area

Case 1.3b (Technology category 3b, De-oxygenation with Inert Gas Generator):



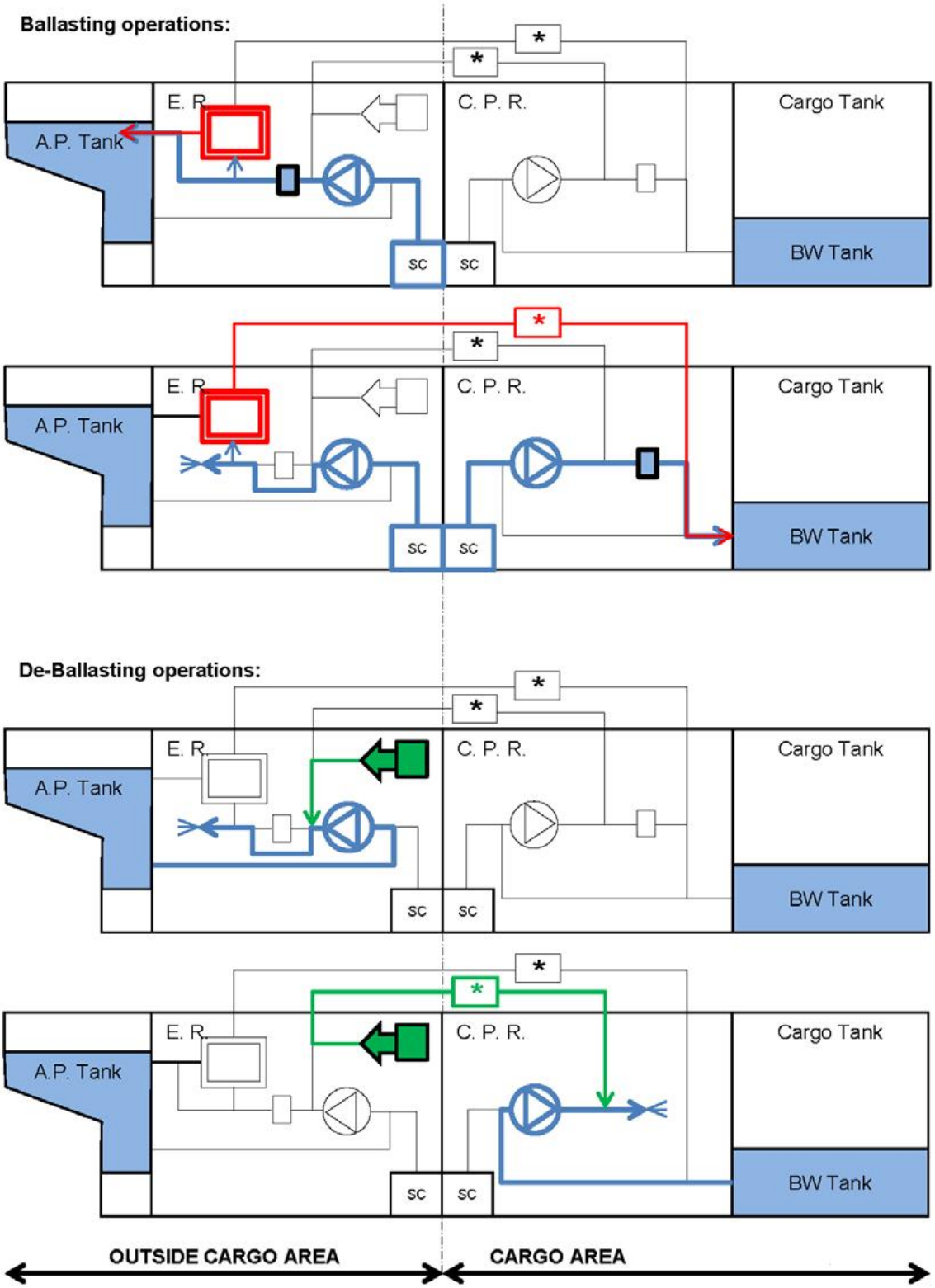
BWMS installed outside the cargo area

Case 1.4 (Technology category 4, Full-flow electrolysis):



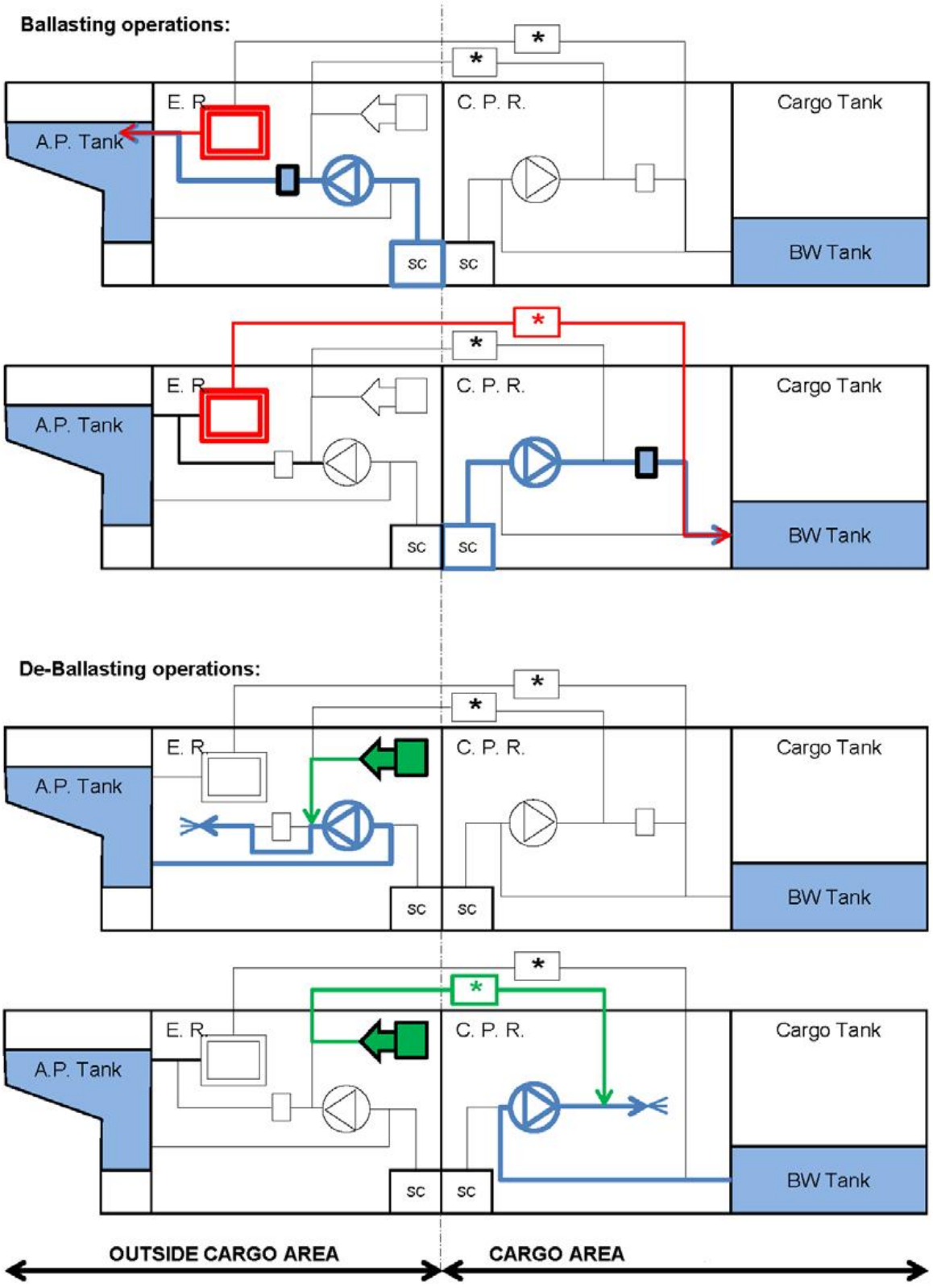
BWMS installed outside the cargo area

Case 1.5 (Technology category 5, Side-stream electrolysis):



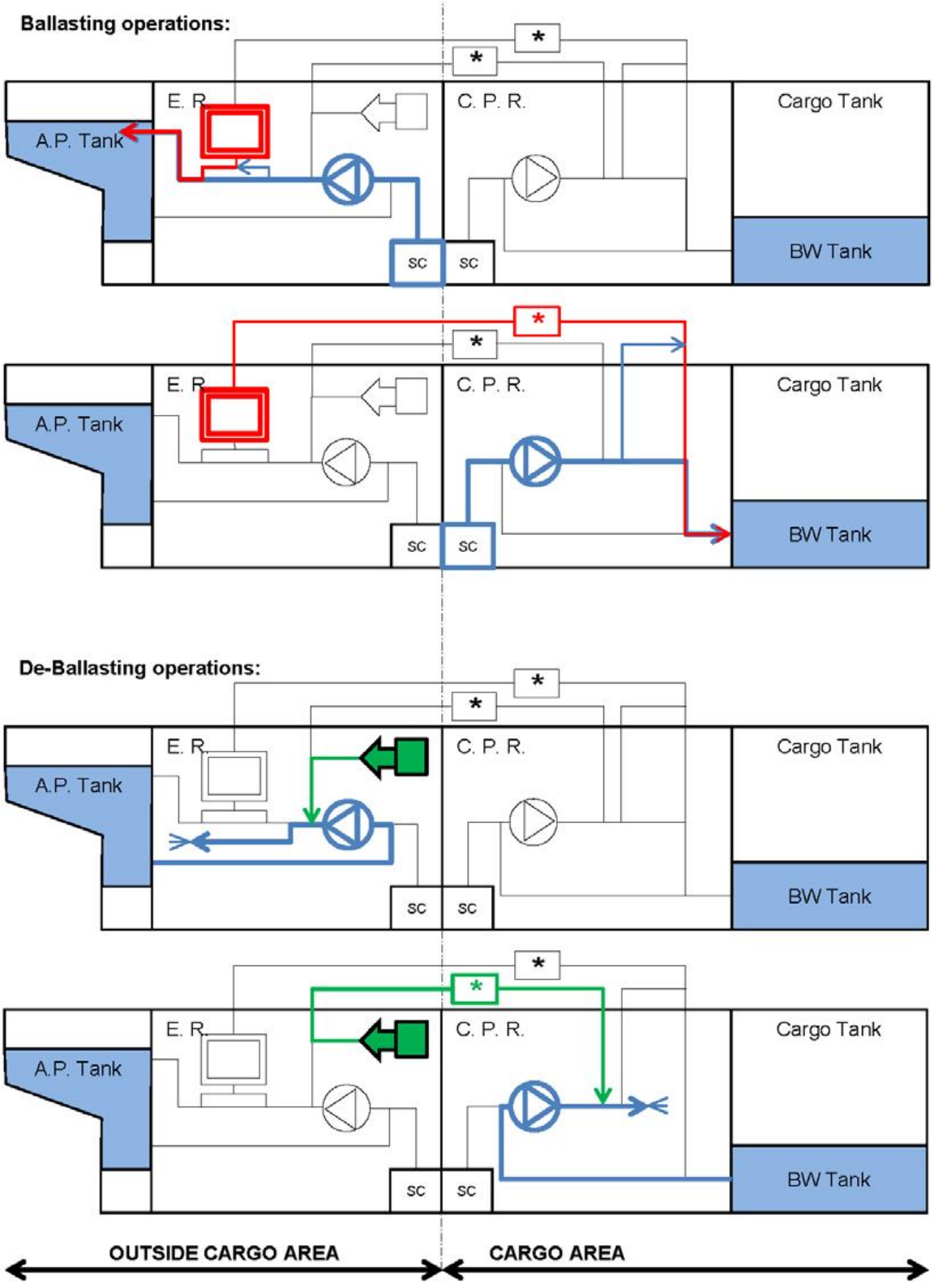
BWMS installed outside the cargo area

Case 1.6 (Technology category 6, Stored chemical injection)



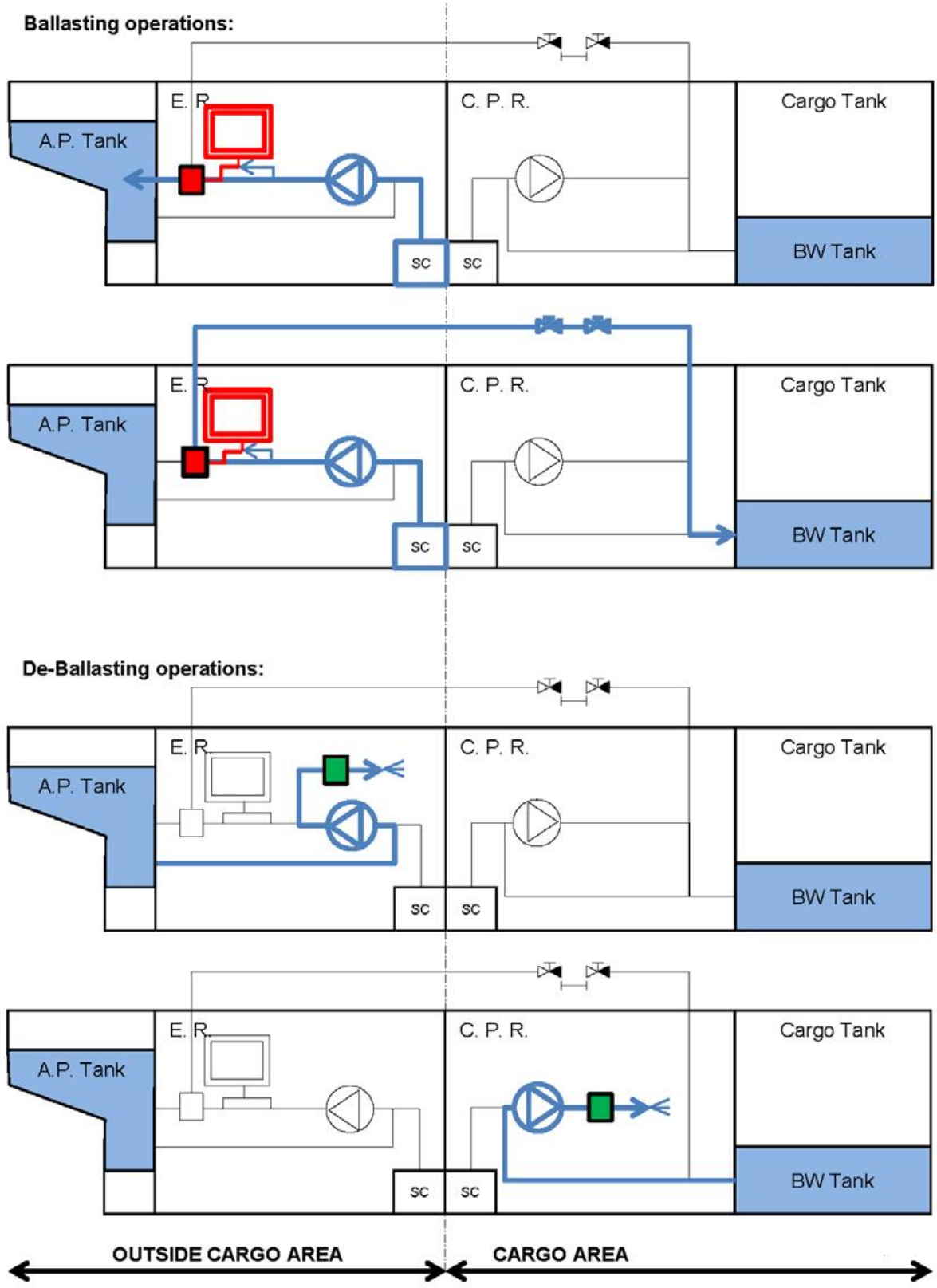
BWMS installed outside the cargo area

Case 1.7a (Technology category 7a, Side-stream ozone injection without gas/liquid separation tank and without discharge water treatment tank):



BWMS installed outside the cargo area

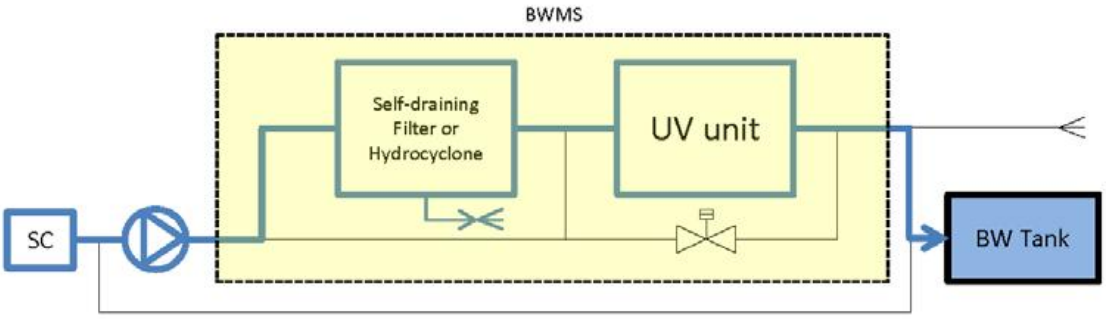
Case 1.7b (Technology category 7b, Side-stream ozone injection with gas/liquid separation tank and discharge water treatment tank):



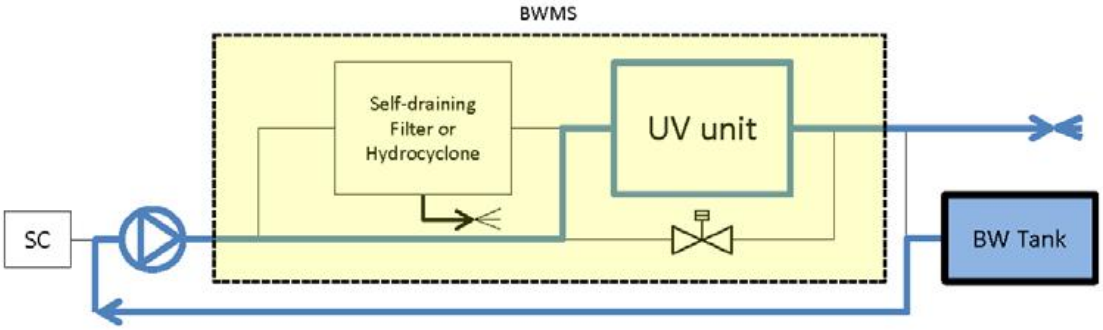
BWMS Technologies categorization

BWMS Technology Group no. 1
In-Line UV
including UV + AOT
Including UV+TiO2)

Ballasting operation:

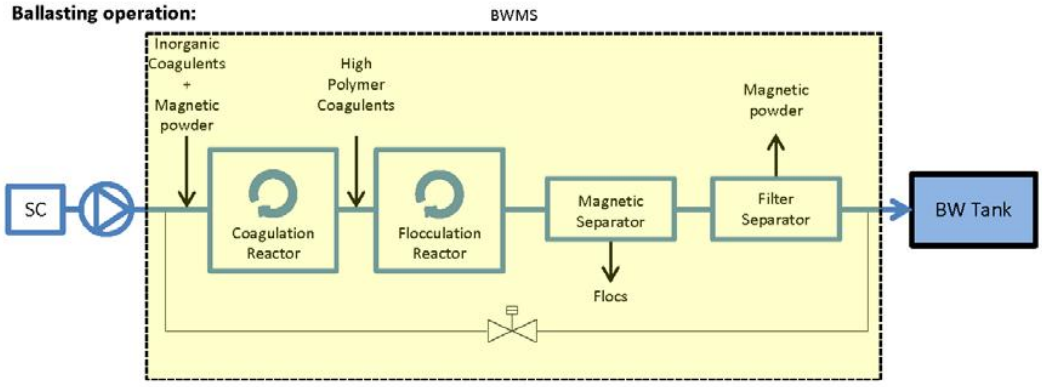


De-ballasting operation:



BWMS Technology Group no. 2
In-Line Flocculation

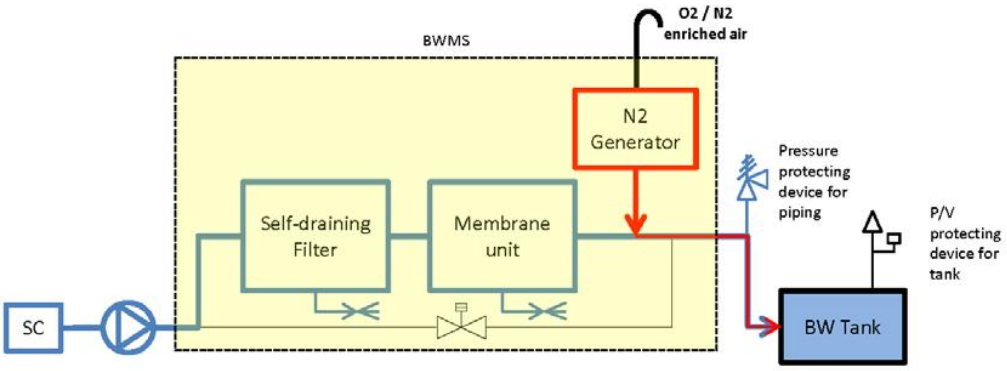
Ballasting operation:



De-ballasting operation: no requirement for after-treatment

BWMS Technology Group no. 3a
In-Line membrane separation and de-oxygenation
(injection of N2 from N2 Generator)

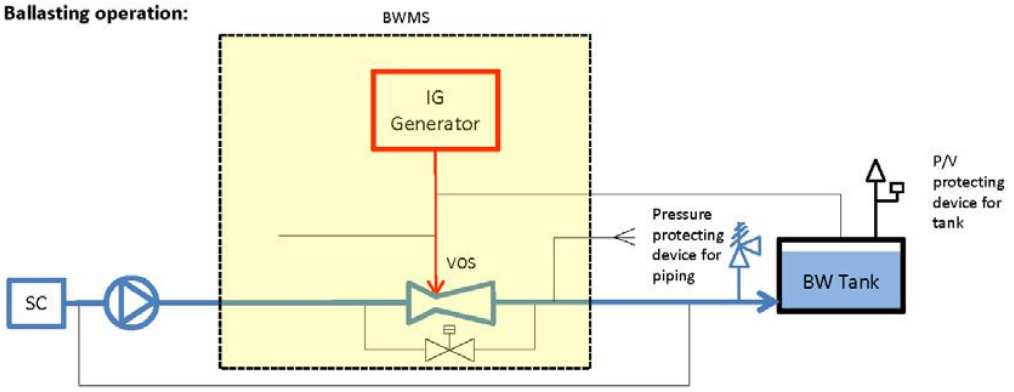
Ballasting operation:



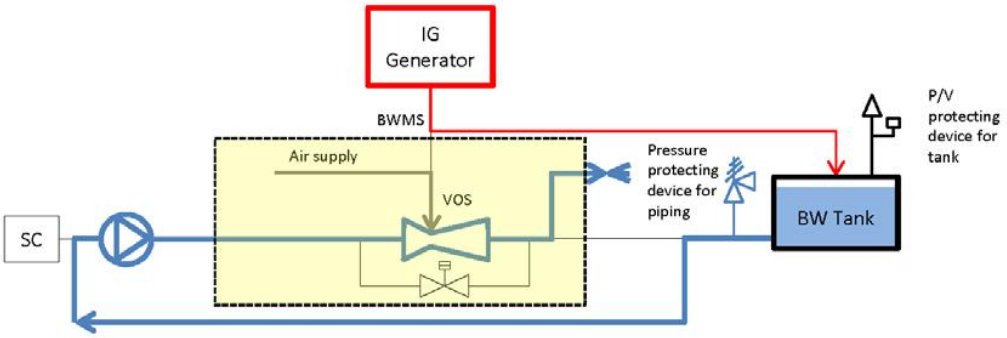
De-ballasting operation: no requirement for after-treatment

BWMS Technology Group no. 3b
In-Line de-oxygenation
(injection of inert gas from either an oil fired inert gas generator or inert gas from treatment of the flue gas from main or auxiliary boilers)

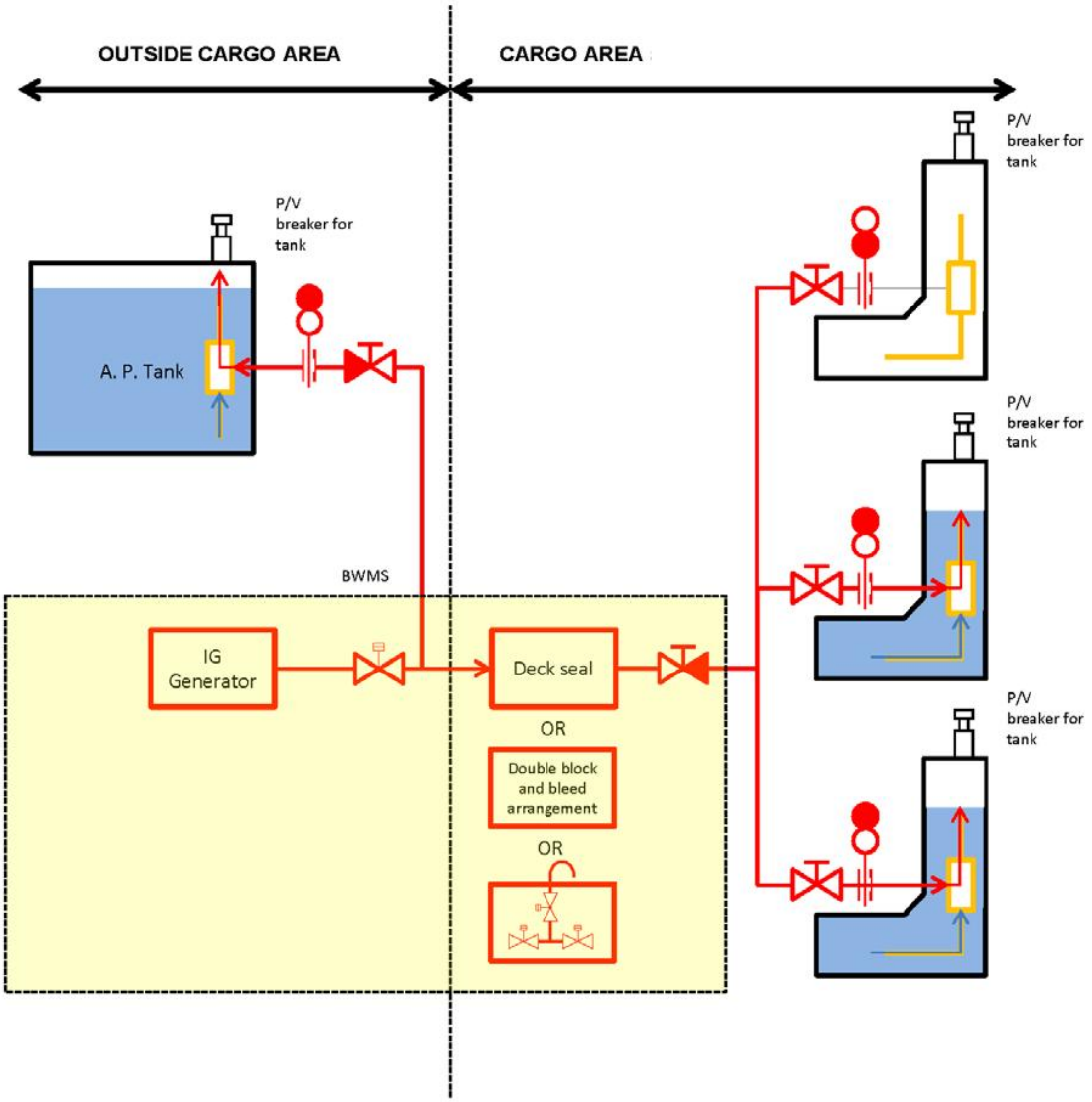
Ballasting operation:



De-ballasting operation:

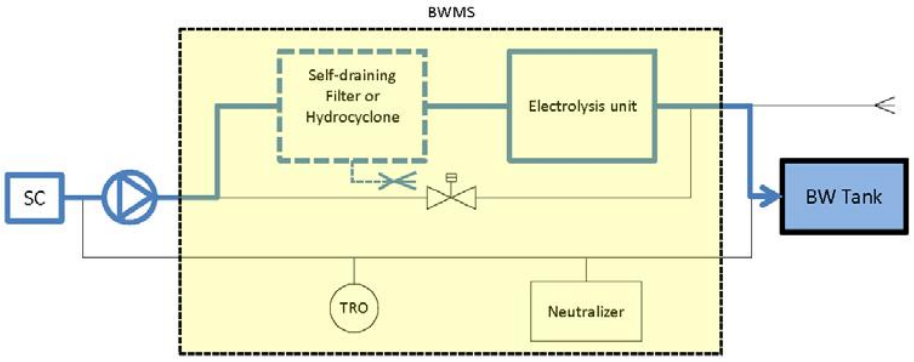


BWMS Technology Group no. 3c
In-tank de-oxygenation with IGG

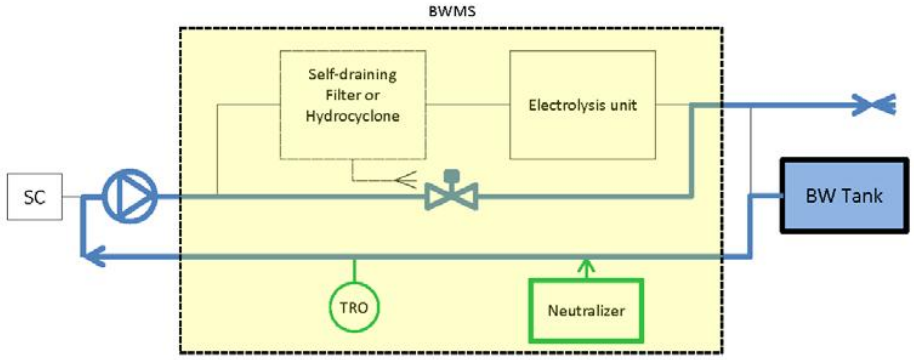


BWMS Technology Group no. 4
In-Line Full flow electrolysis

Ballasting operation:



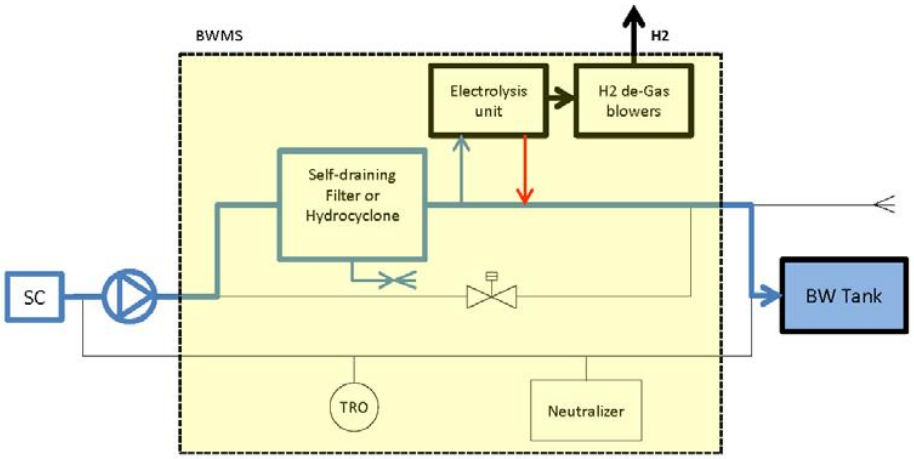
De-ballasting operation:



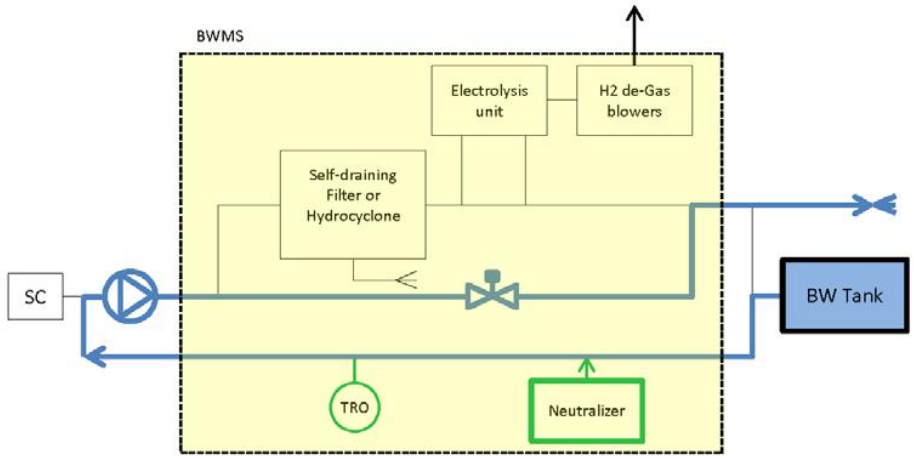
BWMS Technology Group no. 5
In-Line Side-Stream electrolysis (electro-chlorinization)

Note: In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting)

Ballasting operation:

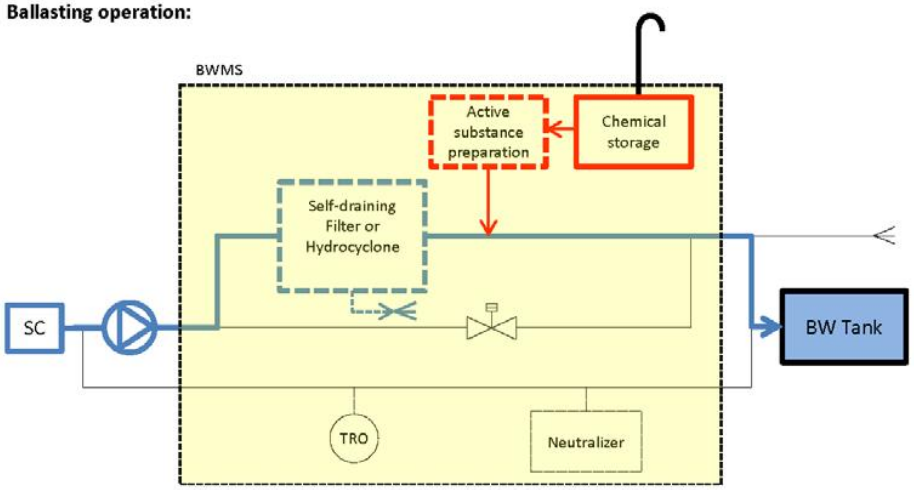


De-ballasting operation:

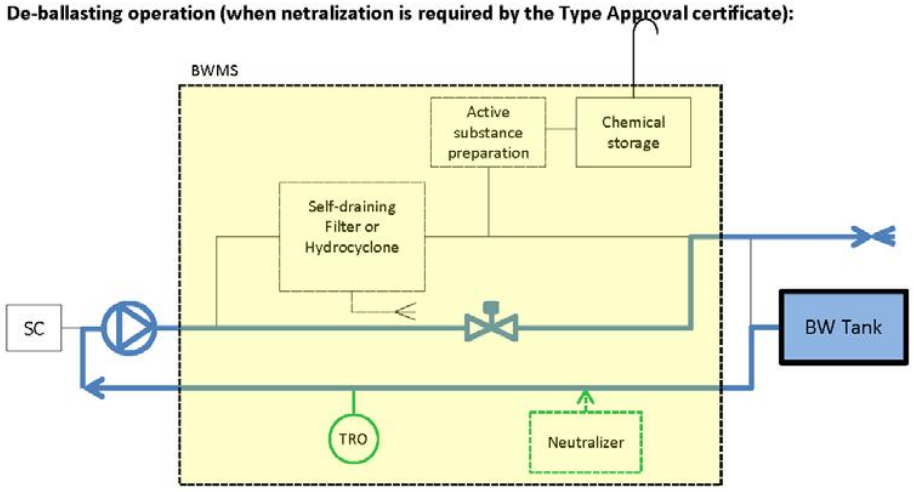


BWMS Technology Group no. 6
In-Line Chemical injection

Ballasting operation:

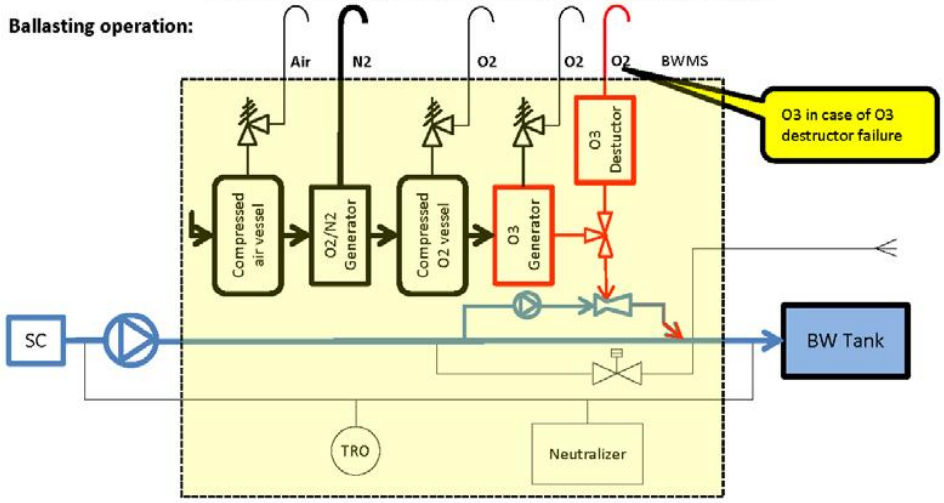


De-ballasting operation (when netralization is required by the Type Approval certificate):

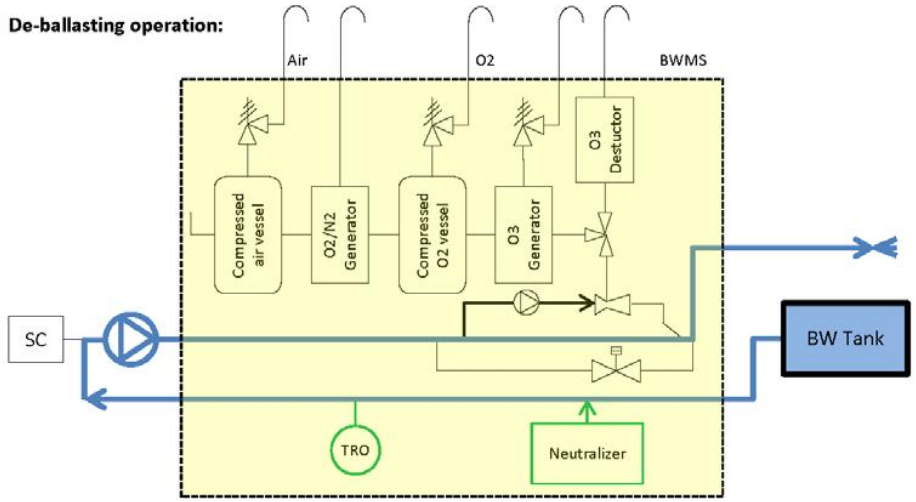


BWMS Technology Group no. 7a
In-Line Side-stream Ozone injection without gas/liquid separation tank and without discharge water treatment tank

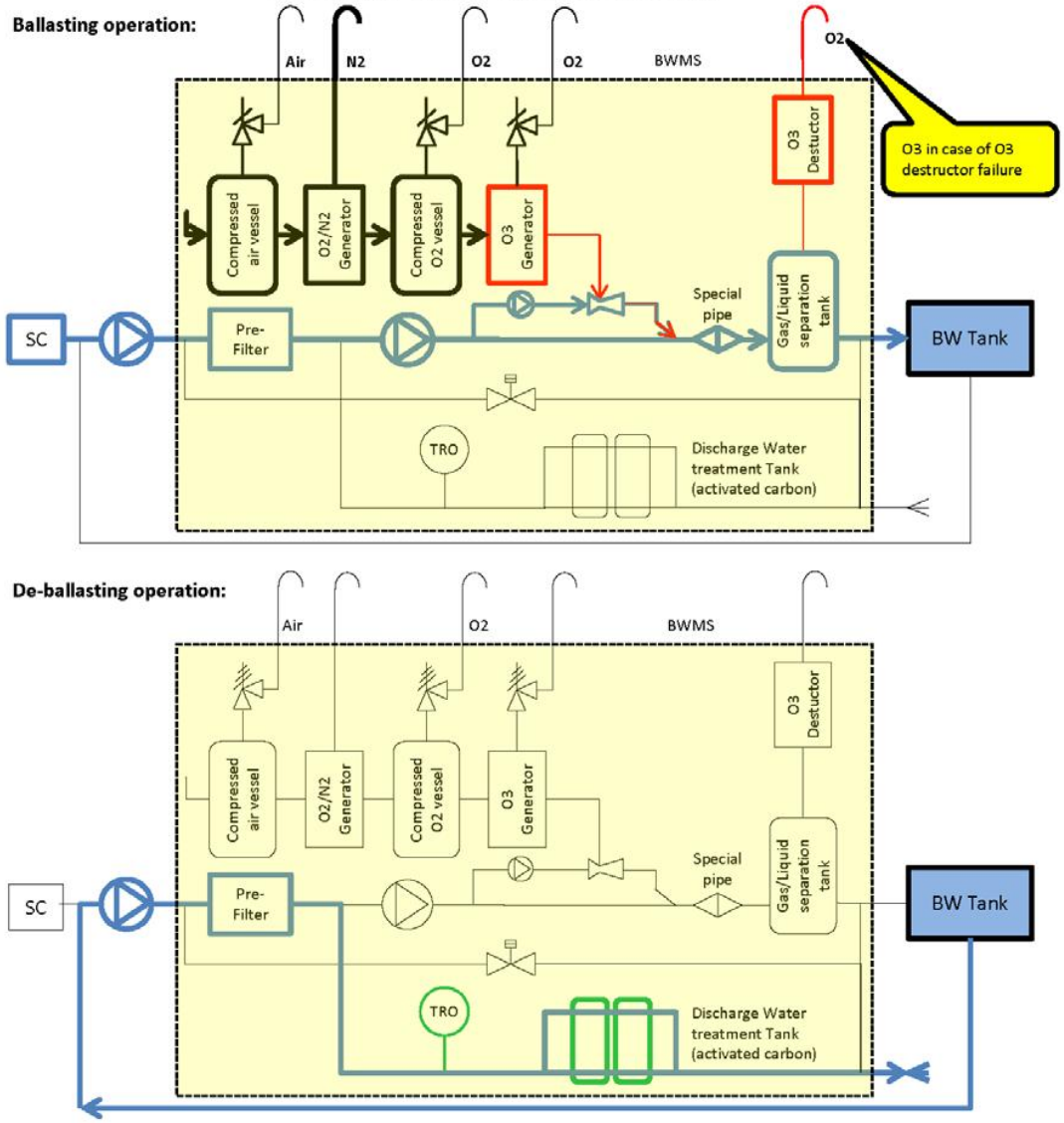
Ballasting operation:



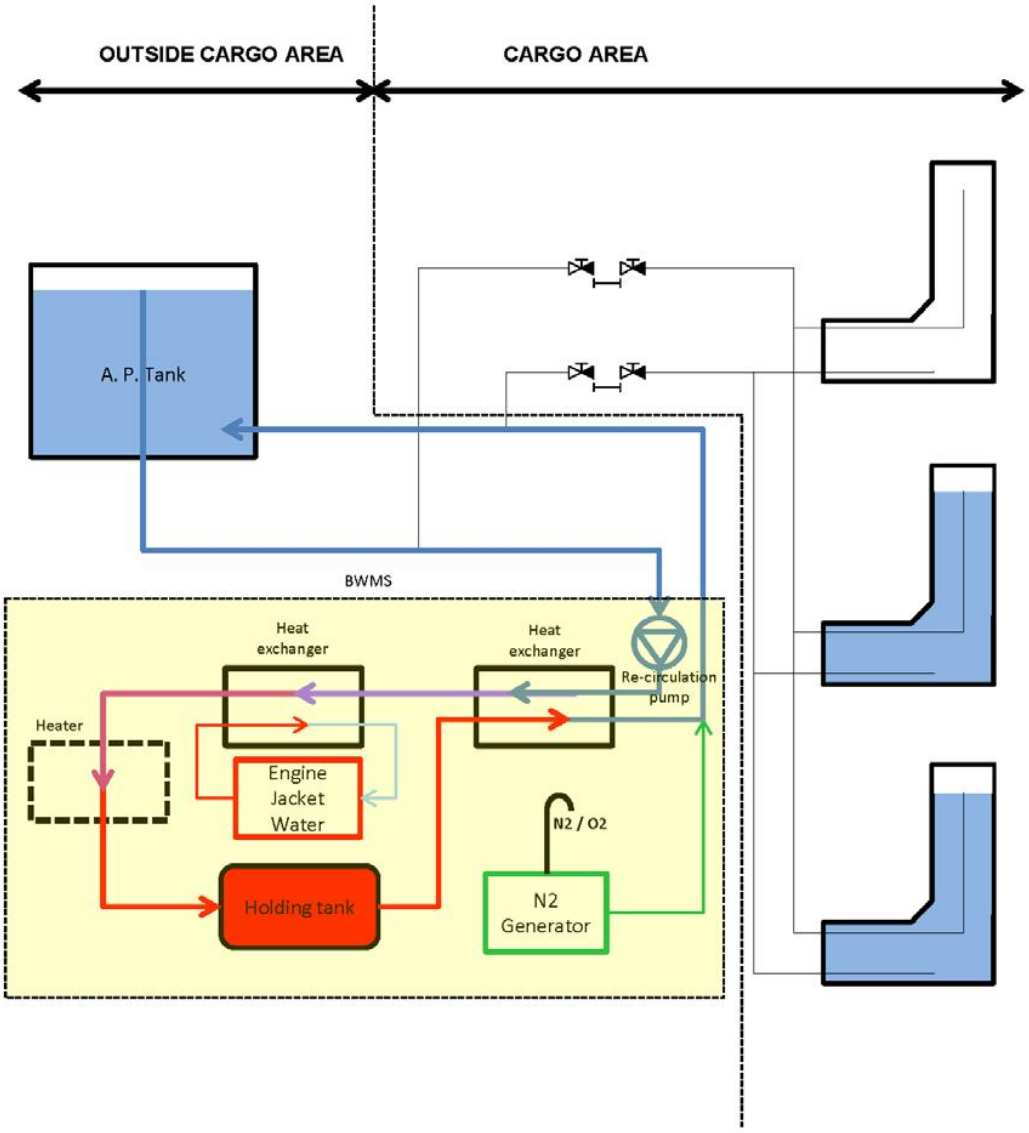
De-ballasting operation:



BWMS Technology Group no. 7b
In-Line Side-stream Ozone injection with gas/liquid separation tank and with discharge water treatment tank



BWMS Technology Group no. 8
In-tank Pasteurization + de-oxygenation with N2 Generator



CHAPTER 27 BOW LOADING SYSTEMS

Section 1 GENERAL PROVISIONS

27.1.1 Application

27.1.1.1 This Chapter applies to oil tankers provided with bow loading systems.

27.1.1.2 Oil tankers provided with bow loading systems are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules

27.1.2 Notation

27.1.2.1 Oil tankers complying with the provisions of Sections 1 to 8 of this Chapter may be assigned the notation: Bow Loading System.

27.1.2.2 Oil tankers complying with the provisions of Section 9 of this Chapter may be assigned the notation: Bow Loading System*.

27.1.3 Definition

27.1.3.1 For the purpose of this Chapter:

(1) Bow loading control station means a control station performing all operations concerning positioning of the ship, operation and monitoring of bow loading safety systems, and monitoring of mooring and loading parameters.

27.1.4 Plans and documents

27.1.4.1 The following plans and documents are to be submitted for approval. If they have been included in plans and documents required for ship's classification, re-submission may be omitted:

(1) general arrangement of bow loading systems, including bow loading control stations;

(2) mooring arrangement of bow loading system areas;

(3) lower hull supporting structure of mooring equipment of bow loading systems;

(4) cargo lines of bow loading systems;

(5) bow loading hydraulic oil systems;

(6) foam fire-extinguishing piping and equipment capacity calculations of bow loading system areas;

(7) water-spraying fire-extinguishing piping and equipment capacity calculations of bow loading system areas;

(8) ventilation piping arrangement of bow loading system areas;

(9) arrangement of the ship showing dangerous zones and spaces of bow loading system areas;

(10) arrangement of electrical equipment in hazardous areas of bow loading system areas;

(11) fire-resisting divisions of bow loading system areas;

(12) fire control plans of bow loading system areas;

(13) schematic diagram of control and monitoring systems of bow loading systems;

(14) schematic diagram of communication systems related to the bow loading control station.

27.1.4.2 The following plans and documents are to be submitted for information:

(1) operation manual of bow loading systems.

27.1.4.3 For special structures and arrangement, expansion of the submission scope of plans and documents may be required if deemed necessary by CCS.

Section 2 ARRANGEMENT

27.2.1 Arrangement of bow loading systems

27.2.1.1 Cargo lines used for bow loading are to be arranged outside accommodation spaces, service spaces, machinery spaces and control stations, and they are to be clearly identified.

27.2.1.2 The bow loading system is to be so arranged as not to interfere with the operation and use of life-saving appliances and embarkation stations at bow. The stowage position of life-saving appliances and embarkation stations are to have a distance of not less than 10 m from the coupling.

27.2.1.3 Enclosed spaces containing the working area of bow loading coupler are to be provided with mechanical ventilation system capable of giving at least 30 air changes per hour.

27.2.1.4 For oil tankers provided with emergency towing arrangements at bow, the bow loading system is

to be so designed as not to interfere with the operation and use of emergency towing arrangements.
27.2.1.5 The working area of bow loading coupler is to be provided with sufficient lighting that ensures good working environment.

27.2.2 Bow loading control station
27.2.2.1 For ships provided with bow loading systems, a control station for bow loading is to be arranged within the bow area or on the navigation bridge.
27.2.2.2 Where the bow loading control station is arranged within the bow area, positive pressure mechanical ventilation is to be provided.
27.2.2.3 Where the bow loading control station is arranged within the bow area, at least one lifejacket and one immersion suit are to be provided for each person on watch.

27.2.3 Classification of hazardous areas and electrical equipment in hazardous areas
27.2.3.1 For oil tankers provided with bow loading systems, classification of hazardous areas and electrical equipment in hazardous areas are, in addition to additional requirements for oil tankers in Section 16, Chapter 2, PART FOUR of the Rules, to comply with the provisions of this Section.
27.2.3.2 Where the cargo hose joint is arranged outside the cargo tank area, for the purpose of electrical equipment or ignition devices, areas within 3 m from the manifold are to be considered as hazardous area zone 1, with corresponding requirements to electrical equipment and wiring.
27.2.3.3 Spaces housing the loading pipe (fitted with detachable joint) and bow loading coupling are to be considered as hazardous area zone 1, with corresponding requirements to electrical equipment and wiring.
27.2.3.4 Entrances, air inlets and openings to service and machinery spaces and control stations are not to face the bow loading coupling, and are to be located at least 10 m from the bow loading coupling. Direct access from the hazardous bow loading coupler room to non-hazardous spaces in the forecastle area is acceptable provided protected from gas ingress as follows:
An air lock in accordance with IEC60092-502 is provided between the bow loading coupler room and an intermediate space. The air lock will be considered as a hazardous zone 2. The intermediate space complies with the requirements to an air lock in IEC60092-502. The intermediate space will be considered as a non-hazardous space.
27.2.3.5 Spaces considered as non-hazardous are not to have any connections with hazardous spaces or areas, and are to be ventilated in accordance with IEC60092-502.

Section 3 EQUIPMENT AND OUTFITS

27.3.1 Mooring equipment and its supporting structures
27.3.1.1 The ship is to be provided with suitable mooring equipment that can be used in conjunction with the ship's manoeuvring system to ensure that the ship is moored during bow loading. The mooring equipment is to be arranged to prevent the mooring load from being transferred to the oil pipeline used for loading.
27.3.1.2 Mooring equipment and its arrangement are to meet Oil Companies International Marine Forum (OCIMF) mooring equipment guidelines
27.3.1.3 The arrangement plan of mooring equipment is to indicate the safe working load of equipment.
27.3.1.4 The design load of the hull supporting structure of the mooring equipment is to be 2 times the safe working load of the equipment, and the calculated stress is not to exceed the minimum yield limit of the material used.

Section 4 PIPING SYSTEMS

27.4.1 General provisions
27.4.1.1 Materials, design and manufacture and testing of piping systems, valves and fittings of bow loading systems are to comply with applicable requirements of Chapter 2 of PART THREE of the Rules.
27.4.1.2 For ships to which this Chapter is applicable, requirements for bow loading in Chapter 5 of PART THREE of the Rules are replaced by requirements of this Chapter.

27.4.2 Cargo lines
27.4.2.1 Cargo lines used for the bow loading system which are outside the cargo area are to have welded

connections. Flanged connections may be used in way of the coupler. If necessary, expansion joints of flanged connection may be permitted when compensation is needed for lines subject to expansion and contraction.

27.4.2.2 Lines of the bow loading system and lines within the cargo area are to be effectively segregated in the cargo area by the following methods or equivalent means:

(1) a spool piece and blanking the line ends; or

(2) a valve and blanking the line ends; or

(3) two valves which can be secured in the closed position and provided that the efficiency of the segregation can be checked.

27.4.2.3 The bow loading coupling is to be fitted with a shut-off valve and a blank flange. The blank flange may be omitted when a patent hose coupling is fitted. A spill tray or coaming arrangement is to be provided in way of the bow loading coupling. Means for draining the spill tray to the cargo tank or slop tank are to be provided.

27.4.2.4 The cargo line is to be arranged to drain cargoes in the line to the cargo tank or slop tank by itself or by means of a draining device, where necessary by connection to a stripping device.

27.4.2.5 Spray shields are to be provided in way of valves or joints with potential leakage of the loading manifold of bow loading system except where the loading manifold is located outboard.

27.4.2.6 Means of inerting, purging and gas freeing for relevant lines of bow loading piping system are to be arranged, and the connected vent pipes are to be located in the cargo area. The relevant joints to the lines are to be fitted with shut-off valves and blank flanges.

Section 5 CONTROL AND MONITORING

27.5.1 General requirements

27.5.1.1 The control and monitoring of electrical installations are, in addition to the applicable requirements of the Rules, to comply with the provisions of this Section.

27.5.1.2 For instrumentation, equipment and automation, including computer based control and monitoring, the requirements of Chapter 2, PART SEVEN of the Rules are to be complied with.

27.5.1.3 From the control station for bow loading, all operations concerning positioning of the ship, operation and monitoring of bow loading safety systems, and monitoring of mooring and loading parameters are to be performed. The station is in general arranged on the navigation bridge and may also be arranged within the bow area Where the bow loading control station is arranged on the navigation bridge, it is to have concentrated arrangement and control and monitoring functions above. The bow area may also be provided with local operation which a necessary operation function of the bow loading system. Where the bow loading control station is only arranged within the bow area, all functions of the station are to be met.

27.5.1.4 Oil tankers applying for the notation DP are to satisfy the applicable requirements of Chapter 11 of this PART.

27.5.2 Instrumentation, equipment and automation

27.5.2.1 Ship manoeuvring instrumentation or equipment is to cover:

(1) thruster(s) control;

(2) main engine(s) emergency stop, or disengagement of clutch, if fitted;

(3) steering gear control, if fitted;

(4) radar;

(5) log.

27.5.2.2 Bow mooring instrumentation or equipment is to cover:

(1) mooring line traction control;

(2) chain stopper control;

(3) data logger system for recording of mooring and load parameters.

The mooring system is to be provided with a tension meter continuously indicating the tension during the bow loading operation. This requirement may be waived if the vessel has in operation an approved dynamic positioning system.

27.5.2.3 The bow loading system is to cover:

(1) indicator for loading connector coupling position;

(2) cargo valve position indicators;

(3) cargo tank level indicators and high level alarm (which may be omitted if the bow loading control station is located on the navigation bridge and such indicators are provided in other areas of the bridge);

(4) a system for automatic transfer of signals from the control and safety system, to enable automatic

termination of cargo supply from the offshore terminal;
(5) cargo pressure monitoring in the bow loading line in way of the bow loading coupling with high and low pressure alarms.
27.5.2.4 An emergency disconnection system is to be provided, which is to be activated from the control station.
- tripping the main crude oil transfer pumps;
- closing the connector and loading hose end coupler valves;
- start of the water sprinkler system;
- opening of the bow loading coupling claws;
- opening of the chain stopper.
In addition to the above automatic disconnection systems, a manually-operated backup emergency disconnection system is to be provided. Such a system may be based on accumulators providing hydraulic pressure.

27.5.3 Communication
27.5.3.1 Means of communication between the ship's cargo oil control station and bow loading control station and the offshore loading terminal are to be provided and certified safe for hazardous areas, if necessary.
27.5.3.2 Means of emergency communication between the bow loading control station and the offshore terminal are to be arranged.
27.5.3.3 Both primary and secondary methods are to be provided to ensure that continuous communication can be maintained between the bow loading control station and the offshore terminal in the event of any equipment failure or other problems arising during the operations.

Section 6 FIRE SAFETY

27.6.1 Fire protection, fire detection and fire extinction
27.6.1.1 Where the bow loading control station is arranged within the bow compartment, a protected escape route is to be provided and protected by a self-closing A-class door with the control station. The exit of the escape route is to be 10 m away from the coupling and not to face the joint of coupling.
27.6.1.2 Where the bow loading control station is arranged within the bow compartment, A-60 insulation protection is to be provided for boundaries adjacent to the space containing the coupling, including doors, windows and side scuttles.
27.6.1.3 At least one fire hydrant with associated fire hose and nozzle is to be provided in the working area of bow loading coupler.
27.6.1.4 The compartment containing the working area of bow loading coupler is to be provided with fixed combustible gas system and fire detection and alarm system. The alarm of the above systems is to be provided locally and in the bow loading control station.
27.6.1.5 The bow area is to be additionally provided with at least one additional foam monitor and one additional foam applicator complying with 2.2.2, Chapter 14 of the FSS Code, which are to be capable of effectively protecting the cargo lines and loading areas at bow.
27.6.1.6 Where the coupling and cargo lines are arranged in the compartment, a fixed foam fire-extinguishing system complying with the following requirements or other equivalent fire-extinguishing system is to be provided:
(1) foam sprinkler system. The system is to be capable of operating continuously for at least 30 minutes at a rate of not less than 6 L/m2 to protect the compartment; or
(2) fixed high-expansion foam system. The system is to be arranged to meet the requirements of the foam fire extinguishing system for the cargo pump room in Chapter 6 of the FSS Code.
The control of the fixed foam fire-extinguishing system required by this paragraph is to be located in an easily operable position outside the protected space.
27.6.1.7 The bow area is to be provided with a water spraying system with a spraying intensity not less than 5L/m^2 per minute. The system is to cover potential spark generating equipment and location, e.g. mooring related equipment and coupling etc. The water spraying system is to be capable of being started within and outside the working area of bow loading coupler, and in addition, its control is to meet starting requirements in case of emergency disconnection.

Section 7 OPERATION MANUAL

27.7.1 Operation manual

27.7.1.1 An operation manual is to be provided on board, generally containing the bow loading operation procedure and safety measures that need to be taken during operation.

27.7.1.2 The operation manual is in general to give information regarding the following:

(1) Arrangement and equipment

① tank arrangement;

② arrangement and explanation of mooring equipment;

③ cargo loading and transfer system;

④ control station;

⑤ communication equipment;

⑥ other relevant equipment.

(2) Operation procedures

① communication procedure;

② mooring procedure;

③ connection and disconnection of cargo hose coupling;

④ transfer/distribution/storage of oil cargo;

⑤ oil spillage alarm of tanks.

(3) Safety measures

① emergency disconnection system;

② emergency communication system;

③ ventilation system;

④ fire safety system;

⑤ emergency escape routes.

(4) Cleaning and gas-freeing.

Section 8 TESTING AND SURVEY

27.8.1 Inspection and testing of products

27.8.1.1 Equipment forming the bow loading system is to be furnished with CCS certificates in accordance with the requirements of Chapter 3, PART ONE of the Rules.

27.8.1.2 Equipment forming the bow loading system is to be inspected and tested in accordance with approved plans and relevant standards.

27.8.2 Ship survey

27.8.2.1 For newbuildings and ships in service, the first survey after onboard installation is to comply with the provisions of 27.8.2.2 of this Chapter. The survey after construction is to comply with the provisions of 27.8.2.3 and 27.8.2.4 of this Chapter.

27.8.2.2 Initial classification survey

(1) checking the product certificate of equipment forming the bow loading system;

(2) checking the arrangement and installation of equipment forming the bow loading system comply with approved plans;

(3) After completion of installation, related equipment and systems of the bow loading system are subject to the following examination and testing:

① visual examination;

② examining and testing the function of instrument, automation and communication equipment in the bow loading control station (including the bow area and navigation bridge);

③ examining and testing the function of emergency disconnection system;

④ examining and testing the function of water spraying system;

⑤ interlock functional testing of mooring equipment and the bow loading system;

⑥ calibration testing of mooring line tension sensor;

⑦ functional test of the interconnection effect between the bow loading coupling and the connecting hose joint or equivalent device.

27.8.2.3 Annual survey

(1) The bow loading system is subject to the following examination:

① visual examination;

② examining and testing the function of instrument, automation and communication equipment in the bow loading control station (including the bow area and navigation bridge);

③ examining and testing the function of emergency disconnection system;

④ examining and testing the function of water spraying system.

27.8.2.4 The requirements for intermediate and special surveys are the same as those for annual survey.

Section 9 REQUIREMENTS FOR BOW LOADING SYSTEM*

27.9.1 General requirements

27.9.1.1 Oil tanks applying for Bow Loading System* may be exempted from the requirements of 27.5.2.3(4) of this Chapter, but are to comply with other requirements of this Chapter and the provisions of this Section.

27.9.2 System requirements

27.9.2.1 Reliable control and safety signal transmission are to be achieved between the bow loading system control station and offshore terminal. The offshore terminal is responsible for safe control of cargo oil supply.

27.9.2.2 The communication system required by 27.5.3 of this Chapter is to be capable of sending emergency signal in case of communication failure during the operation and timely terminate the operation.

27.9.2.3 The emergency disconnection system required by 27.5.2.4 of this Chapter can disconnect the main crude oil transfer pumps of the offshore terminal by means of 27.5.3 and 27.9.2.2 of this Chapter.

CHAPTER 28 ADDITIONAL REQUIREMENTS FOR CABLE LAYERS

Section 1 GENERAL PROVISIONS

28.1.1 Application

28.1.1.1 This Chapter applies to ships provided with special systems/equipment for cable laying .

28.1.1.2 Cable layers are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of CCS Rules for Materials and Welding and of the flag State Administration, if any.

28.1.2 Notation

28.1.2.1 Ships complying with the provisions of this Chapter may be assigned the notation: Cable Layer.

28.1.3 Definition

28.1.3.1 Cable layers mean ships provided with special systems/equipment for cable laying which are generally used for laying and servicing of under-sea cables, flexible hoses, umbilical cables, etc., and provided with corresponding equipment (e.g. cable reels/cable tanks, cable laying machinery, plow systems and their hoisting devices, etc.).

28.1.4 Plans and documents

28.1.4.1 In addition to those required in the relevant PARTs and Chapters of the Rules, the following plans and documents are to be submitted to CCS for approval:

(1) Diagram for structural strengthening of cable laying equipment;

(2) Diagram for structural strengthening of positioning and towing equipment for cable laying operation;

28.1.4.2 The following plans and documents are to be submitted to CCS for information:

(1) Installation and arrangement of cable laying equipment;

(2) Strength calculations for structural strengthened cable laying equipment;

(3) Strength calculations for holds in cable capstan areas;

(4) Arrangement of positioning and towing equipment for cable laying operation;

(5) Strength calculations for structural strengthened positioning and towing equipment for cable laying operation.

For special structures and arrangement, expansion of the submission scope of plans and documents may be required if deemed necessary by CCS.

Section 2 HULL STRUCTURE AND ARRANGEMENT

28.2.1 Hull structure

28.2.1.1 Hull structural strength is normally to comply with the requirements of main class rules, with consideration of the necessary reinforcement of the support structure of the equipment used in cable laying operation. For special hull structures, hull structural strength will be specially considered.

28.2.2 Cable capstan

28.2.2.1 Structural strength of holds in cable capstan areas is to be checked by means of direct assessment. For the checking methods, reference may be made to the Appendix “Method of Checking Transverse Strength of Pontoon Barges” of Chapter 12 of PART TWO of the Rules. During the check, the maximum bearing load of cable capstan is taken as the deck load in the cable laying area, which is applied on the deck according to the actual force forms.

28.2.3 Cable laying equipment

28.2.3.1 Strength of the strengthened structures of the cable laying equipment, and of the positioning and towing equipment during cable laying operation is to be checked in accordance of Sections 6 and 7 of Chapter 3 of PART TWO of the Rules.

28.2.4 Hold arrangement

28.2.4.1 The bunker cannot be directly positioned under the working deck, unless a void hold, storage hold or ballast tank is arranged between the working deck and the bunker. The working deck is to be distant from the engine room air inlet and outlet as far as possible. The obstacles in way of the hold vents are to be minimized.

CHAPTER 29 ADDITIONAL REQUIREMENTS FOR PIPE LAYERS

Section 1 GENERAL PROVISIONS

29.1.1 Application

29.1.1.1 This Chapter applies to ships provided with special systems/operation lines for laying pipes.

29.1.1.2 Pipe layers are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of CCS Rules for Materials and Welding and of the flag State Administration, if any.

29.1.2 Notation

29.1.2.1 Ships complying with the provisions of this Chapter may be assigned the notation: Pipe Layer.

29.1.3 Definition

29.1.3.1 Pipe layers mean ships provided with special systems/operation lines which are generally used for laying pipes under sea, etc.

29.1.4 Plans and documents

29.1.4.1 In addition to the plans and documents required in the relevant PARTs and Chapters of the Rules, the documents in relation to the pipe laying systems/operation lines (e.g. tensioners, A/R winches, laying towers, conveying systems and stingers) are to be submitted to CCS for approval. For special structures and arrangement, expansion of the submission scope of plans and documents may be required if deemed necessary by CCS.

Section 2 HULL STRUCTURE AND ARRANGEMENT

29.2.1 Hull structure

29.2.1.1 Hull structural strength is normally to comply with the requirements of main class rules, with consideration of the necessary reinforcement of the support structure of the equipment used in pipe laying operation. For special hull structures, hull structural strength will be specially considered.

29.2.2 Bunker

29.2.2.1 The bunker cannot be directly positioned under the working deck, unless a void hold or ballast tank is arranged between the working deck and the bunker.

29.2.3 Hold arrangement

29.2.3.1 The working deck is to be distant from the engine room air inlet and outlet as far as possible. The obstacles in way of the hold vents are to be minimized.

Section 3 EQUIPMENT

29.3.1 General provisions

29.3.1.1 Pipe layers are to be capable of anchor mooring positioning or dynamic positioning.

29.3.2 Wheel house

29.3.2.1 A pipe layer is to be provided with a wheel house with good vision, and communication by means of hardwired connection between the wheel house and the remote control station is to be provided.

CHAPTER 30 ADDITIONAL PROVISIONS ON THE FUNCTIONALITY OF RO-RO PASSENGER SHIPS

Section 1 GENERAL PROVISIONS

30.1.1 Application

30.1.1.1 This Chapter applies to ro-ro passenger ships applying for the notation specified in 30.1.2.

30.1.2 Notation

30.1.2.1 Upon application, ro-ro passenger ships complying with the relevant requirements of this Chapter may be assigned the notation: PVSED (Passenger and Vehicle Separated Embarkation and Disembarkation).

30.1.3 Definition

30.1.3.1 Variable lane, means an arrangement in which both big vehicle lane and small vehicle lane are marked in the same area, and the use of big vehicle lane or small vehicle lane is decided according to the vehicle condition of each voyage.

30.1.4 Plans and documents

30.1.4.1 In addition to those required in relevant Parts and Chapters of the Rules, the following plans and documents are to be submitted:

(1) Passenger and Vehicle Embarkation and Disembarkation Arrangement (approved);

Section 2 PASSENGER AND VEHICLE EMBARKATION AND DISEMBARKATION ARRANGEMENT

30.2.1 Passenger and vehicle separated embarkation and disembarkation arrangement

30.2.1.1 The ship is to be provided with embarkation and disembarkation access and entrance and exit dedicated to passengers.

30.2.1.2 The ship is to be provided with ramps for embarkation and disembarkation of vehicles.

30.2.1.3 Ro-ro spaces or special category spaces is to be provided with access for drivers to go directly to passenger spaces, and clear width of access is not to be less than 700 mm, in which the inclination angle of stairway is not to be greater than 50°. If the access is used as an escape route, it is also to meet the relevant requirements of the Administration of the flag State.

30.2.1.4 If passengers can only embark on and disembark from the ship through the vehicle ramp due to the limited terminal facilities, clear width of the passenger access is not to be less than 900 mm, and means of isolation that are not easy to be surmounted are to be provided on both sides of the access. Dedicated personnel are to guide passengers and vehicles and maintain order during embarkation and disembarkation. This measure is to be included in the safety management documents on board.

30.2.2 Vehicle deck

30.2.2.1 Upper and lower vehicle decks are to be connected by fixed or movable ramps.

30.2.2.2 Where terminal facilities are provided with multi-tier vehicle and/or passenger separated access, on-board vehicle and/or passenger decks are also to be provided with docking facilities with corresponding access of the terminal(if applicable).

30.2.3 Lane arrangement

30.2.3.1 Dedicated lanes in ro-ro spaces or special category spaces are to be clearly marked.

30.2.3.2 The arrangement of variable lanes is acceptable.

30.2.3.3 Where big vehicle and small vehicle dedicated lanes are arranged in vehicle decks or some areas, such lanes are to be clearly marked with different colors and lines.

30.2.4 Lane width

30.2.4.1 Width of small vehicle lanes is not to be less than 2.4 m, and width of big vehicle lanes is not to be less than 3 m.

CHAPTER 31 NOTATIONS FOR OTHER EQUIPMENT

Section 1 GENERAL PROVISIONS

31.1.1 General requirements

31.1.1.1 The provisions of this Chapter are voluntary and optional, which apply to ships with various special equipment.

Section 2 NOTATION FOR VIDEO MONITORING SYSTEM

31.2.1 Notation

31.2.1.1 Upon application, a ship provided with video monitoring system complying with the requirements of this Section may be assigned the following notation: VDMS.

31.2.2 Definitions

31.2.2.1 For the purpose of this Section, the following definitions apply:

(1) Video detection means a kind of detection method to perceive the object by photoelectric imaging technology (from near-infrared to the limit of visible spectrum) and to form video picture signals.

(2) Video monitoring means to monitor the object by adopting with video method and to record object information.

(3) Video transport means or from one equipment to another one directly or through modulation demodulation by adopting with the wire or wireless transmission medium.

(4) Video switcher means the video controller, which is the core device of the operation and controlling of the video system and generally is able to complete the video switching and the controlling of cradle head and lens, etc.

(5) Front-end device means all kinds of equipment distributed on the detection site. In this system, it usually refers to the video camera as well as its relevant matching devices (such as lens, cradle head, decoding driver, shield, etc.).

(6) Video motion alarm means a means of alarm that uses video detection technology to detect changes in scene images and sends out alarm information once the set threshold is reached.

(7) Video signal loss alarm means a system function, i.e. when the video switcher monitors the video signal from the front end, once the peak value of the video signal is less than the set value, the system will consider the video signal loss and provide alarm information.

31.2.3 Plans and documents

31.2.3.1 The following plans are to be submitted for approval:

(1) Electrical system diagram of video monitoring system;

(2) Electrical equipment arrangement plan of video monitoring system.

31.2.4 General requirements

31.2.4.1 Ship video monitoring system is generally composed of four main parts, i.e. front-end device, transport device, control and record display device.

31.2.4.2 The front-end device can be divided into separate combined camera or integrated camera.

31.2.4.3 Control and record display device can be separated or integrated.

31.2.5 Video detection front-end device

31.2.5.1 Video detection front-end device is to be able to clearly and effectively detect and identify pictures of important locations, covering areas such as navigation bridge, engine room, public spaces, corridors and stairways (passenger ship), special category and ro-ro spaces, fire control stations, etc.

31.2.5.2 Video detection front-end device is to be able to adapt to the lighting conditions of the site. When the illumination of the site cannot meet the requirements for clear detection, the equipment is to be provided with night vision function or auxiliary lighting equipment.

31.2.5.3 The enclosure protection grade and certified safe type (if applicable) of the video detection front-end device is to be appropriate to the space where it is installed.

31.2.6 Video monitoring system

31.2.6.1 The video monitoring system is to have automatic storage function, not causing loss of stored data in case of power off or shutdown.

31.2.6.2 The video monitoring system for ro-ro spaces is to monitor the front-end video signal and give a video motion alarm.

31.2.6.3 The video monitoring system is to give a video signal loss alarm at the display terminals, and this alarm is auditory and visual.

31.2.6.4 The video monitoring system is to be able to store monitoring records for at least 30 days.

31.2.6.5 The video monitoring system is to have ports for networking and remote operation and invocation.

Section 3 NOTATION FOR NIGHT VISION EQUIPMENT

31.3.1 Notation

31.3.1.1 Upon application, a ship provided with night vision equipment complying with the requirements of this Section may be assigned the following notation: NVE.

31.3.2 Definition

31.3.2.1 For the purpose of this Section:

(1) Night vision equipment means any technical means enabling the position and aspect of objects above the water surface relative to the ship to be detected at night.

31.3.3 Plans and documents

31.3.3.1 The following plans and documents are to be submitted for approval:

(1) Electrical system diagram of night vision equipment;

(2) Electrical equipment arrangement plan of night vision equipment.

31.3.4 General requirements

31.3.4.1 Night vision equipment① facilitates the detection at night of hazards to navigation above the water surface, thus providing essential information to the navigator for collision avoidance and safe navigation.

31.3.5 Technical requirements

31.3.5.1 Night vision equipment is to be capable of detecting objects within a certain distance from the ship, and of displaying the information pictorially in real time, to assist in collision avoidance and safe navigation.

31.3.5.2 Night vision equipment is to be operational in less than 15 min after the equipment has been switched on, and is to be capable of continuous operation from after sunset until before sunrise.

31.3.5.3 The controls of night vision equipment are to be installed in the work area for navigating and manoeuvring, within easy reach of the navigator. For any failure of the night vision equipment, a visual indication is to be provided on the navigation bridge.

31.3.5.4 The operational controls of night vision equipment are to be clearly identifiable in the dark. If illumination is used, the brightness is to be adjustable.

Section 4 NOTATION FOR FOG NAVIGATION ENHANCED SENSING

31.4.1 Notation

31.4.1.1 Upon application, a ship provided with fog navigation enhanced sensing system complying with the requirements of this Section may be assigned the following notation: EFN-M or EFN-A .

31.4.2 Definitions

31.4.2.1 For the purpose of this Section:

---

① Refer to Annex of resolution MSC.94(72) Recommendation on Performance Standards for Night Vision Equipment for High Speed Craft (HSC).

(1) Typical target identification means the cognition of target characteristics of ships, buoys, shorelines, islands, reefs, etc. Target characteristics are to at least include target position, speed, heading, category, encounter distance, encounter time, movement trend, etc.
(2) Visual fog penetration means the use of optical fog penetration, software fog penetration, thermal imaging and other technologies to detect and identify typical targets in the navigation environment. These targets are visually displayed on the display unit, and the navigator or intelligent system can effectively identify typical targets.
(3) Image identification function means identification using computer programs or algorithms based on the image or thermal imaging of typical targets, by means of of machine learning and other artificial intelligence technologies.
(4) Data fusion function means the automatic fusion of visual fog penetration data and traditional navigation sensing data through computer programs or algorithms for comprehensive identification of typical targets, such as radar echo of collision-avoiding targets, automatic identification instrument, and superposition of image data.
(5) Cradle head means the supporting equipment installed with fog penetration sensor to provide stability function and ensure the stability of target detection during ship navigation.
(6) Fog penetration sensor means the camera or heat source probe with fog penetration function.
(7) Control and data processing unit means the control, data collection, storage and processing of visual fog penetration equipment based on computer technology, which can access the data of traditional navigation sensing equipment, realize image identification and data fusion, continuously detect the operational state of the equipment, and provide man-machine operation interface.
(8) Fault alarm means the alarm information given when the performance of fog navigation enhanced sensing system is significantly reduced or fails.
(9) Traditional navigation sensing equipment means the detection equipment for navigation environment and collision-avoiding targets provided according to the requirements of the existing conventions and rules, such as radar, electronic chart display and information system, automatic identification instrument, etc.
(10) Intelligent identification means identification of the fused data of typical targets by use of artificial intelligence technology or automation technology.
(11) Visibility means the maximum horizontal distance a person with normal vision can see the outline of a target clearly in prevailing weather conditions.

31.4.3 Plans and documents

31.4.3.1 The following plans and documents are to be submitted for approval:
(1) Electrical system diagram of fog navigation enhanced sensing system;
(2) Electrical equipment arrangement plan of fog navigation enhanced sensing system.

31.4.4 General requirements

31.4.4.1 Fog navigation enhanced sensing system is based on optical fog penetration, software fog penetration, thermal imaging, image identification and other technologies. By filtering the impact of haze and fog, smoke and soot, rain and snow on vision, it identifies collision-avoiding targets and reduces collision risk.
31.4.4.2 Fog navigation enhanced sensing system can effectively make up for the defect of navigator's vision in the fog condition, i.e. not being able to effectively find collision-avoiding targets at a long distance.
31.4.4.3 Visual fog penetration equipment is composed of fog penetration sensor, control and data processing unit and display unit.
31.4.4.4 Fog navigation enhanced sensing system is composed of traditional navigation sensing equipment and visual fog penetration equipment, realizing one of the following two functions.
(1) The navigator integrates the data of two types of equipment to manually identify typical targets, i.e., EFN-M;
(2) On the basis of (1), the system can carry out image identification and display for typical targets, and carry out intelligent identification for fusion data of typical targets, i.e., EFN-A.

31.4.5 Technical requirements

31.4.5.1 The fog navigation enhanced sensing system is to have video fog penetration function as a minimum, and the following advanced functions may also be provided:
(1) image identification function;
(2) data fusion function.
31.4.5.2 Video fog penetration can be realized by one or more fog penetration technologies such as

optical fog penetration, software fog penetration and thermal imaging.

31.4.5.3 The application environment of fog navigation enhanced sensing system is haze and fog, smoke and soot, rain and snow as well as other typical marine environment.

31.4.5.4 The camera of video fog penetration is to have optical zoom function.

31.4.5.5 The effective distance of the fog navigation enhanced sensing system is to be not less than 1 nautical mile, including at night.

31.4.5.6 The fog penetration sensor can rotate at least 180°in the horizontal direction and is to be adjustable; the maximum horizontal rotation speed is above 20°/S and adjustable; the detection range in the vertical direction is to be at least +60~-60° and adjustable; the maximum vertical rotation speed is above 20°/S and adjustable. The fog navigation enhanced sensing system shall be able to operate normally in the visibility of 0.28 nautical mile to 0.55 nautical miles, and the operating distance shall be greater than 1 nautical mile, including the dark environment.

31.4.5.7 Video fog penetration camera is to have not less than 2 million pixels. The resolution of the thermal sensor is not to be less than 320×240.

31.4.5.8 On the basis of visual fog penetration, the image identification function can in general automatically identify typical targets such as ships, buoys, shorelines, islands and reefs.

31.4.5.9 The data fusion function needs to fuse the following data, and achieve the artificial identification by navigator or intelligent identification by system of typical targets:

(1) automatic identification instrument data;

(2) electronic chart data;

(3) information of other ships, such as position, heading, speed and encounter distance;

(4) information of other obstacles, such as position, relative direction, relative speed;

(5) navigation radar data;

(6) data of visual fog penetration equipment.

31.4.5.10 The fog navigation enhanced sensing system is to meet the following design principles of bridge equipment:

(1) assisting bridge staff and pilots to perform navigation tasks;

(2) promoting effective and safe management of bridge resources;

(3) enabling bridge staff and pilots to conveniently and continuously obtain important information;

(4) indicating the working state of fog navigation enhanced sensing system;

(5) enabling bridge staff and pilots to process information and make decisions quickly, continuously and effectively;

(6) preventing or minimizing unnecessary work in the bridge that may lead to fatigue of staff and pilots, decreased vigilance and other factors, such as distractive affairs;

(7) identifying and reducing the risk of human error to the maximum extent through monitoring and alarm system, so that bridge staff and pilots can take corresponding actions in a timely manner;

(8) effective maintenance, such as maintenance manual, maintenance plan, etc.

31.4.5.11 The fog navigation enhanced sensing system is to have the functions of self-inspection and alarm, and can provide continuous monitoring during normal operation of the equipment.

When the equipment performance is significantly reduced or failure is detected, the system is to be able to send prompt alarm and fault information.

31.4.5.12 The fog navigation enhanced sensing system shall have an interface connected to the ship voyage recorder.

CHAPTER 32 TRANSVERSE PROPULSION ARRANGEMENT

Section 1 GENERAL PROVISIONS

32.1.1 Application

32.1.1.1 This Chapter applies to ships provided with transverse propulsion arrangement and applying for the T-Propulsion notation.

32.1.1.2 Certification requirements and inspections of products with regard to transverse propulsion arrangement are to comply with relevant provisions of Chapter 3, PART ONE of the Rules.

32.1.2 Notation

32.1.2.1 Ships provided with transverse propulsion arrangement complying with the provisions of this Chapter may be assigned the notation: T-Propulsion.

32.1.3 Definition

32.1.3.1 Transverse propulsion arrangement is a special propelling unit fitted in the transverse duct below the waterline at the ship's bow or stern.

32.1.4 Plans and documents

32.1.4.1 The following plans and documents are to be submitted for approval or information:

(1) arrangement plan of transverse propulsion arrangement (for information);

(2) plan of piping system of hydraulic system (where fitted);

(3) plan of piping system of lubricating oil (where fitted);

(4) plan of electrical system of transverse propulsion arrangement;

(5) list of control, monitoring and alarm.

Section 2 TRANSVERSE PROPULSION ARRANGEMENT

32.2.1 General requirements

32.2.1.1 Transverse propulsion arrangement is to have sufficient transverse thrust to satisfy the working requirements of navigation at low speed and docking and leaving wharf.

32.2.1.2 Material and test of transverse propulsion arrangement and its components are to comply with the relevant requirements of CCS Rules for Materials and Welding.

32.2.1.3 Diesel engines driving transverse propulsion arrangement are to comply with the relevant requirements in Chapter 9, PART THREE of the Rules.

32.2.1.4 Motor and distribution system of driving transverse propulsion arrangement are to comply with the relevant requirements in PART FOUR of the Rules.

32.2.1.5 The design of shafting together with its parts and propeller is to comply with the relevant requirements of Chapter 11, PART THREE of the Rules.

32.2.1.6 The thickness of tunnel of transverse propulsion arrangement is not to be less than the adjacent part of the hull.

32.2.1.7 The shaft sealing box is to be installed to prevent water so as to protect steel shafts from sea water.

32.2.1.8 For installed corrosion prevention of cylinders, means of cathodic protection or corrosion prevention materials are to be provided.

32.2.2 Hydraulic transmission piping system (where fitted)

32.2.2.1 After being assembled as a set, the pipe lines and pressure elements of hydraulic transmission system and control system for controllable pitch propellers are to be subject to tightness test to a pressure of 1.25 times the design pressure. There is to be no leakage in way of permanent sealing and pipe joints.

32.2.2.2 Materials, piping systems and arrangement of hydraulic transmission piping system are to comply with applicable requirements of Section 7, Chapter 4, PART THREE of the Rules.

32.2.3 Lubricating oil piping system (where fitted)

32.2.3.1 Lubricating oil system and tank arrangement are to comply with applicable requirements of

Chapters 3 and 4, PART THREE of the Rules.

Section 3 CONTROL, MONITORING AND ALARM

32.3.1 General requirements

32.3.1.1 Control, monitoring and alarm of the transverse propulsion arrangement are, in addition to requirements of this Chapter, to comply with relevant requirements of PART SEVEN of the Rules.

32.3.1.2 It is to be possible to stop the transverse propulsion arrangement from the bridge by means of a system independent of the remote control system.

32.3.1.3 The transverse propulsion arrangement is to be provided with indications, individual or groupwise alarms specified in Table 32.3.1.3.

Alarm and monitoring **Table 32.3.1.3**

Item	Indication	Alarm
Overload of prime mover and servo unit		X
Power failure of remote control system		X
Power failure of alarm system		X
Level in lubrication oil tank (if fitted)		Low
Lubrication oil pressure (if forced lubrication oil system)		Low
Level in hydraulic daily service tank (where applicable)		Low
Pressure in hydraulic system		Low
Running and stop of prime mover	X	
Propeller pitch for controllable pitch propeller plants	Propeller pitch	
Direction of rotation for fixed propeller plants;	Direction of rotation	
r.p.m. for fixed propeller plants	r.p.m.	

32.3.1.4 Where the ship applies for the dynamic positioning notation at the same time, the transverse propulsion arrangement is to be provided with alarms and indications complying with Chapter 11of this PART in the dynamic positioning control station.

CHAPTER 33 SHIP COMMUNICATION NETWORKS SATISFYING SPECIFIC NEEDS

Section 1 GENERAL PROVISIONS

33.1.1 General requirements

33.1.1.1 The provisions of this Chapter apply to ships of which the communication networks satisfy specific needs.

33.1.1.2 The specific needs mentioned in this Chapter refer to communication needs such as passenger using Internet and remote survey.

33.1.1.3 The ship communication networks mentioned in this Chapter refer to the communication networks which realize the specific needs in 33.1.1.2 through ship communication network equipment, based on hosting modes of communication networks such as satellite broadband communication network and 4G or 5G cellular communication network.

33.2.1.4 The applicant is to be responsible for whether the operator of the ship communication network services meets the requirements of relevant laws and regulations.

33.2.1.5 The applicant is to ensure that the management and operation of the ship communication network meet the requirements of relevant laws and regulations, such as real-name registration for network users.

33.1.2 Class notations

33.1.2.1 Upon its application, a ship the ship communication network of which has undergone plan approval and survey by CCS and satisfied the relevant requirements of this Chapter, may be assigned class notations as follows:

Specific Communication Network (Px, Rx)

where the letters P and R in the parentheses stand for the specific needs of the ship communication network, which may be assigned according to the actual function of the ship and are defined as follows:

P - network provided for passengers to satisfy the daily communication needs of passengers to use the Internet.

R - network provided for crew to satisfy the communication needs for ship remote survey.

x - additional notations for hosting modes of ship communication networks. Each small letter indicates one hosting mode. The ship communication network satisfying one specific need may be realized by one or more hosting modes, which may be assigned one or more additional notations where:

s - ship communication network realized by satellite broadband communication network.

c - ship communication network realized by 4G or 5G cellular communication network.

If the ship realizes the needs for daily use of the Internet by passengers and ship remote survey in accordance with the requirements of this Chapter, based on satellite broadband communication network and 4G or 5G cellular communication network respectively, it may be assigned Specific Communication Network (Ps, Pc, Rs, Rc).

Section 2 TECHNICAL REQUIREMENTS

33.2.1 Hosting modes

33.2.1.1 The hosting modes of ship communication networks may be satellite broadband communication network, 4G or 5G cellular communication network, etc.

33.2.2 Network bandwidth

33.2.2.1 The communication network bandwidth is to satisfy the actual needs through the estimation of communication traffic and network capacity load test.

33.2.2.2 For ships applying for class notation "Ps", the theoretical bandwidth of the communication network is not to be less than 2 Mbps for upstream rate and 4 Mbps for downstream rate, which is to be confirmed by relevant supporting documents provided by the ship communication network service provider. The measured bandwidth is not to be less than 1 Mbps for upstream momentary rate and 2 Mbps for downstream momentary rate. For ships applying for class notation "Pc", the measured bandwidth is not to be less than 5 Mbps for upstream momentary rate and 25 Mbps for downstream momentary rate.

33.2.2.3 For ships applying for class notation "Rs", the theoretical bandwidth of communication network is not to be less than 2 Mbps for upstream rate and 2 Mbps for downstream rate, which is to be confirmed by relevant supporting documents provided by the ship communication network service provider. The measured bandwidth is not to be less than 1 Mbps for upstream momentary rate and 1 Mbps for downstream momentary rate. For ships applying for class notation "Rc", the measured bandwidth is not to be less than 4 Mbps for upstream momentary rate and 4 Mbps for downstream momentary rate.

33.2.3 Equipment arrangements

33.2.3.1 Local area network (LAN) is to be arranged to realize the network coverage of relevant spaces.

33.2.3.2 For ships applying for class notation “P”, the network is to be arranged by fixed LAN devices. The network is to cover the living areas of passengers, including primary accommodation spaces as a minimum, such as public spaces, corridors, cabins, cinemas, game and hobby rooms.

33.2.3.3 For ships applying for class notation “R”, the network may be arranged by fixed LAN devices and/or portable network relay equipment which are readily deployed. The network is to cover the survey areas of remote survey including spaces falling in the scope of annual survey as a minimum, such as engine room, steering gear room, other machinery spaces, accommodation spaces, service spaces, control station, forecastle and cargo area (where applicable).

33.2.4 Equipment requirements

33.2.4.1 The ship communication network is to be isolated from the networks related to the normal operation and safety of the ship, such as navigation equipment network, machinery control system network, alarm system network, etc.

33.2.4.2 Ship communication network equipment, which generally contains receiving unit, signal amplification unit, hub, switch, network bridge, router, gateway, network access point, modem, portable network equipment (including customer terminal equipment (CPE), network relay equipment), etc., is to meet the relevant requirements of Sections 2 and 3, Chapter 1, PART FOUR of the Rules.

33.2.4.3 The cables provided for the ship communication network equipment are to meet the relevant requirements of Section 12, Chapter 2, PART FOUR of the Rules.

33.2.4.4 The ship communication network equipment may be powered by main source of electrical power. For ships applying for class notation "R", there is to be a standby power to supply the network for not less than 0.5 hours (for portable equipment, not less than 4 hours), such as UPS or accumulator batteries, etc.

33.2.4.5 Manufacture’s supporting documents of the ship communication network equipment are to be provided for check. System and equipment installed in places with explosion risk are to be explosion-proof, or corresponding measures are to be taken to avoid explosion risks during use at least.

33.2.4.6 The construction, operation, maintenance and security assessment of the ship communication network system and equipment may be implemented with reference to the relevant requirements in CCS Guidelines for Requirement and Security Assessment of Ship Cyber System.

33.2.4.7 The procedures for daily inspection and maintenance of the ship communication network equipment are to be implemented onboard, including inspection for equipment working status and power supply status, connection identifier for cables, network connectivity, etc., and the results are to be recorded.

Section 3 PLANS AND DOCUMENTS

33.3.1 Plans and documents

33.3.1.1 The following plans and documents are to be submitted to CCS for approval:

(1) Arrangement of ship communication network equipment;

(2) Power supply plan of ship communication network equipment.

33.3.1.2 The following plans and documents are to be submitted to CCS for information:

(1) Topology diagram of ship communication network system;

(2) Estimation of communication traffic for ship communication network;

(3) Specification of cables for ship communication network equipment;

(4) Specification of working conditions for ship communication network equipment;

(5) List of ship communication network equipment, including brand, model, quantity and function description as a minimum;

(6) Operation manual of ship communication network equipment.

33.3.1.3 The following plans and documents are to be submitted to CCS surveyor for approval and/or confirmation:

(1) Test program including test procedures, acceptance criteria and records of test results;

(2) Procedures for daily inspection and maintenance of ship communication network equipment.

Section 4 SURVEY AND TESTS

33.4.1 Initial surveys

33.4.1.1 The surveyor is to confirm the actual installation layout of the ship communication network equipment onboard according to the reviewed plans and documents, and confirm the function and working status of the communication network equipment according to the approved test program. Where necessary, the surveyor is to review the relevant documents provided by the service provider required in 33.2.2.

33.4.1.2 The test for ship communication network is to be carried out under the witness of the surveyor according to the test program, including:

(1) The connectivity test of system and equipment;

(2) The network coverage test: for the network coverage spaces indicated in the plan referred to in 33.3.1.1 (1), at least one representative network access point is to be selected for each space for test;

(3) Communication network capacity load test, bandwidth test, network transmission delay test and network stability test, which are to be carried out simultaneously with the test referred to in 33.4.1.2 (2);

(4) The functional tests of the communication network, such as real-time video communication, document transmission, etc., which are to be carried out simultaneously with the test referred to 33.4.1.2 (2).

33.4.2 Annual surveys

33.4.2.1 After assigned with the class notation specified in this Chapter, as the condition of maintenance of the notation, the following survey is to be carried out during the subsequent class periodical survey:

(1) Relevant plans and documents are to be kept onboard, and no unconfirmed changes by CCS have been made;

(2) The system and equipment are in normal working condition, and no unconfirmed changes by CCS which affect the realization of specific needs specified in this Chapter have been made;

(3) Records for relevant daily inspection and maintenance are checked;

(4) If necessary, some or all tests may be carried out according to 33.4.1.

33.4.3 Intermediate surveys

(1) The requirements for intermediate surveys are the same as those for annual surveys.

33.4.4 Special surveys

(1) The requirements for special surveys are the same as those for annual surveys.

33.4.5 Occasional surveys

33.4.5.1 In case of any change, fault or damage to the approved plans and documents, systems and equipment, which affect the realization of specific needs of the communication network specified in this Chapter, CCS is to be notified in time for occasional surveys to maintain the validity of the class notation.

33.4.6 Maintenance, cancellation and withdrawal of the class notation

33.4.6.1 The ship is to meet the requirements of this Chapter to maintain the validity of the class notation. Otherwise, CCS will cancel the relevant class notation as appropriate.

33.4.6.2 The ship company can apply for cancellation of the relevant class notation specified in this Chapter in written form.

CHAPTER 34 ADDITIONAL REQUIRMENTS FOR ASSESSMENT OF ANTI-COLLISION CAPACITY OF SHIPS

Section 1 GENERAL PROVISIONS

34.1.1 General requirements

34.1.1.1 This Chapter applies to ships applying for the class notation related to assessment of anti-collision capacity on a voluntary basis.

34.1.1.2 Ships applying for assessment of anti-collision capacity generally are subject to, but not limited to the following three critical situations:

(1) Structural damage to cargo tanks with subsequent leakage of, e.g., oil, chemicals or liquefied gas, etc.;

(2) Structural damage leading to water ingress into dry cargo holds during carriage of particularly valuable or dangerous cargo;

(3) Structural damage to fuel oil tanks with subsequent leakage of fuel oil.

34.1.1.3 Assessment of anti-collision capacity of ships is intended to calculate the deformation energy absorbed by the hull structure and critical striking speed of striking ships that the hull structure can bear when the ship structure is struck by another ship and the hull structure shell plate (inner hull plate for a double hull ship) is in the critical damaged state, and to give the displacement – critical striking speed curve of the struck ship, so as to guide the operation of the ship.

34.1.1.4 The simplified method or FE method may be used for assessment of anti-collision capacity. For the FE calculation, the applicable general procedure may be used. If non-general procedures are used, the explanatory documents on the reliability of the computer programs are to be provided by the unit applying for the notation.

34.1.2 Definitions

34.1.2.1 The **critical damaged state** refers to the state when the maximum plastic deformation of the hull structure shell plate (inner hull plate for a double hull ship) of the struck ship occurs without rupture.

34.1.2.2 The **initial striking speed** V_0, in knots, refers to the speed of the striking ship when it comes into contact with the struck ship.

34.1.2.3 The **critical striking speed** V_{cr}, in knots, refers to the maximum striking speed that the struck ship can bear in the damage critical situation. If the speed of the striking ship exceeds this value, the expected critical state will occur.

34.1.2.4 The **critical deformation energy** E_{cr}, in MJ, refers to the plastic deformation energy absorbed by the hull structure when the maximum plastic deformation occurs in the hull structure shell plate (inner hull plate for a double hull ship) of the struck ship without rupture in case of a collision. When that amount of energy is exceeded, the expected critical state will occur.

34.1.3 Class notation

34.1.3.1 Ships that have undergone evaluation of collision resistance capability according to the requirements of this Chapter may be assigned with the notation “COLL”.

34.1.4 Plans and documents

34.1.4.1 The following plans and documents are to be submitted for approval in addition to the plans and documents required by relevant chapters and PARTS of the Rules:

(1) Critical striking speed curve.

34.1.4.2 The following plans and documents are to be submitted for information:

(1) Analysis report for anti-collision capacity, including structural collision deformation energy analysis and critical speed analysis.

(2) List of critical situations in which the ship is involved.

34.1.5 Document retention

34.1.5.1 The shipowner is to keep the plans and documents required by 34.1.4.1 onboard the ship and make them accessible to the operator in case of a collision.

Section 2 EVALUATION METHODS

34.2.1 Evaluation conditions

34.2.1.1 The bow of the striking ship meets the side of the struck ship at 90°, and the struck ship has no speed and remains upright.

34.2.1.2 The impact area is to be taken as the side and deck structure between the two transverse bulkheads of the cargo hold area within 0.4L amidships of the struck ship.

34.2.1.3 The location of collision is to be the most dangerous collision point selected according to the relative draft of the striking ship and the struck ship.

34.2.1.4 The most dangerous bulbous bow form is to be selected according to the ship type and displacement.

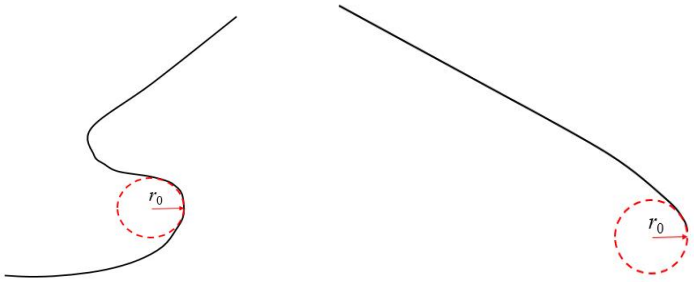
34.2.2 Simplified calculation method for critical deformation energy of the side structure

34.2.2.1 The simplified method is applicable to the assessment condition when the striking ship has a bulbous bow and the impact area is at the side structure of the struck ship. Assuming that the structural response is quasi-static and the material is ideal elastic plastic, the structural plastic deformation energy is calculated when the side structure in the impact area of the struck ship is damaged to the critical state.

34.2.2.2 Simplification of impact mechanics model and determination of material parameters

(1) Simplification of the bulbous bow of the striking ship

The bulbous bow of the striking ship is simplified as a hemispherical rigid ram, and a circle consistent with the profile of the bulbous bow is obtained by taking the central longitudinal section of the ship and the waterplane close to the tip of the bulbous bow. The radius of the circle is the calculated radius r_0 of the hemispherical ram, in mm, as shown in Figure 34.2.2.2.



(a) Central longitudinal section (b) Half-breadth waterplane

Figure 34.2.2.2 Selection of the radius of the hemispherical ram

(2) Simplification of the side structure of the struck ship

The damage side area of the struck ship is simplified as a rectangular area composed of the primary members on the side (such as the shell plate, deck, bulkhead, platform, etc.). The longitudinal length $2l$ of the area, in mm, is to be taken as the distance between the two transverse bulkheads, and the vertical range is the height from the inner bottom to the deck or platform.

For the transverse frames and stiffeners of the side structure, their thickness can be equivalent to the thickness of the side shell plate. The total equivalent thickness of the side shell plate is calculated as follows:

$$t_{eqs} = t_{0s} + \frac{\sum_{i}^{m1} V_{F-i} + \sum_{i}^{m2} V_{s-i}}{A_{0s}} \qquad \text{mm}$$

where: t_{0s}——thickness of the side shell plate, in mm;

V_{F-i}, V_{s-i}——volume of the transverse frames and stiffeners in the side damage area, in mm^3;

$m1$, $m2$——number of the transverse frames and stiffeners in the side damage area;

A_{0S}——area of the side damage area, in mm^2.

(3) Determination of mechanical property parameters of materials

1) The flow stress σ_0 of the material is calculated according to the following formula:

$$\sigma_o = \frac{1}{2}(R_{eH} + R_m) \qquad \text{MPa}$$

where: R_{eH}——yield strength of the material, in MPa;

R_m——tensile strength of the material, in MPa.

2) The hardening index n of the material is calculated according to the following formula:

$$n = 1.5 \ln\left[1 + \frac{1}{0.24 + 0.01395 R_m}\right]$$

3) The hardening strength k of the material is calculated according to the following formula:

$$k = 0.85 R_m \left(\frac{e}{n}\right)^n \qquad \text{MPa}$$

where: e——natural constant.

34.2.2.3 Calculation for critical deformation energy of the side structure of the struck ship

For bulbous bow ramming, the critical deformation energy E_{cr} when the side shell plate is deformed to the critical damaged state is calculated according to the following formula:

$$E_{cr} = 0.5 F_c w_c \times 10^{-6} \qquad \text{MJ}$$

where: F_c——impact force, in N, to be calculated as follows:

$$F_c = 0.758 \pi t_{eqs} r_0 k$$

where: t_{eqs}, r_0, k as defined in 34.2.2.2;

w_c——depth of the ramming, in mm, to be calculated as follows:

$$w_c = 0.5\sqrt{(7n + 0.7) l r_0}$$

where: n, l as defined in 34.2.2.2.

34.2.3 FE method for calculation of critical deformation energy

34.2.3.1 The FE analysis of anti-collision capacity of ships can assess the impact of the bulbous bow and the flare area on the struck ship. The damaged area of the struck ship includes the side and deck structure. The bow of the striking ship ramming into the struck ship at the initial striking speed V_0, and the kinetic energy loss of the striking ship is all transformed into the kinetic energy of the struck ship and the plastic deformation energy absorbed by the structure, until the critical damaged state of the side structure is reached.

34.2.3.2 Structural modelling

(1) Modelling of the striking and struck ships

For the striking ship, the forepeak area of the ship's bow is selected, of which the shell plate, deck, frames and members are modelled by plate elements, and the hull after the forepeak tank may be modelled by rigid beam. The rigid beam is collinear with the center of gravity of the ship. The beam section may be tubular and the outside diameter is close to the moulded breadth, and is to be coupled with the forepeak section.

For the struck ship, the range between two transverse bulkheads in the midship region is selected, of which the plates, frames and members are modelled by plate elements, and the outer part of the hull may be modelled by rigid beam. The rigid beam is collinear with the center of gravity of the ship. The beam section may be tubular and its outer diameter is close to the moulded breadth, and is to be coupled with the hold/tank section of the struck ship.

Considering the influence of hydrodynamical added mass during collision, the total mass of the striking ship is to be 1.04 times its own displacement, and the total mass of the struck ship is to be 1.9 times its own displacement. The density of the FE model is to be based on the total mass of the ship.

(2) Meshing

The FE meshes of the contact area of the striking and struck ships is to be graded as 100 mm × 100 mm while other regions are graded by longitudinals or similar spacing. Where possible, the aspect ratio of plate elements is to be kept close to one and the use of triangular elements is to be avoided.

(3) Material properties and failure criteria

The exponent for reinforced material properties are assigned to the models of the striking bow and the struck hold/tank, and the yield strength R_{eH} and tensile strength R_m of the material are determined according to the grade of the steel, and the hardening index n and hardening strength k of the material are obtained, as shown in 34.2.2.2(3). The material reinforcement formula is as follows:

$$\sigma_{eq} = \begin{cases} R_{eH} & \varepsilon_{eq} \le \varepsilon_{plat} \\ k\varepsilon_{eq}^n & \varepsilon_{eq} > \varepsilon_{plat} \end{cases}$$

where: σ_{eq}, ε_{eq}——equivalent stress and equivalent strain of the element;

ε_{plat}——strain value at the end of the yield phase of the material.

The element failure strain ε_F adopts the following formula:

$$\varepsilon_F(l_e,t) = 2n + (\varepsilon_u - 2\,\mathrm{n})\frac{t}{l_e}$$

where: l_e, t——size and thickness of the element, in mm;
ε_u——failure strain value when $l_e/t = 1$, to be taken as 0.58.
The corrected material failure strain ε_{Fd} after considering the strain rate is determined in accordance with Figure 34.2.3.2.

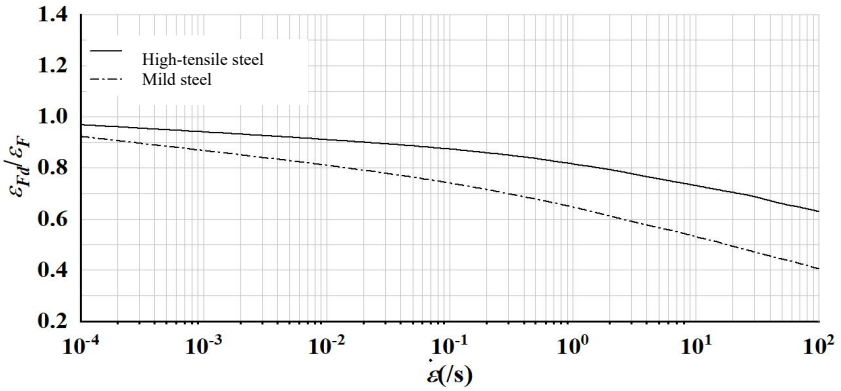


Figure 34.2.3.2 Influence of strain rate on failure strain

34.2.3.3 FE calculation and result extraction
(1) Boundary conditions
For the striking ship, restrain the degree of freedom of rotations in three directions along the hull beam and degree of freedom of displacement along the moulded depth direction.
For the struck ship, no restraint is applied.
(2) Definition of contact
Self-contact is defined. The contact algorithm adopts penalty function method and the friction coefficient is 0.3.
(3) Impact calculation
The initial striking speed V_0 (generally not less than 7 kn) is assigned to the striking ship, and explicit dynamics computation is carried out, and the calculation time is generally not less than 5 s.
(4) Data extraction
The energy absorption-time curve, the impact force-time curve and the structural damage (deformation) diagram of the struck hold/tank section are extracted during the collision. The energy absorption value when the ship structure is in the critical damaged state is taken as the critical deformation energy E_{cr}.

Section 3 EVALUATION CRITERIA

34.3.1 The ultimate energy absorption value of the struck ship

34.3.1.1 During the collision, the ultimate energy absorption value E_u of the struck ship is calculated as follows:

$$E_u = 0.193\frac{m_a m_b V_0^2}{(1.04m_a + 1.09m_b)} \qquad \text{MJ}$$

where: m_a, m_b——mass of the striking and struck ships respectively, in t;
V_0——striking speed, in kn.

34.3.2 Critical striking speed of the striking ship

34.3.2.1 The critical striking speed of the striking ship is calculated according to the following formula:

$$V_{cr} = 2.27\sqrt{E_{cr}\frac{(1.04m_a + 1.09m_b)}{m_a m_b}} \qquad \text{kn}$$

where: m_a, m_b——mass of the striking and struck ships respectively, in t;

E_{cr}——critical deformation energy of the struck ship, in MJ.

34.3.3 Assessment criteria for anti-collision capacity

34.3.3.1 The assessment criteria for anti-collision capacity of the struck ship is as follows:

(1) $E_{cr} > E_u$, and

(2) $V_{cr} > V_0$

Section 4 CRITICAL STRIKING SPEED CURVE

34.4.1 Critical striking speed curve

34.4.1.1 According to the analysis results of collision of ships with different levels of displacement, the relationship curve between the critical striking speed and the displacement of the striking ship is drawn to provide guidance for navigation operation.

34.4.1.2 The range of the struck ship displacement required to draw the critical striking speed curve is to include but not be limited to 0.5~1.5 times the striking ship displacement.

CHAPTER 35 SYSTEM AND EQUIPMENT READY

Section 1 GENERAL PROVISIONS

35.1.1 General requirements

35.1.1.1 This Chapter applies to system and/or equipment ready for which technical requirements are specified for existing class notations.

35.1.1.2 For system and/or equipment for which technical requirements for ready class notation are specified, requirements of relevant CCS rules and guidelines are to be satisfied.

35.1.1.3 For ships assigned relevant ready class notations in accordance with the requirements of this Chapter, corresponding class notations may be assigned upon completion of onboard installation/modification of system and/or equipment and subject to satisfactory survey by CCS, and ready class notations are withdrawn.

Section 2 READY CLASS NOTATIONS

35.2.1 Form of identification

35.2.1.1 Ready (X-i) is used as the form of identification of ready class notations, where "X" indicates class notation for system and/or equipment corresponding to the ready class notation; "i" indicates different ready levels corresponding to X. i=1 for completion of principled design, i=2 for completion of detailed design.

35.2.1.2 With regard to multiple systems and/or equipment ready, they may be filled in the parentheses after Ready. Different class notations are separated by commas (,), e.g. "video monitoring system ready level 1" and "shore connection system ready level 2" may be expressed as Ready (VDMS-1, AMPS-2).

Section 3 TECHNICAL REQUIREMENTS AND PLANS AND INFORMATION

35.3.1 Principled design ready

35.3.1.1 Technical requirements

(1) Comprehensive consideration is to be given to the space for the installation, arrangement and repair of the systems and/or equipment required on the ship, as well as the possible impact on the ship's arrangement, equipment, power load, structural strength, stability, tonnage and deadweight etc.

35.3.1.2 Plans and information

(1) The following plans and information are to be submitted for review as a minimum:

① instructions of the ready plan;

② ready-related principled design plans and information.

35.3.2 Detailed design ready

35.3.2.1 Technical requirements

(1) Based on 35.3.1.1 above, the ship also needs to satisfy applicable provisions of class notations corresponding to the system and/or equipment.

35.3.2.2 Plans and information

(1) The following plans and information are to be submitted for review as a minimum, in addition to applicable plans and information submitted in accordance with requirements of relevant CCS rules and guidelines:

① instructions of the ready plan;

② instructions of the ready system and/or equipment;

③ ready-related detailed design plans and information.

CHAPTER 36 ONBOARD CARBON CAPTURE SYSTEM

Section 1 GENERAL PROVISIONS

36.1.1 General requirements

36.1.1.1 This Chapter applies to ships applying for the Onboard Carbon Capture System notation, for the purpose of providing standards for the design, survey and operational safety of ships provided with OCCS so as to minimize the harm to ships, crew members and the environment caused by OCCS.

36.1.1.2 Ships provided with the onboard carbon capture system are, in addition to the provisions of this Chapter, to satisfy applicable requirements of others parts and chapters of the rules and relevant requirements of CCS Guidelines for Onboard Carbon Capture Systems.

36.1.2 Class notation

36.1.2.1 Ships complying with the provisions of this Chapter are assigned the onboard carbon capture system notation upon satisfactory survey:

OCCS (Onboard Carbon Capture System)

36.1.2.2 For OCCS ready ships, the ready notation and requirements are to satisfy relevant requirements of CCS Guidelines for Onboard Carbon Capture Systems.

36.1.3 Plans and information

36.1.3.1 The following plans and information are to be submitted for approval as a minimum:

(1) relevant piping system plan of onboard carbon capture system;

(2) power load calculations;

(3) electrical system plan of onboard carbon capture system.

36.1.3.2 The following plans and information are to be submitted for information as a minimum:

(1) technical description and installation plan of onboard carbon capture system, including:

① system design parameters;

② system carbon dioxide capture capacity calculation;

③ list of system equipment;

④ system arrangement plan.

(2) operation and maintenance manual of onboard carbon capture system;

(3) carbon dioxide absorber safety data sheet;

(4) risk assessment report of onboard carbon capture system.

36.1.3.3 The scope of plans and information submitted for approval may be expanded when deemed necessary by CCS.

Section 2 DESIGN AND ARRANGEMENT

36.2.1 System design

36.2.1.1 The onboard carbon capture system is to be able to adapt to the environmental and working conditions of the ship's operation.

36.2.1.2 The carbon dioxide capture capacity of the onboard carbon capture system is to meet the expected design objectives, and the capacity of carbon dioxide storage tank is to meet the expected design volume.

36.2.1.3 The strength and tightness design of the onboard carbon capture system is to meet the set conditions and the possible low temperature condition in case of leakage of carbon dioxide.

36.2.1.4 The onboard carbon capture system is to be provided with necessary redundant safety protection measures and capable of preventing and dealing with accidents.

36.2.1.5 The onboard carbon capture system is to be provided with monitoring, alarm and control systems.

36.2.1.6 The design of onboard carbon capture system is to facilitate shipboard operation and maintenance.

36.2.1.7 The energy supply (e.g. electricity, steam etc.) on board is to satisfy the expected operating requirements of the onboard carbon capture system.

36.2.1.8 The onboard carbon capture system is to minimize the potential risk to ships, essential equipment, personnel and the environment. Chemical substances in storage and use are to ensure that they will not cause harm to personnel and the environment.

36.2.2 Arrangement and safety requirements

36.2.2.1 Shipboard installation, arrangement and operation of onboard carbon capture system are to meet the following requirements:

(1) mechanical and high temperature protection is to be considered;

(2) life-saving appliances, muster station and means of escape are not to be affected;

(3) the impact of the change of ship tonnage on the applicable standards after the addition of the system;

(4) navigation bridge visibility is to comply with SOLAS regulation V/22 and the relevant provisions of the flag State;

(5) the normal operation of the ship's essential equipment (e.g. as main engines, generators and boilers, etc.) is not affected.

36.2.2.2 After the onboard carbon capture system is installed, the ship’s structural strength is to satisfy the requirements for longitudinal and local strength of the rules.

36.2.2.3 The effect of windage area, lightship center of gravity, heel and trim on ship stability is to be considered for ships provided with onboard carbon capture system.

36.2.2.4 The mechanical properties, chemical composition, manufacturing and testing of materials used in the equipment and pipelines of onboard carbon capture system are to comply with the relevant provisions of CCS Rules for Materials and Welding, and corrosion prevention measures are be considered (if necessary). Materials (including coatings) used in equipment, pipelines and components in contact with seawater is not to cause any harm to marine organisms.

36.2.2.5 Detectors are to be fitted where carbon dioxide leakage or accumulation is likely to occur. When the detector operates, audible and visual alarm signals are to be given on the bridge and in the onboard carbon capture system control station.

36.2.2.6 The installation and operation of the onboard carbon capture system is to minimize the impact on the fuel combustion device.

36.2.2.7 During the operation and maintenance of the onboard carbon capture system, all operations that may pose risks to personnel are to be provided with appropriate protective equipment on board.

Section 3 SURVEYS

36.3.1 General requirements

36.3.1.1 Equipment and components of the onboard carbon capture system are to satisfy the applicable requirements of Chapter 3, PART ONE of the rules.

36.3.1.2 Equipment constituting the onboard carbon capture system is to be subject to surveys and tests in accordance with approved plans and relevant standards.

36.3.2 Surveys during construction

36.3.2.1 Surveys and functional testing are to be carried out to devices, equipment, systems, components and installation of relevant pipelines of the onboard carbon capture system.

36.3.2.2 Sea trials are to be carried out to the system in accordance with the requirements of the sea trial programme

36.3.3 Surveys after construction

36.3.3.1 Ships provided with the onboard carbon capture system are to be subject to annual surveys, intermediate surveys and special surveys.

CHAPTER 37 ADDITIONAL REQUIREMENTS FOR CARRYING DRY CARGO IN BULK

Section 1 GENERAL PROVISIONS

37.1.1 General requirements

37.1.1.1 Ships which are intended to carry dry cargo in bulk, with a configuration different from that defined in 8.1.1.1, Chapter 8, PART TWO of the rules, are assigned the notation: SOLAS XII where the requirements of this Chapter are satisfied.

37.1.2 Additional requirements for SOLAS XII bulk cargo carriage

37.1.2.1 Ships applying for the SOLAS XII notation are, in addition to satisfying the applicable requirements SOLAS Chapter XII, to satisfy applicable requirements of Chapter 8, PART TWO of the rules based on specific configuration.

CHAPTER 38 ADDITIONAL REQUIREMENTS FOR WINDFARM SERVICE VESSELS

Section 1 GENERAL PROVISIONS

38.1.1 Scope of Application

38.1.1.1 This Chapter applies to vessels that provide support and guarantee services for the operation and maintenance of offshore wind farms.

38.1.1.2 In addition to the provisions of this Chapter, the design, construction and survey of windfarm service vessels are also to comply with other applicable chapters and PARTs of the Rules, the relevant provisions of CCS Rules for Materials and Welding, and the relevant requirements of the flag State Administrations (if any).

38.1.2 Class Notation

38.1.2.1 The class notation " Windfarm Service Vessel" may be assigned to the vessel that meets the provisions of this Chapter.

38.1.3 Personnel Transportation Methods and Functions

38.1.3.1 Windfarm service vessels are to adopt at least one of the following methods to transport the operation and maintenance personnel:

(1) Bow docking method

According to Section 2 of this Chapter, the bow of the vessel is to be equipped with fenders or the bow structure is to meet the strength check requirements, the operation and maintenance personnel are to be transported by the bow docking method.

(2) Gangway method

The vessel is to be equipped with a gangway that meets the requirements of Section 4 of this Chapter, and the gangway is to be used to transport operation and maintenance personnel.

38.1.3.2 The windfarm service vessels are to have the following functions:

(1) Amphibious functions in tidal flats

The bottom structure of the vessel is to meet the sitting requirements of Section 2 of this Chapter, and be able of conducting amphibious operations in tidal flats.

38.1.4 Definitions

38.1.4.1 Windfarm service vessel means a vessel engaged in offshore windfarm operation and maintenance, with the functions of carrying operation and maintenance personnel, operation and maintenance tools, operation and maintenance spare parts, etc.

38.1.4.2 Operation and maintenance personnel means the personnel engaged in offshore windfarm services, except the crew members serving the vessel.

38.1.5 Drawings and information

38.1.5.1 In addition to the drawing and information specified in the relevant chapters and PARTs of the Rules, the following applicable drawing and information are also to be submitted to CCS

for approval:

(1) Arrangement of fenders;

(2) Foundation of gangway and the structure of connection to the hull;

(3) Electrical control system of gangway;

(4) Drawings including the field of view or video monitoring system in bridge room/dynamic positioning (DP) control room.

38.1.5.2 The following applicable drawings and information are to be submitted to CCS for information:

(1) Arrangement of gangway;

(2) Failure Mode and Failure Analysis (FMEA) report of gangway.

38.1.5.3 Special structures and arrangements, if CCS deems it necessary, may be required to increase the scope of submitted drawings and information for approval.

38.1.5.4 The operation manual for gangway is to be kept onboard for the use of the crew members, and the manual is to include the sufficient safety operational and technical requirements.

Section 2 HULL STRUCTURES

38.2.1 General Requirements

38.2.1.1 The hull structures are to comply with the applicable requirements of PART TWO of the Rules or other rules.

38.2.2 Bow docking

38.2.2.1 Where a vessel transfers personnel or equipment by a method of bow docking against wind turbine foundation, it is appropriate to install rubber fenders or equivalent energy absorbing fenders in the berthing area of the vessel.

38.2.2.2 The vessel is to be so docked against the wind turbine foundation to be able to safely contact and detach. The energy absorbed by the fenders under the working environmental load is to meet the following requirements:

$$E_f \le 0.6 \cdot E_{\text{allow}}$$

where: $E_f = 0.5\Delta V_i^2 C_s C_m$, in kJ;

Δ —— displacement of vessel, in t;

V_i —— instantaneous relative velocity between the vessel and the wind turbine foundation during the docking operation, in m/s, not to be less than 0.6;

C_s ——hardness coefficient of fenders, to be taken as 1 for soft fenders and 0.9 for hard fenders;

C_m —— coefficient considering of added mass for ship motion, taken as 1.1;

E_{allow} —— allowable absorbing energy provided by the fender manufacturer, in kJ.

38.2.2.3 Where the vessel is not equipped with fenders or is intended to operate in sea conditions of level 4 or above, direct calculation method is to be used for hydrodynamic motion analysis and hull structural strength check.

38.2.3 Operating aground

38.2.3.1 Where the vessel carries out amphibious operation in tidal flats by way of grounding, it is to meet the relevant requirements of 14.7.2 bottom structure strengthening in Section 7, Chapter 14, PART TWO of the Rules.

Section 3 SUBDIVISION AND STABILITY

38.3.1 Subdivision and Stability

38.3.1.1 The vessel is to be so designed to have watertightness and weathertightness boundaries that can provide sufficient stability criterion in both intact and damaged conditions.

38.3.1.2 Where the number of windfarm service personnel on board exceeds 12, the subdivision and stability requirements of Regulation 2, Part IV in the IMO resolution MSC. 527 (106) on the International Code of Safety for Ships Carrying Industrial Personnel are to be in compliance with.

Section 4 SYSTEMS AND EQUIPMENT

38.4.1 Gangway

38.4.1.1 Where the gangway transferring system is installed, it is to comply with the applicable requirements of CCS “Guidelines for Marine Telescope Gangway”.

38.4.1.2 In order to ensure the safety of the linkage between the vessel and gangway, the bridge room/dynamic positioning (DP) control room and the gangway are to meet the following requirements:

(1) The bridge room/DP control room is to be able to observe the gangway conditions in real time through visual or video monitoring systems;

(2) The gangway control room (station) and the bridge room/DP control room are to be equipped with a real-time communication system;

(3) The failure alarm of the gangway is to be extended to the bridge room/DP control room at least in the form of a group alarm;

(4) Sufficient illumination is required for the gangway area, if there is a need for night boarding operation.

Section 5 SURVEYS

38.5.1 General Requirements

38.5.1.1 The surveys during construction and surveys after construction for windfarm service vessels are to be carried out in accordance with the requirements of 38.5.2~38.5.5, in addition to the PART ONE of the Rules.

38.5.1.2 Where the gangway transferring system is installed, the survey of gangway is to be carried out in accordance with the requirements of the CCS Guidelines for Marine Telescope Gangway (2023) (hereinafter referred to as the Guidelines for Gangway).

38.5.2 Initial Classification

38.5.2.1 According to the functional categories described in 38.1.3 of the vessel, the following applicable items are to be surveyed:

(1) Check that the bow docking fenders are correctly manufactured and installed according to the approved drawings;

(2) Inspect the gangway in accordance with the requirements of Chapter 7 in the Guidelines for Gangway;

(3) Check the communication and alarm between the gangway control room (station) and bridge room/DP control room, and functions of video monitoring systems for the gangway (if any) ;

(4) Check the external lighting system of the gangway (if any).

38.5.3 Annual Survey

38.5.3.1 The following applicable items are to be carried out:

(1) For the vessel using the bow docking method, inspect the bow fenders and bow structures to confirm without any defects such as damage, crack, distortion, corrosion, etc.. If necessary, NDE (Non-Destructive Examining) is to be conducted;

(2) For the vessel using gangway, conduct inspection in accordance with the requirements of 8.1.2, Chapter 8 of the Guidelines for Gangway and the requirements of 38.5.2.1 (3) to (4) of this Section;

(3) For the vessel with amphibious functions in tidal flats, check the bottom structure from the inner of hull to ensure that the bottom plating and internal structural members are free of depression, buckling and cracking.

38.5.4 Intermediate Survey

38.5.4.1 The following applicable items are to be carried out:

(1) For the vessel using the bow docking method, the inspection scope is the same as that of annual survey;

(2) For the vessel using gangway, conduct inspection in accordance with the requirements of 8.1.3, Chapter 8 of the Guidelines for Gangway and the requirements of 38.5.2.1 (3) to (4) of this Section;

(3) For the vessel with amphibious functions in tidal flats, the inspection scope is the same as that of annual survey.

38.5.5 Special Survey

38.5.5.1 The following applicable items are to be carried out:

(1) For the vessel using the bow docking method, the inspection scope is the same as that of annual survey;

(2) For the vessel using gangway, conduct inspection in accordance with the requirements of 8.1.4, Chapter 8 of the Guidelines for Gangway and the requirements of 38.5.2.1 (3) to (4) of this Section;

(3) For the vessel with amphibious functions in tidal flats, the inspection scope is the same as that of annual survey.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2025

PART NINE COMMON STRUCTURAL RULES FORBULK CARRIERS AND OIL TANKERS

CONTENTS

PART 9-1 GENERAL HULL REQUIREMENTS

CHAPTER 1 RULE GENERAL RINCIPLES 9-1
Section 1 APPLICATION 9-1
Section 2 RULE PRINCIPLES 9-8
Section 3 VERIFICATION OF COMPLIANCE 9-20
Section 4 SYMBOLS AND DEFINITIONS 9-26
Section 5 LOADING MANUAL AND LOADING INSTRUMENTS 9-44
CHAPTER 2 GENERAL ARRANGEMENT DESIGN....9-49
Section 1 GENERAL 9-49
Section 2 SUBDIVISION ARRANGEMENT 9-50
Section 3 COMPARTMENT ARRANGEMENT....9-52
Section 4 ACCESS AND ESCAPE ARRANGEMENT 9-55
CHAPTER 3 STRUCTURAL DESIGN PRINCIPLES 9-57
Section 1 MATERIALS 9-57
Section 2 NET SCANTLING APPROACH 9-68
Section 3 CORROSION ADDITIONS 9-73
Section 4 CORROSION PROTECTION 9-77
Section 5 LIMIT STATES 9-79
Section 6 STRUCTURAL DETAIL PRINCIPLES 9-83
Section 7 STRUCTURAL IDEALISATION 9-113
CHAPTER 4 LOADS 9-134
Section 1 INTRODUCTION 9-134
Section 2 DYNAMIC LOAD CASES 9-137
Section 3 SHIP MOTIONS ANDACCELERATIONS 9-149
Section 4 HULL GIRDER LOADS 9-154
Section 5 EXTERNAL LOADS 9-162
Section 6 INTERNAL LOADS 9-183
Section 7 DESIGN LOAD SCENARIOS 9-210
Section 8 LOADING CONDITIONS 9-214
Appendix 1 HOLD MASS CURVES 9-276
CHAPTER 5 HULL GIRDER STRENGTH 9-289
Section 1 HULL GIRDER YIELDING STRENGTH 9-289
Section 2 HULL GIRDER ULTIMATE STRENGTH 9-305
Section 3 HULL GIRDER RESIDUAL STRENGTH 9-308
Appendix 1 DIRECT CALCULATION OF SHEAR FLOW 9-311
Appendix 2 HULL GIRDER ULTIMATE CAPACITY 9-318
CHAPTER 6 HULL LOCAL SCANTLING.... 9-330
Section 1 GENERAL 9-330
Section 2 LOAD APPLICATION.... 9-331
Section 3 MINIMUM THICKNESSES.... 9-334
Section 4 PLATING 9-336

Section 5 STIFFENERS 9-341
Section 6 PRIMARY SUPPORTING MEMBERSAND PILLARS 9-344
CHAPTER 7 DIRECT STRENGTH ANALYSIS 9-348
Section 1 STRENGTH ASSESSMENT 9-348
Section 2 CARGO HOLD STRUCTURAL STRENGTH ANALYSIS 9-351
Section 3 LOCAL STRUCTURAL STRENGTH ANALYSIS..... 9-385
CHAPTER 8 BUCKLING 9-409
Section 1 GENERAL 9-409
Section 2 SLENDERNESS REQUIREMENTS..... 9-412
Section 3 PRESCRIPTIVE BUCKLING REQUIREMENTS 9-419
Section 4 BUCKLING REQUIREMENTS FOR DIRECT STRENGTH ANALYSIS 9-423
Section 5 BUCKLING CAPACITY..... 9-435
Appendix 1 STRESS BASED REFERENCE STRESSES 9-458
CHAPTER 9 FATIGUE 9-462
Section 1 GENERAL CONSIDERATIONS..... 9-462
Section 2 STRUCTURAL DETAILS TO BE ASSESSED 9-467
Section 3 FATIGUE EVALUATION 9-482
Section 4 SIMPLIFIED STRESS ANALYSES 9-497
Section 5 FINITE ELEMENT STRESS ANALYSIS 9-519
Section 6 DETAIL DESIGN STANDARD 9-539
CHAPTER 10 OTHER STRUCTURES 9-564
Section 1 FORE PART 9-564
Section 2 MACHINERY SPACE 9-573
Section 3 AFT PART 9-577
Section 4 TANKS SUBJECT TO SLOSHING..... 9-581
CHAPTER 11 SUPERSTRUCTURE, DECKHOUSES AND HULL OUTFITTING 9-588
Section 1 SUPERSTRUCTURES, DECKHOUSES AND COMPANIONWAYS 9-588
Section 2 BULWARK AND GUARD RAILS..... 9-592
Section 3 EQUIPMENT..... 9-595
Section 4 SUPPORTING STRUCTURE FOR DECK EQUIPMENT AND FITTINGS 9-596
Section 5 SMALL HATCHWAYS 9-602
CHAPTER 12 CONSTRUCTION 9-608
Section 1 CONSTRUCTION AND FABRICATION 9-608
Section 2 FABRICATION BY WELDING 9-611
Section 3 DESIGN OF WELD JOINTS..... 9-614
CHAPTER 13 SHIP IN OPERATION - RENEWAL CRITERIA 9-631
Section 1 PRINCIPLES AND SURVEYREQUIREMENTS 9-631
Section 2 ACCEPTANCE CRITERIA 9-633
CCS Appendix A WAVE LOAD DIRECT CALCULATION METHOD BASED ON EQUIVALENT DESIGN WAVE METHOD.....9-636
1 GENERAL PROVISIONS 9-636
2 PRINCIPLE OF EQUIVALENT DESIGN WAVE METHOD..... 9-637
3 WAVE LOAD CALCULATION AND APPLICATION BASED ON EQUIVALENT DESIGN WAVE METHOD..... 9-639

CCS Appendix B SUPPLEMENTARY REQUIREMENTS FOR DIRECT CALCULATION LOAD CONDITIONS 9-647
1 GENERAL 9-647
2 GENERAL PRINCIPLES 9-647
3 TYPICAL ADDITIONAL LOADING CONDITIONS 9-648
CCS Appendix C ASSESSMENT OF ULTIMATE STRENGTH OF HULL GIRDERS USING NON-LINEAR FEM 9-654
1 GENERAL 9-654
2 SINGLE SPAN FE MODEL 9-654
3 CARGO HOLD FE MODEL 9-655
CCS Appendix D RECOMMENDATION FOR ASSESSING DESIGN INSTANCES BASED ON APPLICATION OF ALTERNATIVE METHODS IN THE HULL STRUCTURAL DESIGN OF CSR SHIPS 9-657
1 GENERAL 9-657
2 SCOPE 9-657
3 DEFINITIONS.APPLICATION 9-657
4 APPLICATION 9-657
5 EQUIVALENCE PRINCIPLE 9-657
6 ASSESSMENT OF ALTERNATIVE(NOVEL) DESIGN INSTANCES 9-657
7 DESCRIPTION OF ALTERNATIVE DESIGN AND CALCULATION METHODS USED IN THE HULL STRUCTURAL DESIGN 9-658
8 DUCUMENTATION 9-659

PART 9-2 SHIP TYPES

CHAPTER 1 BULK CARRIERS 9-660
Section 1 GENERAL ARRANGEMENT DESIGN 9-660
Section 2 STRUCTURAL DESIGN PRINCIPLES 9-662
Section 3 HULL LOCAL SCANTLINGS 9-668
Section 4 HULL LOCAL SCANTLINGS FOR BULK CARRIERS L<150 m 9-681
Section 5 CARGO HATCH COVERS 9-692
Section 6 ADDITIONAL CLASS NOTATION GRAB 9-710
CHAPTER 2 OIL TANKERS 9-711
Section 1 GENERAL ARRANGEMENT DESIGN 9-711
Section 2 STRUCTURAL DESIGN PRINCIPLES 9-713
Section 3 HULL LOCAL SCANTLING 9-714
Section 4 HULL OUTFITTING 9-732
CCS Appendix A IACS REC.14 - HATCH COVER SECURING AND TIGHTNESS (CORR.1 OCT. 2005) 9-734
CCS Appendix B IACS REC.34 - Standard Wave Data (CORR. Nov. 2001) 9-738

Chapter 1 RULE GENERAL PRINCIPLES

Section 1 APPLICATION

1 SCOPE OF APPLICATION

1.1 General

1.1.1

These Rules apply to the following ships:

a) Bulk carriers and double hull oil tankers and;
b) Being self-propelled ships with unrestricted navigation, and;
c) Contracted for construction on or after 1st July 2015.

CCS 1.1.1a Oil tankers and bulk carriers having a length of 150m and above and contracted for construction on and after 1 July 2016 are to comply with applicable CCS Guidelines for Construction Monitoring of Hull Structures(2014) and to be assigned the class notation CM.

Note1: Unrestricted navigation means that the ship is not subject to any geographical restrictions (i.e. any oceans, any seasons) except that limited by the ship's capability for operation in ice.

Note2: The 'contracted for construction' means the date on which the contract to build the ship is signed between the prospective owner and the builder. For further details regarding the date of 'contracted for construction', refer to IACS Procedural Requirement (PR) No. 29.

1.1.2

These Rules apply to ships constructed of welded steel structures and composed of stiffened plate panels. The ship's structure is to be longitudinally or transversely framed with full transverse bulkheads and intermediate web frames.

The typical arrangements of ships covered by the rules assume that the structural arrangements include:

- Double bottom, the depth of which is to be in accordance with applicable statutory requirements.
- Engine room located aft of the cargo tank/hold region.

1.1.3

Ships for which these Rules are not applicable are to comply with the relevant Rules of the Society.

*CCS 1.1.3*a *Unless provided otherwise, "the Society" in this PART means "CCS".*

1.2 Scope of application for bulk carriers

1.2.1

These Rules apply to the hull structures of single side skin and double side skin bulk carriers having a freeboard length L_{LL} of 90 m or above.

Bulk carriers are ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in cargo hold region and intended primarily to carry dry cargoes in bulk. Typical arrangements of bulk carriers are shown in Figure 1.

Hybrid bulk carriers, where at least one cargo hold is constructed with hopper tank and topside tank, see typical arrangements in Figure 1, and other cargo holds are constructed without hopper tank and/or topside tanks, see examples of a transverse section in Figure 2, are to comply with the strength criteria defined in these Rules.

These Rules are not applicable to the following ship types:

- Ore carriers.
- Combination carrier.
- Woodchip carrier.
- Cement, fly ash and sugar carriers provided that loading and unloading is not carried out by grabs heavier than 10 tons, power shovels and other means which may damage cargo hold structure.
- Ships with inner bottom construction adapted for self-unloading.

1.3 Scope of application for oil tankers

1.3.1 Length and structural arrangement application

These Rules apply to the hull structures of double hull oil tankers having a freeboard length L_{LL} of 150 m or above. Oil tanker is defined as a ship which has to comply with Annex I of MARPOL73/78.

The typical arrangements of oil tankers covered by the rules are shown in Figure 3 and assume that the structural arrangements include:

- Double side structure with breadth in accordance with statutory requirements.
- Side longitudinal, centreline longitudinal or transverse bulkheads of plane, corrugated or double skin construction.
- Single deck structure.

The cross sections shown in Figure 3 are typical examples only and other variations of cross tie and web frame arrangements are also covered.

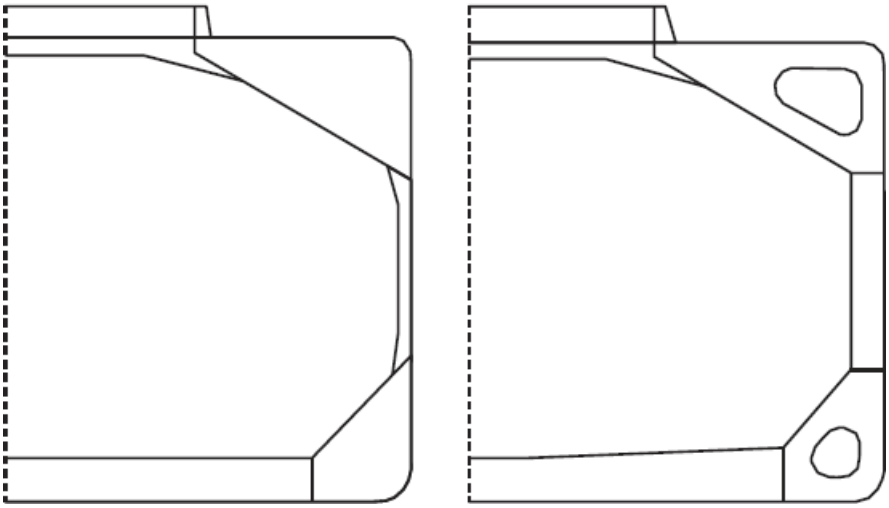


Figure 1 Typical arrangements of bulk carriers

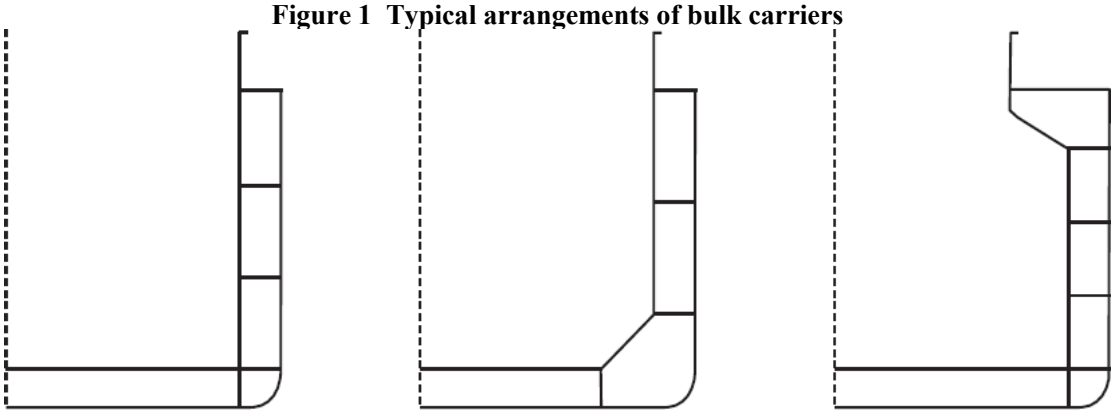


Figure 2 Examples of transverse sections of cargo hold without hopper tank and/or topside tank

1.3.2 Cargo temperature application

The Rules are based on the following design temperatures for the cargo:

a) maximum temperature: 80°C
b) minimum temperature: 0°C.

2 RULE APPLICATION

2.1 Rule description

2.1.1 Rule structure

The rules contain 2 parts:

- Part 1: General hull requirements.
- Part 2: Ship types.

The parts are structured in chapters giving instructions for detail application and requirements which are applied in order to satisfy the rule objectives.

2.1.2 Numbering

The system of numbering is given in Table 1.

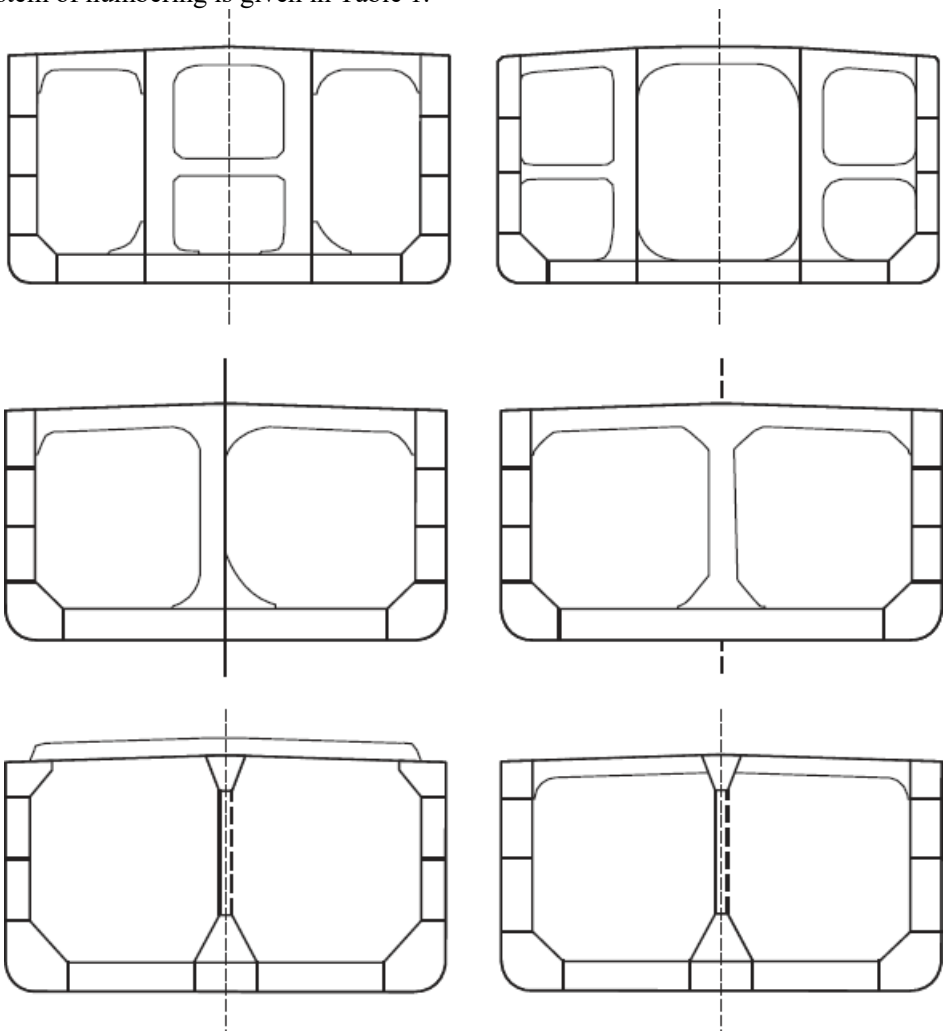


Figure 3 Typical arrangements of double hull oil tankers

Rule numbering and abbreviations **Table 1**

Order	Levels	Example	Abbreviations
1	Part	Part 1 – General Hull Requirements	Pt 1
2	Chapter	Chapter 1 – Rule General Principle	Ch 1
3	Section	Section 1 – Application	Sec 1
4	Article	1. Scope of Application	[1]
5	Sub-article	1.1 General	[1.1]
6	Requirements	1.1.1 These Rules apply to...	[1.1.1]

2.2 Rule Requirements

2.2.1 Part 1

Part 1 of the Rules provides requirements common to all ship types as follow:

- Chapter 1: Rule General Principles.
- Chapter 2: General Arrangement Design.
- Chapter 3: Structural Design Principles.
- Chapter 4: Loads.
- Chapter 5: Hull Girder Strength.
- Chapter 6: Hull Local Scantling.
- Chapter 7: Direct Strength Analysis.
- Chapter 8: Buckling.
- Chapter 9: Fatigue.
- Chapter 10: Other Structure.
- Chapter 11: Superstructure, Deckhouses and Hull Outfitting.
- Chapter 12: Construction.
- Chapter 13: Ship in Operation - Renewal Criteria.

The provisions of the Ch 1, 2, 3, 4, 5, 6, 8, 12, 13 and Ch 10, Sec 4 are applicable all over the ships length.

The Ch 7, 9, 10 and 11 define their own scope of application.

2.2.2 Part 2

Part 2 of the Rules provides requirements coming in addition to those of Part 1 specific for ship types and is divided as follow:

- Chapter 1: Bulk Carriers.
- Chapter 2: Oil Tankers.

2.2.3 Application of the Rules

The ship arrangement and scantlings are to comply with the relevant parts and chapters of the Rules as it is given in Figure 4.

2.2.4 General criteria

The ship arrangement, the proposed details and the offered scantling in net or gross, as the case may, are to comply with the requirements and the minimum scantling given in the Rules.

2.3 Structural requirements

2.3.1 Materials and welding

The Rules applies to welded hull structures made of steel having characteristics complying with requirements in Ch 3, Sec 1. The Rules applies also to welded steel ships in which parts of the hull, such as superstructures or small hatch covers, are built in material other than steel, complying with requirements in Ch 3, Sec 1.

Ships whose hull materials are different than those given in the first paragraph are to be individually considered by the Society, on the basis of the principles and criteria adopted in the present rules.

2.4 Ship parts

2.4.1 General

For the purpose of application of the present rules, the ship is considered as divided into the following five parts:

- Fore part.
- Cargo hold region.
- Machinery space.
- Aft part.
- Superstructures and deckhouses.

2.4.2 Fore part

The fore part is that part of the ship located forward of the collision bulkhead, i.e.:

- The fore peak structures.

- The stem.

2.4.3 Cargo hold region

The cargo hold region is the part of the ship that contains cargo holds, cargo tanks, and slop tanks. It includes the full breadth and depth of the ship, the collision bulkhead and the transverse bulkhead at its aft end. The cargo hold region does not include the pump room, if any.

2.4.4 Machinery space

The machinery space is the part of the ship between the aft peak bulkhead and the transverse bulkhead at the aft end of the cargo hold region and includes the pump room, if any.

2.4.5 Aft part

The aft part includes the structures located aft of the aft peak bulkhead.

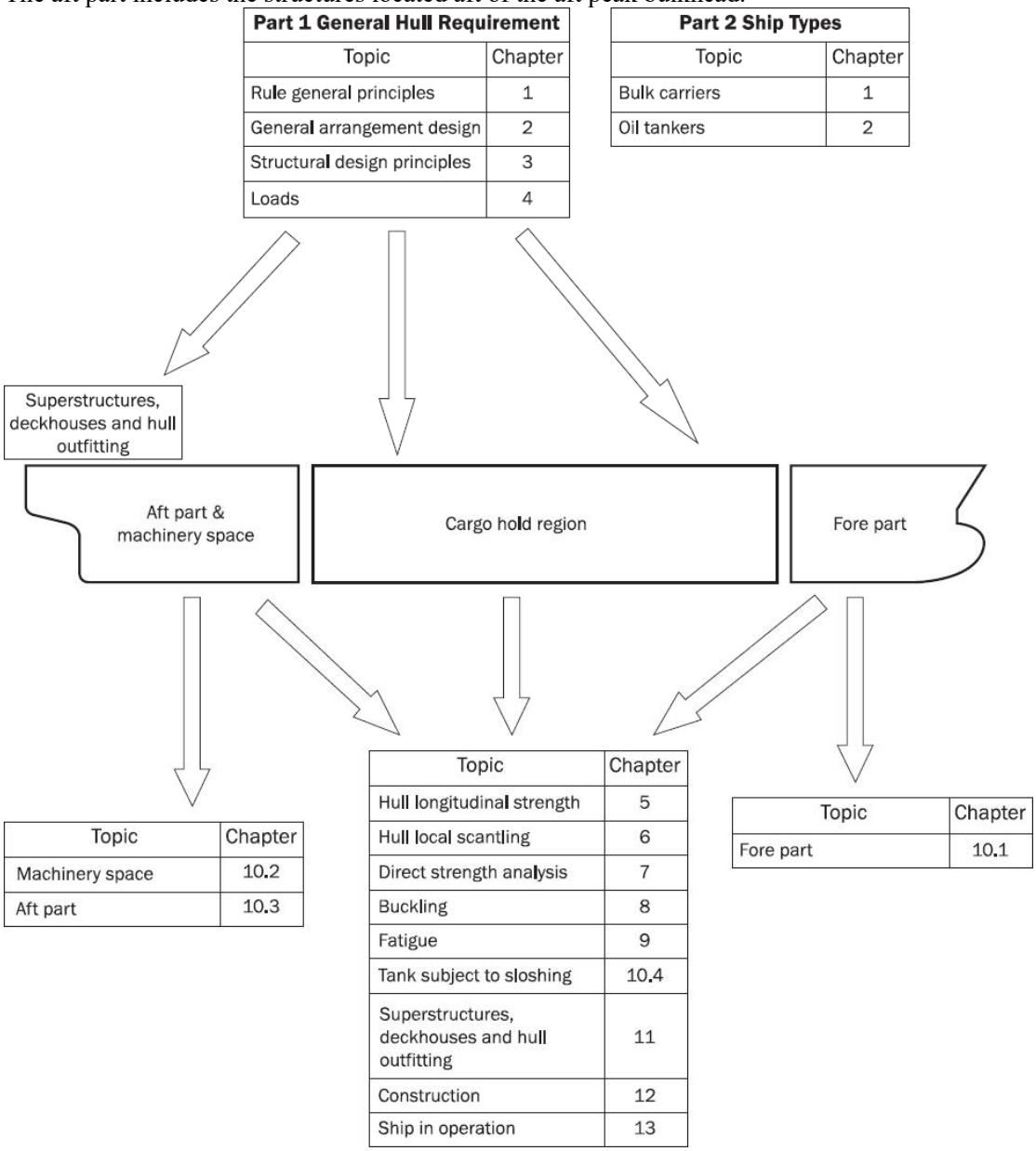


Figure 4 Application of Rules

2.4.6 Superstructures and deckhouses

A superstructure is a decked structure on the freeboard deck extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0.04 *B*.

A deckhouse is a decked structure on the freeboard or superstructure deck which does not comply

with the definition of a superstructure.

2.5 Limits of application to lifting appliances

2.5.1 Definition

The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the ship's hull (for instance, crane pedestals, masts, king posts, derrick heel seatings, etc, excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any removable parts), only for that part directly interacting with the hull structure.

2.5.2 Rule application for lifting appliances

The fixed parts of lifting appliances and their connections to the ship's structure may be covered by the Society's rules for lifting appliances, and/or by the certification (especially the issuance of the Register of ship's lifting appliances and cargo handling gear) of lifting appliances when required.

CCS 2.5.2a The supporting structures of lifting appliances are to comply with the requirements of 4, Section 4, Chapter 11 of this PART.

2.5.3 Structures supporting fixed lifting appliances

The design of the structure supporting fixed lifting appliances and the structure that might be called to support a mobile appliance is to be designed taking into account the additional loads that may be imposed on them by the operation of the appliance and environmental conditions as declared by the builder or its sub-contractors.

2.6 Novel designs

2.6.1

Ships with novel features or unusual hull design are to comply with Ch 1, Sec 3, [6.2].

3 CLASS NOTATIONS

3.1 Class notation CSR

3.1.1 Application

In addition to the class notations granted by the Society and to the service features and additional class notations defined hereafter, ships fully complying with these Rules are assigned the notation CSR.

3.2 Class notation for bulk carriers

3.2.1 Additional service features BC-A, BC-B and BC-C

The following requirements apply to ships, as defined in [1.2.1], having a freeboard length L_{LL} of 150 m or above. Bulk carriers are to be assigned one of the following additional service features:

a) BC-A: For bulk carriers designed to carry dry bulk cargoes of cargo density 1.0 t/m^3 and above with specified holds empty at maximum draught in addition to BC-B conditions.
b) BC-B: For bulk carriers designed to carry dry bulk cargoes of cargo density of 1.0 t/m^3 and above with all cargo holds loaded in addition to BC-C conditions.
c) BC-C: For bulk carriers designed to carry dry bulk cargoes of cargo density less than 1.0 t/m^3.

The following additional service features are to be provided giving further detailed description of limitations to be observed during operation as a consequence of the design loading condition applied during the design in the following cases:

- {Maximum cargo density in t/m3} for additional service features BC-A and BC-B if the maximum cargo density is less than 3.0 t/m3, see also Ch 4, Sec 8, [4.1].
- {No MP} for all additional service features when the ship has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in Ch 4, Sec 8, [4.2.2].
- {Holds a, b, … may be empty} for additional service feature BC-A, see also Ch 4, Sec 8, [4.1].
- {Block loading} for additional service feature BC-A, when the ship is intended to

operate in alternate block load condition, see also Ch 4, Sec 8, [4.2.3] ,item d.

3.2.2 Additional class notation GRAB [X]

The additional class notation GRAB [X] is mandatory for ships having one of the additional service features BC- A or BC-B, according to [3.2.1]. For these ships, the requirements for the GRAB [X] notation given in Pt 2, Ch 1, Sec 6 are to comply with for an unladen grab weight X taken not less than:

- 35 t for ships with $L \geqslant 250$ m,
- 30 t for ships with 200 m $\leqslant L < 250$ m,
- 20 t otherwse.

For all other ships, the additional class notation GRAB [X] is voluntary.

4 APPLICATION OF THE RULES OF THE SOCIETY

4.1 Structural parts not covered by these Rules

4.1.1.

Designer should take care that parts of the structure that these Rules do not cover comply with the relevant requirements of the Society's Rule.

Section 2 RULE PRINCIPLES

1 GENERAL

1.1 Rule objectives

1.1.1

The objectives of the Rules are to establish the classification minimum requirements to mitigate the risks of major hull structural failure in order to help improve the safety of life, environment and property and to contribute to the durability of the hull structure for the ship's design life.

1.1.2

The sub-sections contain:

- The general assumptions pertaining to the design, construction and operation of the ship and give information on the assumed roles of the Society, builders, designers and owners.
- The design basis which specifies the premises on which the Rules are based in terms of design parameters and assumptions about the ship operation.
- The design principles which define the fundamental principles used for the structural requirements in the Rules with respect to loads and structural capacity.
- The rule design methods which describe how the design principles are applied and the criteria are used in view of [1.1.1].

2 GENERAL ASSUMPTIONS

2.1 International and national regulations

2.1.1

Ships are to be designed, constructed and operated in compliance with the regulatory framework prescribed by the International Maritime Organisation (IMO) and implemented by National Administrations or the Society on their behalf. The builder is to give due consideration to the influence on the structural design and arrangement from the relevant requirements of the International Labour Organization (ILO) implemented by National Administrations or the Society on their behalf.

2.1.2

The Rules are based on the assumption that the applicable statutory requirements are complied with.

2.2 Application and implementation of the Rules

2.2.1

The Society develops and publishes the rules for classification of ships, containing minimum requirements for the hull structure and essential engineering systems. The Society verifies compliance with the classification requirements and the applicable international regulations when authorised by a National Administration during design, construction and operation of the ship.

2.2.2

These Rules address the hull structural aspects of classification and do not include requirements related to the verification of compliance with the Rules during construction and operation. In order to achieve the safety level targeted by the Rules, a number of aspects related to design, construction and operation of the ship are assumed to be adhered to by the parties involved in the application and implementation of the Rules. A summary of these assumptions are given in the following:

a) General aspects:
   - Relevant information and documentation involved in the design, construction and operation is communicated between the builder, the designer, the Society and the owner as agreed between builder and owner. Design documentation according to Rule requirements is provided.
   - Quality systems are applied to the design, construction, operation and maintenance activities by owners and other relevant parties to ensure the compliance with the

requirements of the Rules.

b) Design aspects:
- The owner specifies the intended use of the ship, and the ship is designed according to operational requirements as well as the structural requirements given in the Rules.
- The builder identifies and documents the operational limits for the ship so that the ship can be safely and efficiently operated within these limits.
- Verification of the design is performed by the builder to check compliance with provisions contained in the Rules in addition to national and international regulations.
- The design is performed by appropriately qualified, competent and experienced personnel.
- The Society performs a technical appraisal of the design plans and related documents for a ship to verify compliance with the appropriate classification Rules.
- For spaces where lighting and ventilation are to be fitted, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of International Conventions such as SOLAS and MLC2006 Regulation 3.1 - Accommodation and recreational facilities, and Society's rules if any. Human element considerations, including enhanced safety and productivity, may be considered using Recommendation No. 132 or other ergonomic standards accepted by the Society.
- For continually manned spaces where noise is to be minimised, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of SOLAS Ch II-1, Reg.3-12 and "The Code on Noise Levels Onboard Ships" adopted at MSC.337(91).
- For continually manned spaces where vibration is to be minimised, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of relevant statutory requirements such as MLC 2006 Regulation 3.1 - Accommodation and recreational facilities. Human element considerations, including enhanced safety and productivity, may be considered using Recommendation No. 132 or other ergonomic standards accepted by the Society.

c) Construction aspects:
- The builder provides adequate supervision and quality control during the construction.
- Construction is carried out by qualified and experienced personnel.
- Workmanship, including alignment and tolerances, is in accordance with acceptable shipbuilding standards.
- The Society performs surveys to verify that the construction and quality control are in accordance with the classification features of approved plans and procedures.

d) Operational aspects:
- Personnel involved in operations are aware of, and comply with, the operational limitations of the ship.
- Operations personnel receive sufficient training such that the ship is properly handled so that the loads and resulting stresses imposed on the structure are minimised.
- The ship is maintained in adequate condition and in accordance with the Society survey scheme and international and national regulations and requirements.
- The Society performs surveys to verify that the ship is maintained in class in accordance with the Society survey scheme.

CCS 2.2.2a The applicable requirements in CCS Guidelines on Application of Marine Ergonomics may be applied as an ergonomic standard in [2.2.2] b).

3 DESIGN BASIS

3.1 General

3.1.1

This sub-section specifies the design parameters and the assumptions about the ship operation that are used as the basis of the design principles of the Rules.

3.1.2
Ships are to be designed to withstand, in the intact condition, the environmental conditions as defined in [5.3.2] and [5.3.3] anticipated during the design life, for the appropriate loading conditions. Structural strength is to be determined against buckling and yielding. Ultimate strength calculations have to include ultimate hull girder capacity and ultimate strength of plates and stiffeners.

3.1.3 Residual strength
Ships having a freeboard length L_{LL} of 150 m or above are to be designed to have sufficient reserve strength to withstand the loads in damaged conditions, e.g. collision, grounding or flooded scenarios. Residual strength calculations are to take into account the ultimate reserve capacity of the hull girder, considering permanent deformation and post-buckling behaviour as specified in Ch 5, Sec 3.

3.1.4 Finite element analysis
The scantling of the structural members within the cargo hold region of ships having a freeboard length L_{LL} of 150 m or above is to be assessed according to the requirements specified in Pt 1, Ch 7.

3.1.5 Fatigue life
Ships having a freeboard length L_{LL} of 150 m or above are to be assessed according to the design fatigue life for structural details specified in Pt 1, Ch 9.

3.1.6
The Rules are applicable for ships in compliance with the specified design basis. Special consideration is given to deviations from this design basis.

CCS 3.1.6a This PART applies to ships complying with the design basis specified in this Section. For ships which are not designed on this basis, equivalence or substitution is to be granted in accordance with the requirements in CCS Appendix D of PART 9-1.

3.1.7
The design basis used for the design of each ship, as communicated by the builder to the owner, is to be documented and submitted to the Society as part of the design review and approval. All changes of the design basis are to be formally advised to the Society and the owner for approval.

3.2 Hull form limit
3.2.1
The Rules assume the following hull form with respect to environmental loading:

- $L < 500$ m
- $C_B > 0.6$
- $L/B > 5$
- $B/D < 2.5$

For ships over 350 m in length, special consideration is to be made for the wave loads by the Society.

CCS 3.2.1a For ships not complying with the conditions of 3.2.1, the dynamic hull girder loads, ship motions, ship accelerations and sea water dynamic pressures are to be calculated in accordance with the following requirements:
1) Where the ship length L is greater than 350 m,
a) Vertical wave bending moments, vertical wave shear forces, horizontal wave bending moments and torsional moments of hull girder are to be calculated respectively in accordance with the requirements of the following chapters and sections, the greater of which is used for strength assessment and fatigue assessment:

- *CCS Appendix A of PART 9-1;*
- *Section 4, Chapter 4 of PART 9-1 (CB is to be taken not less than 0.6 during*

calculation);

b) Ship motions, ship accelerations and sea water dynamic pressures are to be calculated respectively in accordance with the requirements of the following chapters and sections and used for strength assessment and fatigue assessment:

- *CCS Appendix A of PART 9-1;*
- *Chapter 4 of PART 9-1.*

2) Where the ship length L is not greater than 350 m, for ships not complying with conditions of other hull form limit in 3.2.1,

a) Vertical wave bending moments and vertical wave shear forces of hull girders are to be calculated according to Section 4, Chapter 4 of PART 9-1 (C_B is to be taken not less than 0.6 during calculation) and used for strength assessment and fatigue assessment;

b) Horizontal wave bending moments and torsional moments of hull girder are to be calculated respectively in accordance with the requirements of the following chapters and sections, the greater of which is used for strength assessment and fatigue assessment:

- *CCS Appendix A of PART 9-1;*
- *Section 4, Chapter 4 of PART 9-1 (C_B is to be taken not less than 0.6 during calculation);*

c) Ship motions, ship accelerations and sea water dynamic pressures are to be calculated respectively in accordance with the requirements of the following chapters and sections and used for strength assessment and fatigue assessment:

- *CCS Appendix A of PART 9-1;*
- *Chapter 4 of PART 9-1.*

3.3 Design life

3.3.1

A design life of 25 years is assumed for selecting ship design parameters. The specified design life is the nominal period that the ship is assumed to be exposed to operating conditions.

3.4 Environmental conditions

3.4.1 North Atlantic wave environment

The rule requirements are based on a ship trading in the North Atlantic wave environment for its entire design life.

3.4.2 Wind and current

The effects of wind and current with regard to the strength of the structure are not considered.

3.4.3 Ice

The effects of ice and ice accretion are not taken into account by the Rules.

3.4.4 Design temperatures

The Rules assume that the structural assessment of hull strength members is valid for the following design temperatures:

- Lowest mean daily average temperature in air is -10℃.
- Lowest mean daily average temperature in seawater is 0℃.

Ships intended to operate in areas with lower mean daily average temperature, e.g. regular service during winter seasons to Arctic or Antarctic waters are subject to the requirements as specified by the Society.

In the above, the following definitions apply:

Mean: Statistical mean over observation period (at least 20 years).

Daily Average: Average during one day and night.

Lowest: Lowest during year.

For seasonally restricted service the lowest value within the period of operation applies.

CCS 3.4.4a For ships operating for long periods in areas with lower mean daily average temperature, the steels used for hull structures exposed to low temperature are to comply with the requirements of CCS 2.4.1a to CCS 2.4.1e, Section 1, Chapter 3 of this PART.

3.4.5 Thermal loads
The effects of thermal loads and residual stresses are not taken into account in the Rules.

3.5 Operating conditions
3.5.1
The Rules specify minimum loading conditions that are to be assessed for compliance.
Specification of loading conditions other than those required by the Rules is the responsibility of the owner. These other loading conditions are to be documented and also be assessed for compliance.

3.5.2
The Rules assume the following:
- The ballast cargo hold of bulk carriers is not to be partly filled in seagoing operations.
- Ballasting and deballasting operations in the ballast cargo hold of bulk carriers are not to be performed when the weather is not fair.

3.6 Operating draughts
3.6.1
The design operating draughts are to be specified by the builder/designer subject to acceptance by the owner and are to be used to derive the appropriate structural scantlings. All operational loading conditions in the loading manual are to comply with the specified design operating draughts. The following design operating draughts are as a minimum to be considered:
- Scantling draught for the assessment of structure.
- Minimum ballast draught at midship for assessment of structure.
- Minimum heavy ballast draught at midship for assessment of bulk carrier structure.
- Minimum forward draughts for the assessment of bottom structure forward subjected to slamming loads, $T_{F\text{-}e}$ and $T_{F\text{-}f}$, with and without ballast tanks in way filled.
  $T_{F\text{-}e}$ and $T_{F\text{-}f}$ are defined in Ch 4, Sec 5, [3.2.1]
  - For oil tankers: maximum draughts amidships for both conditions:
    - with all cargo tanks abreast empty.
    - with centre cargo tank empty and wing cargo tanks full.
    - with centre cargo tank full and wing cargo tanks empty.
  - For bulk carriers carrying steel coils: maximum draught amidships for steel coil loading conditions.

3.7 Internal environment
3.7.1 Oil cargo density for strength assessment
A density of 1.025t/m^3, or a higher value if specified by the designer, is to be used for oil cargoes for the strength assessment of all relevant tank structures.

3.7.2 Oil cargo density for fatigue assessment
For the fatigue assessment of cargo tank structures, the mean density is to be taken as 0.9t/m^3, or a higher value if specified by the designer.

3.7.3 Dry cargo density
The density for dry bulk cargo is to be taken according to the specifications in Ch 4, Sec 6, [2.3].

3.7.4 Water ballast density
A density of 1.025t/m^3 is to be used for water ballast.

3.8 Structural construction and inspection
3.8.1
The structural requirements included in the Rules are developed with the assumption that construction and repair follow acceptable shipbuilding and repair standards and tolerances. The Society may require that additional attention is paid to critical areas of the structure by the builder during construction and by the owner for repair after the ship’s delivery.

3.8.2
As an objective, ships are to be built in accordance with controlled quality production standards using approved materials as necessary.

3.8.3
The Rules define the renewal criteria for the individual structural items. The structural requirements included are developed on the assumption that the structure is subject to appropriate monitoring by the owner once the ship is in operation and to periodical survey in accordance with Society rules and regulations.

3.8.4
Tank strength and tightness testing are to be carried out as a part of the verification scheme according to the Rules and /or documents of the individual Society which incorporate IACS UR S14.

3.8.5
Specifications for material manufacturing, assembling, joining and welding procedures, steel surface preparation and coating are to be included in the ship construction quality procedures. It is assumed that the owner has approved these builder specifications.

3.9 Maximum service speed
3.9.1
The maximum service speed is to be specified in the design specification. Although the hull structure verification criteria takes into account the service speed this does not relieve the responsibilities of the owner and personnel to properly handle the ship, see item (d) in [2.2.2].

3.10 Owner's extras
3.10.1
Owner's specification of requirements above the general classification or statutory requirements may affect the structural design. Owner's extras may include requirements for:

- Vibration analysis.
- Maximum percentage of high strength steel.
- Additional scantlings above that required by the Rules.
- Additional design margin on the loads specified by the Rules, etc.
- Improved fatigue resistance, in the form of a specified increase in design fatigue life or equivalent. Owner's extras are not specified by these Rules. Owner's extras, if any, that may affect the structural design are to be clearly specified in the design documentation.

4 DESIGN PRINCIPLES

4.1 Overall principles

4.1.1 Introduction

This sub-section defines the underlying design principles of the Rules in terms of loads, structural capacity models and assessment criteria and also construction and in-service aspects.

4.1.2 General

The Rules are based on the following overall principles:

- The safety of the structure can be assessed by addressing the potential structural failure mode(s) when the ship is subjected to operational loads and environmental loads/conditions.
- The design complies with the design basis, see Ch 1, Sec 3.
- The structural requirements are based on consistent design load sets which cover the appropriate operating modes of a bulk carrier or oil tanker.

The ship's structure is designed such that:

- It has a degree of redundancy. The ship's structure should work in a hierarchical manner and, in principle, failure of structural elements lower down in the hierarchy do not result in immediate consequential failure of elements higher up in the hierarchy.
- It has sufficient reserve strength to withstand the wave and internal loads in damaged

conditions that are reasonably foreseeable e.g. collision, grounding or flooding scenarios. Residual strength calculations are to take into account the ultimate reserve capacity of the hull girder, considering permanent deformation and post-buckling behaviour.

- The incidence of in-service cracking is minimised, particularly in locations which affect the structural integrity or containment integrity, affect the performance of structural or other systems or are difficult to inspect and repair.
- It has adequate structural redundancy to survive in the event that the structure is accidentally damaged by a minor impact leading to flooding of any compartment.

4.1.3 Limit state design principles

The rules are based on the principles of limit state design.

Limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design scenarios identified. For each retained failure mode, one or more limit states may be relevant. By consideration of all relevant limit states, the limit load for the structural element is found as the minimum limit load resulting from all the relevant limit states.

The limit states defined in Ch 3, Sec 5 are divided into the four categories: Serviceability Limit State (SLS), Ultimate Limit State (ULS), Fatigue Limit State (FLS) and Accidental Limit State (ALS).

The Rules include requirements to cover the relevant limit states for the various parts of the structure.

4.2 Loads

4.2.1 Design load scenarios

The structural assessment of the structure is based on the design load scenarios encountered by the ship. Refer to Ch 4, Sec 7.

The design load scenarios are based on static and dynamic loads as given below:

- Static design load scenario (S):
  Covers application of relevant static loads and typically covers load scenarios in harbour, sheltered water, or tank testing.
- Static plus Dynamic design load scenario (S+D):
  Covers application of relevant static loads and simultaneously occurring dynamic load components and typically cover load scenarios for seagoing operations.
- Impact design load scenario (I):
  Covers application of impact loads such as bottom slamming and bow impact encountered during seagoing operations.
- Sloshing design load scenario (SL):
  Covers application of sloshing loads encountered during seagoing operations.
- Fatigue design load scenario (F):
  Covers application of relevant dynamic loads.
- Accidental design load scenario (A):
  Covers application of some loads not occurring during normal operations.

4.3 Structural capacity assessment

4.3.1 General

The basic principle in structural design is to apply the defined design loads, identify plausible failure modes and employ appropriate capacity models to verify the required structural scantlings.

4.3.2 Capacity models for ULS, SLS and ALS

The strength assessment method is to be capable of analysing the failure mode in question to the required degree of accuracy.

The structural capacity assessment methods are in either a prescriptive format or require the use of more advanced calculations such as finite element analysis methods.

The formulae used to determine stresses, deformations and capacity are deemed appropriate for the selected capacity assessment method and the type and magnitude of the design load set.

4.3.3 Capacity models for FLS

The fatigue assessment method provides Rule requirements to assess structural details against fatigue failure.

The fatigue capacity model is based on a linear cumulative damage summation (Palmgren-Miner's rule) in combination with a design S-N curve, a reference stress range and an assumed long-term stress distribution curve.

The fatigue capacity assessment models are in either a prescriptive format or require the use of more advanced calculations, such as finite element analysis methods. These methods account for the combined effects of global and local dynamic loads.

4.3.4 Net scantling approach

The objective of the net scantling approach is to:

- Provide a relationship between the thickness used for strength calculations during the newbuilding stage and the minimum thickness accepted during the operational phase.
- Enable the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the ship.

The net scantling approach distinguishes between local and global corrosion. Local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener. Global corrosion is defined as the overall average corrosion of larger areas, such as primary supporting members and the hull girder. Both the local and global corrosion are used as a basis for the newbuilding review and are to be assessed during operation of the ship.

No credit is given in the assessment of structural capability for the presence of coatings or similar corrosion protection systems.

The application of the net thickness approach to assess the structural capacity is specified in Ch 3, Sec 2.

4.3.5 Intact structure

All strength calculations for ULS, SLS and FLS are based on the assumption that the structure is intact. The residual strength of the ship in a structurally damaged condition is assessed for ALS.

5 RULE DESIGN METHODS

5.1 General

5.1.1 Design methods

Scantling requirements are specified to cover the relevant limit states (ULS, SLS, FLS and ALS) as necessary for various structural parts.

The criteria for the assessment of the scantlings are based on one of the following design methods:

- Working Stress Design (WSD) method, also known as the permissible or allowable stress method.
- Partial Safety Factor (PSF) method, also known as Load and Resistance Factor Design (LRFD).

For both WSD and PSF, two design assessment conditions and corresponding acceptance criteria are given. These conditions are associated with the probability level of the combined loads, A and B.

- The WSD method has the following composition:

  $W_{stat} \le \eta_1 R$ for condition A.

  $W_{stat} + W_{dyn} \le \eta_2 R$ for condition B.

  where:

  W_{stat}: Simultaneously occurring static loads (or load effects in terms of stresses).

  W_{dyn}: Simultaneously occurring dynamic loads. The dynamic loads are typically a combination of local and global load components.

  R : Characteristic structural capacity (e.g. specified minimum yield stress or buckling capacity).

  i : Permissible utilisation factor (resistance factor). The utilisation factor includes consideration of uncertainties in loads, structural capacity and the consequence of failure.

- The PSF method has the following composition:

$$\gamma_{stat-1} W_{stat} + \gamma_{dyn-1} W_{dyn} \le \frac{R}{\gamma_R} \text{ for condition A.}$$

$$\gamma_{stat-2} W_{stat} + \gamma_{dyn-2} W_{dyn} \le \frac{R}{\gamma_R} \text{ for condition B.}$$

where:

γ_{stat-i} : Partial safety factor that accounts for the uncertainties related to static loads.

γ_{dyn-i} : Partial safety factor that accounts for the uncertainties related to dynamic loads.

γ_R : Partial safety factor that accounts for the uncertainties related to structural capacity.

The acceptance criteria for both the WSD method and PSF method are calibrated for the various requirements such that consistent and acceptable safety levels for all combinations of static and dynamic load effects are derived.

5.2 Minimum requirements

5.2.1

Minimum requirements specify the minimum scantling requirements which are to be applied irrespective of all other requirements, hence thickness below the minimum is not allowed.

The minimum requirements are usually in one of the following forms:

- Minimum thickness, which is independent of the specified minimum yield stress.
- Minimum stiffness and proportion, which are based on buckling failure modes.

5.3 Load-capacity based requirements

5.3.1 General

In general, the Working Stress Design (WSD) method is applied in the requirements, except for the hull girder ultimate strength criteria where the Partial Safety Factor (PSF) method is applied. The partial safety factor format is applied for this highly critical failure mode to better account for uncertainties related to static loads, dynamic loads and capacity formulations.

The identified load scenarios are addressed by the Rules in terms of design loads, design format and acceptance criteria set, as given in Table 2. The table is schematic and only intended to give an overview.

Load based prescriptive requirements provide scantling requirements for all plating, local support members, most primary supporting members and the hull girder and cover all structural elements including deckhouses, foundations for deck equipment.

In general, these requirements explicitly control one particular failure mode and hence several requirements may be applied to assess one particular structural member.

5.3.2 Design loads for SLS, ULS and ALS

The structural assessment of compartment boundaries, e.g. bulkheads, is based on loading condition deemed relevant for the type of ship and the operation the ship is intended for.

To provide consistency of approach, standardised Rule values for parameters, such as GM, R_{roll}, T_{sc} and C_B are applied to calculate the Rule load values.

The probability level of the dynamic global, local and impact loads (see Table 1) is 10-8 and is derived using the long-term statistical approach.

The probability level of the sloshing loads (see Table 1) is 10^{-4}.

The design load scenarios for structural verification apply the applicable simultaneously acting local and global load components. The relevant design load scenarios are given in Ch 4, Sec 7.

The simultaneously occurring dynamic loads are specified by applying a dynamic load combination factor to the dynamic load values given in Ch 4. The dynamic load combination factors that define the dynamic load cases are given in Ch 4, Sec 2.

Design load conditions for the hull girder ultimate strength are given in Ch 5, Sec 2.

5.3.3 Design loads for FLS

For the fatigue requirements given in Ch 9, the load assessment is based on the expected load history and an average approach is applied. The expected load history for the design life is characterised by the 10^{-2} probability level of the dynamic load value, the load history for each structural member is represented by Weibull probability distributions of the corresponding

stresses.

The considered wave induced loads include:

- Hull girder loads (i.e. vertical and horizontal bending moments).
- Dynamic wave pressures.
- Dynamic pressure from cargo.

The load values are based on Rule parameters corresponding to the loading conditions, e.g. *GM*, C_B, and the applicable draughts at amidships.

The simultaneously occurring dynamic loads are accounted for by combining the stresses due to the various dynamic load components. The stress combination procedure is given in Ch 9.

Load scenarios and corresponding rule requirements **Table 1**

Operation	Load type	Design load scenario	Acceptance criteria
Seagoing operations			
Transit	Static and dynamic loads in heavy weather	S + D	AC-SD
	Impact loads in heavy weather	Impact (I)	AC-I
	Internal sloshing loads	Sloshing (SL)	AC-S
	Cyclic wave loads	Fatigue (F)	-
BWE by flow through or sequential methods	Static and dynamic loads in heavy weather	S + D	AC-SD
Harbour and sheltered operations			
Loading, unloading and ballasting	Typical maximum loads during loading, unloading and ballasting operations	S	AC-S
Tank testing	Typical maximum loads during tank testing operations	S	AC-S
Special conditions in harbour	Typical maximum loads during special operations in harbour, e.g. propeller inspection afloat or dry-docking loading conditions	S	AC-S
Accidental condition			
Flooded conditions	Typically maximum loads on internal watertight subdivision structure in accidental flooded conditions	A	AC-SD AC-S

Acceptance criteria - prescriptive requirements **Table 2**

Acceptance criteria	Plate panels and local support members (1)		Primary supporting members(1)		Hull girder members	
	Yield	Buckling	Yield	Buckling	Yield	Buckling
AC-S AC-SD	Permissible stress: Ch 6, Sec 4 Ch 6, Sec 5	Control of stiffness and proportions: Ch 8, Sec 2	Permissible stress: Ch 6, Sec 6 Pt 2, Ch 1, Sec 4 Pt 2, Ch 2, Sec 3	Control of stiffness and proportions: Ch 8, Sec 1 Ch 8, Sec 2 Pillar buckling	Permissible stress: Ch 5, Sec 1	Allowable buckling utilisation factor: Ch 8, Sec 1, [3]

Acceptance criteria	Plate panels and local support members (1)		Primary supporting members(1)		Hull girder members	
	Yield	Buckling	Yield	Buckling	Yield	Buckling
AC-I	Plastic criteria: Ch 10, Sec 1, [3]	Control of stiffness and proportions: Ch 8, Sec 2 Ch 10, Sec 1, [3]	Plastic criteria: Ch 10, Sec 1, [3]	Control of stiffness and proportions: Ch 8, Sec 2 Ch 10, Sec 1, [3]	N/A	N/A
(1) Refer to Ch 10 for Other structures and to Ch 11 for Superstructure, deckhouses and hull outfitting						

Acceptance criteria - FE analysis **Table 3**

Acceptance criteria	Cargo hold analysis		Fine mesh analysis
	Yield	Buckling	Yield
AC-S AC-SD	Permissible stress: Ch 7, Sec 2, [5]	Allowable buckling utilisation factor: Ch 8, Sec 1, [3]	Permissible Von Mises stress: Ch 7, Sec 3, [6] Screening criteria: Ch 7, Sec 3, [3.3]

5.3.4 Structural response analysis

In general, the following approaches are applied for determination of the structural response to the applied design load combinations.

a) Beam theory:
   - Used for prescriptive requirements.

b) FE analysis:
   - Coarse mesh for cargo hold model.
   - Fine mesh for local models.
   - Very fine mesh for fatigue assessment.

5.4 Acceptance criteria

5.4.1 General

The acceptance criteria are categorised into three acceptance criteria sets. These are explained below and shown in Table 2 and Table 3. The specific acceptance criteria set that is applied in the rule requirements is dependent on the probability level of the characteristic combined load.

The acceptance criteria set AC-S is applied for the static design load combinations, and for the sloshing design loads. The allowable stress for such loads is lower than that for an extreme load to take into account effects of:

- Repeated yield.
- Allowance for some dynamics.
- Margins for some selected limited operational mistakes.

The acceptance criteria set AC-SD is applied for the S+D design load combinations where considered loads are extreme loads with a low probability of occurrence.

The acceptance criteria set AC-I is typically applied for impact loads, such as bottom slamming and bow impact loads.

5.4.2 Acceptance criteria

The specific acceptance criteria applied in the working stress design requirements are given in the detailed

Rule requirements in Pt 1, Ch 5 to Ch 8, Ch 10, Ch 11 and Pt 2, Ch 1 and Ch 2.

To provide a general informational summary overview of the acceptance criteria, refer to Table 2 and Table 3 below for the different design load scenarios covered by these Rules for the yield and buckling failure modes. For the yield criteria the permissible stress is proportional to the specified minimum yield stress of the material. For the buckling failure mode, the acceptance criteria are based on the control of stiffness and proportions as well as on the buckling utilisation factor.

5.5 Design verification

5.5.1 Design verification – hull girder ultimate strength

The requirements for the ultimate strength of the hull girder are based on a Partial Safety Factor (PSF) method. A safety factor is assigned to each of the basic variables, the still water bending moment, wave bending moment and ultimate capacity. The safety factors were determined using a structural reliability assessment approach, the long-term load history distribution of the wave bending moment was derived using ship motion analysis techniques suitable for determining extreme wave bending moments.

The purpose of the hull girder ultimate strength verification is to demonstrate that one of the most critical failure modes of a ship is controlled.

5.5.2 Design verification – global finite element analysis

The global finite element analysis is used to verify the scantlings given by the load-capacity based prescriptive requirements to better consider the complex interactions between the ship's structural components, complex local structural geometry, change in thicknesses and member section properties as well as the complex load regime with sufficient accuracy.

A linear elastic three dimensional finite element analysis of the cargo region (a FE model length of three holds is required) is carried out to assess and verify the structural response of the proposed hull girder and primary supporting members and assist in specifying the scantling requirements for the primary supporting members. The purpose with the finite element analysis is to verify that the stresses and buckling capability of the primary supporting members are within acceptable limits for the applied design loads.

5.5.3 Design verification – fatigue assessment

The fatigue assessment is required to verify that the fatigue life of critical structural details is adequate. A simplified fatigue requirement is applied to details such as end connections of longitudinal stiffeners using stress concentration factors (SCF) to account the actual detail geometry. A fatigue assessment procedure using finite element analysis for determining the actual hot spot stress of the geometric detail is applied to selected details. In both cases, the fatigue assessment method is based on the Palmgren-Miner linear damage model.

5.5.4 Relationship between prescriptive scantling requirements and FE analysis

The scantlings defined by the prescriptive requirements are not to be reduced by any form of alternative calculations such as FE analysis, unless explicitly stated.

Section 3 VERIFICATION OF COMPLIANCE

1 GENERAL

1.1 Newbuilding

1.1.1

For newbuildings, the plans and documents submitted for approval, as indicated in [2], are to comply with applicable requirements in these Rules, taking account of the relevant criteria, such as additional service features and classification notations assigned to the ship or the ship length.

1.1.2

When a ship is surveyed by the Society during construction, the Society:

- Approves the plans and documentation submitted as required by the Rules.
- Proceeds with the appraisal of the design of materials and equipment used in the construction of the ship and their inspection at works.
- Carries out surveys or obtains appropriate evidence to satisfy itself that the scantlings and construction meet the Rule requirements in relation to the approved drawings.
- Attends tests and trials provided for in the Rules.
- Assigns the classification character of the Society's notation.

1.1.3

The Society defines in specific Rules which materials and equipment used for the construction of ships built under survey are, as a rule, subject to appraisal of their design and to inspection at works, and according to which particulars.

CCS 1.1.3a The appraisal of the design of materials and equipment used in the construction of the ship and their inspection at works are to comply with the relevant requirements of Chapter 3, PART ONE of the Rules.

1.1.4

As part of his/her interventions during ship's construction, the surveyor:

- Conducts an overall examination of the parts of the ship covered by the Rules.
- Examines the construction methods and procedures when required by the Rules.
- Checks selected items covered by the Rule requirements.
- Attends tests and trials where applicable and deemed necessary.

1.1.5

Through all stages of ship construction, it is the builder's responsibility to promptly inform the Society of modifications or departures from approved plans. The builder is to ensure that any deviations from the requirements of the Rules or approved plans are, in any case, accepted by the Society.

1.2 Ships in service

1.2.1

For ships in service, the requirements in Ch 13 are to be complied with.

2 DOCUMENTS TO BE SUBMITTED

2.1 Documentation and data requirements

2.1.1 Loading information

Loading information containing sufficient information to enable the master of the ship to maintain the ship within the stipulated operational limitations is to be provided on board the ship. The loading information is to include an approved loading manual and loading instrument complying with the requirements given in Ch 1, Sec 5.

2.1.2 Calculation data and results

Where calculations have been carried out in accordance with the procedures given in the Rules, one copy of the following is to be submitted for information as applicable:

a) Reference to the calculation procedure and technical program used.
b) A description of the structural modelling.
c) A summary of the analysed parameter including properties and boundary conditions for direct analysis, when applicable.
d) Details of the loading conditions and the means of applying loads for direct analysis, when applicable.
e) A comprehensive summary of calculation results.
f) Sample calculations where appropriate.

The responsibility for error free specification and input of program data and the subsequent correct transposal of output resides with the designer.
Reference is made to Ch 7, Sec 1, [4.1] for required reporting of finite element analysis.

2.2 Submission of plans and supporting calculations

2.2.1 Plans and supporting calculations are to be submitted for approval

For the application of these Rules, the plans and supporting calculations to be submitted to the Society for approval are listed in Table 1.
Plans are to be submitted electronically or physically. When physically submitted plans are to be submitted in triplicate, with one copy necessary for supporting documents and calculations. In addition, the Society may request the submission of information, other plans and documents deemed necessary for the review of the design.
Structural plans are to show scantling, details of connection of the various parts and are to specify the design materials including, in general, their grades, manufacturing processes, welding procedures and heat treatments, and are to include information related to the renewal thickness as specified in Ch 13.
For welding requirements, see Ch 12, Sec 2 and Ch 12, Sec 3.
In case there are deviations from the design basis, then these are to be documented and submitted to the Society.

Plans and supporting calculation to be submitted for approval **Table 1**

Plan or supporting calculation	Containing also information on
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, Wash bulkheads Standard construction details	Class characteristics Ship's main dimensions Minimum ballast draught Frame spacing Maximum service speed Density of cargoes Design loads on decks and double bottom Steel grades Corrosion protection Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures Welding
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	-
Aft part structure	-
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and RPM of propulsion machinery Mass and centre of gravity of machinery and boilers
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Hatch covers and hatch coamings	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the summer load waterline and from the fore end

Plan or supporting calculation	Containing also information on
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	-
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the freeboard deck and superstructure deck
Windows and side scuttles, arrangements and details	-
Scuppers and sanitary discharges	-
Mooring and towing arrangement	-
Supporting structure and foundations for shipboard fittings associated with mooring and towing operations	Design loads and directions of load actions, rated pull and holding load for mooring winches Reaction forces Details of connection of the foundations to the deck, including specifications for holding down bolts for mooring winches Material specifications and welding
Supporting structure and foundations for windlasses and chain stoppers	Design loads and directions of load actions Reaction forces Details of connection of the foundations to the deck, including specifications for holding down bolts for windlasses Material specifications and welding
Stern frame or sternpost, sterntube Propeller shaft boss and brackets (1)	-
Plan of watertight doors and scheme of relevant closing devices	Closing devices Electrical diagrams of power control and position indication circuits
Plan of weathertight or outer doors and hatchways	-
Supporting structure for lifting appliances	Design loads (forces and moments) SWL and self weight of lifting appliances Maximum sea state in offshore operation, if any Connections to the hull structures
Supporting structure for life saving appliances	Design loads (forces and moments) SWL and self weight of lifting appliances Connections to the hull structure
Sea chests, stabiliser recesses, etc	-
Plan of access to and escape from spaces	-
Plan of ventilation including ventilators and tank vents	Use of spaces and location and height of air vent outlets of various compartments
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Equipment number calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
Anchoring arrangement	-

Plan or supporting calculation	Containing also information on
Hawse pipes	-
Loading manual and/or trim and stability booklet	-
(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted.	

2.2.2 Plans to be submitted for information

In addition to those in [2.2.1], the following plans are to be submitted to the Society for information:

a) General arrangement.
b) Capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks.
c) Lines plan, when deemed necessary by the Society.
d) Hydrostatic curves.
e) Lightweight distribution.
f) Docking plan.
g) Arrangement of lifting appliances.
h) Plan of manholes.

2.2.3 Plans and instruments to be supplied onboard the ship

As a minimum, the following plans and instrument are to be supplied onboard:

a) One copy of the following plans indicating the newbuilding and renewal thickness for each structural item is to be supplied onboard the ship: plans of midship sections, construction profiles, shell expansion, transverse bulkheads, aft and fore part structures, machinery space structures
One copy of the following plans indicating the newbuilding thickness for each structural item is to be supplied onboard the ship: plans of superstructures deckhouses and casing
b) One copy of the final approved loading manual, see [2.1.1].
c) One copy of the final approved loading instrument, see [2.1.1].
d) Welding.
e) Details of the extent and location of higher tensile steel together with details of the specification and mechanical properties, and any recommendations for welding, working and treatment of these steels.
f) Details and information on use of special materials, such as an aluminium alloy, used in the hull construction.
g) Towing and mooring arrangements plan.
h) Structural access manual.
i) Structural details for which post weld treatment methods are applied, showing the description of the details and their locations.

Other plans or instrument may be required by the Society.

CCS 2.2.3a For other plans and documents available on board which are to be submitted, see Appendix 1, Chapter 4, PART ONE of the Rules.

3 SCOPE OF APPROVAL

3.1 General

3.1.1

The attention of owners, designers and builders is directed to the regulations of international, national, canal, and other authorities dealing with those requirements which may affect structural aspects, in addition to or in excess of the classification requirements.

3.1.2

The documentation, plans and data requirements specified in [2] are to be submitted. The Society is to review such documentation to verify compliance with the requirements.

3.1.3
An appropriate term to indicate that the plans, reports or documents have been reviewed for compliance with these Rules is to be used according to the procedures of the Society.

CCS 3.1.3a Relevant procedures are to comply with the requirements of Section 5 Submission and Examination of Plans, Chapter 2, PART ONE of the Rules.

3.2 Requirements of international and national regulations
3.2.1 Responsibility
It is the responsibility of the designer to ensure that the design complies with the national and international regulations applicable to the ship.
The Society is not responsible for assessing compliance with international and national regulations as part of the general classification process. However, the Society may enter into an agreement with the flag administration of the ship under which they are explicitly instructed to review and approve a ship design for compliance with specified regulations.

4 WORKMANSHIP
4.1 Requirements to be complied with by the manufacturer
4.1.1
The manufacturing plant is to be provided with suitable equipment and facilities to enable proper handling of the materials, manufacturing processes and structural components. The manufacturing plant is to have at its disposal sufficiently qualified personnel. The Society is to be advised of the names and areas of responsibility of the supervisory and control personnel in charge of the project.

4.2 Quality control
4.2.1
As far as required and expedient, the manufacturer's personnel has to examine all structural components both during manufacture and on completion, to verify that they are complete, that the dimensions are correct and that workmanship is satisfactory and meets the standard of good shipbuilding practice.
Upon inspection and corrections by the manufacturing plant, the structural components are to be shown to the surveyor of the Society for inspection, in suitable sections, normally unpainted condition and enabling proper access for inspection.
The Surveyor may reject components that have not been adequately checked by the plant and may demand their re-submission upon successful completion of such checks and corrections by the plant.

5 STRUCTURAL DETAILS
5.1 Details in manufacturing documents
5.1.1
Significant details concerning quality and functional ability of the component concerned are to be entered in the manufacturing documents (e.g. workshop drawing). This includes not only scantlings but, where relevant, such items as surface conditions (e.g. finishing of flame cut edges and weld seams), and special methods of manufacture involved as well as inspection and acceptance requirements and where relevant permissible tolerances. When a standard is used (works or national standard), it is to be submitted to the Society. For weld joint details, see Ch 12, Sec 2.
If, due to missing or insufficient details in the manufacturing documents, the quality or functional ability of the component is doubtful, the Society may require appropriate improvements to be submitted by the manufacturer. This includes the provision of supplementary or additional parts (for example, reinforcements) even if these were not required at the time of plan approval.

6 EQUIVALENCE PROCEDURES
6.1 Rule applications
6.1.1
These Rules apply to ships of normal form, proportions, speed and structural arrangements. Relevant design parameters defining the assumptions made are given in Ch 1, Sec 2, [3].

6.1.2
Special consideration is to be given to the application of the Rules incorporating design parameters which are outside the design basis as specified in Ch 1, Sec 2, [3], for example, increased fatigue life.

CCS 6.1.2a The procedure for assessing the alternative methods used in hull structural design should be followed in accordance with the requirements in CCS Appendix D of PART 9-1.

6.2 Novel designs
6.2.1
Ships of novel design, i.e. those of unusual form, proportions, speed and structural arrangements outside those specified in Ch 1, Sec 2, [3.2], are specially considered according to the contents of [6.2.2] to [6.2.4].

6.2.2
Information is to be submitted to the Society to demonstrate that the structural safety of the novel design is at least equivalent to that intended by the Rules.

6.2.3
In such cases, the Society is to be contacted at an early stage in the design process to establish the applicability of the Rules and additional information required for submission.

6.2.4
Dependent on the nature of the deviation, a systematic review may be required to document equivalence with the Rules.

6.3 Alternative calculation methods
6.3.1
Where indicated in specific sections of the Rules, alternative calculation methods to those shown in the Rules may be accepted provided it is demonstrated that the scantling and arrangements are of at least equivalent strength to those derived using the Rules.

Section 4 SYMBOLS AND DEFINITIONS

1 PRIMARY SYMBOLS AND UNITS

1.1 General

1.1.1

Unless otherwise specified, the general symbols and their units used in these Rules are those defined in Table 1.

Primary symbols **Table 1**

Symbol	Meaning	Units
A	Area	m^2
	Sectional area of stiffeners and primary members	cm^2
C	Coefficient	-
F	Force and concentrated loads	kN
I	Hull girder inertia	m^4
	Inertia of stiffeners and primary members	cm^4
M	Bending moment	kNm
M	Mass	t
P	Pressure	kN/m^2
Q	Shear force	kN
T	Draught of ship, see [3.1.5]	m
Z	Hull girder section modulus	m^3
	Section modulus of stiffeners and primary supporting members	cm^3
a_i	Acceleration for the effect 'i'	m/s^2
b	Width of attached plating	mm
	Width of face plate of stiffeners and primary supporting members	mm
g	Gravity acceleration, taken equal to 9.81 m/s2	m/s^2
h	Height	m
	Web height of stiffeners and primary supporting members	mm
l	Length/span of stiffeners and primary supporting members	m
n	Number of items	-
r	Radius	mm
	Radius of curvature of plating or bilge radius	mm
t	Thickness	mm
x	*X* coordinate along longitudinal axis, see [3.6]	m
y	*Y* coordinate along transverse axis, see [3.6]	m
z	*Z* coordinate along vertical axis, see [3.6]	m
η	Permissible utilisation factor (usage factor)	-
γ	Safety factor	-
δ	Deflection/displacement	mm
θ	Angle	deg
ρ	Density of seawater, taken equal to 1.025 t/m3	t/m^3

Symbol	Meaning	Units
σ	Normal stress	N/mm^2
τ	Shear stress	N/mm^2

2 SYMBOLS

2.1 Ship's main data

2.1.1

Unless otherwise specified, symbols regarding ship's main data and their units used in these Rules are those defined in Table 2.

Ship's main data **Table 2**

Symbol	Meaning	Units
L	Rule length	m
L_{LL}	Freeboard length	m
L_{PP}	Length between perpendiculars	m
L_0	Rule length, L, but not to be taken less than 110 m	m
L_1	Rule length, L, but need not be taken greater than 250 m	m
L_2	Rule length, L, but need not be taken greater than 300 m	m
B	Moulded breadth of ship	m
D	Moulded depth of ship	m
T	Moulded draught	m
T_{SC}	Scantling draught	m
T_{BAL}	Ballast draught (minimum midship)	m
T_{BAL-H}	Heavy ballast draught at midship	m
T_{BAL-E}	Emergency ballast draught or gale ballast draught at midship	m
T_{LC}	Midship draught at considered loading condition	m
$T_{F\text{-}f}$, $T_{F\text{-}e}$	Minimum draught at forward perpendicular for bottom slamming, with respectively all ballast tanks full or with any tank empty in bottom slamming area	m
Δ	Moulded displacement at draught T_{SC}	t
C_B	Block coefficient at draught T_{SC}	-
V	Maximum service speed	knot
x, y, z	X,Y,Z coordinates of the calculation point with respect to the reference coordinate system	m

2.2 Materials

2.2.1

Unless otherwise specified, symbols regarding materials and their units used in these Rules are those defined in Table 3.

Materials **Table 3**

Symbol	Meaning	Units
E	Young's modulus, see Ch 3, Sec 1, [2]	N/mm^2
G	Shear modulus, $G = \dfrac{E}{2(1+\nu)}$	N/mm^2

Symbol	Meaning	Units
R_{eH}	Specified minimum yield stress, see Ch 3, Sec 1, [2]	N/mm^2
τ_{eH}	Specified shear yield stress, $\tau_{eH} = \frac{R_{eH}}{\sqrt{3}}$	N/mm^2
ν	Poisson's ratio, see Ch 3, Sec 1, [2]	-
k	Material factor, see Ch 3, Sec 1, [2]	-
R_m	Specified minimum tensile strength, see Ch 3, Sec 1, [2]	N/mm^2
R_Y	Nominal yield stress, taken equal to 235/k	N/mm^2

2.3 Loads

2.3.1

Unless otherwise specified, symbols regarding loads and their units used in these Rules are those defined in Table 4.

Loads **Table 4**

Symbol	Meaning	Units
C_w	Wave coefficient	-
T_θ	Roll period	s
θ	Roll angle	deg
T_φ	Pitch period	s
φ	Pitch angle	deg
a_o	Common acceleration parameter	-
a_z	Vertical acceleration	m/s^2
a_y	Transverse acceleration	m/s^2
a_x	Longitudinal acceleration	m/s^2
f_p	Probability factor	-
k_r	Roll amplitude of gyration	m
GM	Metacentric height	m
λ	Wave length	m
S	Static load case	-
S+D	Dynamic load case	-
P_{ex}	Total sea pressure, see Ch 4, Sec 5, [1.1]	kN/m^2
P_{in}	Total internal pressure due to liquid, see Ch 4, Sec 6, [1], or due to dry bulk cargo, see Ch 4, Sec 6, [2.4.1]	kN/m^2
P_s	Static sea pressure	kN/m^2
P_{ls}	Static tank pressure	kN/m^2
P_w	Dynamic wave pressure	kN/m^2
P_{ld}	Dynamic tank pressure	kN/m^2
P_D	Green sea deck pressure	kN/m^2
$P_{slh\text{-}j}$	Sloshing pressure, j=direction	kN/m^2
P_{dl}	Total pressure due to distributed load on deck or platform, see Ch 4, Sec 5, [2.3] or Ch 4, Sec 6, [5.2]	kN/m^2

Symbol	Meaning	Units
P_{SL}	Bottom slamming pressure	kN/m^2
P_{FB}	Bow impact pressure	kN/m^2
P_{fs}	Static pressure in flooded conditions	kN/m^2
P_{fd}	Dynamic pressure in flooded conditions	kN/m^2
P_{ST}	Tank testing pressure (static)	kN/m^2
F_U	Total force due to concentrated load on deck or platform, see Ch 4, Sec 5, [2.3] or Ch 4, Sec 6, [5.3]	kN
$M_{sw\text{-}j}$	Vertical still water bending moment, $j = h, s, p$ (hog, sag, harbour)	kNm
Q_{sw}	Vertical still water shear force	kN
$M_{wv\text{-}j}$	Vertical wave bending moment, $j = h, s$ (hog, sag)	kNm
Q_{wv}	Vertical wave shear force	kN
M_{wt}	Torsional wave moment	kNm
M_{wh}	Horizontal wave bending moment	kNm

2.4 Scantlings

2.4.1

Unless otherwise specified, symbols regarding scantlings and their units used in these Rules are those defined in Table 5.

Scantlings **Table 5**

Symbol	Meaning	Units
$I_{y\text{-}n50}$	Net vertical moment of inertia of hull girder	m^4
$I_{z\text{-}n50}$	Net horizontal moment of inertia of hull girder	m^4
$Z_{D\text{-}n50}$, $Z_{B\text{-}n50}$	Net vertical hull girder section moduli, at deck and bottom respectively	m^3
z_n	Vertical distance from BL to horizontal neutral axis	m
a	Length of EPP, as defined in Ch 3, Sec 7, [2.1.1]	mm
b	Breadth of EPP, as defined in Ch 3, Sec 7, [2.1.1]	mm
s	Stiffener spacing (see Ch 3, Sec 7, [1.2.1])	mm
S	Primary supporting member spacing (see Ch 3, Sec 7, [1.2.2])	m
l	Span of stiffeners or primary supporting member (see Ch 3, Sec 7, [1])	m
l_b	Bracket arm length	m
t	Net thickness with full corrosion reduction	mm
t_{n50}	Net thickness with half corrosion reduction	mm
t_c	Corrosion addition	mm
t_{gr}	Gross thickness	mm
t_{as_built}	As built thickness	mm
t_{gr_off}	Gross thickness offered	mm
t_{gr_req}	Gross thickness required	mm
t_{off}	Net thickness offered	mm
t_{req}	Net thickness required	mm
t_{vol_add}	Thickness for voluntary addition	mm
t_{res}	Reserve thickness	mm

Symbol	Meaning	Units
t_{c1}, t_{c2}	Corrosion addition on each side of structural member	mm
h_w	Web height of stiffener or primary supporting member	mm
t_w	Web thickness of stiffener or primary supporting member	mm
b_f	Face plate width stiffener or primary supporting member	mm
h_{stf}	Height of stiffener	mm
t_f	Face plate/flange thickness of stiffener or primary supporting member	mm
t_p	Thickness of the plating attached to a stiffener or a primary supporting member	mm
b_{eff}	Effective breadth of attached plating, in bending, for yield and fatigue	mm
A_{eff} or $A_{eff\text{-}n50}$	Net sectional area of stiffeners or primary supporting members, with attached plating (of width s)	cm^2
A_{shr} or $A_{shr\text{-}n50}$	Net shear sectional area of stiffeners or primary supporting members	cm^2
I_p	Net polar moment of inertia of stiffener about its connection to plating	cm^4
I	Net moment of inertia of the stiffener, with attached shell plating, about its neutral axis parallel to the plating	cm^4
Z or Z_{n50}	Net section modulus of a stiffener or primary supporting member with attached plating (of breadth b_{eff})	cm^3

3 DEFINITIONS

3.1 Principal Particulars

3.1.1 *L*, Rule length

The Rule length L is the distance, in m, measured on the waterline at the scantling draught *TSC* from the forward side of the stem to the centre of the rudder stock. L is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught T_{SC}.

In ships without rudder stock (e.g. ships fitted with azimuth thrusters), the Rule length L is to be taken equal to 97% of the extreme length on the waterline at the scantling draught T_{SC}.

In ships with unusual stem or stern arrangements, the Rule length is considered on a case-by-case basis.

CCS 3.1.1a For ships with unusual stem or stern arrangements, the Rule length L is 97% of the distance, in m, measured on the waterline at the scantling draught T_{SC} from the forward side of the stem to the after side of the stern frame.

3.1.2 L_{LL}, freeboard length

The freeboard length L_{LL}, in m, is to be taken as 96% of the total length on a waterline at 85% of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that be greater.

For ships without a rudder stock, the length L_{LL} is to be taken as 96% of the waterline at 85% of the least moulded depth.

Where the stem contour is concave above the waterline at 85% of the least moulded depth, both the forward end of the extreme length and the forward side of the stem are to be taken at the vertical projection to that waterline of the aftermost point of the stem contour (above that waterline), see Figure 1.

3.1.3 Moulded breadth

The moulded breadth B is the greatest moulded breadth, in m, measured amidships at the scantling draught, T_{SC}.

3.1.4 Moulded depth

D, the moulded depth, is the vertical distance, in m, amidships, from the moulded baseline to the

moulded deck line of the uppermost continuous deck measured at deck at side. On ships with a rounded gunwale, *D* is to be measured to the continuation of the moulded deck line.

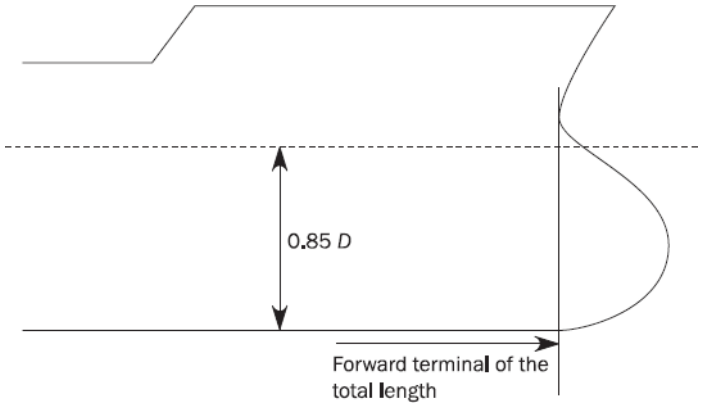


Figure 1 Concave stem contour

3.1.5 Draughts

T, the draught in m, is the summer load line draught for the ship in operation, measured from the moulded baseline at midship. Note this may be less than the maximum permissible summer load waterline draught.

T_{SC} is the scantling draught, in m, at which the strength requirements for the scantlings of the ship are met and represents the full load condition. The scantling draught T_{SC} is to be not less than that corresponding to the assigned freeboard. The draught of ships to which timber freeboards are assigned corresponds to the loading condition of timber, and the requirements of the Society are to be applied to this draught.

T_{BAL} is the minimum design normal ballast draught amidships, in m, at which the strength requirements for the scantlings of the ship are met. This normal ballast draught is the minimum draught of ballast conditions including ballast water exchange operation. If any, for any ballast conditions in the loading manual including both departure and arrival conditions.

$T_{BAL\text{-}H}$ is the minimum design heavy ballast draught, in m, at which the strength requirements for the scantlings of the ship are met. This heavy ballast draught is to be considered for ships having heavy ballast condition.

3.1.6 Moulded displacement

Moulded displacement, in t, corresponds to the underwater volume of the ship, at a draught, in seawater with a density of 1.025 t/m^3.

3.1.7 Maximum service speed

V, the maximum ahead service speed, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught at the maximum propeller RPM and corresponding engine MCR (Maximum Continuous Rating).

3.1.8 Block coefficient

C_B, the block coefficient at the draught, T_{SC} is defined in the following equation:

$$C_B = \frac{\Delta}{1.025LBT_{SC}}$$

where:

Δ: Moulded displacement of the ship at draught T_{SC}.

3.1.9 Lightweight

The lightweight is the ship displacement, in t, complete in all respects, but without cargo, consumable stores, crew and their effects, and without any liquids on board except that machinery and piping fluids, such as lubricants and hydraulics, are at operating levels.

3.1.10 Deadweight

The deadweight DWT is the difference, in t, between the displacement, at the summer draught in

seawater of density ρ= 1.025 t/m^3, and the lightweight.

3.1.11 Fore end

The fore end (FE) of the rule length *L*, see Figure 2, is the perpendicular to the scantling draught waterline at the forward side of the stem.

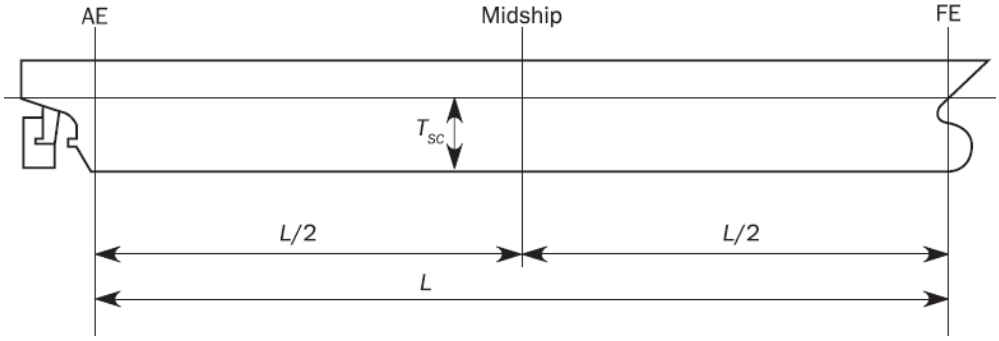


Figure 2 Ends and midship

3.1.12 Aft end

The aft end (AE) of the rule length *L*, see Figure 2, is the perpendicular to the scantling draught waterline at a distance *L* aft of the fore end.

3.1.13 Midship

The midship is the perpendicular to the scantling draught waterline at a distance 0.5 *L* aft of the fore end.

3.1.14 Midship part

The midship part of a ship is the part extending 0.4 *L* amidships, unless otherwise specified.

3.1.15 Forward freeboard perpendicular

The forward freeboard perpendicular, FP_{LL}, is to be taken at the forward end of the length L_{LL} and is to coincide with the foreside of the stem on the waterline on which the length L_{LL} is measured.

3.1.16 After freeboard perpendicular

The after freeboard perpendicular, AP_{LL}, is to be taken at the aft end of the length L_{LL}.

3.2 Position 1 and Position 2

3.2.1 Position 1

Position 1 includes:

- Exposed freeboard and raised quarter decks.
- Exposed superstructure decks situated forward of 0.25 L_{LL} from FP_{LL}.

3.2.2 Position 2

Position 2 includes:

- Exposed superstructure decks situated aft of 0.25 L_{LL} from FP_{LL} and located at least one standard height of superstructure above the freeboard deck.
- Exposed superstructure decks situated forward of 0.25 L_{LL} from FP_{LL} and located at least two standard heights of superstructure above the freeboard deck.

3.3 Standard height of superstructure

3.3.1

The standard height of superstructure is defined in Table 6.

Standard height of superstructure **Table 6**

Freeboard length L_{LL}, in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
$90 < L_{LL} \leq 125$	$0.3 + 0.012\ L_{LL}$	$1.05 + 0.01\ L_{LL}$

Freeboard length L_{LL}, in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
$L_{LL} > 125$	1.80	2.30

3.3.2
A tier is defined as a measure of the extent of a deckhouse. A deckhouse tier consists of a deck and external bulkheads. In general, the first tier is the tier situated on the freeboard deck.

3.4 Type A and Type B freeboard ships
3.4.1 Type A ship
Type A ship is one which:
- Is designed to carry only liquid cargoes in bulk.
- Has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasketed covers of steel or equivalent material.
- Has low permeability of loaded cargo compartments.

Type A ship is to be assigned a freeboard following the requirements specified in the ICLL.

3.4.2 Type B ship
All ships which do not come within the provisions regarding Type A ships stated in [3.4.1] are to be considered as Type B ships.
Type B ship is to be assigned a freeboard following the requirements specified in ICLL.

3.4.3 Type B-60 ship
Type B-60 ship is any Type B ship of over 100 m in length which, according to applicable requirements of ICLL is assigned with a value of tabular freeboard which can be reduced up to 60% of the difference between the 'B' and 'A' tabular values for the appropriate ship lengths.

3.4.4 Type B-100 ship
Type B-100 ship is any Type B ship of over 100 m in length which, according to applicable requirements of ICLL is assigned with a value of tabular freeboard which can be reduced up to 100% of the difference between the 'B' and 'A' tabular values for the appropriate ship lengths.

3.5 Operation definition
3.5.1 Multiport
Multiport corresponds to short voyage with loading and unloading in multiple ports.

3.5.2 Sheltered water
Sheltered waters are generally calm stretches of water when the wind force does not exceed 6 Beaufort scale, i.e. harbours, estuaries, roadsteads, bays, lagoons.

3.6 Reference coordinate system
3.6.1
The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand coordinate system, see Figure 3:
Origin : At the intersection among the longitudinal plane of symmetry of ship, the aft end of *L* and the baseline.
X axis : Longitudinal axis, positive forwards.
Y axis : Transverse axis, positive towards portside.
Z axi : Vertical axis, positive upwards.

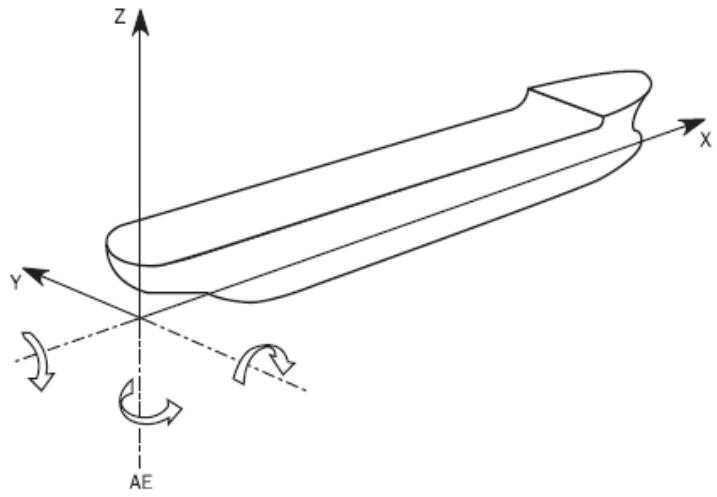


Figure 3 Reference coordinate system

3.7 Naming convention

3.7.1 Structural nomenclature

Figure 4 to Figure 8 show the common structural nomenclature used within these Rules.

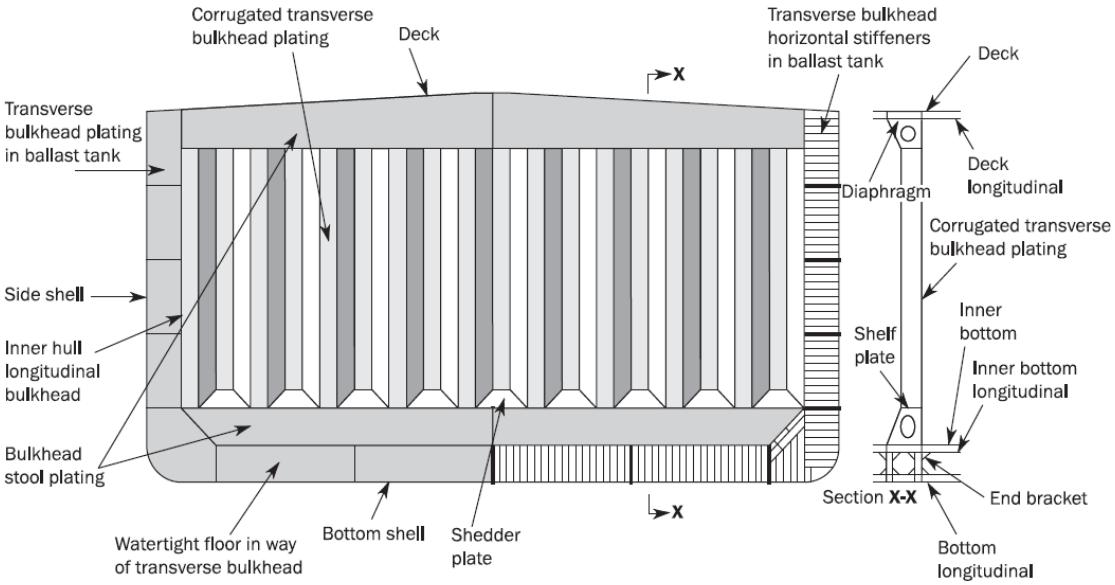


Figure 4 Corrugated transverse bulkhead of double hull tanker

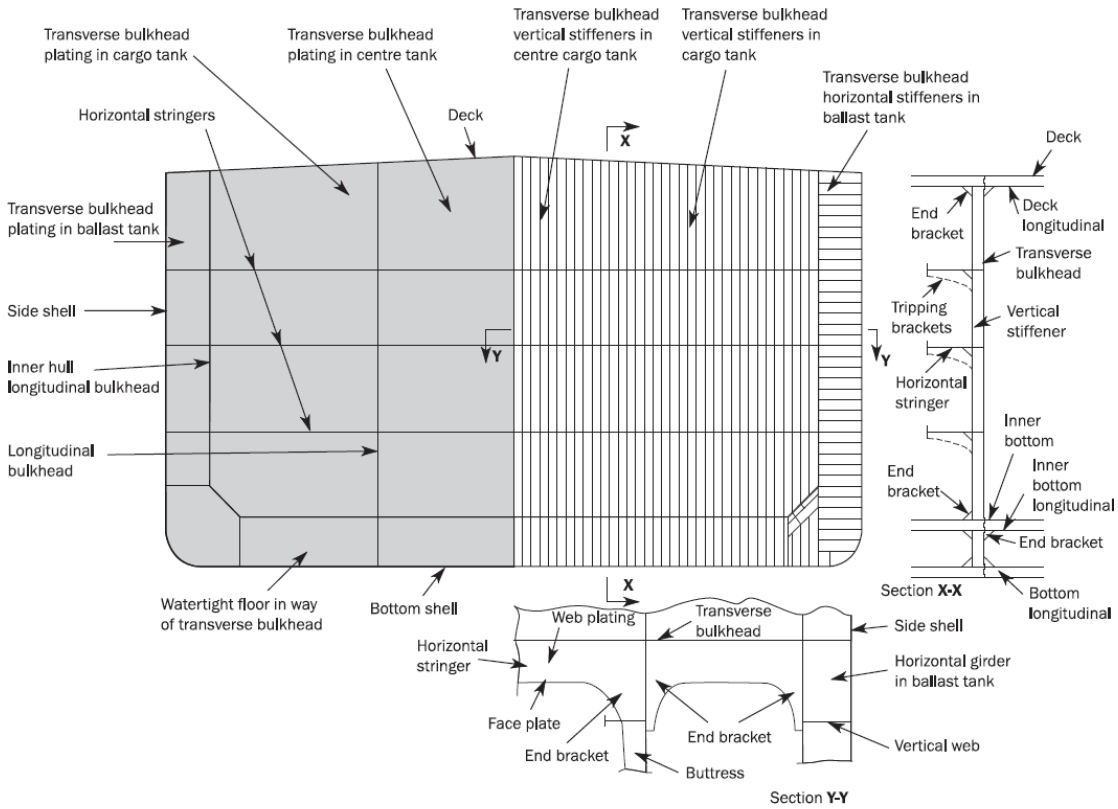


Figure 5 Transverse bulkhead of double hull tanker

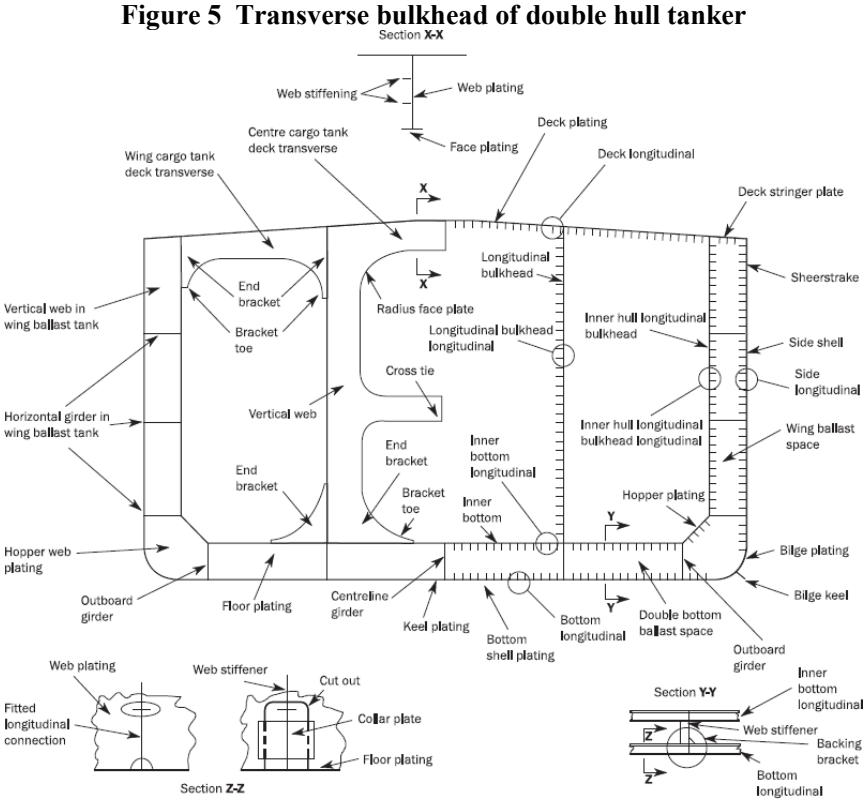


Figure 6 Mid cargo hold transverse section of double hull tanker

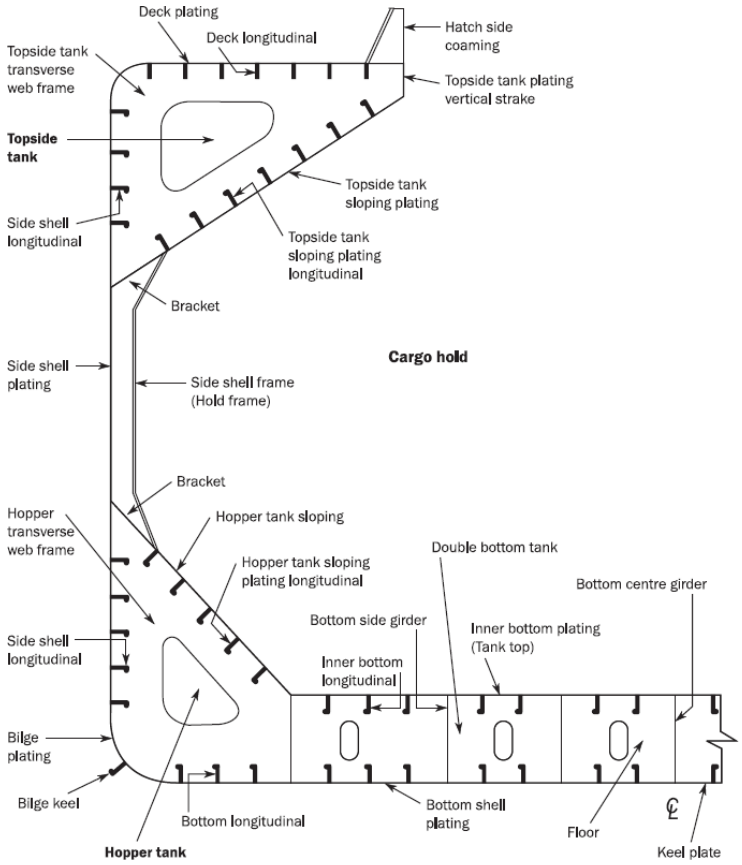


Figure 7 Mid cargo hold transverse section of single side bulk carrier

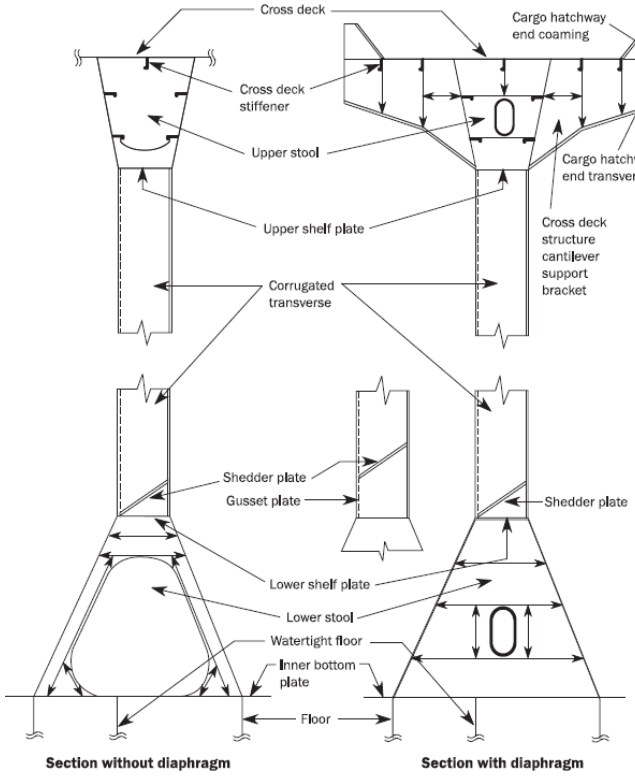


Figure 8 Transverse bulkhead of bulk carrier

3.8 Glossary

3.8.1 Definitions of term

Definition of terms **Table 7**

Terms	Definition
Accommodation deck	A deck used primarily for the accommodation of the crew.
Accommodation ladder	A portable set of steps on a ship's side for people boarding from small boats or from a pier.
Aft peak	The area aft of the aft peak bulkhead.
Aft peak bulkhead	The first main transverse watertight bulkhead forward of the stern.
Aft peak tank	The compartment in the narrow part of the stern aft of the aft peak bulkhead.
Anchor	A device which is attached to anchor chain at one end and lowered into the sea bed to hold a ship in position; it is designed to grip the bottom when it is dragged by the ship trying to float away under the influence of wind and current, usually made of heavy casting or casting.
Ballast tank	A compartment used for the storage of water ballast.
Bay	The area between adjacent transverse frames or transverse bulkheads.
Bilge hopper tank	The tank used for ballast or for stability when carrying certain cargoes in bulk carriers.
Bilge keel	A piece of plate set perpendicular to a ship's shell along the bilges to reduce the rolling motion.
Bilge plating	The bilge plating is the curved plating between the bottom shell and side shell. It is to be taken as follows: Within the cylindrical part of the ship: From the start of the curvature at the lower turn of bilge on the bottom to the end of the curvature at the upper turn of the bilge, Outside the cylindrical part of the ship: From the start of the curvature at the lower turn of the bilge on the bottom to the lesser of: ● A point on the side shell located 0.2*D* above the baseline/local centreline elevation. ● The end of the curvature at the upper turn of the bilge.
Bilge strake	The lower strake of bilge plating.
Boss	The boss of the propeller is the central part to which propeller blades are attached and through which the shaft end passes.
Bottom shell	The shell envelope plating forming the predominantly flat bottom portion of the shell envelope including the keel plate.
Bow	The structural arrangement and form of the forward end of the ship.
Bower anchor	An anchor carried at the bow of the ship.
Bracket	An extra structural component used to increase the strength of a joint between two structural members.
Bracket toe	The narrow end of a tapered bracket.
Breakwater	Inclined and stiffened plate structure on a weather deck to break and deflect the flow of water coming over the bow.
Breast hook	A triangular plate bracket joining port and starboard side structural members at the stem.
Bridge	An elevated superstructure having a clear view forward and at each side, and from which a ship is steered.
Buckling panel	Elementary plate panel considered for the buckling analysis.
Builder	The party contracted by the owner to build a ship in compliance with the specifications including Rules.
Bulb profile	A stiffener utilising an increase in steel mass on the outer end of the web instead of a separate flange.

Terms	Definition
Bulkhead	A structural partition wall sub-dividing the interior of the ship into compartments.
Bulkhead deck	The uppermost continuous deck to which transverse watertight bulkheads and shell are carried.
Bulkhead stool	The lower or upper base of a corrugated bulkhead.
Bulkhead structure	The transverse or longitudinal bulkhead plating with stiffeners and girders.
Bulwark	The vertical plating immediately above the upper edge of the ship's side surrounding the exposed deck(s).
Bunker	A compartment for the storage of fuel oil used by the ship's machinery.
Cable	A rope or chain attached to the anchor.
Camber	The upward rise of the weather deck from both sides towards the centreline of the ship.
Cargo hold region	See Ch 1, Sec 1, [2.4.3].
Cargo hold	Generic term for spaces intended to carry cargo, liquid or dry bulk.
Cargo tank	Tank carrying cargoes
Cargo tank bulkhead	A boundary bulkhead separating cargo tanks.
Carlings	A stiffening member used to supplement the regular stiffening arrangement.
Casing	The covering or bulkhead around or about any space for protection.
Cellular construction	A structural arrangement where there are two closely spaced boundaries and internal diaphragm plates arranged in such a manner to create small compartments.
Centreline girder	A longitudinal member located on the centreline of the ship.
Chain	Connected metal rings or links used for holding anchor, fastening timber cargoes, etc.
Chain locker	A compartment usually at the forward end of a ship which is used to store the anchor chain.
Chain pipe	A section of pipe through which the anchor chain enters or leaves the chain locker.
Chain stopper	A device for securing the chain cable when riding at anchor as well as securing the anchor in the housed position in the hawse pipe, thereby relieving the strain on the windlass.
Coaming	The vertical boundary structure of a hatch or skylight.
Cofferdams	See Ch 2, Sec 3, [1].
Collar plate	A patch used to, partly or completely, close a hole cut for a longitudinal stiffener passing through a transverse web.
Collision bulkhead	The foremost main transverse watertight bulkhead.
Companionway	A weathertight entrance leading from a ship's deck to spaces below.
Compartment	An internal space bounded by bulkheads or plating.
Continually manned space	A space in which the continuous or prolonged presence of seafarers is necessary for normal operational periods. This includes spaces routinely occupied for a period of 20 minutes or more during normal operational periods.
Corrugated bulkhead	A bulkhead including corrugations and usually fitted with lower and upper stools.
Corrugation	Plating arranged in a corrugated fashion, shedder and gusset plates excluded.
Cross deck	The area between cargo hatches.

Terms	Definition
Cross ties	Large transverse structural members joining longitudinal bulkheads or joining a longitudinal bulkhead with double side structures and used to support them against hydrostatic and hydrodynamic loads.
Deck	A horizontal structure element that defines the upper or lower boundary of a compartment.
Deckhouse	See Ch 1, Sec 1, [2.4.6].
Deck structure	The deck plating with stiffeners, girders and supporting pillars.
Deck transverse	Transverse PSM at the deck.
Deep tank	Any tank which extends between two decks or the shell/inner bottom and the deck above or higher.
Designer	A party who creates documentation submitted to the Society necessary for approval or for information. The designer can be the builder or a party contracted by the builder or owner to create this documentation.
Discharges	Any piping leading through the ship's sides for conveying bilge water, circulating water, drains etc.
Docking bracket	A bracket located in the double bottom to locally strengthen the bottom structure for the purposes of docking.
Double bottom structure	The shell plating with stiffeners below the top of the inner bottom and other elements below and including the inner bottom plating.
Doubler	Small piece of plate which is attached to a larger area of plate that requires strengthening in that location. Usually at the attachment point of a stiffener.
Double skin member	Double skin member is defined as a structural member where the idealised beam comprises webs, with top and bottom flanges formed by attached plating.
Duct keel	A keel built of plates in box form. It is used to house ballast and other piping leading forward which otherwise would have to run through the cargo tanks and/or ballast tanks.
Enclosed superstructure	The superstructure with bulkheads forward and/or aft fitted with weather tight doors and closing appliances.
Engine room bulkhead	A transverse bulkhead either directly forward or aft of the engine room.
EPP	Elementary plate panel, the smallest plate element surrounded by structural members, such as stiffeners, PSM, bulkheads, etc.
Face plate	The section of a stiffening member attached to the plate via a web and is usually parallel to the plated surface.
Flange	The section of a stiffening member, typically attached to the web, but is sometimes formed by bending the web over. It is usually parallel to the plated surface.
Flat bar	A stiffener comprised only of a web.
Floor	A bottom transverse member.
Forecastle	A short superstructure situated at the bow.
Fore peak	The area of the ship forward of the collision bulkhead.
Fore peak deck	A short raised deck extending aft from the bow of the ship.
Freeboard deck	Generally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all exposed openings.
Freeing port	An opening in the bulwarks to allow water shipped on deck to run freely overboard.

Terms	Definition
Gangway	The raised walkway between superstructure, such as between the forecastle and bridge, or between the bridge and poop.
Girder	A collective term for primary supporting structural members.
Gudgeon	A block with a hole in the centre to receive the pintle of a rudder; located on the stern post, it supports and allows the rudder to swing.
Gunwale	The upper edge of the ship's sides.
Gusset	A plate, usually fitted to distribute forces at a strength connection between two structural members.
Hatch cover	A cover fitted over a hatchway to prevent the ingress of water into the ship's hold.
Hatchways	Openings, generally rectangular, in a ship's deck affording access into the compartment below.
Hawse pipe	Steel pipe through which the hawser or cable of anchor passes, located in the ship's bow on either side of the stem, also known as spurling pipe.
Hawser	Large steel wire or fibre rope used for towing or mooring.
Hopper plating	Plating running the length of a compartment sloping between the inner bottom and vertical portion of inner hull longitudinal bulkhead.
HP	Bulb profile in accordance with the Holland profile standard.
IACS	International Association of Classification Societies
ICLL	IMO International Convention on Load Lines, 1966, as amended.
IMO	International Maritime Organisation
Independent tank	A self supporting tank.
Inner hull	The innermost plating forming a second layer to the hull of the ship.
Intercostal	Non-continuous member between stiffeners or PSM.
JIS	Japanese industrial standard.
Keel	The main structural member or backbone of a ship running longitudinally along the centreline of the bottom. Usually a flat plate stiffened by a vertical plate on its centreline inside the shell.
Keel line	Keel line is the line parallel to the slope of the keel intersecting the top of the keel at amidships.
Knuckle	A discontinuity in a structural member.
Lightening hole	A hole cut in a structural member to reduce its weight.
Limber hole	A small drain hole cut in a frame or plate to prevent water or oil from collecting.
Local support members	Local stiffening members which only influence the structural integrity of a single panel, e.g. deck beams.
Longitudinal centreline bulkhead	A longitudinal bulkhead located on the centreline of the ship.
Longitudinal hull girder structural members	Structural members that contribute to the longitudinal strength of the hull girder, including: deck, side, bottom, inner bottom, inner hull longitudinal bulkheads including upper sloped plating where fitted, hopper, bilge plate, longitudinal bulkheads, double bottom girders and horizontal girders in wing ballast tanks.
Longitudinal hull girder shear structural members	Structural members that contribute to strength against hull girder vertical shear loads, including: side, inner hull longitudinal bulkheads, hopper, longitudinal bulkheads and double bottom girders.
Manhole	A round or oval hole cut in decks, tanks, etc, for the purpose of providing access.

Terms	Definition
Margin plate	The outboard strake of the inner bottom and when turned down at the bilge the margin plate (or girder) forms the outer boundary of the double bottom.
MARPOL	IMO International Convention for the Prevention of Pollution from Ships, 1973 and Protocol of 1978, as amended.
Mid-hold	Middle hold(s) of the three cargo hold length FE model as defined in Pt 1, Ch 7, Sec 2, [1.2.2]
Normally unmanned space	A space not normally manned (without the continuous or prolonged presence of seafarers) during normal operational periods. This includes spaces routinely occupied for a period of less than 20 minutes during normal operational periods.
Notch	A discontinuity in a structural member caused by welding.
Oil fuel tank	A tank used for the storage of fuel oil.
Outer shell	Same as shell envelope.
Owner	The party that has assumed all duties and responsibilities for registration and operation of the ship and who on assuming such responsibilities has agreed to take over all the duties and responsibilities on delivery of the ship from the builder with valid certificates prepared for the owner.
Pillar	A vertical support placed between decks where the deck is unsupported by the shell or bulkhead.
Pipe tunnel	The void space running in the midships fore and aft lines between the inner bottom and shell plating forming a protective space for bilge, ballast and other lines extending from the engine room to the tanks.
Plate panel	Unstiffened plate surrounded and supported by structural members, such as stiffeners, PSM, bulkheads, etc. See also EPP.
Plating	Sheet of steel supported by stiffeners, primary supporting members or bulkheads.
Poop	The space below an enclosed superstructure at the extreme aft end of a ship.
Poop deck	The first deck above the shelter deck at the aft end of a ship.
Primary supporting members PSM	Members of the beam, girder or stringer type which provide the overall structural integrity of the hull envelope and tank boundaries, e.g. double bottom floors and girders, transverse side structure, deck transverses, bulkhead stringers and vertical webs on longitudinal bulkheads.
Propeller post	The forward post of stern frame, which is bored for propeller shaft.
Rudder post	After post of stern frame to which the rudder is hung (also called stern post).
Scallop	A hole cut into a stiffening member to allow continuous welding of a plate seam.
Scarfing bracket	A bracket used between two offset structural items.
Scantlings	The physical dimensions of a structural item.
Scupper	Any opening for carrying off water from a deck, either directly or through piping.
Scuttle	A small opening in a deck or elsewhere, usually fitted with a cover or lid or a door for access to a compartment.
Shedder plates	Slanted plates that are fitted to minimize pocketing of residual cargo in way of corrugated bulkheads.
Sheer strake	The top strake of a ship’s side shell plating.
Shelf plate	A horizontal plate located on the top of a bulkhead stool.
Shell envelope plating	The shell plating forming the effective hull girder exclusive of the strength deck plating.

Terms	Definition
Side frame	A vertical member attached to the side shell in bulk carriers.
Side shell	The shell envelope plating forming the side portion of the shell envelope above the bilge plating.
Single skin member	A structural member where the idealised beam comprises a web, with a top flange formed by attached plating and a bottom flange formed by a face plate.
Skylight	A deck opening fitted with or without a glass port light and serving as a ventilator for engine room, quarters, etc.
Slop tank	A tank in an oil tanker which is used to collect the oil and water mixtures from cargo tanks after tank washing.
SOLAS	IMO International Convention for the Safety of Life at Sea, 1974 as amended.
Spaces	Separate compartments including tanks.
Stay	Bulwark and hatch coaming brackets.
Stem	The piece of bar or plating at which a ship's outside plating terminates at the forward end.
Stern	The after end of the vessel.
Stern frame	The heavy strength members attached to the after end of a hull to form the ship's stern. It includes rudder post, propeller post, and aperture for the propeller.
Stern tube	A tube through which the shaft passes to the propeller; and acts as an after bearing for the shafting. It may be water or oil lubricated.
Stiffener	A collective term for secondary supporting structural members.
Stool	A structure supporting tank bulkheads.
Strake	A course, or row, of shell, deck, bulkhead, or other plating.
Strength deck	The uppermost continuous deck.
Stringer	Horizontal girders linking vertical web frames.
Stringer plate	The outside strake of deck plating.
Superstructure	See Ch 1, Sec 1, [2.4.6].
SWL	Safe working load
Tank	Generic term for spaces intended to carry liquid, such as, seawater, fresh water, oil, liquid cargoes, FO, DO, etc.
Tank top	The horizontal plating forming the bottom of a cargo tank.
Towing pennant	A long rope which is used to effect the tow of a ship.
Topside tank	The tank that normally stretches along the length of the ship's side and occupies the upper corners of the cargo hold in bulk carriers.
Transom	The structural arrangement and form of the aft end of the ship.
Transverse ring	All transverse material appearing in a cross section of the ship's hull, in way of a double bottom floor, vertical web and deck transverse girder.
Transverse web frame	The primary transverse girders which join the ships longitudinal structure.
Tripping bracket	A bracket used to strengthen a structural member under compression against torsional forces.
Trunk	A decked structure similar to a deckhouse, but not provided with a lower deck.
'Tween deck	An abbreviation of between decks, placed between the upper deck and the tank top in the cargo tanks.
Ullage	The quantity represented by the unoccupied space in a tank.
Void	An enclosed empty space in a ship.

Terms	Definition
Wash bulkhead	A perforated or partial bulkhead in a tank.
Watertight	Watertight means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed.
Weather deck	A deck or section of deck exposed to the elements which has means of closing weathertight, all hatches and openings.
Weathertight	Weathertight means that in any sea conditions water will not penetrate into the ship.
Web	The section of a stiffening member attached perpendicular to the plated surface.
Web frame	Transverse PSM including deck transverse.
Wind and water strakes	The strakes of a ship's side shell plating between the ballast and the deepest load waterline.
Windlass	A winch for lifting and lowering the anchor chain.
Wing tank	The space bounded by the inner hull longitudinal bulkhead and side shell.

Section 5 LOADING MANUAL AND LOADING INSTRUMENTS

1 GENERAL REQUIREMENTS

1.1 Application

1.1.1
This Section contains minimum requirements for loading guidance information.

1.1.2
An approved loading manual and an approved loading instrument are to be supplied onboard.

1.1.3
A ship may in actual operation be loaded differently from the loading conditions specified in the loading manual, provided limitations for longitudinal and local strength as defined in the loading manual and loading instrument onboard and applicable stability requirements are not exceeded.

1.1.4
The requirements concerning the loading manual are given in [2] and those concerning the loading instruments in [3].

1.2 Annual and class renewal survey

1.2.1
At each annual and class renewal survey, it is to be checked that the approved loading manual is available onboard.

1.2.2
The loading instrument is to be checked for accuracy at regular intervals by the ship's master by applying test loading conditions.

1.2.3
At each class renewal survey this checking is to be done in the presence of the surveyor.

2 LOADING MANUALS

2.1 General requirements

2.1.1 Definition

The approved loading manual is to be based on the final data of the ship.
A loading manual is a document which describes:

- The loading conditions on which the design of the ship has been based for seagoing and harbour/sheltered water, including permissible limits of still water bending moment and shear force. The conditions specified in the ballast water exchanging procedure and dry docking procedure are to be included in the loading manual,
- The results of the calculations of still water bending moments, shear forces and where applicable limitations due to lateral loads,
- The allowable local loading for the structure (e.g. hatch covers, decks, double bottom, etc), where applicable,
- The relevant operational limitations.

2.1.2 Condition of approval

The approved loading manual is to be based on the final data of the ship.
Modifications resulting in changes to the main data of the ship (e.g. lightship weight, buoyancy distribution, tank volumes or usage, etc), require the loading manual to be updated and re-approved, and subsequently the loading computer system to be updated and re-approved. However, new loading guidance and an updated loading manual need not be resubmitted provided that the resulting draughts, still water bending moments and shear forces do not differ from the originally approved data by more than 2%.
The loading manual is to be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

2.1.3 Loading conditions

The loading manual is to include the design (cargo and ballast) loading conditions, subdivided into departure and arrival conditions as appropriate, upon which the approval of the hull scantlings is based, as defined in Ch 4, Sec 8.

The loading conditions common to both oil tankers and bulk carriers are listed in Ch 4, Sec 8, [2].

2.1.4 Operational limitations

The loading manual is to describe relevant operational limitations:

- Scantling draught,
- Design minimum ballast draught at midships,
- Design slamming ballast draught forward with forward double bottom ballast tanks filled,
- Design slamming ballast draught forward with any of the forward double bottom ballast tanks empty,
- Maximum allowable cargo density,
- Maximum cargo density in any loading condition in the Loading Manual,
- Maximum service speed,
- Envelope results and permissible limits of still water bending moments and shear forces.

The loading manual must indicate that bulk carriers cannot be operated in seagoing conditions with ballast cargo holds partially filled.

2.2 Requirements specific to oil tankers

2.2.1

The loading manual is to contain the loading conditions described in Ch 4, Sec 8, [3]. This requirement applies in addition to [2.1].

2.3 Requirements specific to bulk carriers

2.3.1

The loading manual is to contain the loading conditions described in Ch 4, Sec 8, [4]. This requirement applies in addition to [2.1].

2.3.2

The loading manual is to describe:

- Envelope results and permissible limits of still water bending moments and shear forces in the flooded conditions according to Ch 4, Sec 4,
- The cargo hold(s) or combination of cargo holds that might be empty at full draught. If no cargo hold is allowed to be empty at full draught, this is to be clearly stated in the loading manual,
- Maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of the draught at mid-hold position as defined in Ch 4, Sec 8, [4.3],
- Maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught may be calculated by averaging the draught of the two mid-hold positions as defined in Ch 4, Sec 8, [4.3],
- Maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes,
- Maximum allowable load on deck and hatch covers. If the ship is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual,
- Maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast.

2.3.3

The additional following loading conditions, subdivided into departure and arrival conditions as appropriate, are to be included in the loading manual:

- Homogeneous light and heavy cargo loading conditions at maximum draught,
- Alternate light and heavy cargo loading conditions at maximum draught, where

applicable,

- Ballast conditions. For ships having ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty,
- Short voyage conditions, i.e. the ship is loaded to maximum draught but with a limited amount of bunkers, where appropriate,
- Multiple port loading/unloading conditions,
- Deck cargo conditions, where applicable,
- Typical sequences for change of ballast at sea, where applicable,
- Typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions are also to be included. The typical loading/unloading sequences are also to be developed to not exceed applicable strength limitations. The typical loading sequences are also to be developed paying due attention to loading rate and the deballasting capability. Figure 1 contains, as guidance only, an example of a Loading Sequence Summary Form.

3 LOADING INSTRUMENT

3.1 General requirements

3.1.1 Definition

A loading computer system is a system, which is either analog or digital, by means of which it can be easily and quickly ascertained that, at specified read-out points, relevant operational limitations, such as the still water bending moments, shear forces, and lateral loads, where applicable, in any load or ballast condition do not exceed the specified permissible values.

The loading instrument is ship specific onboard equipment and the results of the calculations are only applicable to the ship for which it has been approved.

An approved loading instrument can not replace an approved loading manual.

3.1.2 Conditions of approval of loading instruments

The loading instrument is subject to approval based on the Rules of the individual Society. The approval is to include:

- Verification of type approval, if any,
- Verification that the final data of the ship has been used,
- Acceptance of number and position of read-out points,
- Acceptance of relevant limits for all read-out points,
- Checking of proper installation and operation of the instrument onboard, in accordance with agreed test conditions, and that a copy of the operation manual is available.

Modifications resulting in changes to the main data of the ship (e.g. lightship weight, buoyancy distribution, tank volumes or usage, etc), require the loading manual to be updated and re-approved, and subsequently the loading instrument to be updated and re-approved. However, new loading guidance and an updated loading instrument need not be resubmitted provided that the resulting draughts, still water bending moments and shear forces do not differ from the originally approved data by more than 2%.

An operational manual is always to be provided for the loading instrument. The operation manual and the instrument output are to be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

The operation of the loading instrument is to be verified upon installation. It is to be checked that the agreed test conditions and the operation manual for the instrument is available onboard.

CCS 3.1.2a The loading instruments are to comply with the requirements of Appendix 1, Chapter 2, PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

3.2 Requirements specific to bulk carriers

3.2.1 General

For BC-A, BC-B and BC-C ships, the loading instrument is to ascertain as applicable:

- The mass of cargo and double bottom contents in way of each hold as a function of the

draught at mid- hold position,
- The mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds,
- That the still water bending moment and shear forces in the hold flooded conditions do not exceed the specified permissible values.

3.2.2 Condition of approval

For BC-A, BC-B and BC-C ships, the approval is to include, as applicable:
- Acceptance of hull girder bending moment limits for all read-out points,
- Acceptance of hull girder shear force limits for all read-out points,
- Acceptance of limits for the mass of cargo and double bottom contents of each hold as a function of draught,
- Acceptance of limits for the mass of cargo and double bottom contents in any two adjacent holds as a function of draught.

4 LOADING SPECIFIC TO BULK CARRIERS

4.1 Guidance for loading/unloading sequences

4.1.1 Scope of application

The requirements given in [4] are applicable to bulk carriers having a freeboard length L_{LL} of 150 m or above.

4.1.2

The typical loading/unloading sequences are to be developed paying due attention to the loading/unloading rate, the ballasting/deballasting capacity and the applicable strength limitations.

4.1.3

Typical loading and unloading sequences are to be prepared and submitted for approval by the builder.

4.1.4

The typical loading sequences as relevant are to include:
- Alternate light and heavy cargo load condition,
- Homogeneous light and heavy cargo load condition,
- Short voyage condition where the ship is loaded to maximum draught but with limited bunkers,
- Multiple port loading/unloading condition,
- Deck cargo condition,
- Block loading.

4.1.5

The loading/unloading sequences may be port specific or typical.

4.1.6

The sequence is to be built up step by step from commencement of cargo loading to reach full deadweight capacity. Each time the loading equipment changes position to a new hold defines a step. Each step is to be documented and submitted to the Society. In addition to longitudinal strength, the local strength of each hold is to be considered.

4.1.7

For each loading condition, a summary of all steps is to be included. This summary is to highlight the essential information for each step, such as:
- How much cargo is filled in each hold during the different steps,
- How much ballast is discharged from each ballast tank during the different steps,
- The maximum still water bending moment and shear force at the end of each step,
- The ship’s trim and draught at the end of each step.

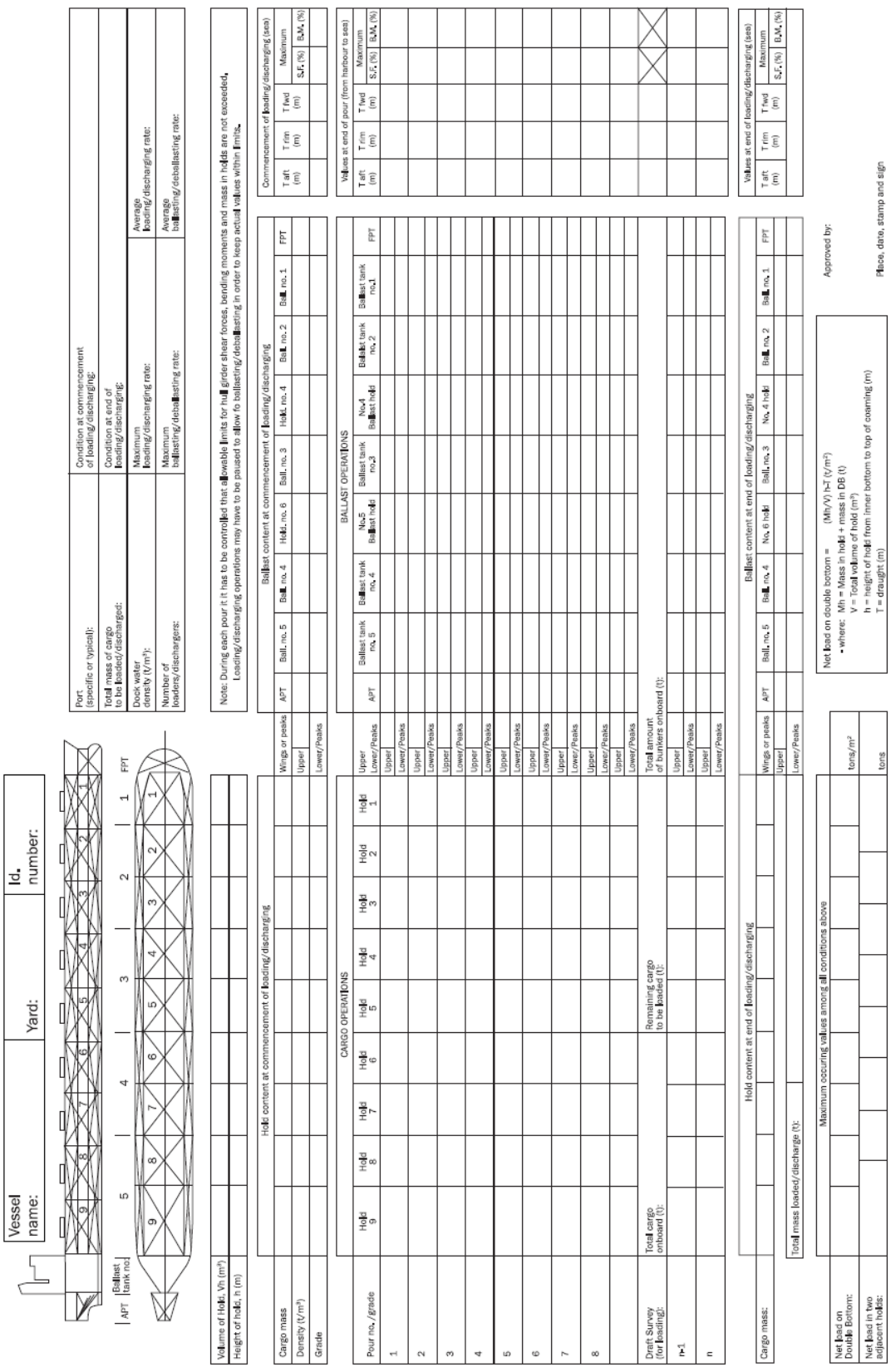


Figure 1 Loading Sequence Summary Form

Chapter 2 GENERAL ARRANGEMENT DESIGN

Section 1 GENERAL

1 GENERAL

1.1 General

1.1.1

This chapter covers the general structural arrangement requirements for the ship.

1.1.2

Arrangements for continually manned spaces are to include consideration of ventilation, lighting, noise and whole-body vibration in accordance with industry standards accepted by the Society. See also Sec 4, [1.1.1] to [1.1.3].

CCS 1.1.2a The applicable requirements given in CCS Guidelines on Application of Marine Ergonomics may be applied.

1.1.3

Arrangements for normally unmanned spaces are to include consideration of lighting and ventilation for periodic inspections, survey and maintenance in accordance with industry standards accepted by the Society. See also Sec 4,[1.1.1] to [1.1.5].

CCS 1.1.3a The applicable requirements given in CCS Guidelines on Application of Marine Ergonomics may be applied.

Section 2 SUBDIVISION ARRANGEMENT

1 WATERTIGHT BULKHEAD ARRANGEMENT

1.1 Number and disposition of watertight bulkheads

1.1.1

All ships are to have at least the following transverse watertight bulkheads:

a) One collision bulkhead.
b) One aft peak bulkhead.
c) One bulkhead forward of the machinery space, and one bulkhead at the aft end of the machinery space which may be the aft peak bulkhead.

1.1.2

In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

1.1.3

In addition to the requirements of [1.1.1] and [1.1.2], the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of national regulations.

1.1.4

For bulk carriers with freeboard length L_{LL} less than 150 m not required to comply with subdivision requirements, bulkheads not less in number than indicated in Table 1 are to be fitted.

Number of bulkheads for bulk carriers with freeboard length L_{LL} less than 150 m Table 1

Freeboard length in m	Number of bulkheads for ships with aft machinery(1)
$90 \leqslant L_{LL} < 105$	4
$105 \leqslant L_{LL} < 120$	5
$120 \leqslant L_{LL} < 145$	6
$145 \leqslant L_{LL} < 150$	7
(1) Aft peak bulkhead and aft machinery bulkhead are the same.	

1.1.5

The bulkheads in the cargo hold region are to be spaced at uniform intervals as far as practicable.

2 COLLISION BULKHEAD

2.1 Extent and position of collision bulkhead

2.1.1

A collision bulkhead is to be fitted on all ships and is to extend to the freeboard deck. It is to be located between 0.05 L_{LL} or 10 m, whichever is less, and except as may be permitted by the Administration, 0.08 L_{LL} or 0.05 L_{LL}+3 m, whichever is the greater, aft of the reference point, where the reference point is as defined in [2.1.2].

2.1.2

For ships without bulbous bows the reference point is to be taken where the forward end of L_{LL} coincides with the forward side of stem, on the waterline which L_{LL} is measured. For ships with bulbous bows, it is to be measured from the forward end of L_{LL} a distance x forward; where x is to be taken as the lesser of the following:

a) Half the distance, from FP_{LL} to the extreme forward end of the bulb extension.
b) 0.015 L_{LL}.
c) 3.0 m.

2.2 **Arrangement** of collision bulkhead

2.2.1

In general, the collision bulkhead is to be in one plane; however, the bulkhead may have steps or recesses provided that they are within the limits prescribed in [2.1.1] and [2.1.2].

2.2.2
Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead below the freeboard deck. Where the collision bulkhead is extended above the freeboard deck, the number of openings in the extension is to be kept to a minimum compatible with the design and proper working of the ship. Reference is made to Ch1, Sec 2, [2.1].

3 AFT PEAK BULKHEAD

3.1 General

3.1.1
An aft peak bulkhead, enclosing the stern tube and rudder trunk in a watertight compartment, is to be provided. Where the shafting arrangements make enclosure of the stern tube in a watertight compartment impractical, alternative arrangements are specially considered.

CCS 3.1.1a Where the shafting arrangements make enclosure of the stern tube in a watertight compartment impractical, equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules and effective means are to be provided to ensure the watertightness of the stern tube.

3.1.2
The aft peak bulkhead may be stepped below the freeboard deck, provided that the degree of safety of the ship as regards subdivision is not thereby diminished.

3.1.3
The aft peak bulkhead location on ships powered and/or controlled by equipment that do not require the fitting of a stern tube and/or rudder trunk are also subject to special consideration.

CCS 3.1.3a The location of the aft peak bulkhead on ships powered and/or controlled by equipment that does not require the fitting of a stern tube and/or rudder trunk is to be in accordance with paragraph 2.2.5, Section2, Chapter2, PART ONE of the Rules and if the relevant requirements of paragraph 1.1 of this Section are complied with, may be specially considered.

3.1.4
Provided that the aft peak bulkhead extends above the deepest load line, termination of the afterpeak bulkhead on a watertight deck lower than the freeboard deck can be accepted. In order to provide such a watertight deck a tight sealing of the rudder stock shall be fitted I n way of this deck or above.

Section 3 COMPARTMENT ARRANGEMENT

1 COFFERDAMS

1.1 Definition

1.1.1

A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be kept gas-tight and is to be properly ventilated, provided with drainage arrangement, and of sufficient size to allow proper inspection, maintenance and safe evacuation.

1.2 Arrangement of cofferdams

1.2.1

Cofferdams are to be provided between compartments intended for liquid hydrocarbons (including fuel oil, lubricating oil) and those intended for fresh water (water for propelling machinery and boilers) as well as tanks intended for the carriage of liquid foam for fire extinguishing.

1.2.2

Furthermore, tanks carrying fresh water for human consumption are to be separated from other tanks containing substances hazardous to human health by cofferdams or other means as approved by the Society.

Note 1: Normally, tanks for fresh water and water ballast are considered non-hazardous.

1.2.3

Where a corner to corner situation occurs, tanks are not considered to be adjacent.

1.2.4

The cofferdams specified in [1.2.1] may be waived when deemed impracticable or unreasonable by the Society in relation to the characteristics and dimensions of the spaces containing such tanks, provided that:

- the thickness of common boundary plates of adjacent tanks is increased, with respect to the thickness obtained according to Ch6, Sec4, by 2 mm in the case of tanks carrying fresh water or boiler feed water, and by 1 mm in all other cases,
- the sum of the throats of the weld fillets at the edges of these plates is not less than the thickness of the plates themselves,
- the structural test is carried out with a test pressure increased by 1 m with respect to Ch1, Sec2, [3.8.4].

2 DOUBLE BOTTOM

2.1 General

2.1.1

A double bottom need not be fitted in way of watertight tanks, including dry tanks of moderate size provided the safety of the ship is not impaired in the event of bottom or side damage as regulated in SOLAS II-1, Reg 9.

CCS 2.1.1a For bulk carriers, a double bottom may not be fitted in way of watertight tanks (including dry tanks) of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage.

2.2 Extent of double bottom

2.2.1

For bulk carriers, a double bottom is to be fitted extending from the collision bulkhead to the aft peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

For oil tankers, a double bottom is to be fitted to protect the cargo hold region and pump rooms. However the double bottom below pump rooms may be omitted provided that it is in compliance

with MARPOL, Annex I, Ch 4, Reg 22.

2.2.2
Where double bottom is required to be fitted, the inner bottom is to be continued out to the ship side in such a manner as to protect the bottom to the turn of the bilge in areas where hopper or double side spaces are not provided.

2.3 Height of double bottom
2.3.1
Unless otherwise specified, the height of the double bottom is not to be less than the lesser of:

- For oil tankers: *B*/15 or 2 m, however not less than 1.0 m measured at right angles to the shell plating at any cross section.
- For bulk carriers: *B*/20 or 2 m, however not less than 0.76 m measured vertically from the plane parallel with keel line to inner bottom.

2.4 Small wells in double bottom tank
2.4.1
Small wells constructed in the double bottom are not to extend in depth more than necessary. A well extending to the outer bottom, may, however, be permitted at the after end of the shaft tunnel of the ship. Other wells may be permitted by the Society if it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom that complies with [2.1].

CCS 2.4.1a Small wells constructed in the double bottom in connection with drainage arrangements of holds, etc., are not to extend downward more than necessary. A well extending to the outer bottom is, however, permitted at the after end of the shaft tunnel. Other wells (e.g., for lubricating oil under main engines) may be permitted if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with requirements. In no case is the vertical distance from the bottom of such a well to a plane coinciding with the keel line to be less than 500 mm.

3 DOUBLE SIDE
3.1 Double side width
3.1.1 Oil tankers
The minimum double side width, W_{ds}, in m, is to be taken as the lesser of:

$$W_{ds} = 0.5 + \frac{DWT}{20000} \text{ but less not than } 1.0$$

W_{ds} =2.0

3.1.2 Bulk carriers
Double side skin means a configuration where each ship side is constructed by the side shell and a longitudinal bulkhead connecting the double bottom and the deck. Hopper side tanks and topside tanks may, where fitted, be integral parts of the double side skin configuration.
The minimum double side width, W_{ds}, is not to be less than 1 m measured perpendicular to the side shell.

3.2 Minimum clearance inside the double side
3.2.1 Definition
The minimum clearance is defined as the shortest distance measured between assumed lines connecting the inner surfaces of the stiffeners on the inner and outer hulls.

3.2.2 Minimum clearance dimensions
The minimum clearance between the inner surfaces of the stiffeners inside the double side is not to be less than:

- 600 mm when the inner and/or the outer hulls are transversely framed,
- 800 mm when the inner and the outer hulls are longitudinally framed.

Outside the parallel part of the cargo hold, the clearance may be reduced but is not to be less than 600 mm.

4 BALLAST TANKS

4.1 Capacity and disposition of ballast tanks

4.1.1

All ships are to have ballast tanks of sufficient capacity that the ship may operate safely on ballast voyage. The capacity of ballast is to be at least such that, in any ballast condition at any part of the voyage, including the conditions consisting of lightweight plus ballast only, the ship's draught and trim can meet the requirements defined in:

- For oil tankers, Ch4, Sec 8, [3.1].
- In addition, for oil tankers, the moulded draught amidships, T_{mid}, excluding any hogging or sagging correction, is not to be less than:
  $T_{mid} = 2.0 + 0.02L_{LL}$, in m
- For bulk carriers, Ch4, Sec8, [4.1].

Section 4 ACCESS AND ESCAPE ARRANGEMENT

1 ENCLOSED SPACES

1.1 General

1.1.1 Special considerations

Human element considerations, including enhanced safety and productivity, may be considered using Recommendation No. 132 or other ergonomic standards accepted by the Society.

Where spaces have special considerations or requirements for access; e.g. security restrictions for the CO2 room to prevent unintentional release, these are to be considered in conjunction with the requirements of this section, and any conflicts should be raised as soon as possible for consideration by the Society.

CCS 1.1.1a The applicable requirements given in CCS Guidelines on Application of Marine Ergonomics may be applied.

1.1.2 Enclosed spaces

All enclosed spaces are to be accessible with appropriate access arrangements for easy inspection, survey and maintenance i.e. access is to allow unobstructed passage to items for inspection for personnel wearing the appropriate clothing, including personal protective equipment, and using all necessary tools and test equipment.

Provision is also to be made for appropriate arrangements to facilitate emergency egress of inspection personnel or ships' crew in accordance with industry standards accepted by the Society, notwithstanding the requirements set out in SOLAS or other relevant regulatory instruments.

CCS 1.1.2a The applicable requirements given in CCS Guidelines on Application of Marine Ergonomics may be applied.

1.1.3 Spaces not explicitly covered by SOLAS

For spaces which are not explicitly covered by SOLAS, ChII-1, Reg 3-6, the builder is to provide appropriate accesses arrangements for easy inspection, survey and maintenance in accordance with industry standards accepted by the Society. See also [1.1.5].

Provision is also to be made for appropriate arrangements to facilitate emergency egress of inspection personnel or ships' crew in accordance with industry standards accepted by the Society. Special measures for inspection and maintenance are to be put in place for small closed spaces for which the design causes impracticality for the access.

CCS 1.1.3a The applicable requirements given in CCS Guidelines on Application of Marine Ergonomics may be applied.

1.1.4 Ventilation of normally unmanned spaces

Unless otherwise specifically detailed in these Rules, normally unmanned spaces are to be capable of being ventilated through natural or forced ventilation. Such ventilation could be achieved through the inclusion of mushroom ventilators, gooseneck ventilators, ventilators with weather proof covers etc. Exchange air may be provided through permanent or temporary mechanical ventilation and air trunk systems or a suitable air exchange path through tank openings and ventilators.

1.1.5 Permanent means of access to normally unmanned spaces

Unless otherwise specifically detailed in these Rules, permanent means of access to normally unmanned spaces is to be provided in accordance with SOLAS, Ch II-1, Reg. 3-6.

For enclosed spaces, which are not explicitly covered by SOLAS, Ch II-1, Reg. 3-6, the requirements of the Convention and associated Resolutions should be applied as far as practicable. The size of openings providing access to or emergency egress from spaces not entered during operation, entered for maintenance or entered for regular inspections shall, in general, not be less than 600mm x 400mm if oval or in accordance with industry standards accepted by the Society if

circular.

CCS 1.1.5a The applicable requirements given in CCS Guidelines on Application of Marine Ergonomics may be applied.

2 CARGO AREA AND FORWARD SPACES

2.1 General

2.1.1 Means of access

Each space is to be provided with means of access as regulated in SOLAS, ChII-1, Reg 3-6. This requirement applies to:

- Oil tankers.
- Bulk carriers having a length of 150 m or above, irrespective of their gross tonnage.

2.1.2

All tanks are to be accessible for easy inspection.

Chapter 3 STRUCTURAL DESIGN PRINCIPLES

Section 1 MATERIAL

1 GENERAL

1.1 Standard of material

1.1.1

Materials used during construction are to comply with the Rules for Materials of the Society.

CCS 1.1.1a Materials used for hull structures are to comply with the relevant provisions of PART ONE of CCS Rules for Materials and Welding.

1.1.2

Other materials than those covered under [1.1.1] may be accepted, provided their specification (e.g. manufacture, chemical composition, mechanical properties, welding) is submitted to the Society for approval.

1.2 Testing of materials

1.2.1

Materials are to be tested in compliance with the applicable requirements of Rules for Materials of the Society.

CCS 1.2.1a Materials are to be tested in compliance with the applicable requirements of Chapter 1, PART ONE of CCS Rules for Materials and Welding.

1.3 Manufacturing process

1.3.1

The requirements of this section presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice defined in the Rules and/or documents of the individual Society which incorporate IACS UR W and the applicable requirements of Rules for Materials of the Society.

In particular:

- Parent material and welding processes are to be within the limits stated for the specified type of material for which they are intended.
- Specific preheating may be required before welding.
- Welding or other cold or hot manufacturing processes may need to be followed by an adequate heat treatment.

CCS 1.3.1a Welding and other cold or hot manufacturing processes of this Section are to comply with the applicable requirements of Section 1, Chapter 5, PART THREE of CCS Rules for Materials and Welding.

2 HULL STRUCTURAL STEEL

2.1 General

2.1.1 Young's modulus and Poisson's ratio

The Young's modulus for Carbon steel materials is equal to 206,000 N/mm^2 and the Poisson's ratio equal to 0.3.

2.1.2 Steel material grades and mechanical properties

Steel having a specified minimum yield stress of $235N/mm^2$ is regarded as normal strength hull structural steel and is denoted by 'MS' for mild steel. Steel having a higher specified minimum yield stress is regarded as higher strength hull structural steel and is denoted 'HT' for high tensile steel.

Material grades of hull structural steels are referred to as follows:

a) A, B, D and E denote normal strength steel grades.
b) AH, DH and EH denote higher strength steel grades.

Table1 gives the mechanical characteristics of steels generally used in the construction of ships.

2.1.3

Higher strength steels other than those indicated in Table 1 are considered by the Society on a case-by-case basis.

CCS 2.1.3a For higher tensile steels other than those indicated in Table 1, the chemical composition, deoxidation method, condition of supply and mechanical properties of the steels are to be submitted to CCS for approval.

Mechanical properties of hull steels **Table1**

Steel grades for plates with t_{as_built} 100 mm	R_{eH}, specified minimum yield stress, in N/mm^2	R_m, specified tensile strength, in N/mm^2
A-B-D-E	235	400 - 520
AH32-DH32-EH32-FH32	315	440 - 570
AH36-DH36-EH36-FH36	355	490 - 630
AH40-DH40-EH40-FH40	390	510 - 660

2.1.4 High tensile steel

When steels with a specified minimum yield stress R_{eH} other than 235 N/mm^2 are used, hull girder strength and hull scantlings are to be determined by taking into account the material factor, k defined in [2.2].

2.1.5 Onboard documents

It is required to keep onboard a plan indicating the steel types and grades adopted for the hull structures. Where steels other than those indicated in Table 1 are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, are to be available onboard together with the above plan.

2.2 Material factor, *k*

2.2.1

Unless otherwise specified, the material factor, k of normal and higher strength steel for hull girder strength and scantling purposes is to be taken as defined in Table 2, as a function of the specified minimum yield stress R_{eH}.

For intermediate values of R_{eH}, k is obtained by linear interpolation.

Steels with a specified minimum yield stress R_{eH}, greater than 390 N/mm^2 are considered by the Society on a case-by-case basis.

Material factor, *k* **Table2**

R_{eH}, specified minimum yield stress, in N/mm^2	k
235	1.00
315	0.78
355	0.72
390	0.68

2.3 Steel grades

2.3.1

Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Table 3 to Table 7. General requirements are given in Table 3, while additional minimum requirements for ships with length exceeding 150m and 250m, single side bulk carriers with length exceeding 150 m, are given in Table 4 to Table 6. The

material grade requirements for hull members of each class depending on the thickness are defined in Table 7.

Material classes and grades **Table3**

Structural member category		Material class/grade
Secondary	A1. Longitudinal bulkhead strakes, other than those belonging to the Primary category A2. Deck plating exposed to weather, other than that belonging to the Primary or Special category A3. Side plating	- Class I within 0.4 *L* amidships - Grade A/AH outside 0.4 *L* amidships
Primary	B1. Bottom plating, including keel plate B2. Strength deck plating, excluding that belonging to the Special category B3. Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings B4. Uppermost strake in longitudinal bulkhead B5. Vertical strake (hatch side girder) and uppermost sloped strake in topside tank	- Class II within 0.4 *L* amidships - Grade A/AH outside 0.4 *L* amidships
Special	C1. Sheer strake at strength deck (1) C2. Stringer plate in strength deck (1) C3. Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships (1)	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships
	C4. Strength deck plating at outboard corners of cargo hatch openings for ships with hatch opening configurations similar to those of container carriers	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships - Min. Class III within cargo hold region
	C5. Strength deck plating at corners of cargo hatch openings	- Class III within 0.6 *L* amidships - Class II within rest of cargo hold region
	C6. Bilge strake of ships with double bottom over the full breadth and with length less than 150 m	- Class II within 0.6 *L* amidships - Class I outside 0.6 *L* amidships
	C7. Bilge strake in other ships (1)	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships
	C8. Longitudinal hatch coamings of length greater than 0.15 *L* including coaming top plate and flange C9. End brackets and deckhouse transition of longitudinal cargo hatch coamings	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships - Not to be less than Grade D/DH
(1) Single strakes required to be of class III within 0.4*L* amidships are to have breadths not less than 800+5*L*, in mm, need not be greater than 1800 mm, unless limited by the geometry of the ship's design.		

Minimum material grades for ships with length exceeding 150 m **Table4**

Structural member category	Material grade
Longitudinal plating of strength deck where contributing to the longitudinal strength	Grade B/AH within 0.4 *L* amidships
Continuous longitudinal plating of strength members above strength deck	Grade B/AH within 0.4 *L* amidships
Single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and the strength deck	Grade B/AH within cargo hold region

Minimum material grades for ships with length exceeding 250 m Table 5

Structural member category(1)	Material grade
Sheer strake at strength deck	Grade E/EH within 0.4 *L* amidships
Stringer plate in strength deck	Grade E/EH within 0.4 *L* amidships
Bilge strake	Grade D/DH within 0.4 *L* amidships

(1) Single strakes required to be of Grade D/DH or Grade E/EH as shown in the above table and within 0.4*L* amidships are to have breadths not less than 800+5*L* (mm), need not be greater than 1800 (mm), unless limited by the geometry of the ship's design.

Minimum material grades for single side skin bulk carriers with length exceeding 150 m Table 6

Structural member category	Material grade
Lower bracket of ordinary side frame (1), (2)	Grade D/DH
Side shell strakes included totally or partially between the two points located to 0.125 above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate (2)	Grade D/DH

(1) The term 'lower bracket' means webs of lower brackets and webs of the lower part of side frames up to the point of 0.125 above the intersection of side shell and bilge hopper sloping plate or inner bottom plate.
(2) The span of the side frame, *l*, is defined as the distance between the supporting structures (see Pt 2, Ch1, Sec 2, Figure 2).

Material grade requirements for classes I, II and III Table7

Class	I		II		III	
As-built thickness, in mm	MS	HT	MS	HT	MS	HT
$t \leqslant 15$	A	AH	A	AH	A	AH
$15 < t \leqslant 20$	A	AH	A	AH	B	AH
$20 < t \leqslant 25$	A	AH	B	AH	D	DH
$25 < t \leqslant 30$	A	AH	D	DH	D	DH
$30 < t \leqslant 35$	B	AH	D	DH	E	EH
$35 < t \leqslant 40$	B	AH	D	DH	E	EH
$40 < t \leqslant 50$	D	DH	E	EH	E	EH

2.3.2
For strength members not mentioned in Table 3 to Table 6, Grade A/AH may be used upon agreement of the Society.

CCS 2.3.2a For strength members not mentioned in Table 3 to Table 6, Grade A/AH is generally to be used.

2.3.3
Plating materials for stern frames and shaft brackets are in general not to be of lower grades than corresponding to Class II.

2.4 Structures exposed to low air temperature
2.4.1
For ships intended to operate in areas with low air temperatures refer to Ch1, Sec 2, [3.4.4].

CCS 2.4.1a For ships intended to operate in areas with low air temperatures (with design temperature below and including -10℃),e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D of CCS 2.4.1e and in accordance with the provisions of CCS 2.4.1b to CCS 2.4.1e.

CCS 2.4.1b Grades of hull structural steel above the lowest ballast waterline (BWL) exposed to low air temperatures are not to be lower than those as given in Table CCS 2.4.1b.

CCS 2.4.1c Grades of steel for hull structural members of different material classes are to be selected according to Table CCS 2.4.1cdepending on plate thickness and design temperature. Where the design temperature t_D is below -55℃, the grades of steel are to be subject to special consideration by CCS.

CCS 2.4.1d Single *strakes required to be of Class III or of grade E/EH or FH are to have breadths not less than 800+5L mm (L being length of the ship), but need not be greater than 1,800 mm.*

Material Classes at Low Air Temperatures ***Table CCS 2.4.1b***

Structural member category	*Structural member*	*Material class*	
		Within 0.4L amidships	*Outside 0.4L amidships*
Secondary	*Deck plating exposed to weather in general, side plating above BWL, transverse bulkheads above BWL*	*I*	*I*
Primary	*Strength deck plating①* *Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings* *Longitudinal bulkhead above BWL* *Top wing tank bulkhead above BWL*	*II*	*I*
Special	*Sheer strake at strength deck, including rounded gunwale②* *Stringer plate in strength deck②* *Deck strake at longitudinal bulkhead③* *Continuous longitudinal hatch coamings④*	*III*	*II*

Notes:① Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.

② Not to be less than grade E/EH within 0.4 L amidships in ships with length exceeding 250 m.

③ In ships with breadth exceeding 70 m at least three deck strakes to be Class III.

④ Not to be less than grade D/DH.

Material Grade Requirements for Classes I, II and III at Low Temperatures
Table CCS 2.4.1c

Class I										
Plate thickness (mm)	*–11 ~ –15 ℃*		*–16 ~ –25 ℃*		*–26 ~ –35 ℃*		*–36 ~ –45 ℃*		*–46 ~ –55 ℃*	
	Mild steel	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*
t≤10	*A*	*AH*	*A*	*AH*	*B*	*AH*	*D*	*DH*	*D*	*DH*
10<t≤15	*A*	*AH*	*B*	*AH*	*D*	*DH*	*D*	*DH*	*D*	*DH*
15<t≤20	*A*	*AH*	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
20<t≤25	*B*	*AH*	*D*	*DH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
25<t≤30	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
30<t≤35	*D*	*DH*	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*

Class I										
Plate thickness (mm)	*–11 ~ –15 ℃*		*–16 ~ –25 ℃*		*–26 ~ –35 ℃*		*–36 ~ –45 ℃*		*–46 ~ –55 ℃*	
	Mild steel	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*
35<t≤45	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*	*–*	*FH*
45<t≤50	*D*	*DH*	*E*	*EH*	*E*	*EH*	*–*	*FH*	*–*	*FH*
Class II										
Plate thickness (mm)	*–11 ~ –15 ℃*		*–16 ~ –25 ℃*		*–26 ~ –35 ℃*		*–36 ~ –45 ℃*		*–46 ~ –55 ℃*	
	Mild steel	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*
t≤10	*A*	*AH*	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
10<t≤20	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
20<t≤30	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*	*–*	*FH*
30<t≤40	*D*	*DH*	*E*	*EH*	*E*	*EH*	*–*	*FH*	*–*	*FH*
40<t≤45	*E*	*EH*	*E*	*EH*	*–*	*FH*	*–*	*FH*	*–*	*–*
45<t≤50	*E*	*EH*	*E*	*EH*	*–*	*FH*	*–*	*FH*	*–*	*–*
Class III										
Plate thickness (mm)	*–11 ~ –15 ℃*		*–16 ~ –25 ℃*		*–26 ~ –35 ℃*		*–36 ~ –45 ℃*		*–46 ~ –55 ℃*	
	Mild steel	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*	*Mild steel*	*Higher tensile steel*
t≤10	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
10<t≤20	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*	*–*	*FH*
20<t≤25	*D*	*DH*	*E*	*EH*	*E*	*EH*	*E*	*FH*	*–*	*FH*
25<t≤30	*D*	*DH*	*E*	*EH*	*E*	*EH*	*–*	*FH*	*–*	*FH*
30<t≤35	*E*	*EH*	*E*	*EH*	*–*	*FH*	*–*	*FH*	*–*	*–*
35<t≤40	*E*	*EH*	*E*	*EH*	*–*	*FH*	*–*	*FH*	*–*	*–*
40<t≤50	*E*	*EH*	*–*	*FH*	*–*	*FH*	*–*	*–*	*–*	*–*

Note: "–" in the Table = Not applicable.

CCS 2.4.1e The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

mean: statistical mean over observation period (at least 20 years)

average: average during one day and night

lowest: lowest during year

For seasonally restricted service the lowest value within the period of operation applies. Figure

CCS 2.4.1e illustrates the temperature definition.

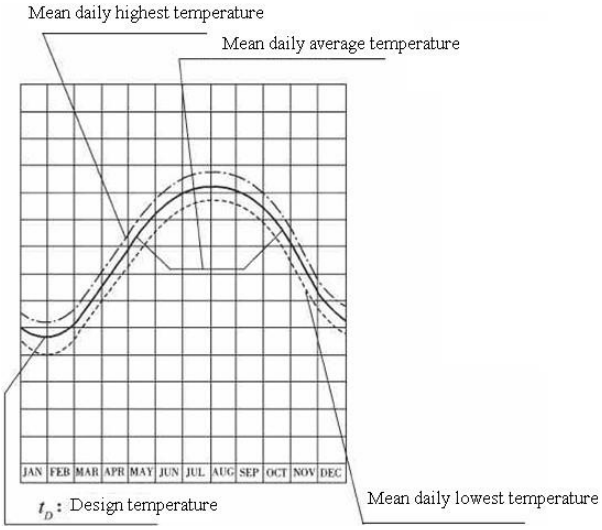


***Figure CCS 2.4.1e Commonly Used Definitions of Temperature*s**

2.5 Through thickness property

2.5.1

Where tee or cruciform connections employ partial or full penetration welds, and the plate material is subject to significant tensile strain in a direction perpendicular to the rolled surfaces, consideration is to be given to the use of special material with specified through thickness properties, in accordance with the Rules for Materials of the Society. These steels are to be designated on the approved plan by the required steel strength grade followed by the letter Z (e.g. EH36Z).

CCS 2.5.1a Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant stress in through-thickness direction, Z-direction steels with full thickness properties are to be used, which are to comply with the requirements of Section 10, Chapter 3, PART ONE of CCS Rules for Materials and Welding.

2.6 Stainless steel

2.6.1

The reduction of strength of stainless steel with increasing temperature is to be taken into account in the calculation of the material factor, *k* and in the material Young's modulus, *E*.

Stainless steels are considered by the Society on a case-by-case basis.

CCS 2.6.1a The material Young's modulus, E, the material factor, k, and minimum yield stress, R_{eH}, are to comply with the requirements respectively, for elastic modulus specified in [1.3.6.2] and for material factor K and minimum yield strength Re_{HT} specified in [1.3.6.3], Section 3, Chapter 1, Part 2 of CCS Rules for Classification of Sea-Going Steel Ships.

3 STEELS FOR FORGING AND CASTING

3.1 General

3.1.1

Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of the Rules for Materials of the Society.

CCS 3.1.1a Mechanical properties and chemical composition of steel forgings and castings to be used for structural members are to comply with the requirements of Section 2, Chapter 5 and Section 2, Chapter 6 of PART ONE of CCS Rules for Materials and Welding.

3.1.2
Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by the Society on a case-by-case basis.

CCS 3.1.2a Steels of structural members intended to be welded are to comply with the applicable requirements of Section 2, Chapter 5 and Section 2, Chapter 6 of PART ONE of CCS Rules for Materials and Welding.

3.1.3
The steels used are to be tested in accordance with the applicable requirements of the Rules for Materials of the Society.

CCS 3.1.3a The steel forgings and castings used are to be tested in accordance with the applicable requirements of 5.1.5, Section 1, Chapter 5 and 6.1.6, Section 1, Chapter 6 of PART ONE of CCS Rules for Materials and Welding.

3.2 Steels for forging
3.2.1
Rolled bars may be accepted in lieu of forged products, after consideration by the Society on a case-by-case basis. In such case, compliance with the applicable requirements of the Rules for Materials of the Society, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

CCS 3.2.1a Rolled bars in general may not be accepted in lieu of steel forgings for primary hull structures (e.g. rudder stock). Where they are used for those other than primary structural members, they are to be subject to the agreement of CCS. In this case, the quality and testing are to comply with relevant requirements for forgings in Chapter 5, PART ONE of CCS Rules for Materials and Welding.

3.3 Steels for casting
3.3.1
Cast parts intended for stems and stern frames in general may be made of C and C-Mn weldable steels, having specified minimum tensile strength, R_m=400N/mm^2, in accordance with the applicable requirements of the Society's Rules for Materials.

CCS 3.3.1a Steel castings intended for stems, stern frames, rudders, parts of steering gear and deck machinery are to comply with the requirements for carbon and carbon-manganese weldable steels having minimum tensile strength, R_m= 400 N/mm^2, specified in Section 2, Chapter 6, PART ONE of CCS Rules for Materials and Welding.

3.3.2
The welding of cast parts to main plating contributing to hull strength members is considered by the Society on a case-by-case basis.

The Society may require additional properties and tests for such casting, in particular impact properties which are appropriate to those of the steel plating on which the cast parts are to be welded and non-destructive examinations.

CCS 3.3.2a For the welding of steel castings to main plating contributing to hull strength members, the technological measures such as preheating temperature and post-weld heat treatment are to be determined in accordance with the carbon equivalent and structural rigidness, subject to the agreement of CCS.
The impact properties and non-destructive examinations of steel castings for primary hull structures are to comply with the respective requirements of 6.2.4.3, Section 2 and 6.1.8, Section 1, Chapter 6, PART ONE of CCS Rules for Materials and Welding.

4 ALUMINIUM ALLOYS

4.1 General

4.1.1

The use of aluminium alloys in superstructures, deckhouses, hatch covers, helicopter platforms, or other local components is to be specially considered. A specification of the proposed alloys and their proposed method of fabrication is to be submitted for approval.

Material requirements and scantlings are to comply with the Rules for Materials of the Society. Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are to be used.

CCS 4.1.1a Aluminium alloys are to comply with the requirements of Chapter 8, PART ONE of CCS Rules for Materials and Welding.

4.1.2

In the case of structures subjected to low service temperatures or intended for other specific applications, the alloys to be employed are to be agreed by the Society.

CCS 4.1.2a When the design temperature of aluminium alloy structures for low temperature service is lower than -55℃, 5083 aluminium alloys in annealed condition are to be used.

4.1.3

Unless otherwise agreed, the Young's modulus for aluminium alloys is equal to 70,000 N/mm^2 and the Poisson's ratio equal to 0.33.

4.1.4

Details of the proposed method of joining any aluminium and steel structures are to be submitted for approval.

4.2 Extruded plating

4.2.1

Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

4.2.2

In general, the application of extruded plating is limited to decks, bulkheads, superstructures and deckhouses. Other uses may be permitted by the Society on a case-by-case basis.

CCS 4.2.2a In general, the application of extruded plating is limited to decks, bulkheads, superstructures and deckhouses. For other uses, equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2 of the Rules.

4.2.3

Extruded plating is to be oriented so that the stiffeners are parallel to the direction of main stresses.

4.2.4

Connections between extruded plating and primary members are to be given special attention.

4.3 Mechanical properties of weld joints

4.3.1

Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition O or H111) or by heat treatment (series 6000).

4.3.2

The as-welded properties of aluminium alloys of series 5000 are in general those of condition O or H111. Higher mechanical characteristics may be considered, provided they are duly justified.

4.3.3

The as-welded properties of aluminium alloys of series 6000 are to be agreed by the Society.

CCS 4.3.3a The as-welded properties of aluminium alloys of series 6000 are to comply with the requirements of 3.2.6.1, Section 2, Chapter 3, PART THREE of CCS Rules for Materials and Welding.

4.4 Material factor, *k*

4.4.1

The material factor, *k* for aluminium alloys is to be obtained from the following formula:

$$k = \frac{235}{R'_{\lim}}$$

where:

R'_{lim} : Minimum guaranteed yield stress of the parent metal in welded condition $R'_{p0.2}$, in N/mm^2, but not to be taken greater than 70% of the minimum guaranteed tensile strength of the parent metal in welded condition R'_m, in N/mm^2.

$R'_{p0.2}$: Minimum guaranteed yield stress, in N/mm^2, of material in welded condition.
$R'_{p0.2} = \eta_1 R_{p0.2}$

R'_m : Minimum guaranteed tensile strength, in N/mm^2, of material in welded condition.
$R'_m = \eta_2 R_m$

$R_{p0.2}$: Minimum guaranteed yield stress, in N/mm^2, of the parent metal in delivery condition.

R_m : Minimum guaranteed tensile strength, in N/mm^2, of the parent metal in delivery condition.

η_1, η_2 : Specified in Table 8.

Aluminium alloys - Coefficients for welded construction **Table 8**

Aluminium alloy	η_1	η_2
Alloys without work-hardening treatment (series 5000 in annealed condition O or annealed flattened condition H111)	1	1
Alloys hardened by work hardening (series 5000 other than condition O or H111)	$R'_{p0.2}/R_{p0.2}$	R'_m/R_m
Alloys hardened by heat treatment (series 6000) (1)	$R'_{p0.2}/R_{p0.2}$	0.6
(1) When no information is available, coefficient η_1, is to be taken equal to the metallurgical efficiency coefficient β as defined in Table 9.		

Aluminium alloys - Metallurgical efficiency coefficient **Table 9**

Aluminium alloy	Temper condition	As-built thickness, in mm	β
6005A(Open sections）	T5 or T6	$t \leqslant 6$	0.45
		$t > 6$	0.40
6005A(Closed sections）	T5 or T6	All	0.50
6061（Sections）	T6	All	0.53
6082（Sections）	T6	All	0.45

4.4.2

In the case of welding of two different aluminium alloys, the material factor, *k* to be considered for the scantlings is the greater material factor of the aluminium alloys of the assembly.

4.5 Others

4.5.1

Aluminium fittings in tanks used for the carriage of oil, and in cofferdams and pump rooms are to be avoided. Where fitted, aluminium fittings, units and supports, in tanks used for the carriage of oil, cofferdams and pump rooms are to satisfy the requirements of Pt 2, Ch2, Sec 2, [1.2] for aluminium anodes.

4.5.2
The underside of heavy portable aluminium structures such as gangways, is to be protected by means of a hard plastic or wood cover, or other approved means, in order to avoid the creation of smears. Such protection is to be permanently and securely attached to the structures.

5 OTHER MATERIALS AND PRODUCTS

5.1 General

5.1.1
Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are to comply with the applicable requirements of the Rules for Materials of the Society.

CCS 5.1.1a Other materials and products such as parts made of iron castings, products made of copper alloys, rivets, anchors, chain cables and wire ropes are in general to comply with the applicable requirements of Chapters 7 to 10 of PART ONE of CCS Rules for Materials and Welding.

CCS 5.1.1b The materials of cranes, masts, derrick posts, derricks and accessories are to be selected based on factors such as design temperatures, plate thickness and type of cranes in accordance with the requirements of Chapter 6 of CCS Rules for Lifting Appliances of Ships and Offshore Installations.

5.1.2
The use of plastics or other special materials not covered by these Rules is to be considered by the Society on a case-by-case basis. In such cases, the requirements for the acceptance of the materials concerned are to be agreed by the Society.

CCS 5.1.2a Plastics and other non-metallic materials are to comply with the requirements of PART TWO of CCS Rules for Materials and Welding.

5.2 Iron cast parts

5.2.1
As a rule, the use of grey iron, malleable iron or spheroidal graphite iron cast parts with combined ferritic/perlitic structure is allowed only to manufacture low stressed elements of secondary importance.

5.2.2
Ordinary iron cast parts may not be used for windows or sidescuttles; the use of high grade iron cast parts of a suitable type is to be considered by the Society on a case-by-case basis.

CCS 5.2.2a Iron castings are in general not be used for windows or sidescuttles. Iron castings not less than 300 N/mm^2 in specified minimum tensile strength and not less than 15% in specified minimum elongation may be used subject to the agreement of CCS.

Section 2 NET SCANTLING APPROACH

SYMBOLS

For symbols not defined in this section, refer to Ch1, Sec 4

t : Net thickness in mm.

t_c : Corrosion addition in mm.

t_{gr} : Gross thickness in mm.

h_{stf} : Height of stiffener or primary supporting member in mm.

h_w : Web height of stiffener or primary supporting member in mm.

t_w : Web thickness of stiffener or primary supporting member in mm.

b_f : Face plate width of stiffener or primary supporting member in mm.

t_f : Face plate thickness of stiffener or primary supporting member in mm.

t_p : Thickness of the plating attached to a stiffener or to a primary supporting member in mm.

d_f : Distance in mm, for the extension of flange for L2 profiles, see Figure 3.

t_{as_built} : As-built thickness, in mm, taken as the actual thickness provided at the newbuilding stage.

t_{gr_off} : Gross offered thickness, in mm, as defined in [1.2.2].

t_{gr_req} : Gross required thickness, in mm, as defined in [1.2.1].

t_{off} : Net offered thickness, in mm, as defined in [1.2.3].

t_{dm} : Design production margin, in mm, taken as the thickness difference between offered gross thickness and required gross thickness (equal also to the difference between offered net and required net thickness) as a result of scantlings applied by the designer or builder to suit design or production situation. This difference in thickness is not to be considered as an additional corrosion margin.

t_{req} : Net required thickness, in mm, as required in [1.3.1].

t_{vol_add} : Thickness for voluntary addition, in mm, taken as the thickness voluntarily added as the owner's extra margin or builder's extra margin for corrosion wastage in addition to t_c.

t_{res} : Reserve thickness, in mm, taken equal to 0.5 mm.

t_{c1}, t_{c2} : Corrosion addition on one side of the considered structural member, in mm, as defined in Ch3, Sec 3, Table 1.

1 GENERAL

1.1 Application

1.1.1 Net thickness approach

The net thickness, t, of a structural element is required for structural strength in compliance with the design basis. The corrosion addition, t_c, for a structural element is derived independently from the net scantling requirements as shown in Figure 1. This approach clearly separates the net thickness from the thickness added to address the corrosion that is likely to occur during the ship-in-operation phase. This approach enables the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the ship.

1.1.2 Local and global corrosion

The net thickness approach distinguishes between local and global corrosion. Local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener. Global corrosion is defined as the average corrosion of larger areas, such as primary supporting members and the hull girder.

1.1.3 Exceptions in gross scantling

Items that are directly determined in terms of gross scantlings do not follow the net scantling approach, i.e. they already include additions for corrosion but without any owner's extra margin. Gross scantling requirements are identified with the suffix "gr" and examples are:

- Scantlings of superstructures and deckhouses as given in Ch11, Sec 1.
- Scantlings of massive pieces made of steel forgings and steel castings.

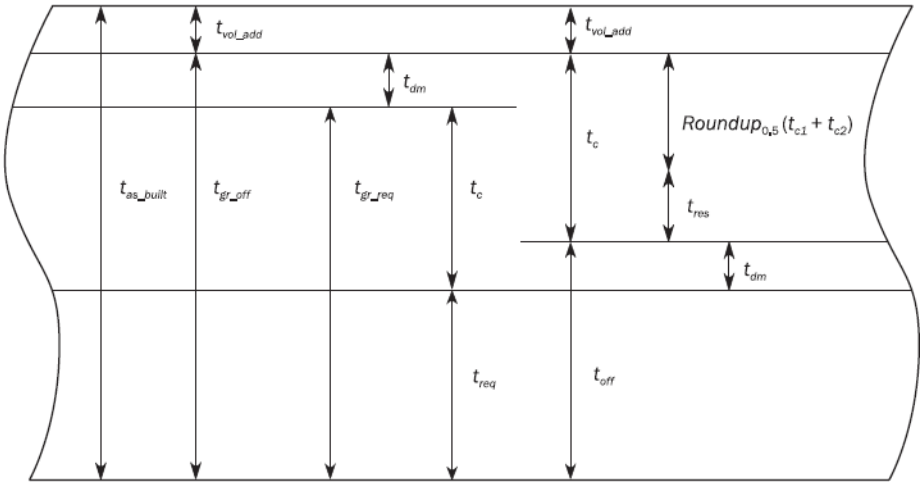


Figure1 Net scantling approach scheme

1.2 Gross and net scantling definitions

1.2.1 Gross required thickness

The gross required thickness, t_{gr_req}, is the thickness obtained by adding the corrosion addition as defined in Ch3, Sec 3 to the net required thickness, as follows:

$t_{gr_req} = t_{req} + t_c$

1.2.2 Gross offered thickness

The gross offered thickness, t_{gr_off}, is the gross thickness provided at the newbuilding stage, which is obtained by deducting any thickness for voluntary addition from the as-built thickness, as follows:

$t_{gr_off} = t_{as_built} - t_{vol_add}$

1.2.3 Net offered thickness

The net offered thickness, t_{off}, is obtained by subtracting the corrosion addition from the gross offered thickness, as follows:

$t_{off} = t_{gr_off} - t_c = t_{as_built} - t_{vol_add} - t_c$

1.3 Scantling compliance

1.3.1

The net required thickness, t_{req}, is obtained by rounding the net thickness calculated according to the Rules to the nearest half millimetre. For example:

- For $10.75 \leqslant t < 11.25$ mm, the Rule required net thickness is 11.0 mm.
- For $11.25 \leqslant t < 11.75$ mm, the Rule required net thickness is 11.5 mm.

1.3.2

Scantling compliance in relation to the Rules is as follow:

- The net offered thickness of plating is to be equal to or greater than the net required thickness of plating.
- The required net section modulus, moment of inertia and shear area properties of local supporting members are to be calculated using the net thickness of the attached plate, web and flange. The net sectional dimensions of local supporting members are defined in Figure 2. The required section modulus and web net thickness apply to areas clear of the end brackets.
- The offered net sectional properties of primary supporting members and the hull girder are to be equal to or greater than the required net sectional properties which are to be based on the gross offered scantling with a reduction of the applicable corrosion addition, as specified in Table 1, applied to all component structural members.
- The strength assessment methods prescribed are to be assessed by applying the corrosion reduction specified in Table 1 to the offered gross scantlings. Half of the applied corrosion addition specified in Table 1 is to be deducted from both sides of the

structural members being considered.

- Corrosion additions are not to be taken less than those given in Ch3, Sec 3, [1.2].

Any additional thickness specified by the owner or the builder is not to be included when considering the compliance with the Rules.

The net cross-sectional area, the moment of inertia about the y-axis and the associated neutral axis position are to be determined applying a corrosion magnitude of 0.5 t_c deducted from the surface of the profile cross- section.

Assessment for corrosion applied to the gross scantlings Table1

Structural requirement	Property/analysis type	Applied corrosion addition
Minimum thickness (all members including PSM)	Thickness	t_c
Local strength (plates, stiffeners, and hold frames)	Thickness/sectional properties	t_c
	Stiffness / proportions /Buckling capacity	t_c
Primary supporting members (prescriptive)	Sectional properties	$0.5t_c$
	Stiffness/proportions of web and flange Buckling capacity	t_c
Strength assessment by FEM	Cargo tank/cargo hold	$0.5t_c$
	Buckling capacity	t_c
	Local fine mesh	$0.5t_c$
	Specified fine mesh areas	$0.5t_c$
Hull girder strength	Sectional properties	$0.5t_c$
	Buckling capacity	t_c
Hull girder ultimate strength Hull girder residual strength	Sectional properties	$0.5t_c$
	Buckling/collapse capacity	$0.5t_c$
Fatigue assessment (simplified stress analysis)	Hull girder section properties Local support member	$0.5t_c$
Fatigue assessment (FE Stress analysis)	Coarse mesh FE model Very fine mesh portion	$0.5t_c$

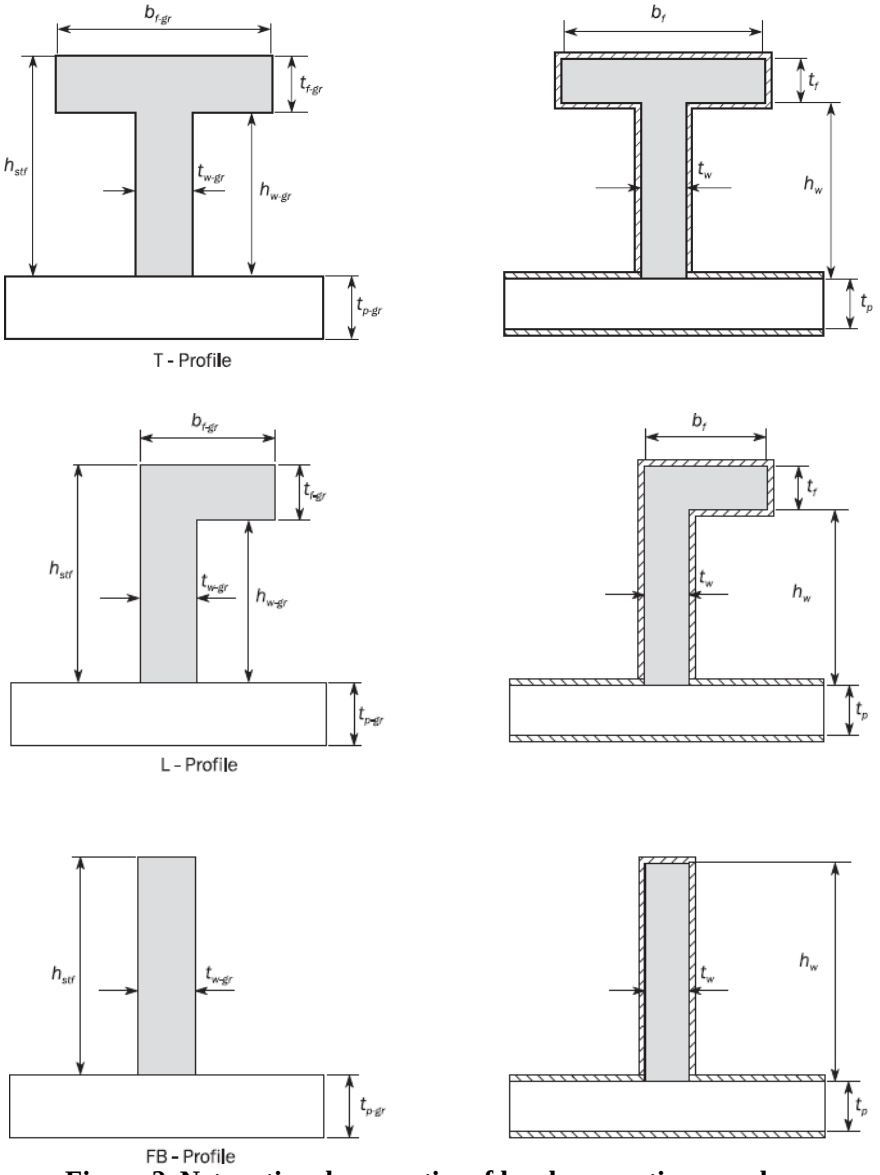


Figure 2 Net sectional properties of local supporting members

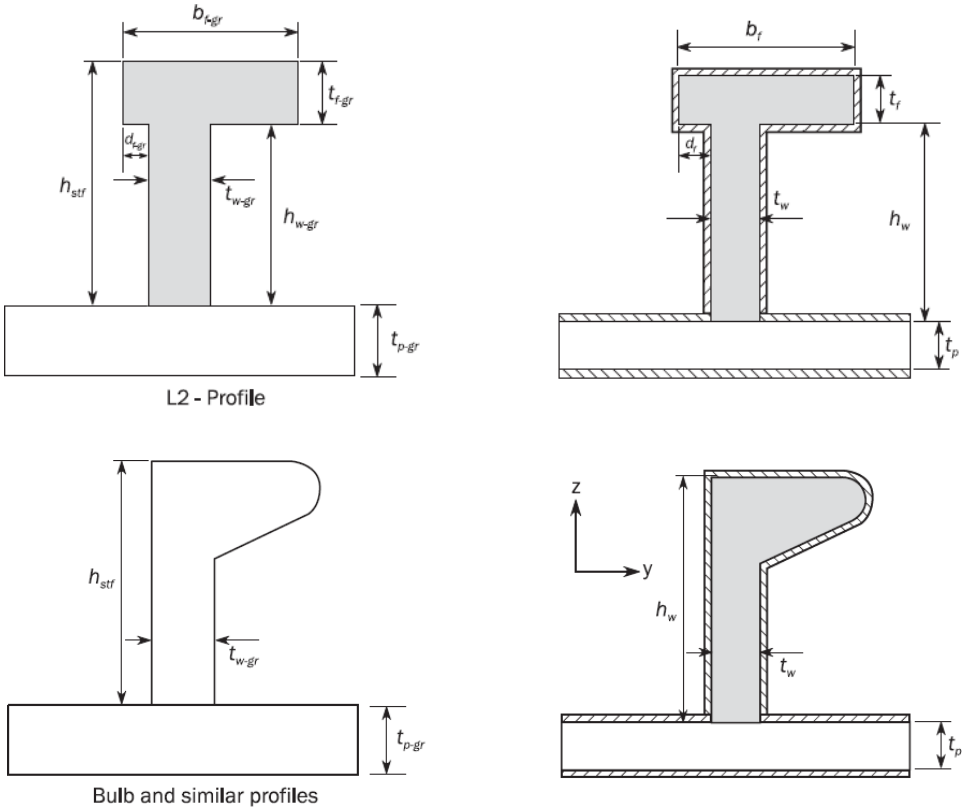


Figure 3 Net sectional properties of local supporting members (continued)

Section 3 CORROSION ADDITIONS

SYMBOLS

t_c : Corrosion addition, in mm.

t_{c1}, t_{c2} : Corrosion addition, in mm, on one side of the considered structural member, as defined in Table 1.

t_{res} : Reserve thickness, taken as 0.5 mm.

1 GENERAL

1.1 Applicability

1.1.1

The corrosion additions given in these Rules are applicable to carbon-manganese steels, stainless steels, stainless clad steels and aluminium alloys. Corrosion addition for the exposed carbon steel side of stainless clad structure is to be as required in Table 1 for the corresponding compartment.

The corrosion additions for other materials are to be in accordance with the requirements of the Society.

CCS 1.1.1a Where other materials are used, the corrosion additions of materials are to be determined in accordance with the submitted corrosion resistance information of materials. Such information is to include testing and/or historic data demonstrating that corrosion additions meet the design life of 25 years and is subject to the agreement of CCS.

1.2 Corrosion addition determination

1.2.1

The corrosion addition for each of the two sides of a structural member, t_{c1} or t_{c2}, is specified in Table 1.

The total corrosion addition, *tc*, in mm, for both sides of the structural member is obtained by the following formula:

$t_c = Roundup_{0.5}(t_{c1} + t_{c2}) + t_{res}$

For an internal member within a given compartment, the total corrosion addition, *tc* is obtained from the following formula:

$t_c = Roundup_{0.5} (2t_{c1}) + t_{res}$

where t_{c1} is the value specified in Table 1 for one side exposure to that compartment.

$Roundup_{0.5}$ (t) means that *t* is rounded to the upper half millimetre.

The total corrosion addition, t_c, in mm, for compartment boundaries and internal members made from stainless steel, or aluminium is to be taken as:

$t_c = t_{res} = 0.5$

In case of stainless clad steel, the corrosion additions, t_{c1}, for the carbon steel side and t_{c2}, for the stainless steel side are respectively to be taken as:

- t_{c1} as specified for the corresponding compartment in Table 1
- $t_{c2} = 0$

1.2.2 Minimum value of total corrosion addition

The total corrosion addition is not to be taken less than 2 mm except for web and face plate of stiffeners or in way of internals of dry spaces where 1.5 mm is applicable.

These minimum values of corrosion addition are not applicable to structural members made of stainless steels, stainless clad steels or aluminium alloys.

1.2.3 Stiffener

The corrosion addition of a stiffener is determined according to the location of its connection to the attached plating.

1.2.4

When a local structural member/plate is affected by more than one value of corrosion addition, the most onerous value is to be applied to the entire strake.

However, for the vertical corrugations arranged by vertical seams in oil tankers, the actual corrosion additions above and below the line 3m below top of tank (as defined in Table 1) can be used for the parts above and below the line, respectively.

Corrosion addition for one side of a structural member **Table1**

Compartment type	Structural member		t_{c1} or t_{c2}		
			Oil tankers	BC-A or BC-B ships with $L_{LL} \geqslant 150$ m	Other BC ships
Ballast water tank, bilge tank, drain storage tank, chain locker (1)	Face plate of PSM	Within 3m below top of tank (4)	2.0		
		Elsewhere	1.5		
	Other members (2) (3)	Within 3m below top of tank (4)	1.7		
		Elsewhere	1.2		
Cargo oil tank, slop tank	Face plate of PSM	Within 3m below top of tank (4)	1.7	N/A	
		Elsewhere	1.4		
	Inner-bottom plating/bottom of tank		2.1		
	Other members	Within 3m below top of tank (4)	1.7		
		Elsewhere	1.0		
Dry bulk cargo hold (5)	Transverse bulkhead	Upper part (6)	N/A	2.4	1.0
		Lower stool: sloping plate, vertical plate and top plate (7)		5.2	2.6
		Other parts		3.0	1.5
	Sloped plating of hopper tank, inner bottom plating			3.7	2.4
	Other members	Upper part (6)		1.8	1.0
		Webs and flanges of the upper end brackets of side frames of single side bulk carriers			
		Webs and flanges of lower brackets of side frames of single side bulk carriers		2.2	1.2
		Other parts		2.0	1.2
Exposed to atmosphere	Weather deck plating		1.7		
	Other members		1.0		
Exposed to seawater	Shell plating between the minimum design ballast draught waterline and the scantling draught waterline		1.5		
	Shell plating elsewhere		1.0		
Fuel and lube oil tank			0.7		
Fresh water tank			0.7		
Void spaces (8)	Spaces not normally accessed, e.g. access only via bolted manhole openings, pipe tunnels, inner surface of stool space not common with a dry bulk cargo hold or ballast cargo hold, etc.		0.7		
Dry spaces	Internals of machinery spaces, pump room, store rooms, steering gear space, etc.		0.5		

Compartment type	Structural member	t_{c1} or t_{c2}		
		Oil tankers	BC-A or BC-B ships with $L_{LL} \geqslant 150$ m	Other BC ships

(1) 1.0 mm is to be added to the plate surface within 3m above the upper surface of the chain locker bottom.
(2) 0.5 mm is to be added to the plate surface exposed to ballast for the plate boundary between water ballast and heated cargo oil tanks/slop tanks. 0.3mm is to be added to each surface of the web and face plate of a stiffener in a ballast tank and attached to the boundary between water ballast and heated cargo oil tanks or heated fuel/lube oil tanks/slop tanks. Heated oil tanks are defined as tanks/slop tanks arranged with any form of heating capability (the most common type is heating coils).
(3) 0.7 mm is to be added to the plate surface exposed to ballast for the plate boundary between water ballast and heated fuel oil or lube oil tanks.
(4) Only applicable to cargo tanks/slop tanks and ballast tanks with weather deck as the tank top. The 3 m distance is measured vertically from and parallel to the top of the tank.
(5) Dry bulk cargo hold includes holds intended for the carriage of dry bulk cargoes, which may carry water ballast.
(6) Upper part of the cargo holds correspond to an area above the connection between the topside and the inner hull or side shell.
If there is no topside, the upper part corresponds to the upper one third of the cargo hold height (where a plane bulkhead is fitted in way of a dry bulk cargo hold, the upper part of the bulkhead is defined in the same manner).
(7) If there is no lower stool fitted (i.e. engine room bulkhead or fore peak bulkhead) or if a plane bulkhead is fitted, then this corrosion addition should be applied up to a height level with the opposing bulkhead stool in that hold. In the case where a stool is not fitted on the opposing bulkhead, the vertical extent of this zone is to be from the inner bottom to a height level with the top of the adjacent hopper sloping plate, but need not be taken as more than 3 m.
(8) For the determination of the corrosion addition of the outer shell plating, the pipe tunnel is considered as for a water ballast tank.

Section 4 CORROSION PROTECTION

1 GENERAL

1.1 Structures to be protected

1.1.1 Dedicated seawater ballast tanks

All dedicated seawater ballast tanks are to have an efficient corrosion prevention system.

CCS 1.1.1a Dedicated seawater ballast tanks of all types of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards are to comply with the requirements of IMO SOLAS Regulation II-1/3-2 and to be coated during construction in accordance with the Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers (PSPC-WBT).

1.1.2 Cargo oil tanks

Cargo oil tanks are to be protected in compliance with the requirements specified in Pt 2, Ch2, Sec 2, [1].

CCS 1.1.2a Cargo oil tanks of crude oil tankers of 5,000 tons deadweight and above are to comply with the requirements of IMO SOLAS Regulation II-1/3-11 and to be coated during construction in accordance with the Performance standard for protective coatings for cargo oil tanks of crude oil tankers (PSPC-COT) or protected by alternative means of corrosion protection or utilization of corrosion resistance material to maintain required structural integrity for 25 years in accordance with the Performance standard for alternative means of corrosion protection for cargo oil tanks of crude oil tankers.

1.1.3 Bulk carriers

Void double side skin spaces and cargo holds of bulk carriers are to be protected in compliance with the requirements specified respectively in Pt 2, Ch1, Sec 2, [2.2] and Pt 2, Ch1, Sec 2, [2.3].

1.1.4 Narrow spaces

Narrow spaces are generally to be filled by an efficient protective product, particularly at the ends of the ship where inspections and maintenance are not easily practicable due to their inaccessibility.

2 SACRIFICIAL ANODES

2.1 Attachment of anodes to the hull

2.1.1

All anodes are to be attached to the structure in such a way that they remain securely fastened both initially and during service even when it is wasted. The following methods are acceptable:

a) Steel core connected to the structure by continuous fillet welds.
b) Attachment to separate supports by bolting, provided a minimum of two bolts with lock nuts are used. However, other mechanical means of clamping may be accepted.

2.1.2

Anodes are to be attached to stiffeners or aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.1.3

Where cores or supports are welded to local support members or primary supporting members, they are to be kept clear of end supports, toes of brackets and similar stress raisers. Where they are welded to asymmetrical members, the welding is to be at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate, but well clear of the free edges. Generally, anodes are not to be fitted to a face plate of higher strength steel.

2.1.4 Cargo oil tanks

Cathodic protection systems, if fitted in cargo oil tanks, are to comply the requirements specified Pt 2, Ch2, Sec 2, [1].

Section 5 LIMIT STATES

1 GENERAL

1.1 Limit states

1.1.1 Definition

A limit state is defined as a state beyond which the structure no longer satisfies the requirements. The following categories of limit states are relevant for structures:

- Serviceability limit state (SLS), which corresponds to conditions beyond which specified requirements are no longer met.
- Ultimate limit state (ULS), which corresponds to the maximum load carrying-capacity or, in some cases, to the maximum applicable strain or deformation, under intact (undamaged) conditions.
- Fatigue limit state (FLS), which corresponds to degradation due to effect of time varying (cyclic) loading.
- Accidental limit state (ALS), which concerns the ability of the structure to resist accident situations.

1.1.2 Serviceability limit state

Serviceability limit state, which concerns the normal use, includes:

- Local damage which may reduce the working life of the structure or affect the efficiency or appearance of structural members or non-structural elements.
- Unacceptable deformations which affect the efficient use and appearance of structural or non- structural elements or the functioning of safety equipment.

In the context of serviceability limit state, the term ‘appearance’ is concerned with such criteria as high deflection and extensive cracking, rather than aesthetics.

1.1.3 Ultimate limit state

Ultimate limit state, which corresponds to the maximum load-carrying capacity, or in some cases, the maximum applicable strain or deformation, includes:

- Attainment of the maximum resistance capacity of sections, members or connections by rupture or excessive deformations or instability (buckling).
- Excessive yielding, transforming the structure or part of it into a plastic mechanism.

1.1.4 Fatigue limit state

Fatigue limit states assess that the fatigue capacity of structural members due to cyclic loads is greater than the design fatigue life.

1.1.5 Accidental limit state

Accidental limit states are concerned with the ability of the structure to resist accident situations or abnormal events. Flooded conditions of any compartment without progression of the flooding to another compartment are considered. The limit states are concerned with the following in intact (undamaged) conditions with accidental or abnormal loads, or in damaged conditions with environmental loads the ship meets during a limited time frame:

- The safety of life.
- Environment.
- Property (ship and cargo).

Accidental limit state includes:

- Loss of structural strength without loss of containment.
- Loss of structural strength and loss of containment.

1.2 Failure modes

1.2.1

A number of possible failure modes may be relevant for the various parts of the ship structure. For each failure mode, one or more limit states may be relevant. The failure modes to be considered for the assessment of ship structural safety with relation to the limit states are shown in Table 1.

Failure modes in relation to the limit states to be considered **Table1**

Possible failure modes to be considered	Limit states(1)			
	SLS	ULS	FLS	ALS
Yielding	Y	Y	-	Y
Plastic collapse	-	Y	-	Y
Buckling	Y	Y	-	Y
Rupture	-	Y	-	Y
Fatigue cracking	-	-	Y	-
Brittle fracture (2)	-	-	-	-

(1) "Y" indicates that the structural assessment is to be carried out.
(2) Controlled by the material rule requirement of steel grade.

1.2.2 Yielding
The yielding failure mode is the mode in which plastic strain locally occurs in the structural members to be considered under combined in-plane and normal stresses. Local plastic strain is controlled in SLS, ULS and ALS by checking that the stresses caused in the structural members remains below a permissible value.

1.2.3 Plastic collapse
The plastic collapse failure mode usually appears in the local structural members under large lateral impact pressure. In this failure mode, permanent lateral deflection in the local structural members occurs, but does not influence the global strength. This mode is controlled in ULS and ALS by using conventional plastic design method.

1.2.4 Buckling
The buckling failure mode is the instability phenomena of structural members under compressive loads. When the stress in structural members just attains the elastic buckling stress, elastic (reversible) buckling occurs during the compressive load. This buckling failure mode is controlled in SLS. By further increasing the compressive load, stress redistribution occurs due to buckling of the weakest structural member and the stress in some structural members reaches the yield stress. This buckling failure mode with large elastic deflection is controlled in ULS or ALS. When compression is unloaded, no consequence of failure due to buckling is seen.

On the other hand, plastic (irreversible) buckling occurs when the stress in structural members exceeds the yield stress. As a result, the substantial permanent deflections due to plastic buckling appear. This irreversible buckling failure mode is controlled only in ULS or ALS for global hull girder strength.

1.2.5 Rupture
The rupture failure mode is the mode in which breaking occurs in the structural members to be considered under large tensile stress beyond the yield stress of the material. This failure mode is controlled in ULS or ALS, but the assessment of this failure mode is covered by controlling the yielding failure.

1.2.6 Brittle fracture
Brittle fracture is dependent upon the material, temperature and thickness. Therefore, this mode is controlled by the material rule requirement of steel grade.

1.2.7 Fatigue cracking
This failure mode is different from the failure modes mentioned above and is controlled in FLS.

2 CRITERIA

2.1 General

2.1.1

Criteria are prescribed in the Rules to check the relevant limit states for the various structural elements. The strength assessments included in the Rules are defined in terms of yield check, buckling check, ultimate strength check, and fatigue check as indicated in Table 2.

Structural assessment **Table2**

Structural Elements (1)		Yielding check	Buckling check	Ultimate strength check	Fatigue check
Local Structures	Stiffeners	Y	Y	Y(2)	Y
	Plating	Y	Y	Y(3)	-
Primary supporting members		Y	Y	Y(2)	Y
Hull girder		Y	Y(4)	Y	-

(1) "Y" indicates that the structural assessment is to be carried out.
(2) The ultimate strength check is included in the buckling check.
(3) The ultimate strength check of plating is included in the yielding check formula of plating.
(4) The buckling check of stiffeners and plating taking part in hull girder strength is performed against stress due to hull girder bending moment and hull girder shear force.

2.2 Serviceability limit states

2.2.1 Hull girder

For the yielding check of the hull girder, the stress corresponds to a load at 10^{-8} probability level.

2.2.2 Plating

For the yielding check and buckling check of platings constituting a primary supporting member, the stress corresponds to a load at 10^{-8} probability level.

2.2.3 Stiffeners

For the yielding check of stiffeners, the stress corresponds to a load at 10^{-8} probability level.

2.3 Ultimate limit states

2.3.1 Hull girder

The ultimate strength of the hull girder is to be checked against the hull girder loads at 10^{-8} probability level, amplified with the partial safety factor.

2.3.2 Plating

The ultimate strength of the plating between stiffeners and primary supporting members is to be checked against the loads at 10^{-8} probability level.

2.3.3 Stiffeners

The ultimate strength of stiffeners is to be checked against the loads at 10^{-8} probability level.

2.4 Fatigue limit state

2.4.1 Structural details

The fatigue life of representative welded structural details such as connections of stiffeners and primary supporting members and free edge of bulk carrier deck plating in way of hatch corner is to be assessed from long term distribution loads based on loads at 10^{-2} probability level including the whipping-springing effects.

2.5 Accidental limit state

2.5.1 Hull girder

For bulk carriers, the yielding and ultimate strength of the hull girder in cargo hold flooded condition and in the damaged condition is to be assessed in accordance with Ch 5, Sec 1 and Ch 5, Sec 2.

The residual strength of oil tankers and bulk carriers is to be assessed according to Ch 5, Sec 3, for damages resulting from collision or grounding.

2.5.2 Double bottom structure

For bulk carriers, the double bottom structure in cargo hold flooded condition is to be assessed in accordance with Pt 2, Ch 1, Sec 3.

2.5.3 Bulkhead structure

For bulk carriers, the bulkhead structure in cargo hold flooded condition is to be assessed in accordance with Pt 2, Ch 1, Sec 3 and Pt 2, Ch 1, Sec 4.

2.5.4 Plating, stiffeners and PSM

The plating, stiffeners and PSM are to be assessed in flooded conditions in accordance with Ch 6 for yielding criteria and with Ch 8, Sec 3 for buckling criteria.

3 STRENGTH CHECK AGAINST IMPACT LOADS

3.1 General

3.1.1

Structural response against impact loads such as forward bottom slamming, bow impact and grab chocks depends on the loaded area, magnitude of loads and structural grillage.

3.1.2

The ultimate strength of structural members that constitute the grillagei.e. platings between stiffeners and primary supporting members and stiffeners with attached platingis to be checked against the maximum impact loads acting on them.

Section 6 STRUCTURAL DETAIL PRINCIPLES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

1 APPLICATION

1.1 General

1.1.1

If not specified otherwise, the requirements of this section apply to the hull structure except superstructures and deckhouses.

2 GENERAL PRINCIPLES

2.1 Structural continuity

2.1.1 General

Attention is to be paid to the structural continuity, in particular in the following areas:

- In way of changes in the framing system.
- At end connections of primary supporting members or ordinary stiffeners.
- In way of the transition zones between cargo hold region and fore part, aft part and machinery space.
- In way of side and end bulkheads of superstructures.

At the termination of a structural member, structural continuity is to be maintained by the fitting of suitable supporting structure.

Abrupt changes in transverse section properties of longitudinal members are to be avoided. Smooth transitions are to be provided.

2.1.2 Longitudinal members

Longitudinal members are to be arranged in such a way that continuity of strength is maintained.

Longitudinal members contributing to the hull girder longitudinal strength are to extend continuously as far as practicable towards the ends of the ship.

In particular, the structural continuity in way of longitudinal bulkheads within the cargo hold region, is to be maintained outside the cargo hold region. Large transition brackets (e.g. scarfing brackets) fitted in line with the longitudinal bulkhead are a possible means to achieve such structural continuity.

2.1.3 Primary supporting members

Primary supporting members are to be arranged in such a way that continuity of strength is maintained. Abrupt changes of web height or cross section are to be avoided.

2.1.4 Stiffeners

Stiffeners are to be arranged in such a way that continuity of strength is maintained.

Stiffeners contributing to the hull girder longitudinal strength are to be continuous when crossing primary supporting members within the 0.4L amidships and as far as practicable outside 0.4L amidships.

Where stiffeners are terminated in way of large openings, foundations and partial girders, compensation is to be arranged to provide structural continuity in way of the end connection.

2.1.5 Plating

Where plates with different thicknesses are joined, the change in the as-built plate thickness is not to exceed 50% of larger plate thickness in the load carrying direction. This also applies to the strengthening by local inserts, e.g. insert plates in double bottom girders, floors and inner bottom.

2.1.6 Weld joints

Weld joints are to be avoided in areas with high stress concentration.

2.2 Local reinforcements

2.2.1 Reinforcements at knuckles

a) Knuckles are in general to be stiffened to achieve out-of-plane stiffness by fitting ordinary stiffeners or equivalent means in line with the knuckle.

b) Whenever a knuckle in a main member (shell, longitudinal bulkhead etc) is arranged, stiffening in the form of webs, brackets or profiles is to be connected to the members to which they are to transfer the load (in shear). See example of reinforcement at upper hopper knuckle in Figure 1.

c) For longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high in-plane loads across the knuckle, such as deck camber knuckles.

d) Generally, the distance between the knuckle and the support stiffening in line with the knuckle is not to be greater than 50 mm. Otherwise, fatigue analysis according to Ch 9 is to be submitted by the designer.

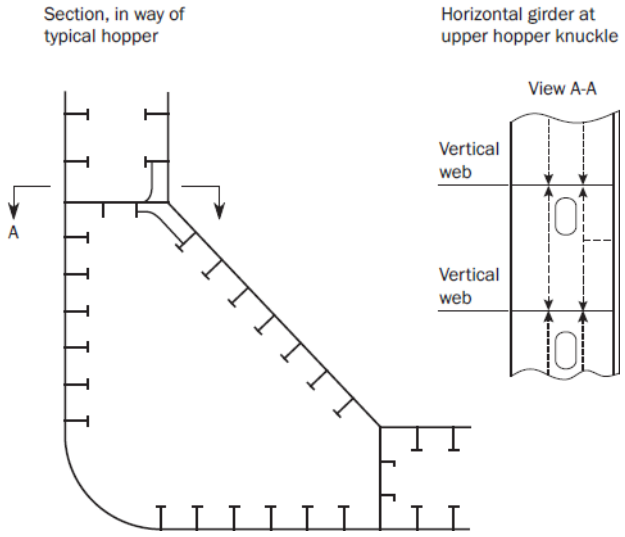


Figure 1 Example of reinforcement at knuckles

2.2.2 Reinforcement in way of attachments for permanent means of access

Local reinforcement, considering location and strength, is to be provided in way of attachments to the hull structure for permanent means of access.

2.2.3 Reinforcement of deck structure in way of concentrated loads

The deck structure is to be reinforced in way of concentrated loads, such as anchor windlass, deck machinery, cranes, masts and derrick posts.

2.2.4 Reinforcement by insert plates

Insert plates are to be made of materials with, at least, the same specified minimum yield stress and the same grade as the plates to which they are welded. See also [2.1.5].

2.3 Connection of longitudinal members not contributing to the hull girder longitudinal strength

2.3.1

Where the hull girder stress at the strength deck or at the bottom as defined in Ch 5, Sec 1, [2.2.2] is higher than the permissible stress as defined in Ch 5, Sec 1, [2.2.1] for normal strength steel, longitudinal members not contributing to the hull girder longitudinal strength and welded to the strength deck or bottom plating and bilge plating, such as longitudinal hatch coamings, gutter bars, strengthening of deck openings, bilge keel, are to be made of steel with the same specified

minimum yield stress as the strength deck or bottom structure steel.

2.3.2
The requirement in [2.3.1] is also applicable to non-continuous longitudinal stiffeners welded on the web of a primary structural member contributing to the hull girder longitudinal strength such as hatch coamings, stringers and girders or on the inner bottom when the hull girder stress on those members is higher than the permissible stress as defined in Ch 5, Sec 1, [2.2.1] for normal strength steel.

3 STIFFENERS

3.1 General

3.1.1
All types of stiffeners (excluding web stiffeners) are to be connected at their ends. However, in special cases such as isolated areas of the ship where end connections cannot be applied, sniped ends may be permitted. Requirements for the various types of connections (bracketed, bracketless or sniped ends) are given in [3.2] to [3.4].

3.1.2
Where the angle between the web plate of the stiffener and the attached plating is less than 50 deg as shown on Figure 2, a tripping bracket is to be fitted. If the angle between the web plate of an unsymmetrical stiffener and the attached plating is less than 50 deg, the face plate of the stiffener is to be fitted on the side of open angle.

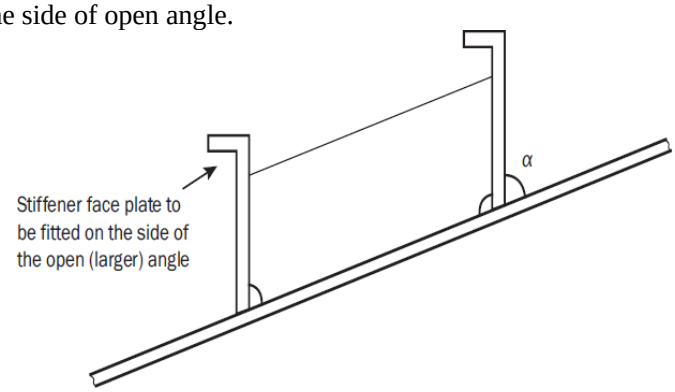


Figure 2 Stiffener on attached plating with an angle less than 50 deg

3.2 Bracketed end connections of non-continuous stiffeners

3.2.1
Where continuity of strength of longitudinal members is provided by brackets, the alignment of the brackets on each side of the primary supporting member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross sectional area are not less than those of the member.

3.2.2
At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member.

3.2.3
The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection, is the section modulus to be less than that required for the stiffener.

3.2.4 Net web thickness
The net bracket web thickness, t_b, in mm, is to comply with the following:

$t_b \geq (2 + f_{bkt}\sqrt{Z})\sqrt{\frac{R_{eH-stf}}{R_{eH-bkt}}}$ and need not be greater than 13.5 mm.

where:
f_{bkt} : Coefficient taken as:

f_{bkt} = 0.2 for brackets with flange or edge stiffener.

f_{bkt} = 0.3 for brackets without flange or edge stiffener.

Z : Net required section modulus, of the stiffener, in cm*3*. In the case of two stiffeners connected, Z is the smallest net required section modulus of the two connected stiffeners.

$R_{eH\text{-}stf}$: Specified minimum yield stress of the stiffener material, in N/mm^2.

$R_{eH\text{-}bkt}$: Specified minimum yield stress of the bracket material, in N/mm^2.

3.2.5 Brackets at the ends of non-continuous stiffeners

Brackets are to be fitted at the ends of non-continuous stiffeners, with arm lengths, l_{bkt}, in mm, taken as:

$$l_{bkt} = c_{bkt}\sqrt{\frac{Z}{t_b}}$$

l_{bkt} is not to be taken less than:

- l_{bkt} = 1.8h_{stf} for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web or with offset necessary to enable welding, see item (c) in Figure 3.
- l_{bkt} = 2.0h_{stf} for other cases, see items (a), (b) and (d) in Figure 3.

where:

c_{bkt}: Coefficient taken as:

- c_{bkt} =65 for brackets with flange or edge stiffener.
- c_{bkt} =70 for brackets without flange or edge stiffener.

Z: Net required section modulus, for the stiffener, in cm*3*, as defined in [3.2.4].

t_b: Minimum net bracket thickness, in mm, as defined in [3.2.4].

For connections similar to item (b) in Figure 3, but not lapped, the bracket arm length is to comply with $l_{bkt} \geqslant 2.0h_{stf.}$

For connections similar to items (c) and (d) in Figure 3 where the smaller stiffener is connected to a primary supporting member or bulkhead, the bracket arm length is not to be less than two times of h_{stf}.

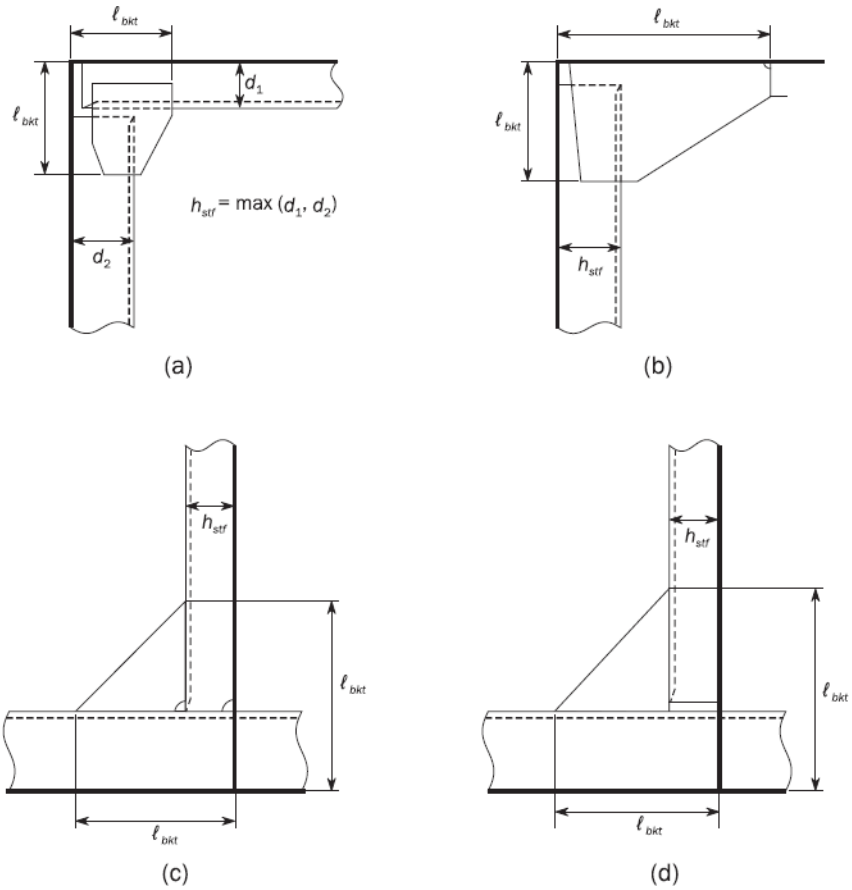


Figure 3 Bracket arm length of non-continuous stiffeners

3.2.6 Brackets with different arm lengths

The lengths of the arms, measured from the plating to the toe of the bracket, are to be such that the sum of them is greater than $2l_{bkt}$ and each arm not to be less than 0.8 l_{bkt}, where l_{bkt} is as defined in [3.2.5].

3.2.7 Edge stiffening of bracket

Where an edge stiffener is required, the web height of the edge stiffener, h_w, in mm, is not to be less than:

$$h_w = 45\left(1 + \frac{Z}{2000}\right)$$ but not less than 50 mm.

where:

Z : Net section modulus, of the stiffener, in cm^3, as defined in [3.2.4].

3.3 Bracketless connections

3.3.1

The design of bracketless connections is to be such as to provide adequate resistance to rotation and displacement of the connection.

3.4 Sniped ends

3.4.1

Sniped ends may be used where dynamic loads are small, provided the net thickness of plating supported by the stiffener, t_p, is not less than:

$$t_p = c_1\sqrt{\left(1000l - \frac{s}{2}\right)\frac{sPk}{10^6}}$$

where:

P : Design pressure for the stiffener for the design load set being considered, in kN/m^2.

c_1 : Coefficient for the design load set being considered, to be taken as:

c_1 = 1.2 for acceptance criteria set AC-S.
c_1 = 1.1 for acceptance criteria set AC-SD.

Sniped stiffeners are not to be used on structures in the vicinity of engines or generators in the machinery space, propeller impulse zone in the stern area nor on the shell envelope.

3.4.2
Bracket toes and sniped stiffeners ends are to be terminated close to the adjacent member. The distance is not to exceed 40 mm unless the bracket or member is supported by another member on the opposite side of the plating. Tapering of the sniped end is not to be more than 30 deg, where it is not practical to comply with this requirement, alternative arrangements are specially considered. The depth of toe or sniped end is, generally, not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15 mm.

4 PRIMARY SUPPORTING MEMBERS (PSM)

4.1 General

4.1.1
Primary supporting members web stiffeners, tripping brackets and end brackets are to comply with [4.2] to [4.4]. Where the structural arrangement is such that these requirements cannot be complied with, adequate alternative arrangement has to be demonstrated by the designer.

4.2 Web stiffening arrangement

4.2.1
Web stiffeners arranged on primary supporting members are to comply with the requirements to scantlings of such stiffeners are given in Ch 8, Sec 2, [4.2].

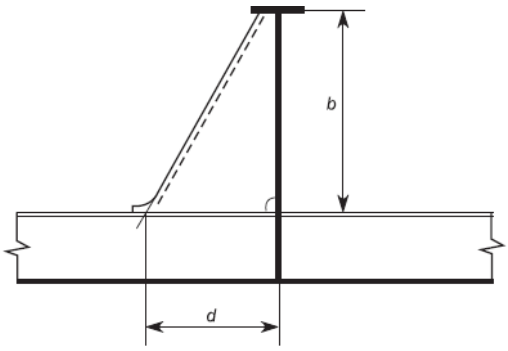
4.3 Tripping bracket arrangement

4.3.1
Tripping brackets (see Figure 4) are generally to be fitted:

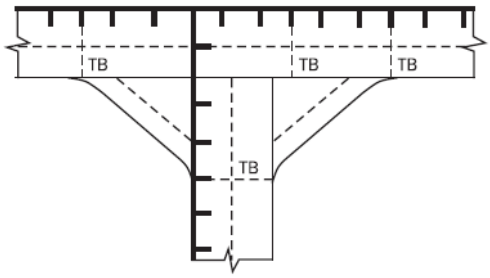
- At positions along the member span such that it satisfies the criteria of Ch 8, Sec 2, [5.1] for tripping bracket spacing and flange slenderness.
- At the toe of end brackets.
- At ends of continuous curved face plates.
- In way of concentrated loads.
- Near the change of section.

4.3.2
Where the width of the symmetrical face plate is greater than 400 mm, backing brackets are to be fitted in way of the tripping brackets.

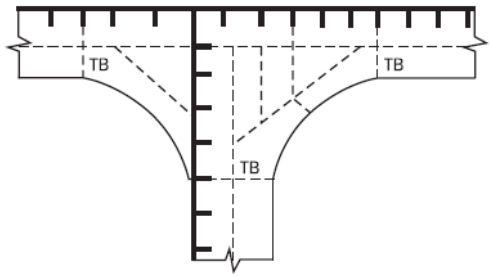
4.3.3
Where the face plate of the primary supporting member exceeds 180 mm on either side of the web, a tripping bracket is to support the face plate.



Tripping bracket in way of stiffener



Tripping brackets at the toe of end brackets



Tripping brackets at the ends of continuous curved face plates

Figure 4 Primary supporting member: Tripping bracket arrangement

4.3.4 Arm length

The arm length of tripping brackets is not to be less than the greater of the following values, in m:

$d = 0.38\,b$

$$d = 0.85b\sqrt{\frac{s_t}{t}}$$

where:

b : Height, in m, of tripping brackets, shown in Figure 4.

s_t : Spacing, in m, of tripping brackets.

t : Net thickness, in mm, of tripping brackets.

For tripping brackets in way of superstructures or deckhouses, only $d = 0.38\,b$ is to be applied.

4.4 End connections

4.4.1 General

Brackets or equivalent structure are to be provided at ends of primary supporting members. End brackets are generally to be soft-toed.

Bracketless connections may be applied provided that there is adequate support of adjoining face plates.

4.4.2 Scantling of end brackets

In general, the arm lengths of brackets connecting PSMs, as shown in Figure 5 are not to be less than the web depth of the member, and need not be taken greater than 1.5 times the web depth.

Within the cargo hold region the thickness of the bracket is, in general, not to be less than that of the adjoining PSM web plate. Outside of the cargo hold region the thickness of the bracket is not to be less than that of the PSM web plate.

Scantlings of the end brackets are to be such that the section modulus of the PSM with end bracket, excluding face plate where it is sniped, is not to be less than that of the primary supporting member at mid-span.

The net cross sectional area, A_f, in cm^2, of face plates of brackets is not to be less than:
$A_f = l_b\, t_b$
where:
l_b : Length of bracket edge, in m, see Figure 5. For brackets that are curved, the length of the bracket edge may be taken as the length of the tangent at the midpoint of the edge.
t_b: Minimum net bracket thickness, in mm, as defined in [3.2.4].

Moreover, the net thickness of the face plate is to be not less than that of the bracket web.

4.4.3 Arrangement of end brackets
Where the length of free edge of bracket, l_b, is greater than 1.5m, the web of the bracket is to be stiffened as follows:

- The net sectional area, in cm^2, of web stiffeners is to be not less than $16.5l$, where l is the span, in m, of the stiffener.
- Tripping flat bars are to be fitted. Where the width of the symmetrical face plate is greater than 400 mm, additional backing brackets are to be fitted.

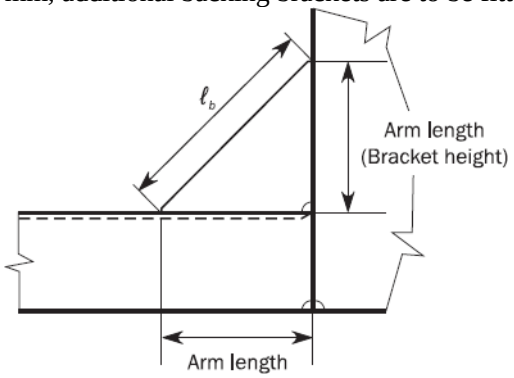


Figure 5 Dimension of brackets

For a ring system where the end bracket is integral with the webs of the members and the face plate is carried continuously along the edges of the members and the bracket, the full area of the largest face plate is to be maintained close to the mid-point of the bracket and gradually tapered to the smaller face plates. Butts in face plates are to be kept well clear of the bracket toes.

Where a wide face plate abuts a narrower one, the taper is not to be greater than 1 to 4.

The toes of brackets are not to land on unstiffened plating. The toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15 mm. In general, the end brackets of primary supporting members are to be soft-toed. Where primary supporting members are constructed of higher strength steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations.

Where a face plate is welded onto the edge or welded adjacent to the edge of the end bracket (see Figure 6), the face plate is to be sniped and tapered at an angle not greater than 30°.

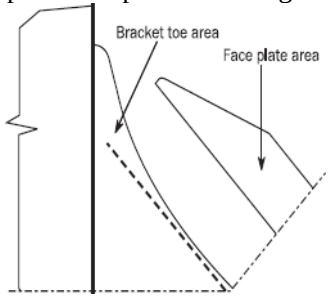


Figure 6 Bracket face plate adjacent to the edge

The details shown in this figure are only used to illustrate items described in the text and are not

intended to represent design guidance or recommendations.

5 INTERSECTION OF STIFFENERS AND PRIMARY SUPPORTING MEMBERS

5.1 Cut-outs

5.1.1

Cut-outs for the passage of stiffeners through the web of primary supporting members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and on the attached web stiffeners.

5.1.2

The total depth of cut-outs without collar plate is to be not greater than 50% of the depth of the primary supporting member.

5.1.3

Cut-outs in way of cross tie ends and floors under bulkhead stools or in high stress areas are to be fitted with full collar plates, see Figure 7.

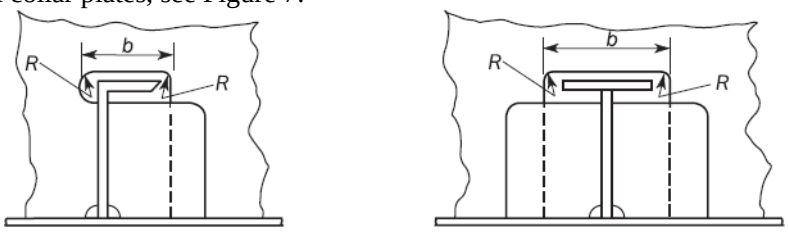
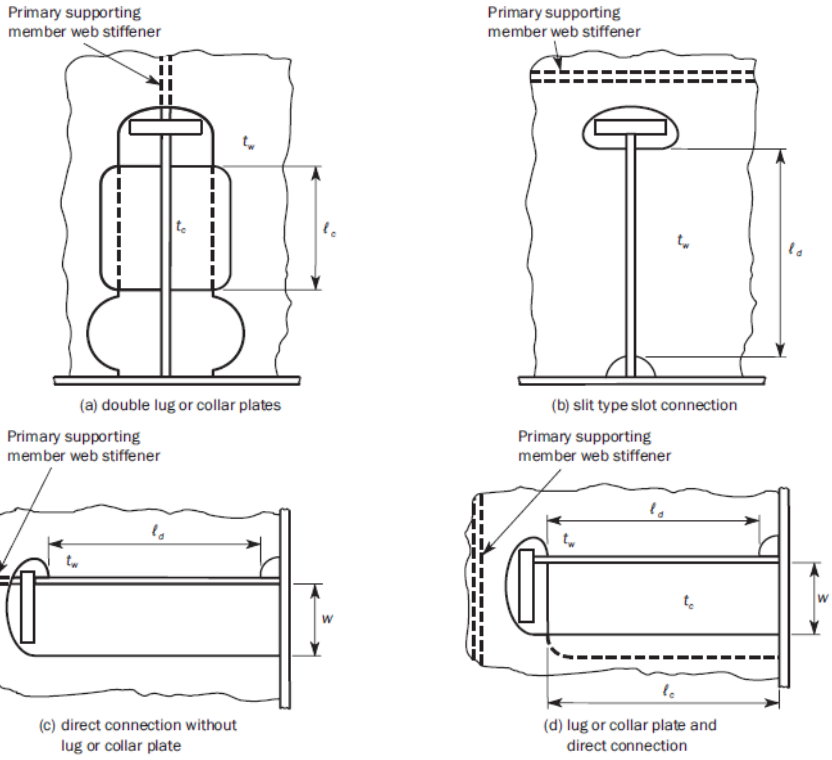
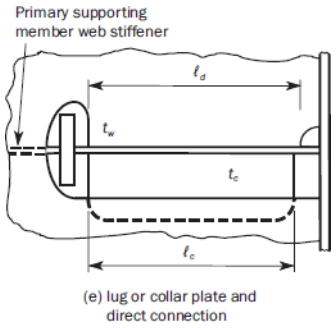


Figure 7 Full collar plates

$R \geqslant 0.2b$ but not less than 25 mm.

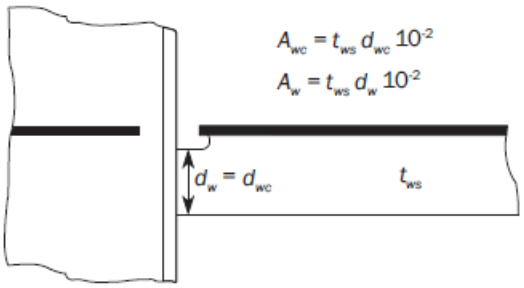




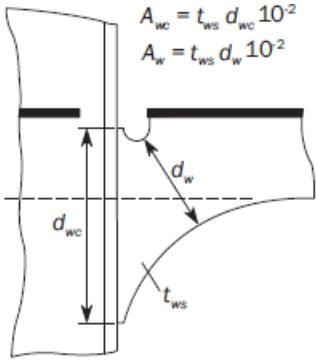
(e) lug or collar plate and direct connection

Figure 8 Symmetric and asymmetric cut-outs

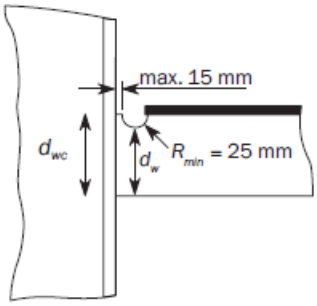
The details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance.



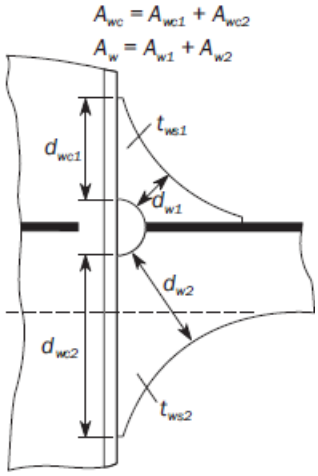
(a) Straight heel no bracket



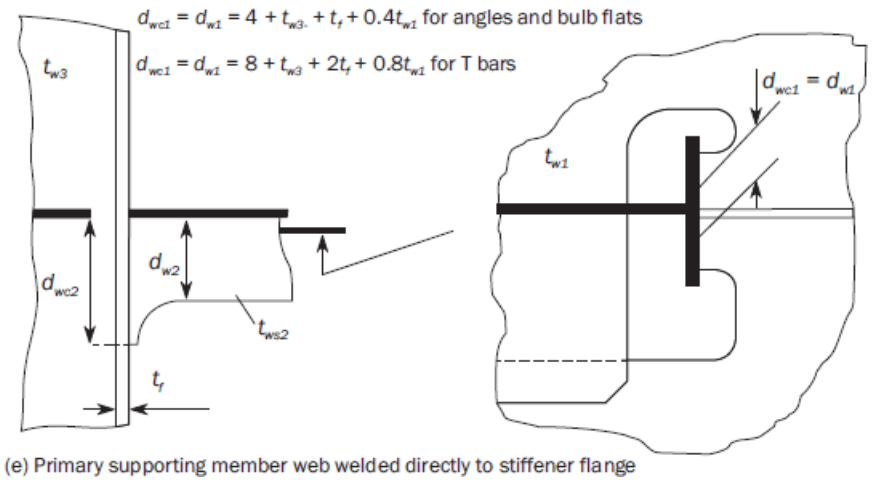
(b) Soft toe and soft heel



(c) Keyhole in way of soft heel



(d) Symmetrical soft toe brackets



(e) Primary supporting member web welded directly to stiffener flange

Figure 9 Primary supporting member web stiffener details

t_{ws}, t_{ws1}, t_{ws2} : Net thickness of the primary supporting member web stiffener/backing bracket, in mm.

d_w, d_{w1}, d_{w2} : Minimum depth of the primary supporting member web stiffener/backing bracket, in mm.

d_{wc}, d_{wc1}, d_{wc2}: Length of connection between the primary supporting member web stiffener/backing bracket and the stiffener, in mm.

t_f : Net thickness of the flange in mm. For bulb profile, t_f is to be obtained as defined in Pt.1 Ch.3 Sec.7 [1.4.1].

5.1.4

Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of [5.2], and in areas of high stress concentrations, e.g. in way of primary supporting member toes. See Figure 8 for typical lug arrangements.

5.1.5

At connection to shell envelope longitudinals below the scantling draught, T_{sc} and at connection to inner bottom longitudinals, a soft heel is to be provided in way of the heel of the primary supporting member web stiffeners when the calculated direct stress, σ_w, in the primary supporting member web stiffener according to [5.2] exceeds 80% of the permissible values. The soft heel is to have a keyhole, similar to that shown in item (c) in Figure 9.

A soft heel is not required at the intersection with watertight bulkheads and primary supporting members, where a back bracket is fitted or where the primary supporting member web is welded to the stiffener face plate.

When calculating the direct stress, σ_w, the bottom slamming or bow impact loads using the design pressures defined in Ch 4, Sec 5, [3.2] and [3.3] need not be applied.

5.1.6

Cut-outs are to have rounded corners and the corner radii, *R*, are to be as large as practicable, with a minimum of 20% of the breadth, *b*, of the cut-out or 25 mm, whichever is greater. The corner radii, *R*, does not need to be greater than 50 mm, see Figure 7. Consideration is to be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

Note 1: Except where specific dimensions are noted for the details of the keyhole in way of the soft heel, the details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

5.2 Connection of stiffeners to PSM

5.2.1 General

For connection of stiffeners to PSM in case of lateral pressure, [5.2.2] and [5.2.3] are to be applied.

The cross sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

5.2.2

The load, W_1, in kN, transmitted through the shear connection is to be taken as follows.

- If the web stiffener is connected to the intersecting stiffener:

$$W_1 = W\left(\alpha_\alpha + \frac{A_1}{4 f_c A_w + A_1}\right)$$

- If the web stiffener is not connected to the intersecting stiffener:

$W_1 = W$

where:

W: Total load, in kN, transmitted through the stiffener connection to the PSM taken equal to:

$$W = \frac{P_1 s_1\left(S_1 - \frac{s_1}{2000}\right) + P_2 s_2\left(S_2 - \frac{s_2}{2000}\right)}{2\sin\varphi_{w1}\sin\varphi_{w2}} 10^{-3}$$

P_1, P_2 : Design pressure applied on the stiffener for the design load set being considered, in kN/m^2, on each side of the considered connection. For bottom slamming or bow impact loads, P_1 and P_2 are the design pressure as defined in Ch 4, Sec 5, [3.2] and [3.3] respectively.

S_1, S_2: Spacing between the considered and the adjacent PSM on each side of the considered connection, in m.

s_1, s_2: Spacing of the stiffener, in mm, on each side of the considered connection.

α_a : Panel aspect ratio, not to be taken greater than 0.25.

$$\alpha_a = \frac{s}{1000S}$$

$$S = \frac{S_1 + S_2}{2}$$

$$s = \frac{s_1 + s_2}{2}$$

φ_{w1} : Angle between primary supporting member and attached plating, in deg, as defined in Ch 3 , Sec 7, Symbols and Ch 10, Sec 1, Figure 5.

φ_{w2} : Angle between stiffener and attached plating, in deg, as defined in Ch 3, Sec 7, Symbols and Ch 3, Sec 7,Figure 14.

A_1 : Effective net shear area, in cm^2, of the connection, to be taken equal to:

$A_1 = A_{1d} + A_{1c}$

In case of a slit type slot connections area, A_1, is given by:

$A_1 = 2A_{1d}$

In case of a typical double lug or collar plate connection area, A_1, is given by:

$A_1 = 2A_{1c}$

A_{1d} : Net shear connection area, in cm^2, excluding lug or collar plate, as given by:

$A_{1d} = l_d\, t_w\, 10^{-2}$

l_d : Length of direct connection between stiffener and PSM web, in mm.

t_w : Net web thickness of the primary supporting member, in mm.

A_{1c} : Net shear connection area, in cm^2, with lug or collar plate, given by:

$A_{1c} = f_1\, l_c\, t_c\, 10^{-2}$

l_c : Length of connection between lug or collar plate and PSM, in mm.

t_c : Net thickness of lug or collar plate, not to be taken greater than the net thickness of the adjacent PSM web, in mm.

f_1 : Shear stiffness coefficient, taken as:

$f_1 = 1.0$, for stiffeners of symmetrical cross section.

$f_1 = 140/w$, not to be taken greater than 1.0, for stiffeners of asymmetrical cross section.

w : Width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in mm, as indicated in Figure 8.

A_w : Effective net cross sectional area, in cm^2, of the PSM web stiffener in way of the connection including backing bracket where fitted, as shown in Figure 9. If the PSM web stiffener incorporates a soft heel ending or soft heel and soft toe ending, A_w is to be measured at the throat of the connection, as shown in Figure 9.

f_c : Collar load factor taken equal to:

For intersecting stiffeners of symmetrical cross section:

$f_c = 1.85$ for $A_w \leqslant 14$

$f_c = 1.85 - 0.0441(A_w - 14)$ for $14 < A_w \leqslant 31$

$f_c = 1.1 - 0.013(A_w - 31)$ for $31 < A_w \leqslant 58$

$f_c = 0.75$ for $A_w > 58$

For intersecting stiffeners of asymmetrical cross section:

$$f_c = 0.68 + 0.0172\frac{l_s}{A_w}$$

ls : Connection length equal to:

For a single lug or collar plate connection to the PSM:

$l_s = l_c$

For a single sided direct connection to the PSM:

$l_s = l_d$

In the case of a lug or collar plus a direct connection:

$l_s = 0.5\ (l_c + l_d)$

5.2.3

The load, W_2, in kN, transmitted through the PSM web stiffener is to be taken as:

- If the web stiffener is connected to the intersecting stiffener:

$$W_2 = W\left(1 - \alpha_\alpha - \frac{A_1}{4 f_c A_w + A_1}\right)$$

- If the web stiffener is not connected to the intersecting stiffener:

$W_2 = 0$

The values of A_w, A_{wc} and A_1 are to be such that the calculated stresses satisfy the following criteria:

- For the connection to the PSM web stiffener not in way of the weld: $\sigma_w \leqslant \sigma_{perm}$
- For the connection to the PSM web stiffener in way of the weld: $\sigma_{wc} \leqslant \sigma_{perm}$
- For the shear connection to the PSM web: $\tau_w \leqslant \tau_{perm}$

where:

W : Load, in kN, as defined in [5.2.2].

f_c : Collar load factor as defined in [5.2.2].

α_a : Panel aspect ratio, as defined in [5.2.2].

A_1 : Effective net shear area, in cm^2, as defined in [5.2.2].

A_w : Effective net cross sectional area, in cm^2, as defined in [5.2.2].

w : Direct stress, in N/mm^2, in the PSM web stiffener at the minimum bracket area away from the weld connection:

$$\sigma_w = \frac{10W_2}{A_w}$$

σ_{wc} : Direct stress, in N/mm^2, in the PSM web stiffener in way of the weld connection:

$$\sigma_{wc} = \frac{10W_2}{A_{wc}}$$

τ_w : Shear stress, in N/mm^2, in the shear connection to the PSM web:

$$\tau_w = \frac{10W_1}{A_1}$$

A_{wc} : Effective net area, in cm^2, of the PSM web stiffener in way of the weld as shown in Figure 9.

σ_{perm} : Permissible direct stress given in Table 1 for AC-S ,AC-SD and AC-I, in N/mm^2.

τ_{perm} : Permissible shear stress given in Table 1 for AC-S , AC-SD and AC-I, in N/mm^2.

5.2.4
Where a backing bracket is fitted in addition to the PSM web stiffener, it is to be aligned with the web stiffener. The arm length of the backing bracket is not to be less than the depth of the web stiffener. The net cross sectional area through the throat of the bracket is to be included in the calculation of A_w as shown in Figure 9.

5.2.5
Lapped connections of PSM web stiffeners or tripping brackets to stiffeners are not permitted in the cargo hold region.

5.2.6
Where built-up stiffeners have their face plate welded to the side of the web, a symmetrical arrangement of connection to the PSM is to be fitted. This may be achieved by fitting backing brackets on the opposite side of the PSM or bulkhead. In way of the cargo hold region, the PSM web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

5.2.7
Where the web stiffener of the PSM is parallel to the web of the intersecting stiffener, but not connected to it, the offset PSM web stiffener is to be located in close proximity to the slot edge as shown in Figure 10. The ends of the offset web stiffeners are to be suitably tapered and softened.

CCS 5.2.7a Alternative arrangements are to be based on their ability to transmit load with equivalent effectiveness, and equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

Permissible stresses for connection between stiffeners and PSMs Table 1

Item	Direct stress, σ_{perm}, in N/mm^2			Shear stress, τ_{perm}, in N/mm^2		
	Acceptance criteria set			Acceptance criteria set		
	AC-S	AC-SD	AC-I	AC-S	AC-SD	AC-I
PSM web stiffener	$0.83R_{eH}$ (2)	R_{eH}	R_{eH}	-	-	-
PSM web stiffener to intersecting stiffener in way of weld connection: ● Double continuous fillet ● Partial penetration weld	$0.58R_{eH}$ (2) $0.83R_{eH}$ (1)(2)	$0.7R_{eH}$ (2) R_{eH} (1)	R_{eH} R_{eH}	- -	- -	- -
PSM stiffener to intersecting stiffener in way of lapped welding	$0.50R_{eH}$	$0.60R_{eH}$	R_{eH}	-	-	-
Shear connection including lugs or collar plates: ● Single sided connection ● Double sided connection	- -	- -	- -	$0.71\tau_{eH}$ $0.83\tau_{eH}$	$0.85\tau_{eH}$ τ_{eH}	τ_{eH} τ_{eH}

(1) The root face is not to be greater than one third of the gross thickness of the PSM stiffener.
(2) Permissible stresses may be increased by 5 percent where a soft heel is provided in way of the heel of the PSM web stiffener.

5.2.8
The size of the fillet welds is to be calculated according to Ch 12, Sec 3, [2.5] based on the weld factors given in Table 2. For the welding in way of the shear connection the size is not to be less than that required for the PSM web plate for the location under consideration.

Weld factors for connection between stiffeners and PSMs Table 2

Item	Acceptance criteria	Weld factor
PSM stiffener to intersecting stiffener	AC-S AC-SD AC-I	$0.6\sigma_{wc}/\sigma_{perm}$ not to be less than 0.38
Shear connection inclusive of lug or collar plate	AC-S AC-SD AC-I	0.38
Shear connection inclusive of lug or collar plate, where the web stiffener of the PSM is not connected to the intersection stiffener	AC-S AC-SD AC-I	$0.6\ \tau_w/\tau_{perm}$ not to be less than 0.44

Note 1:
τ_w : Shear stress, in N/mm^2, as defined in [5.2.3].
σ_{wc} : Stress, in N/mm^2, as defined in [5.2.3].
τ_{perm} : Permissible shear stress, in N/mm^2, see Table 1.
σ_{perm} : Permissible direct stress, in N/mm^2, see Table 1.
W : Load, in kN, as defined in [5.2.2].
A_1 : Effective net shear area, in cm^2, as defined in [5.2.2].
A_w : Effective net cross sectional area, in cm^2, as defined in [5.2.2].

6 OPENINGS

6.1 Openings and scallops in stiffeners

6.1.1

Figure 11 shows examples of air holes, drain holes and scallops. In general, the ratio of a/b, as defined in Figure 11, is to be between 0.5 and 1.0. In fatigue sensitive areas further consideration may be required with respect to the details and arrangements of openings and scallops.

6.1.2

Openings and scallops are to be kept at least 200 mm clear of the toes of end brackets, end connections and other areas of high stress concentration, measured along the length of the stiffener toward the mid-span and 50 mm measured along the length in the opposite direction, see Figure 12. In areas where the shear stress is less than 60 percent of the permissible stress, alternative arrangements may be accepted.

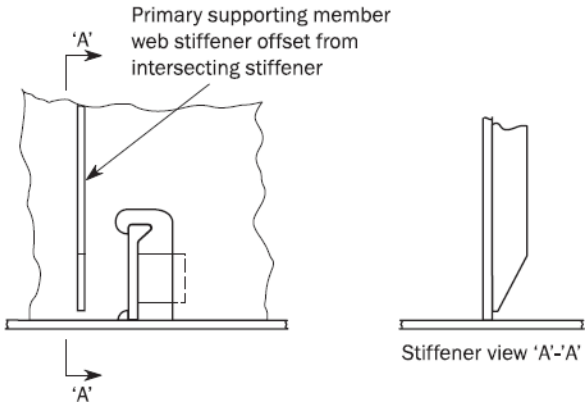
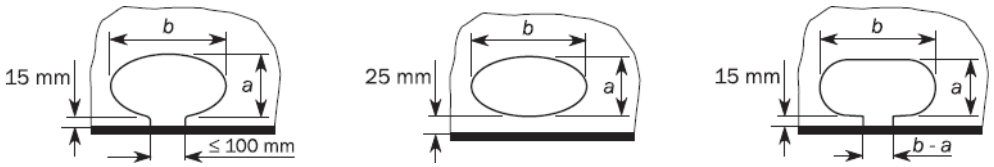


Figure 10 Offset PSM web stiffeners



The details shown in this figure are for guidance and illustration only.

Figure 11 Examples of air holes, drain holes and scallops

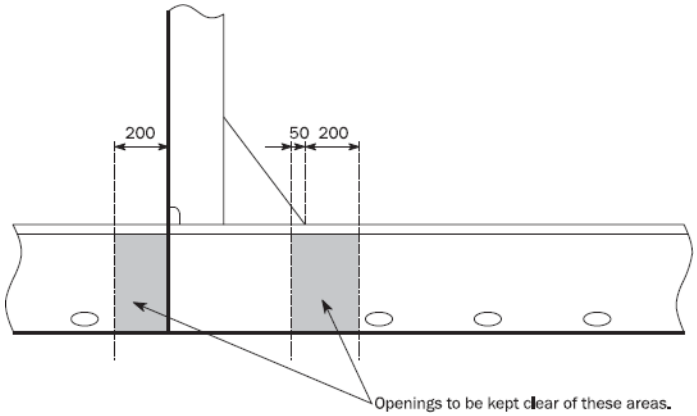


Figure 12 Location of air and drain holes

6.1.3

Closely spaced scallops or drain holes, i.e. where the distance between scallops/drain holes is less than twice the width *b* as shown in Figure 11, are not permitted in stiffeners contributing to the longitudinal strength. For other stiffeners, closely spaced scallops/drain holes are not permitted within 20% of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted provided that they are of elliptical shape or equivalent to minimise stress concentration and are, cut clear of the welds.

6.2 Openings in primary supporting members

6.2.1 General

Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

Examples of high stress areas include:

- Vertical or horizontal diaphragm plates in narrow cofferdams/double plate bulkheads within one-sixth of their length from either end.
- Floors or double bottom girders close to their span ends.
- Primary supporting member webs in way of end bracket toes.
- Above the heads and below the heels of pillars.

Where openings are arranged, the shape of openings is to be such that the stress concentration remains within acceptable limits.

Openings are to be well rounded with smooth edges.

6.2.2 Manholes and lightening holes

Web openings as indicated below do not require reinforcement

- In single skin sections, having depth not exceeding 25% of the web depth and located so that the edges are not less than 40% of the web depth from the faceplate.
- In double skin sections, having depth not exceeding 50% of the web depth and located so that the edges are well clear of cut outs for the passage of stiffeners.

The length of openings is not to be greater than:

- At the mid-span of primary supporting members: the distance between adjacent openings.
- At the ends of the span: 25% of the distance between adjacent openings.

For openings cut in single skin sections, the length of opening is not to be greater than the web depth or 60% of the stiffener spacing, whichever is greater.

The ends of the openings are to be equidistant from the cut outs for stiffeners.

Where lightening holes are cut in the brackets, the distance from the circumference of the hole to the free flange of brackets is not to be less than the diameter of the lightening hole.

Openings not complying with this requirement are to be reinforced according to [6.2.3].

6.2.3 Reinforcements around openings

Manholes and lightening holes are to be stiffened according to this requirement, except where alternative arrangements are demonstrated as satisfactory, in accordance with the analysis methods described in Ch7.

On members contributing to longitudinal strength, stiffeners are to be fitted along the free edges of the openings parallel to the vertical and horizontal axis of the opening. Stiffeners may be omitted in one direction if the shortest axis is less than 400 mm and in both directions if length of both axes is less than 300 mm. Edge reinforcement may be used as an alternative to stiffeners, see Figure 13.

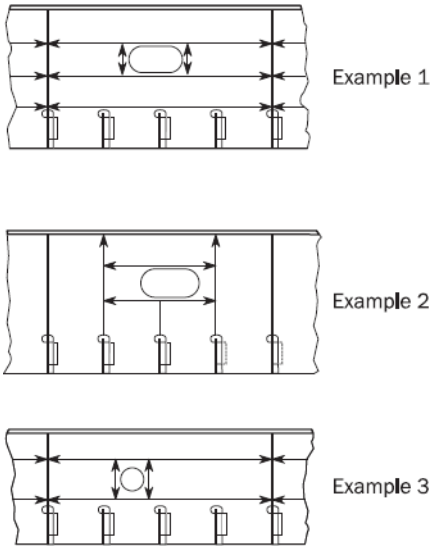


Figure 13 Web plate with openings

In the case of large openings in the web of PSMs (e.g. where a pipe tunnel is fitted in the double bottom), the secondary stresses in PSMs are to be considered for the reinforcement of these openings.

Where no FE analysis is performed, this may be carried out by assigning an equivalent net shear sectional area to the PSM obtained, in cm^2, according from the following formula:

$$A_{s-n50} = \frac{A_{1-n50}}{1+\frac{32 l_{shr}^2 A_{1-n50}}{I_{1-n50}}} + \frac{A_{2-n50}}{1+\frac{32 l_{shr}^2 A_{2-n50}}{I_{2-n50}}}$$

where:

$I_{1\text{-}n50}$, $I_{2\text{-}n50}$: Net moments of inertia, in cm^4, of deep webs (1) and (2), respectively, with attached plating around their neutral axes parallel to the plating.

$A_{1\text{-}n50}$, $A_{2\text{-}n50}$: Net shear sectional areas, in cm^2, of deep webs (1) and (2), respectively, taking account of the web height reduction by the depth of the cut out for the passage of the ordinary stiffeners, if any.

l_{shr} : Shear span, in m, of deep webs (1) and (2) as defined in Ch3, Sec 7, [1.1.2]. Deep web (1) and (2) are defined in Figure 14.

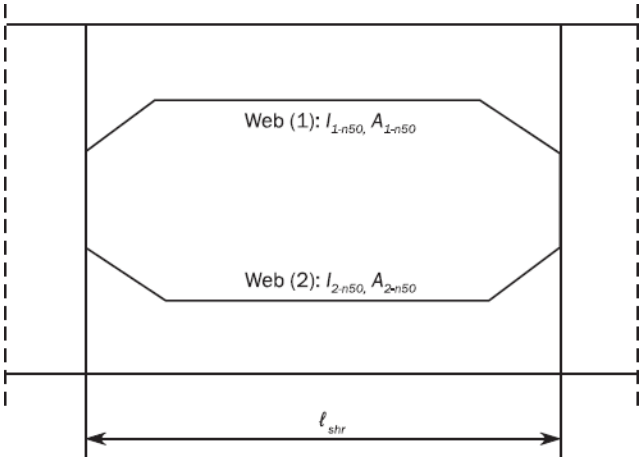


Figure 14 Large openings in the web of primary supporting members

6.3 Openings in the strength deck

6.3.1 General

Openings in the strength deck are to be kept to a minimum and spaced as far as practicable from one another and from the ends of superstructures. Openings are to be located as far as practicable from high stress regions such as side shell platings, hatchway corners, or hatch side coamings.

6.3.2 Small opening location

Openings are generally to be located outside the limits as shown in Figure 15 in dashed area, defined by:

- The bent area of a rounded sheer strake, if any, or the side shell.
- $e = 0.25\ (B - b)$ from the edge of opening.
- $c = 0.07l + 0.1b$ or $0.25b$, whichever is greater.

where:

b : Width, in m, of the hatchway considered, measured in the transverse direction, see Figure 15.

l :Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction, see Figure 15.

Transverse distance between the above limits and openings or between hatchways and openings as shown in Figure 15 is not to be less than:

- $g_2 = 2a_2$ for circular openings.
- $g_1 = a_1$ for elliptical openings.

Transverse distance between openings as shown in Figure 16 is not to be less than:

- $2\ (a_1 + a_2)$ for circular openings.
- $1.5\ (a_1 + a_2)$ for elliptical openings.

where:

a_1 : Transverse dimension of elliptical openings, or diameter of circular openings.

a_2 : Transverse dimension of elliptical openings, or diameter of circular openings.

a_3 : Longitudinal dimension of elliptical openings, or diameter of circular openings.

Longitudinal distance between openings is not to be less than:

- $(a_1 + a_3)$ for circular openings.
- $0.75\ (a_1 + a_3)$ for elliptical openings and for an elliptical opening in line with a circular one.

If the opening arrangements do not comply with these requirements, the hull girder longitudinal strength assessment is to be carried out by subtracting such opening areas, see Ch5, Sec 1, [1.2.11].

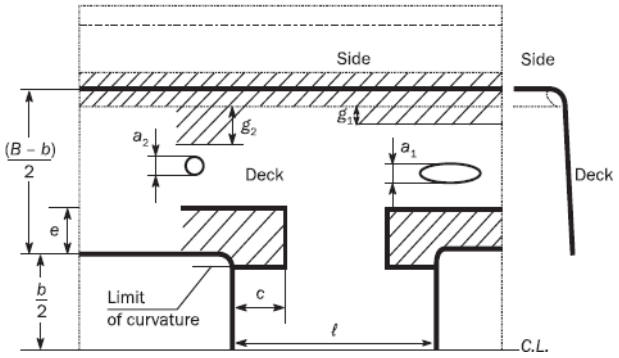


Figure 15 Position of openings in strength deck

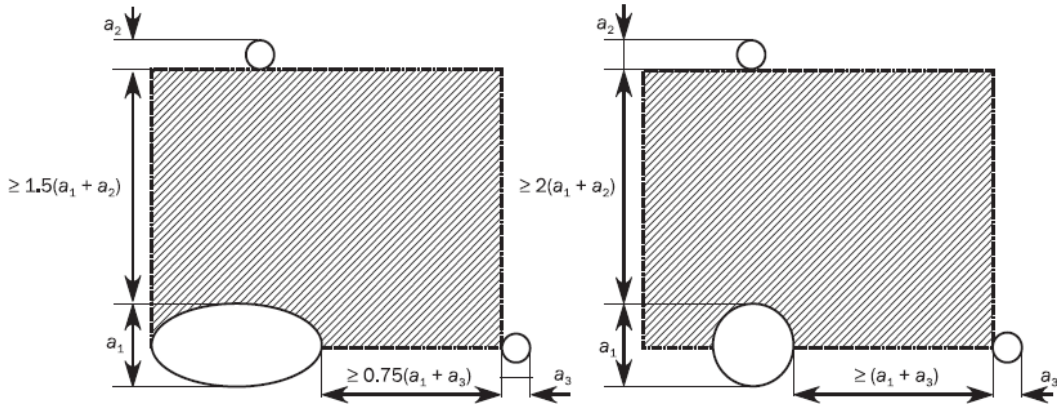


Figure 16 Elliptical and circular openings in strength deck

7 DOUBLE BOTTOM STRUCTURE

7.1 General

7.1.1 Framing system

For ships greater than 120 m in length, the bottom shell, the inner bottom and the sloped bulkheads of hopper tanks, if any, are to be longitudinally framed within the cargo hold region. Where it is not practicable to apply the longitudinal framing system to fore and aft parts of the cargo hold region due to the hull form, transverse framing may be accepted on a case-by-case basis subject to appropriate brackets and other arrangements being incorporated to provide structural continuity in way of changes to the framing system.

7.1.2 Variation in height of double bottom

Any variation in the height of the double bottom is to be made gradually and over an adequate length; the knuckles of inner bottom plating are to be located in way of plate floors. Where such arrangement is not possible, suitable longitudinal structures such as partial girders, longitudinal brackets, fitted across the knuckle are to be arranged.

7.1.3 Breadth of inner bottom

Breadth of inner bottom, in m, is to be measured at mid-length of the cargo hold as shown in Figure 17.

7.1.4 Drainage of tank top

For ships designed to carry solid cargoes, effective arrangements are to be provided for draining water from the tank top. Where wells are provided for the drainage, such wells are not to extend for more than one-half height of the double bottom.

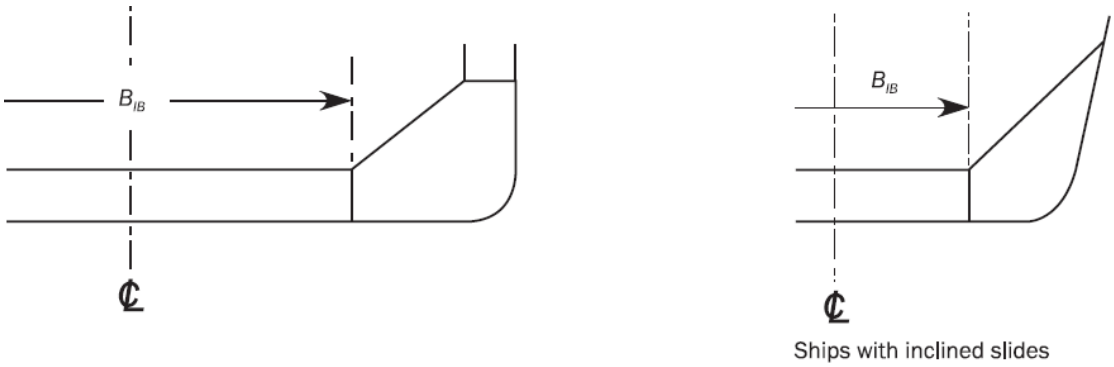


Figure 17 Breadth of inner bottom

7.1.5 Striking plate

Striking plates of adequate thickness or other equivalent arrangements are to be provided under sounding pipes to prevent the sounding rod from damaging the plating.

7.1.6 Duct keel

Where a duct keel is arranged, the centre girder may be replaced by two girders spaced, no more than 3 m apart. Otherwise, for a spacing wider than 3 m, the two girders are to be provided with support of adjacent structure and subject to the Society's approval.

The structures in way of the floors are to provide sufficient continuity of the latter.

7.2 Keel plate

7.2.1

Keel plating is to extend over the flat of bottom for the full length of the ship.

The width of the keel, in m, is not to be less than $0.8 + L/200$, without being taken greater than 2.3 m.

7.3 Girders

7.3.1 Centre girder

When fitted, the centre girder is to extend within the cargo hold region and is to extend forward and aft as far as practicable. Structural continuity of the centre girder is to be maintained within the full length of the ship.

Where double bottom compartments are used for the carriage of fuel oil, fresh water or ballast water, the centre girder is to be watertight, except for the case such as narrow tanks at the end parts or when other watertight girders are provided within $0.25B$ from the centreline.

7.3.2 Side girders

The side girders are to extend within the parallel part of the cargo hold region and are to extend forward and aft of the cargo hold region as far as practicable.

7.4 Floors

7.4.1 Web stiffeners

Floors are to be provided with web stiffeners in way of longitudinal ordinary stiffeners. Where the web stiffeners are not welded to the longitudinal stiffeners, design standard as given in Ch9, Sec 6, [2] applies unless fatigue strength assessment for the cut out and connection of longitudinal stiffener is carried out.

7.5 Bilge keel

7.5.1 Material

The material of the bilge keel and ground bar is to be of the same yield stress as the material to which they are attached.

In addition, when the bilge keel extends over a length more than 0.15 *L*, the material of the bilge keel and ground bar is to be of the same grade as the material to which they are attached.

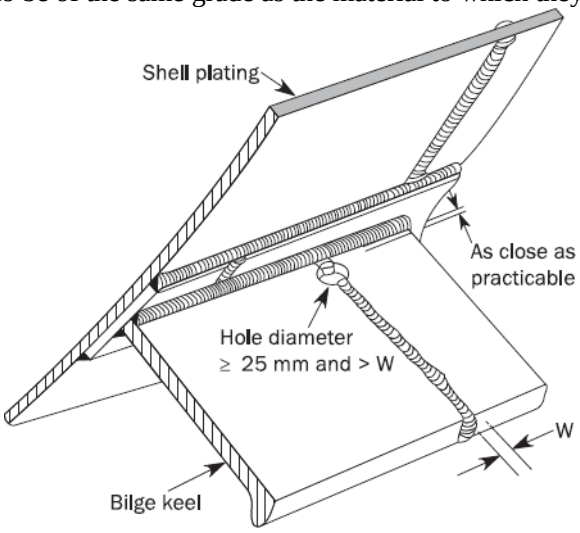
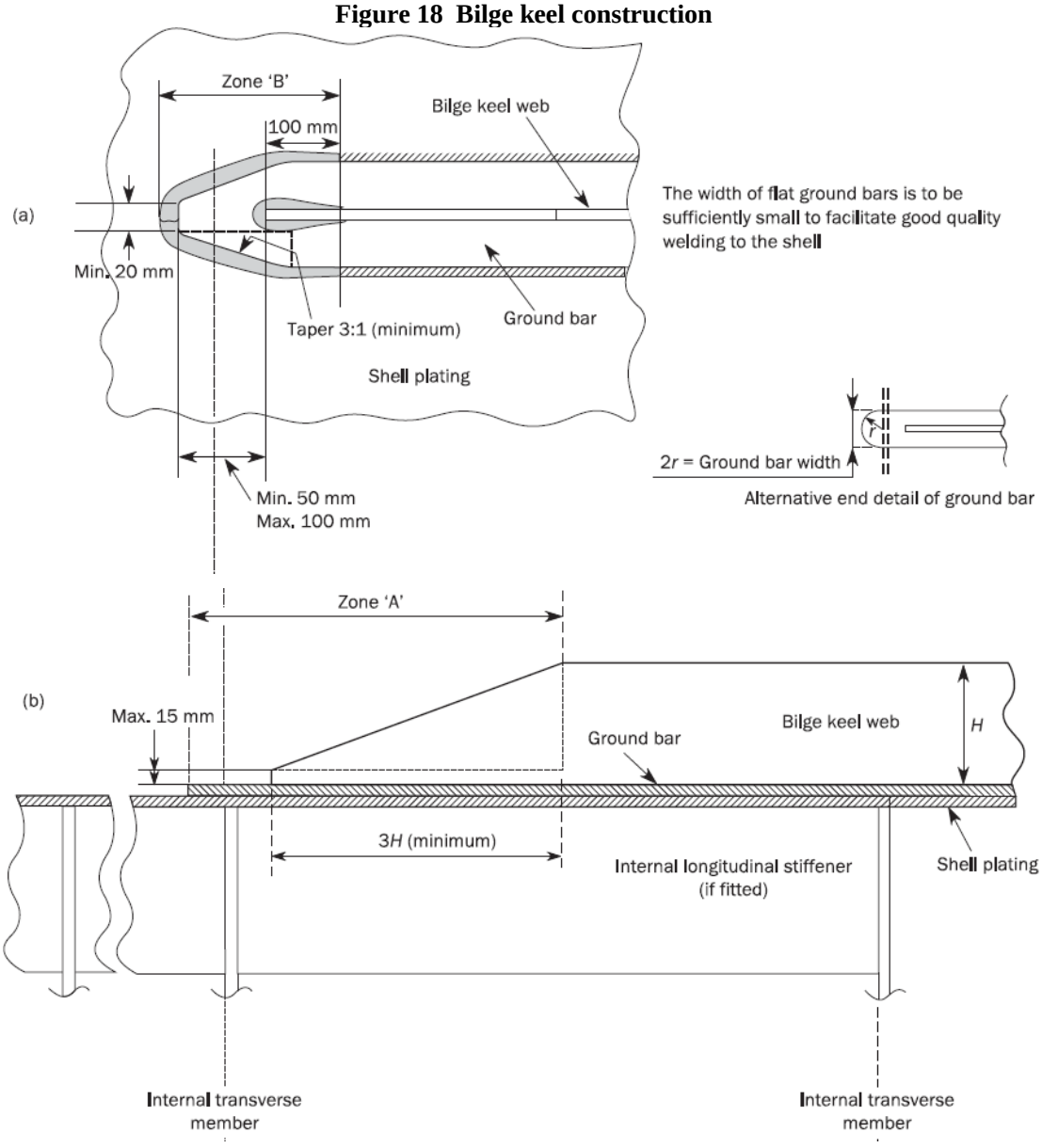


Figure 18 Bilge keel construction



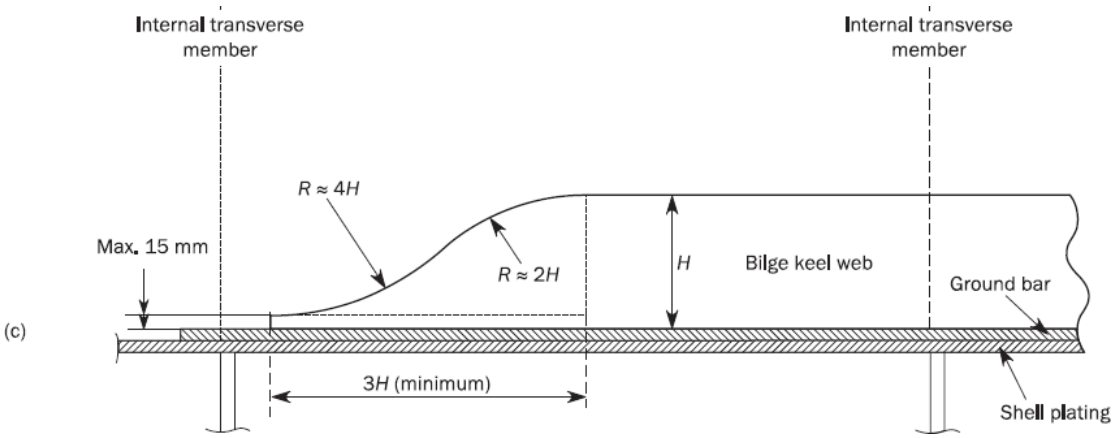


Figure 19 Bilge keel end design

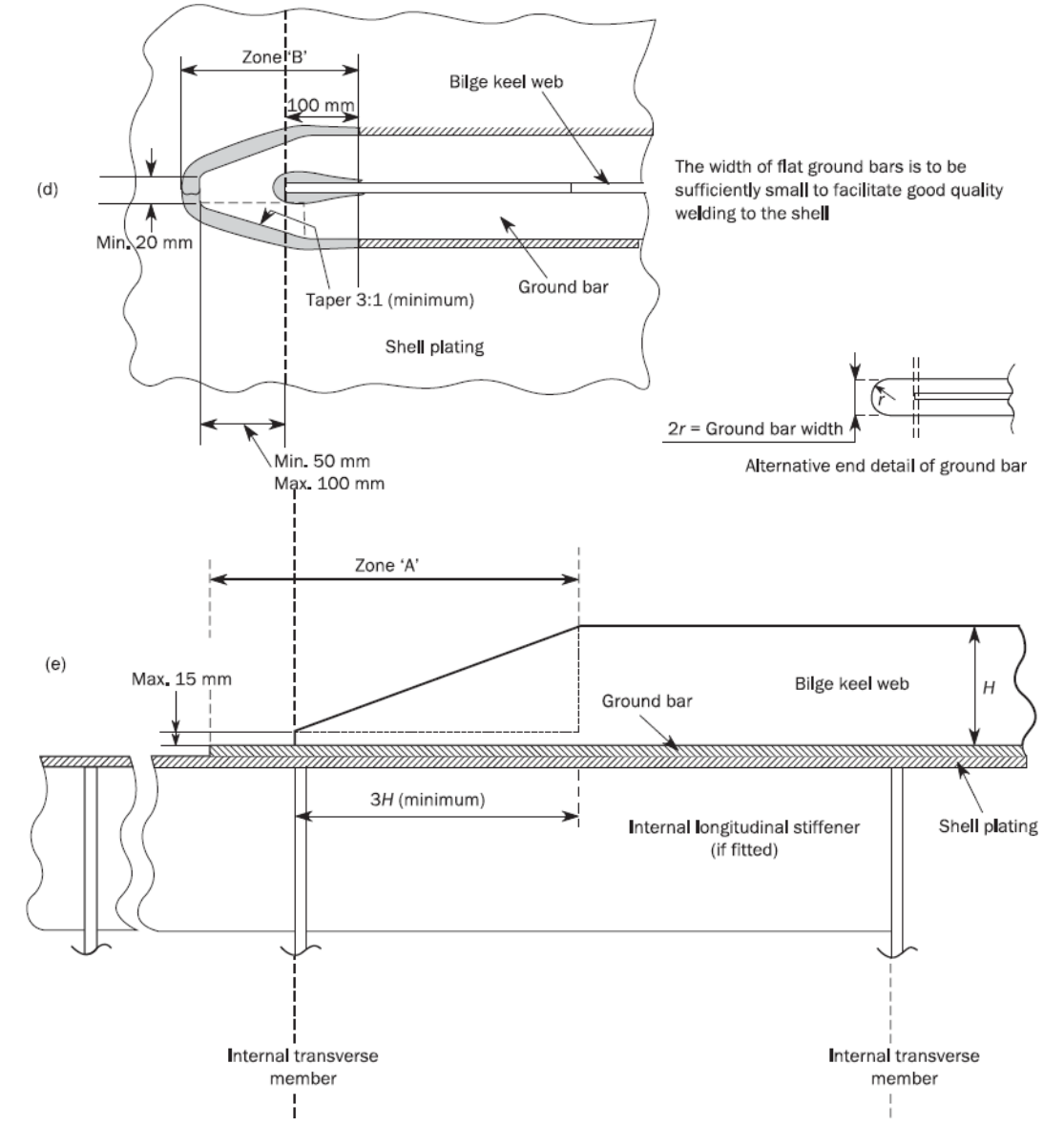


Figure 20 Bilge keel end design (continued)

7.5.2 Design

The design of single web bilge keels is to be such that failure to the web occurs before failure of the ground bar. This may be achieved by ensuring the web thickness of the bilge keel does not

exceed that of the ground bar.

Bilge keels of a different design, from that shown in Figure 18, are to be specially considered by the Society.

CCS 7.5.2a Where bilge keels are fitted, they are not to be welded directly to the shell plating. A ground bar, or doubler, is to be fitted on the shell plating and the ground bar or doubler may be welded directly to the shell and kept continuous. Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating.

7.5.3 Ground bars

Bilge keels are not to be welded directly to the shell plating. A ground bar, or doubler, is to be fitted on the shell plating as shown in Figure 18 and Figure 19. In general, the ground bar is to be continuous.

The gross thickness of the ground bar is not to be less than the gross thickness of the bilge plating or 14mm, whichever is the lesser.

7.5.4 End details

The ground bar and bilge keel ends are to be tapered or rounded. Tapering is to be gradual with a minimum ratio of 3:1, see items (a), (b), (d) and (e) in Figure 19/Figure 20. Rounded ends are to be as shown in item (c) of Figure 19. Cut-outs on the bilge keel web, within zone 'A' (see items (b) and (e) of Figure 19/Figure 20) are not permitted.

The end of the bilge keel web is to be not less than 50 mm and not greater than 100 mm from the end of the ground bar, see items (a) and (d) of Figure 19/Figure 20.

Ends of the bilge keel and ground bar are to be supported by either transverse or longitudinal members inside the hull, as indicated as follows:

- Transverse support member is to be fitted at mid length between the end of the bilge keel web and the end of the ground bar, see items (a), (b) and (c) of Figure 19.
- Longitudinal stiffener is to be fitted in line with the bilge keel web, it is to extend to at least the nearest transverse member forward and aft of zone 'A' (see items (b) and (e) of Figure 19/Figure 20).

Alternative end arrangements may be accepted, provided that they are considered equivalent.

CCS 7.5.4a Other types of end detail design may be accepted provided that bilge keels and flat bars are gradually tapered at their ends and equivalent to 7.5.4.

7.6 Docking

7.6.1 General

The drydocking arrangement itself is not covered in these Rules.

The bottom structure is to withstand the forces imposed by drydocking the ship.

7.6.2 Docking brackets

Docking brackets connecting the centreline girder to the bottom plating, are to be connected to the adjacent bottom longitudinals.

8 DOUBLE SIDE STRUCTURE

8.1 General

8.1.1

Side shell and inner hull bulkheads are generally to be longitudinally framed. Where the side shell is longitudinally framed, the inner hull bulkheads are to be longitudinally framed. Alternative framing arrangements are to be specially considered by the Society.

CCS 8.1.1a Alternative types of framing are to be based on compliance with the requirements for strength and structural arrangements in this PART, and equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

8.1.2

Where the double side space of bulk carriers is void, the structural members bounding this space are to be structurally designed as a water ballast tank. In such a case the corresponding air pipe is considered as extending 0.76 m above the freeboard deck at side. For corrosion addition, the space is to be considered as a void space.

8.2 Structural arrangement

8.2.1 Primary supporting members

Double side web frames are to be fitted in line with web frames in hopper tanks. In addition, double side web frames are to be aligned with web frames or large brackets in topside tanks.

Vertical primary supporting members are to be fitted in way of hatch end beams of bulk carriers or similar large deck opening supporting transverse structure.

In general, horizontal side stringers are to be fitted aft of the collision bulkhead, up to 0.2 L aft of the fore end, in line with fore peak stringers.

8.2.2 Transverse stiffeners

Transverse stiffeners on side shell and inner side, where fitted, are to be continuous or fitted with bracket end connections within the height of the double side. The transverse stiffeners are to be effectively connected to stringers. At their upper and lower ends, shell and inner side transverse stiffeners are to be connected by brackets to supporting stringer plates.

8.2.3 Longitudinal stiffeners

Longitudinal stiffeners on side shell and inner side, where fitted, are to be continuous within the length of the parallel part of the cargo hold region. They are to be fitted with soft toe brackets in way of transverse bulkheads aligned with cargo hold bulkheads and are to be effectively connected to transverse web frames of the double side structure.

Longitudinal framing of the side shell is to extend outside the cargo hold region as far forward as practicable.

8.2.4 Sheer strake

Sheer strakes are to have breadths not less than 0.8+ L/200 m, measured vertically, but need not be greater than 1.8 m.

The heer strake may be either welded to the stringer plate or rounded.

If the sheer strake is rounded, its radius, in mm, is to be not less than $17t_s$, where t_s is the net thickness, in mm, of the sheer strake.

The upper edge of the welded sheer strake is to be rounded smooth and free of notches. Fixtures such as bulwarks, eye plates are not to be directly welded on the upper edge of sheer strake, except in fore and aft parts. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

Longitudinal seam welds of rounded sheer strake are to be located outside the bent area at a distance not less than 5 times the maximum net thicknesses of the sheer strake.

The welding of deck fittings to rounded sheer strakes is to be avoided within 0.6 L amidships.

The transition from a rounded sheer strake to an angled sheer strake associated with the arrangement of superstructures is to be designed to avoid any discontinuities.

8.2.5 Plating connection

Connection between the inner hull plating and the inner bottom plating is to be designed such that stress concentration is avoided.

The connections of hopper tanks plating with inner hull and with inner bottom are to be supported by a primary supporting member.

9 DECK STRUCTURE

9.1 Structural arrangement

9.1.1 Framing system

Deck areas contributing to the longitudinal strength are to be longitudinally framed.

9.1.2 Stringer plate

Stringer plates are to have breadths not less than 0.8 + L/200 m, measured parallel to the deck, but need not be greater than 1.8 m.

Rounded stringer plates, where adopted, are to comply with the requirements in [8.2.4].

9.1.3 Connection of deckhouses and superstructures

Connection of deckhouses and superstructures to the strength deck are to be designed such that loads are transmitted into the under deck supporting structure.

9.2 Deck scantlings

9.2.1

The web depth of deck stiffeners is not to be less than 60 mm.

The web depth of PSMs is not to be less than 10% and 7% of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. Unsupported span in bending is the bending span as defined in Ch3, Sec 7 or in case of a grillage structure, the distance between connections to other PSMs.

10 BULKHEAD STRUCTURE

10.1 Application

10.1.1

The requirements of this article apply to longitudinal and transverse bulkheads, which may be plane or corrugated.

10.2 General

10.2.1

The web height of vertical PSMs on bulkheads may be gradually tapered from bottom to deck.

10.2.2

Bulkheads are to be stiffened in way of deck girders.

10.2.3

Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports not less effective than required for stanchions or pillars that would be located at the same position.

10.2.4

Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way of the connection are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in the pipes.

10.3 Plane bulkheads

10.3.1 General

Plane bulkheads may be horizontally or vertically stiffened.

Horizontally framed bulkheads are made of horizontal stiffeners supported by vertical primary supporting members.

Vertically framed bulkheads are made of vertical stiffeners supported by horizontal stringers, if needed.

The bulkhead stiffener webs of hopper and topside tank watertight bulkheads are to be aligned with the webs of longitudinal stiffeners of sloping plates of inner hull.

Floors are to be fitted in the double bottom in line with the plane transverse bulkhead.

10.3.2 End connection of stiffeners

The crossing of stiffeners through a watertight bulkhead is to be watertight.

End connections of stiffeners are to be bracketed. For isolated areas of the ship where bracketed end connections cannot be applied due to hull lines, other arrangements including sniped ends are acceptable.

10.3.3 Sniped end of stiffener

Sniped ends may be used on bulkheads subject to hydrostatic pressure provided they comply with [3.4].

10.4 Corrugated bulkheads

10.4.1 General

For ships of 18 m moulded depth and above, the transverse vertically corrugated watertight bulkheads are to be fitted with a lower stool, and generally with an upper stool below deck. For ships of 16 m moulded depth and above, the transverse vertically corrugated watertight bulkheads subject to liquid pressure, e.g. tank bulkheads and ballast hold bulkheads, are to be fitted with a lower stool, and generally with an upper stool below deck.Otherwise corrugations may extend from inner bottom to deck.

10.4.2 Construction

The main dimensions $b_{f\text{-}cg}$, R, $b_{w\text{-}cg}$, d_{cg}, t_f, t_w, s_{cg} of corrugated bulkheads are defined in Figure 21.
The corrugation angle φ is not to be less than 55 °.
When welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval.

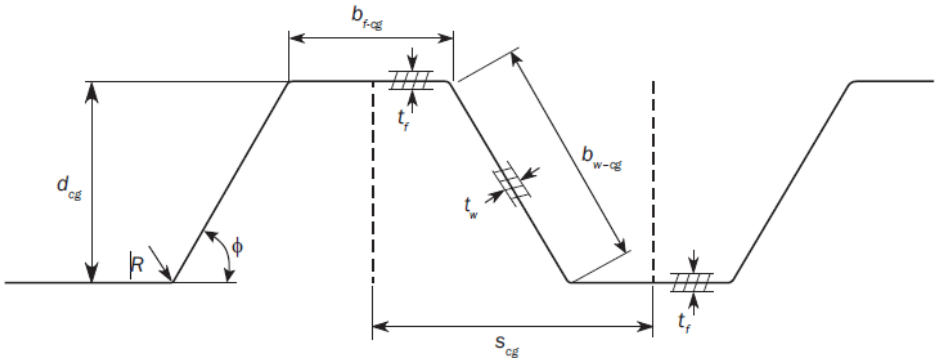


Figure 21 Dimensions of a corrugated bulkhead

10.4.3 Corrugated bulkhead depth

The depth of the corrugation, d, in mm, is not to be less than:

$$d_{cg} = \frac{1000 l_c}{C}$$

where:

l_c : Mean span of considered corrugation, in m, as defined in [10.4.5].

C : Coefficient to be taken as:

C = 15 for tank and water ballast cargo hold bulkheads.

C = 18 for dry cargo hold bulkheads.

10.4.4 Actual section modulus of corrugations

The net section modulus of a corrugation may be obtained, in cm3, from the following formula:

$$Z = \left[\frac{d_{cg}\left(3b_{f-cg}t_f + b_{w-cg}t_w\right)}{6} \right] 10^{-3}$$

where:

t_f, t_w : Net thickness of the plating of the corrugation, in mm, shown in Figure 21.

d_{cg}, $b_{f\text{-}cg}$,$b_{w\text{-}cg}$: Dimensions of the corrugation, in mm, shown in Figure 21.

Where the web continuity is not ensured at ends of the bulkhead, the net section modulus of a corrugation is to be obtained, in cm^3, from the following formula:

$Z = 0.5 b_{f\text{-}cg}\, t_f\, d_{cg} 10^{-3}$

10.4.5 Span of corrugations

The span l_C of the corrugations is to be taken as the distance shown in Figure 22.

For the definition of l_C, the bottom of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:

- 3 times the depth of corrugation, for non rectangular stool.
- 2 times the depth of corrugation, for rectangular stool.

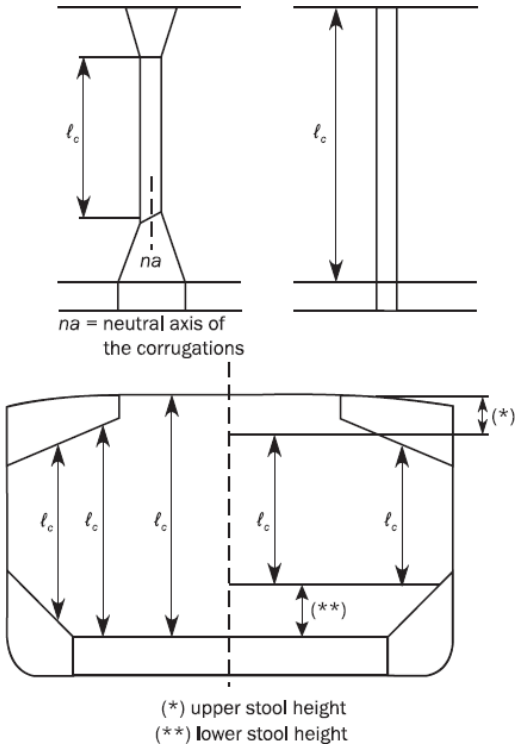


Figure 22 Span of the corrugations

10.4.6 Structural arrangements

Where corrugated bulkheads are cut in way of primary supporting members, corrugations on each side of the primary member are to be aligned with each other.

10.4.7 Bulkhead end supports

The strength continuity of corrugated bulkheads is to be maintained at the ends of corrugations.

Where a bulkhead is provided with a lower stool, floors or girders are to be fitted in line with both sides of the lower stool. Where a bulkhead is not provided with a lower stool, floors or girders are to be fitted in line with both flanges of the vertically corrugated transverse bulkhead.

The supporting floors or girders are to be connected to each other by suitably designed shear plates.

At deck, if no upper stool is fitted, transverse or longitudinal stiffeners are to be fitted in line with the corrugation flanges.

When the corrugation flange connected to the adjoining boundary structures (i.e. inner hull, side shell, longitudinal bulkhead, trunk, etc) is smaller than 50% of the width of the typical corrugation flange, an advanced analysis of the connection is required.

10.4.8 Bulkhead stools

Stool side plating is to be aligned with the corrugation flanges.

10.4.9 Lower stool

The lower stool, when fitted, is to have a height in general not less than:

- 3 corrugation depths, for bulk carriers.
- One corrugation depth, for oil tankers.

The ends of stool side ordinary stiffeners, when fitted in a vertical plane, are to be attached to brackets at the upper and lower ends of the stool. Lower stool side vertical stiffeners and their brackets in the stool are to be aligned with the inner bottom structures such as longitudinals or similar. Lower stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top plate.

The distance *d* from the edge of the stool top plate to the surface of the corrugation flange is to be in accordance with Figure 23.

The lower part of the stool side plates is to be in line with double bottom floors or girders as the case may be, and the stool bottom is to have a width not less than:

- 2.5 corrugation depths, for bulk carriers.
- One corrugation depth, for oil tankers.

The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders or floors. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

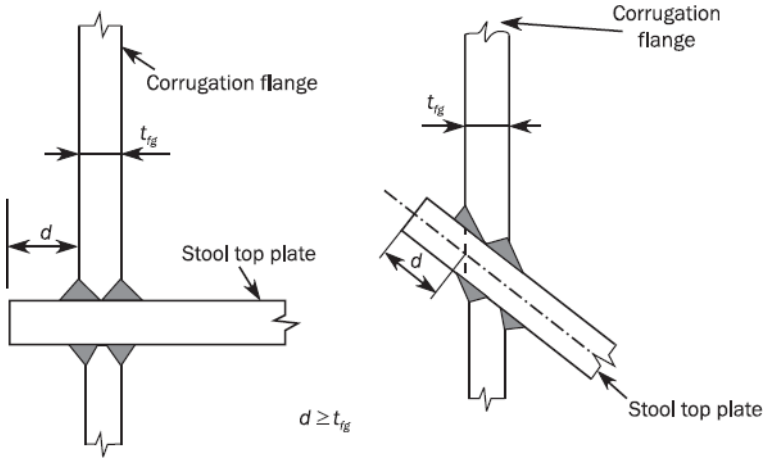


Figure 23 Permitted distance, *d*, from the edge of the stool top plate to the surface of the corrugation flange

The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or partial penetration welds. The supporting floors are to be connected to the inner bottom by either full penetration or partial penetration welds.

10.4.10 Upper stool

The upper stool, when fitted, is to have a height:

- Not less than two times the corrugation depth, for bulk carriers.
- At least one corrugation depth, for oil tankers.

Rectangular stools are to have a height in general equal to twice the depth of corrugations, measured from the deck level and at the hatch side girder or at the inner hull as applicable. Brackets or deep webs are to be fitted to connect the upper stool to the deck transverse or hatch end beams.

The upper stool of a transverse bulkhead is to be properly supported by deck girders or deep brackets between the adjacent hatch end beams. The width of the upper stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non-rectangular stools of bulk carriers is to have a width not less than twice the depth of corrugations. The ends of stool side ordinary stiffeners when fitted in a vertical plane, are to be attached to brackets at the upper and lower end of the stool.

The stool is to be fitted with diaphragms in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders or transverse deck primary supporting members. Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

10.5 Non-tight bulkheads

10.5.1 General

In general, openings in wash bulkheads are to have generous radii and their aggregate area is not to be less than 10% of the area of the bulkhead. The area of non-tight bulkhead is the whole cross sectional area in one plane that covers the tank boundaries.

10.5.2 Non-tight bulkheads not acting as pillars

In general, the maximum spacing of stiffeners fitted on non-tight bulkheads not acting as pillars is to be:

- 0.9 m, for transverse bulkheads.
- Two frame spacings, with a maximum of 1.5 m, for longitudinal bulkheads.

The net thickness of bulkhead stiffener, in mm, is not to be less than:

$t = 3 + 0.015\ L_2$

The depth of bulkhead stiffener of flat bar type is in general not to be less than 1/12 of stiffener length.

A smaller depth of stiffener may be accepted based on calculations showing compliance with Ch10, Sec4, [2.2] and Ch8.

10.5.3 Non-tight bulkheads acting as pillars

Non-tight bulkheads acting as pillars are to be provided with bulkhead stiffeners with a maximum spacing equal to:

- Two frame spacings, when the frame spacing does not exceed 0.75 m.
- One frame spacing, when the frame spacing is greater than 0.75 m.

Where non-tight bulkheads are corrugated, the depth of the corrugation is not to be less than 100 mm.

Each vertical stiffener, in association with a width of plating equal to 35 times the plating net thickness, 1/12 of stiffener length or the stiffener spacing, whichever is the smaller, is to comply

with the applicable requirements in Ch6, for the load being supported.

10.6 Watertight bulkheads of trunks and tunnels

10.6.1

Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

CCS 10.6.1a Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be in compliance with the requirements of Section3, Chapter 4, PART ONE of the Rules.

11 PILLARS

11.1 General

11.1.1

Pillars are to be fitted in the same vertical line wherever possible. If not possible, effective means are to be provided for transmitting their loads to the supports below. Effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

11.1.2

Pillars are to be provided in line with the double bottom girder or as close thereto as practicable, and the structure above and below the pillars is to be of sufficient strength to provide effective distribution of the load. Where pillars connected to the inner bottom are not located in way of the intersection of floors and girders, partial floors or girders or equivalent structures are to be fitted as necessary to support the pillars.

11.1.3

Pillars provided in tanks are to be of solid or open section type.

Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45% of the specified minimum yield stress of the material.

11.2 Connections

11.2.1

Heads and heels of pillars are to be secured by thick doubling plates and brackets as necessary. Alternative arrangements for doubling plates may be accepted, provided that they are considered equivalent as deemed appropriate by the Society. Where the pillars are likely to be subjected to tensile loads, the head and heel of pillars are to be efficiently secured to withstand the tensile loads and the doubling plates replaced by insert plate.

The net thickness of doubling plates, when fitted, is to be not less than 1.5 times the net thickness of the pillar. Pillars are to be attached at their heads and heels by continuous welding.

CCS 11.2.1a Where heads or heels of pillars are secured by alternative arrangements for doubling plates, it is to be ensured that the force acting on heads or heels of pillars can be effectively transmitted and any abrupt change of transmitted force is to be avoided.

Section 7 STRUCTURAL IDEALISATION

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.

φ_w : Angle, in deg, between the stiffener or primary supporting member web and the attached plating, see Figure 14 for stiffener and Ch 10, Sec 1, Figure 5 for primary supporting member. φ_w is to be taken equal to 90 deg if the angle is between 75 and 105 deg including 75 and 105 deg.
l_{bdg} : Effective bending span, in m, as defined in [1.1.2] for stiffeners and [1.1.6] for primary supporting members.
l_{shr} : Effective shear span, in m, as defined in [1.1.3] for stiffeners and [1.1.7] for primary supporting members.
l : Full length of stiffener or of primary supporting member, in m, between their supports.
s : Stiffener spacing, in mm, as defined in [1.2].
S : Primary supporting member spacing, in m, as defined in [1.2].
a : Length, in mm, of EPP as defined in [2.1.1].
b : Breadth, in mm, of EPP as defined in [2.1.1].
h_{stf} : Stiffener height, including the face plate, in mm.
t_p : Net thickness of attached plate, in mm.
t_w : Net web thickness, in mm. For bulb profiles, see [1.4.1].
b_f : Breadth of flange, in mm, see Ch 3, Sec 2, Figure 2. For bulb profiles, see [1.4.1].
t_f : Net thickness of flange, in mm.
PSM : Primary Supporting Member.
EPP : Elementary Plate Panel.
LCP : Load Calculation Point.

1 STRUCTURAL IDEALISATION OF STIFFENERS AND PRIMARY SUPPORTING MEMBERS

1.1 Effective spans

1.1.1 General

Where arrangements differ from those defined in this article, span definition may be specially considered.

CCS 1.1.1a For the definition of a span where the structural arrangement is different from that defined in this Section, equivalence or substitution is to be, based on the geometrical characteristics of end brackets of stiffeners and primary supporting members, their end constraints and actual load-carrying capacity, granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

1.1.2 Effective bending span of stiffeners

The effective bending span l_{bdg} of stiffeners is to be measured as shown in Figure 1 for single skin structures and Figure 2 for double skin structures.

If the web stiffener is sniped at the end or not attached to the stiffener under consideration, the effective bending span is to be taken as the full length between PSMs unless a backing bracket is fitted, see Figure 1.

The effective bending span may be reduced where brackets are fitted to the flange or free edge of the stiffener. Brackets fitted on the side opposite to that of the stiffener with respect to attached plating are not to be considered as effective in reducing the effective bending span.

In single skin structures, the effective bending span of a stiffener supported by a bracket or by a web stiffener on one side only of the primary supporting member web, is to be taken as the total span between primary supporting members as shown in item (a) of Figure 1. If brackets are fitted on both sides of the primary supporting member, the effective bending span is to be taken as in

items (b), (c) and (d) of Figure 1.

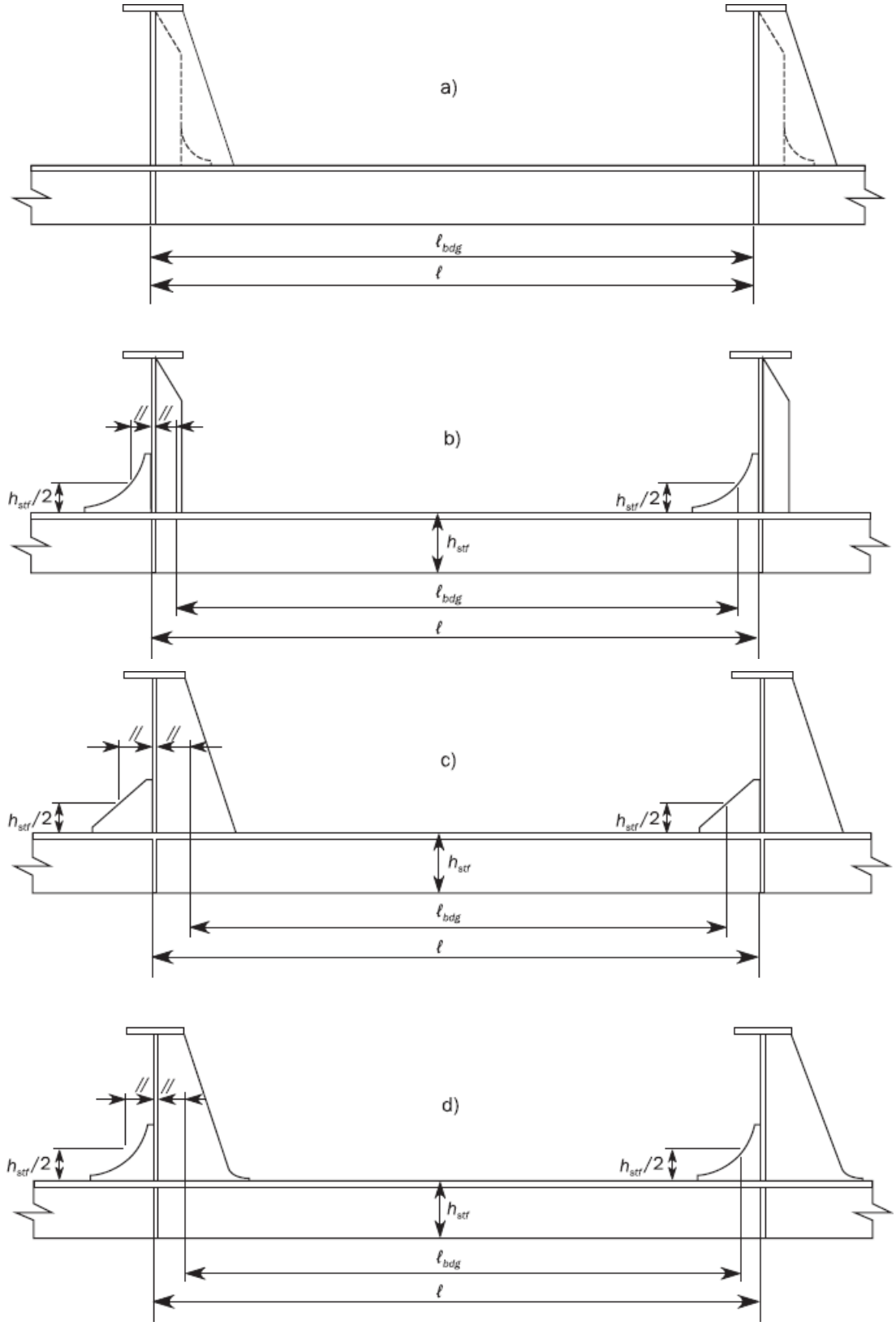


Figure 1 Effective bending span of stiffeners supported by web stiffeners (single skin construction)

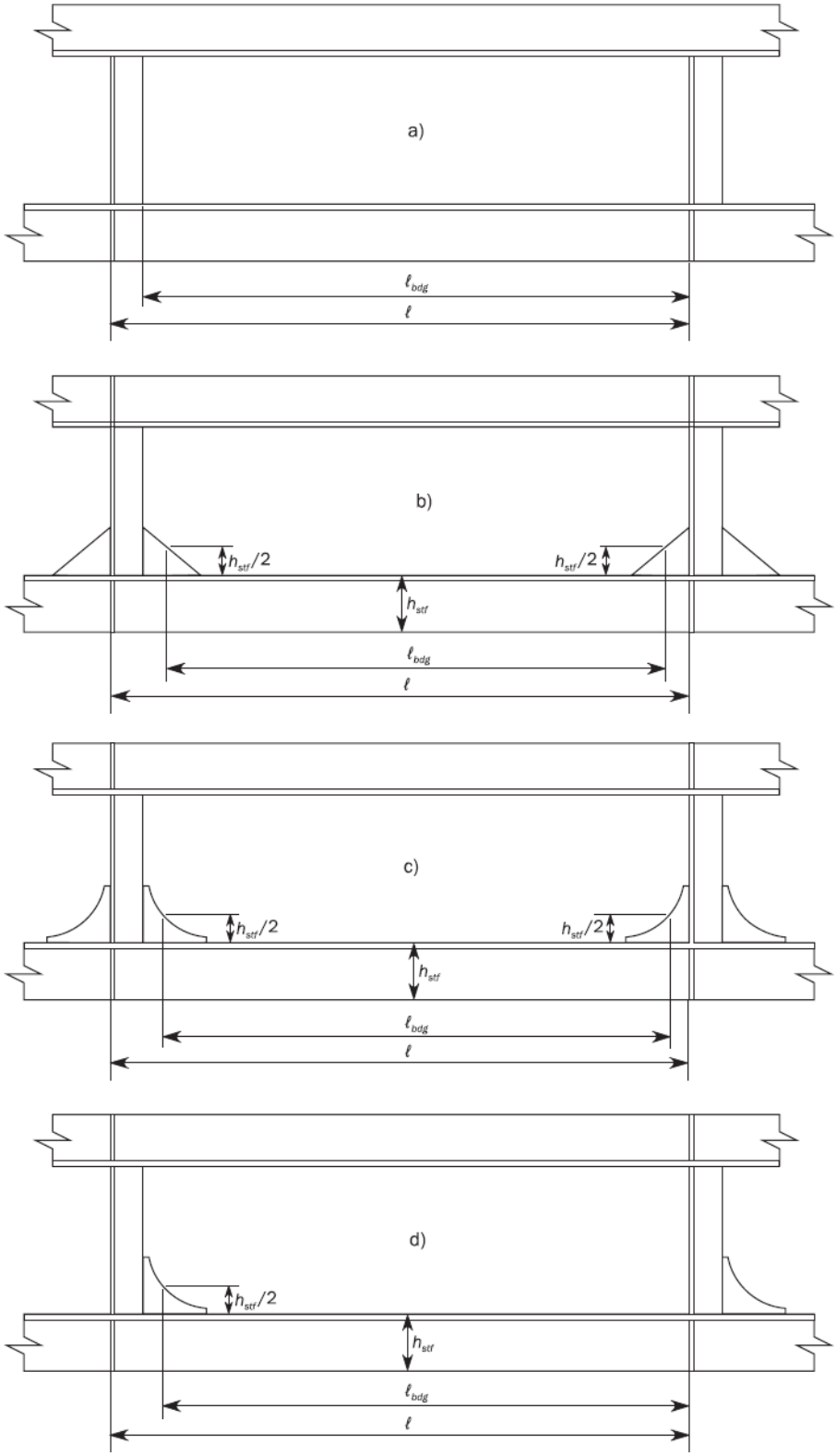


Figure 2 Effective bending span of stiffeners supported by web stiffeners (double skin construction)

Where the face plate of the stiffener is continuous al ong the edge of the bracket the effective bending span is to be taken to the position where the depth of the bracket is equal to one quarter of the depth of the stiffener see Figure 3.

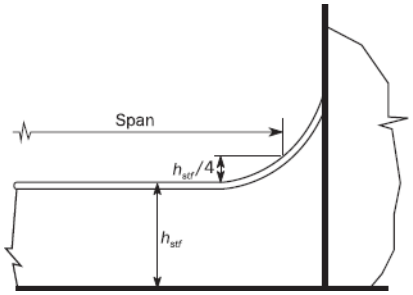


Figure 3 Effective bending span for local support members with continuous face plate along bracket edge

1.1.3 Effective shear span of stiffeners

The effective shear span, l_{shr} in m, of stiffeners is to be measured as shown in Figure 4 for single skin structures and Figure 5 for double skin structures.

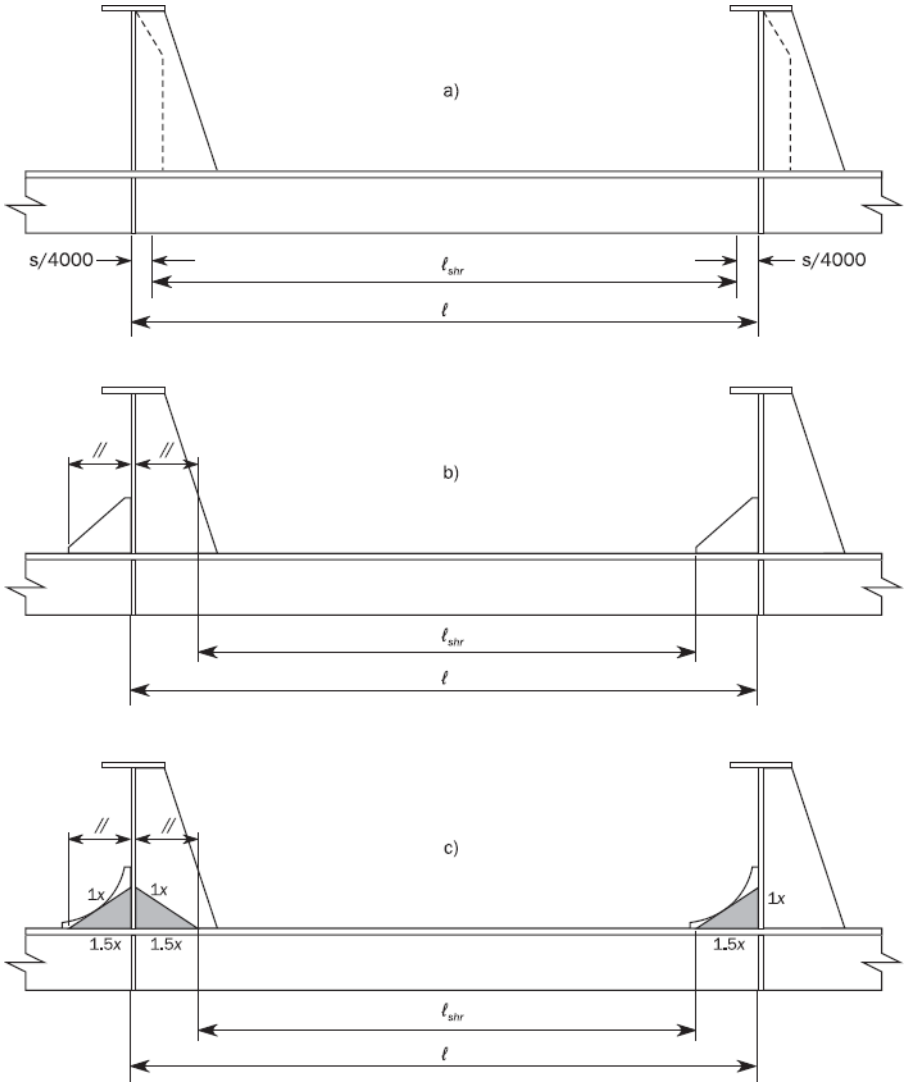


Figure 4 Effective shear span of stiffeners supported by web stiffeners (single skin construction)

The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener.

If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to the stiffener the effective shear span may be reduced using the longer effective bracket arm.

Regardless of support detail, the full length of the stiffener may be reduced by a minimum of *s*/4000 m at each end of the member, hence the effective shear span l_{shr}, is not to be taken greater than:

$$l_{shr} \le l - \frac{s}{2000}$$

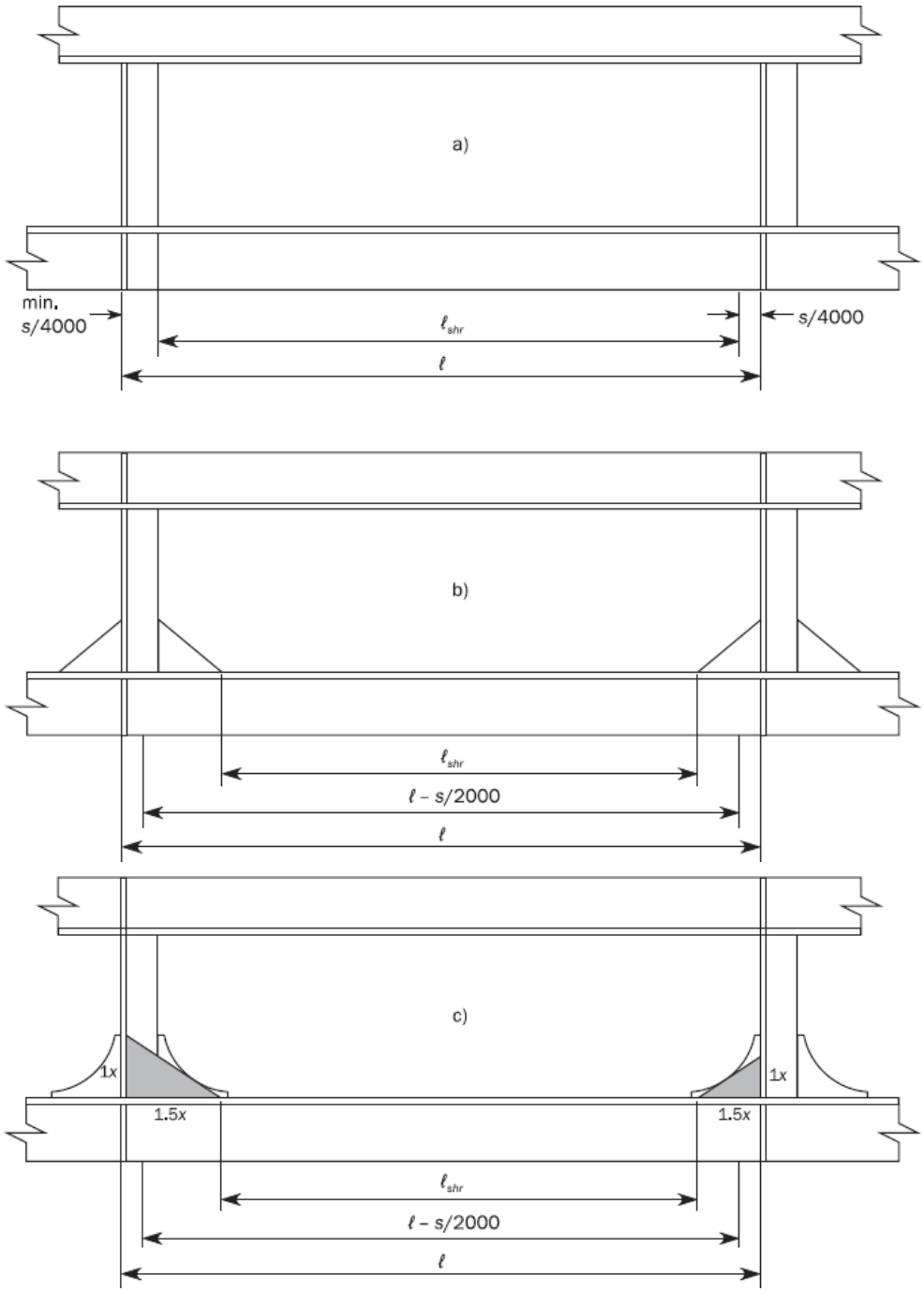


Figure 5 Effective shear span of stiffeners supported by web stiffeners (double skin construction)

For curved and/or long brackets (high length/height ratio), the effective bracket length is to be

taken as the maximum inscribed 1:1.5 right angled triangle as shown in item (c) of both Figure 4 and Figure 5.

Where the face plate of the stiffener is continuous along the curved edge of the bracket, the bracket length to be considered for determination of the span point location is not to be taken greater than 1.5 times the length of the bracket arm as shown in Figure 6.

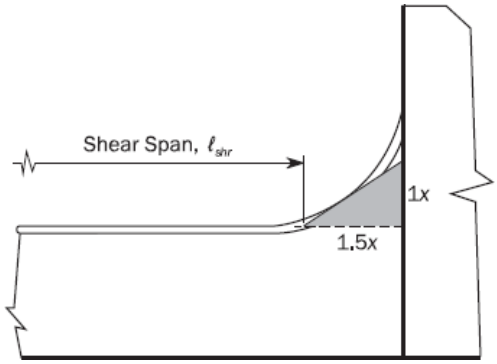


Figure 6 Effective shear span for local support members with continuous face plate along bracket edge

1.1.4 Effect of hull form shape on span of stiffeners

For curved stiffeners, the span is defined as the chord length between span points to be measured at the flange for stiffeners with a flange, and at the free edge for flat bar stiffeners. The calculation of the effective span is to be in accordance with requirements given in [1.1.2] and [1.1.3].

1.1.5 Effective span of stiffeners supported by struts

The arrangement of stiffeners supported by struts is not allowed for ships over 120 m in length.
The span, l of stiffeners supported by one strut fitted at mid distance of the primary supporting members is to be taken as $0.7l_2$.

In case where two struts are fitted at 1/3 and 2/3 length between primary supporting members, the span, l of stiffeners is to be taken as $0.7l_2$.

l_1 and l_2 are the spans defined in Figure 7 and Figure 8.

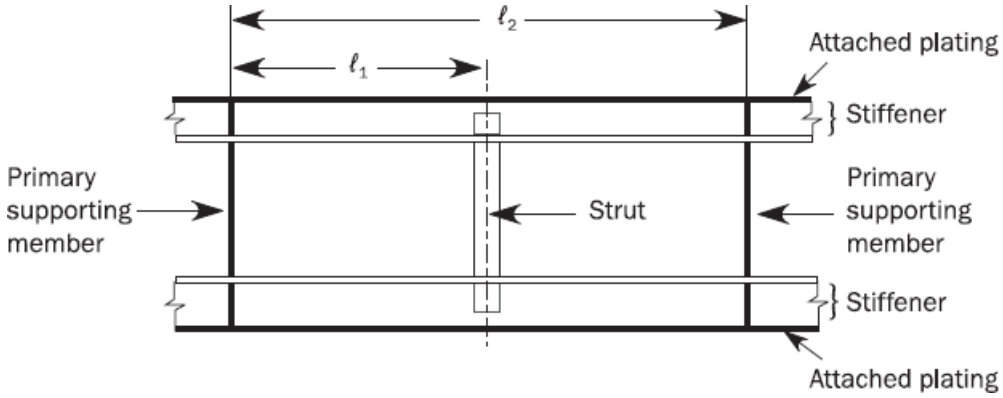


Figure 7 Span of stiffeners with one strut

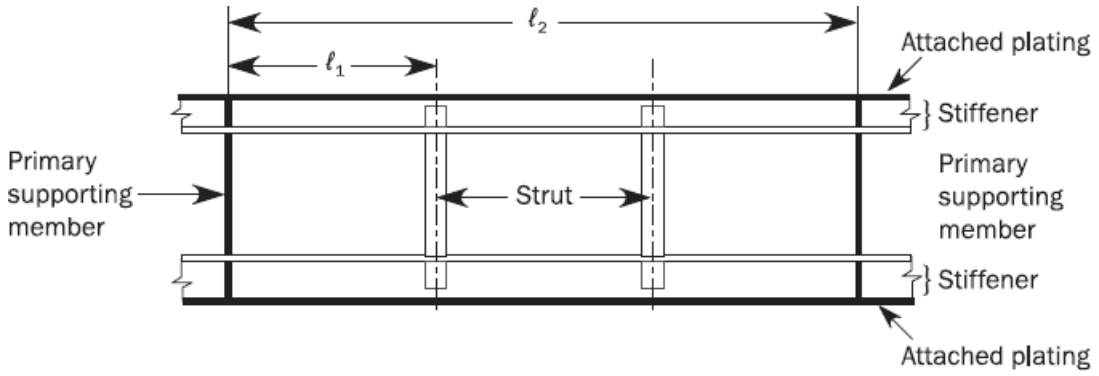
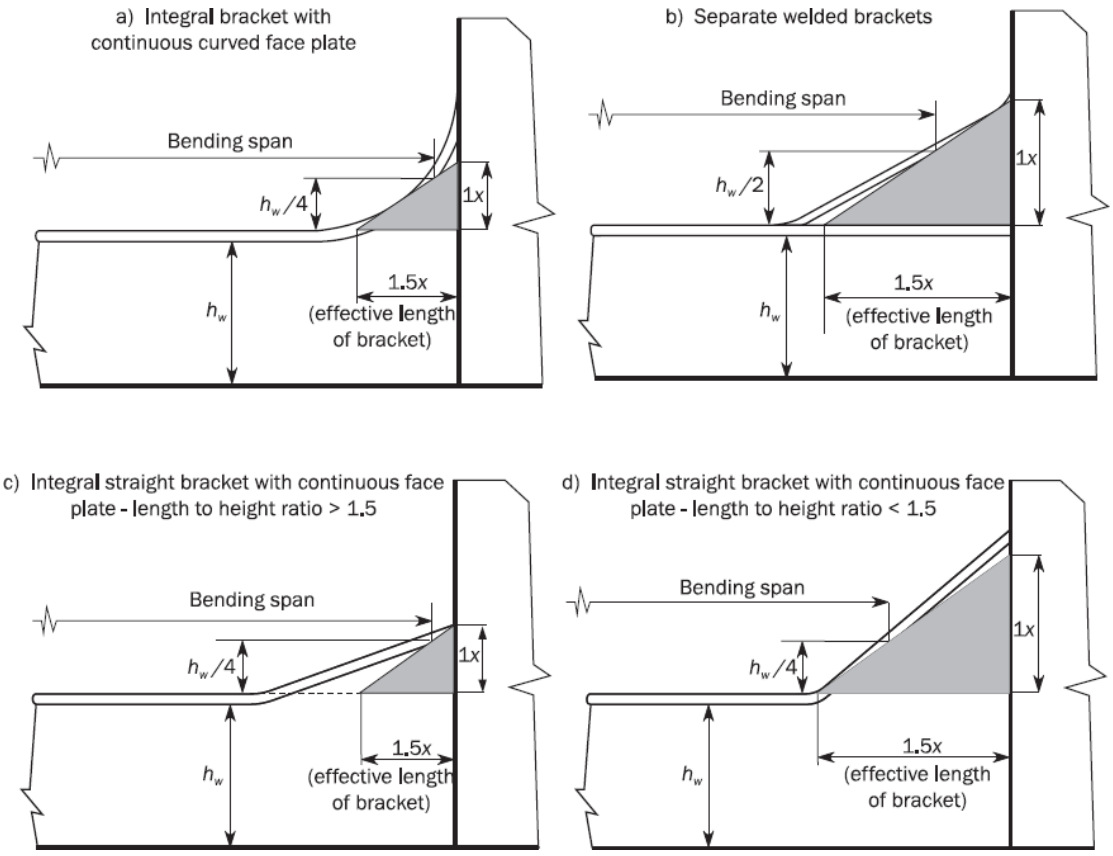


Figure 8 Span of stiffeners with two struts



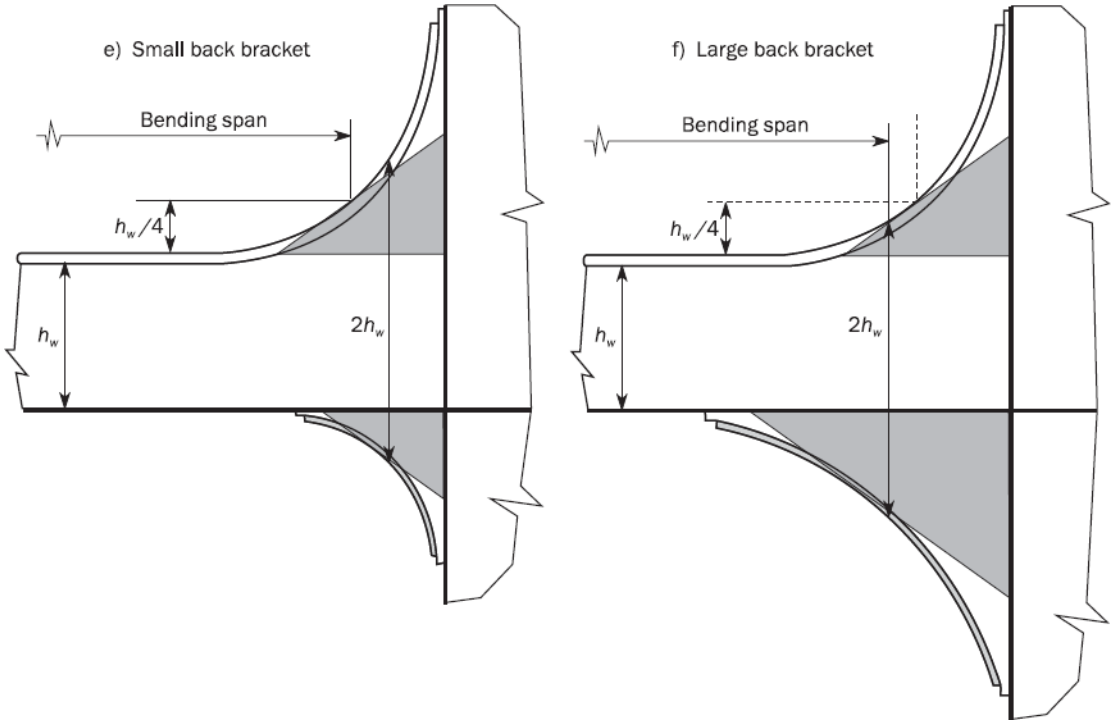
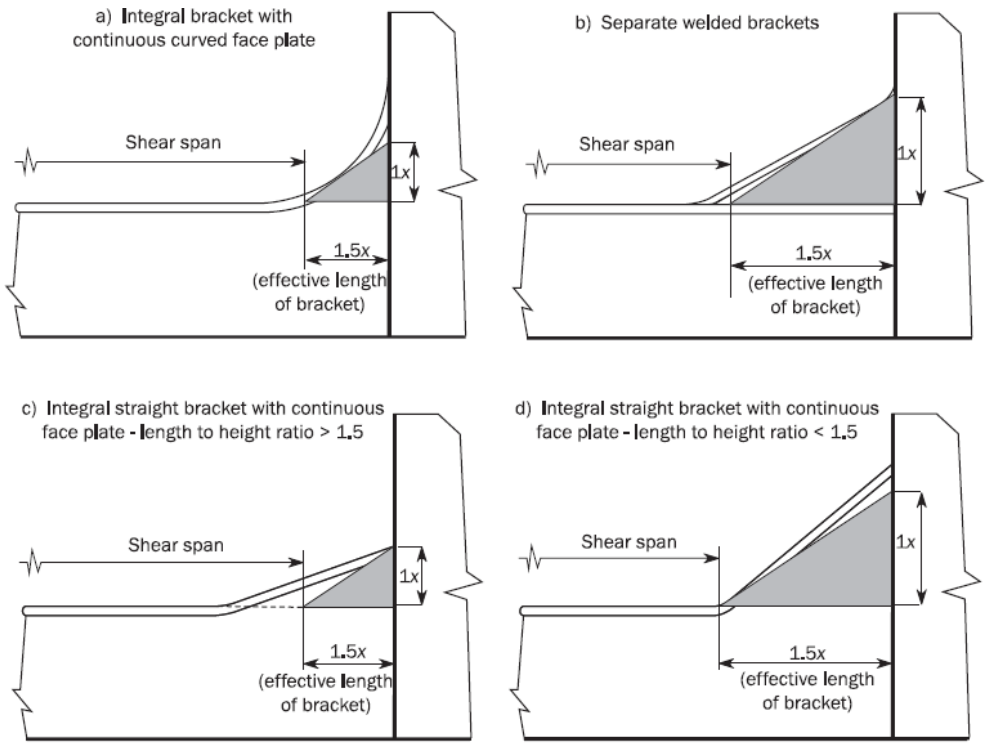


Figure 9 Effective bending span of primary supporting member



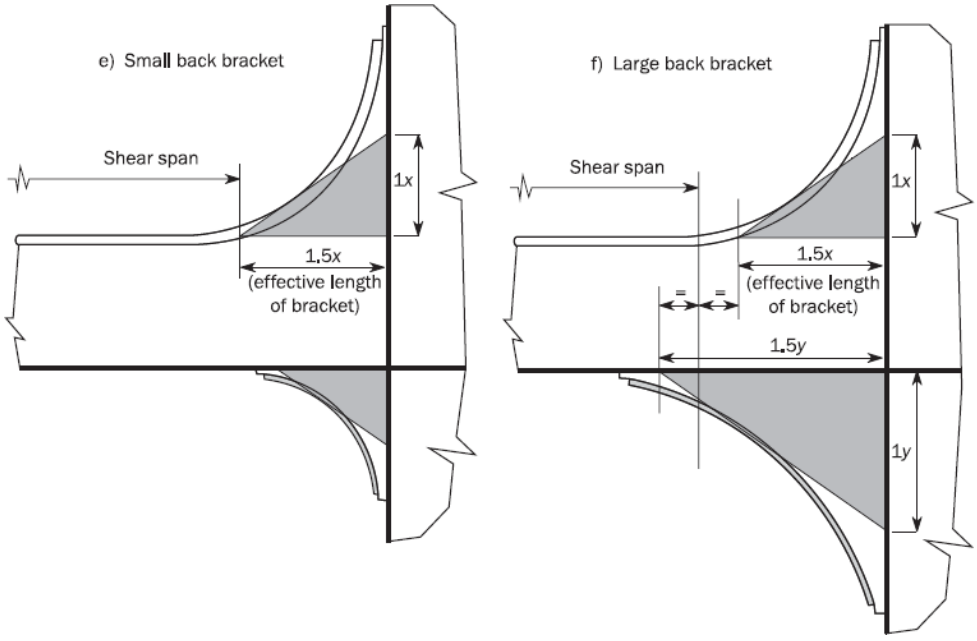


Figure 10 Effective shear span of primary supporting member

1.1.6 Effective bending span of primary supporting members

The effective bending span, l_{bdg}, in m, of a primary supporting member without end bracket is to be taken as the length of the member between supports.

The effective bending span, l_{bdg}, of a primary supporting member may be taken as less than the full length of the member between supports provided that suitable end brackets are fitted.
The effective bending span l_{bdg}, in m, of a primary supporting member with end brackets is taken between points where the depth of the bracket is equal to half the web height of the primary supporting member as shown in item (b) of Figure 9. The effective bracket used to define these span points is to be taken as given in [1.1.8].

In case of brackets where the face plate of the member is continuous along the face of the bracket, as shown in items (a), (c) and (d) of Figure 9, the effective bending span l_{bdg}, in m, is taken between points where the depth of the bracket is equal to one quarter the web height of the primary supporting member. The effective bracket used to define these span points is to be taken as given in [1.1.8].

For straight brackets with a length to height ratio greater than 1.5, the span point is to be taken to the effective bracket; otherwise the span point is to be taken to the fitted bracket.

For curved brackets, for span positions above the tangent point between fitted bracket and effective bracket, the span point is to be taken to the fitted bracket; otherwise, the span point is to be taken to the effective bracket.

For arrangements where the primary supporting member face plate is carried on to the bracket and backing brackets are fitted; the span point need not be taken greater than to the position where the total depth reaches twice the depth of the primary supporting member. Arrangements with small and large backing brackets are shown in items (e) and (f) of Figure 9.

For arrangements where the height of the primary supporting member is maintained and the face plate width is increased towards the support; the effective bending span may be taken to a position where the face plate breadth reaches twice the nominal breadth.

1.1.7 Effective shear span of primary supporting members

The effective shear span of the primary supporting member may be reduced compared to effective bending span, and taken between the toes of the effective brackets supporting the member, where the toes of effective brackets are as shown in Figure 10. The effective bracket used to define the toe point is given in [1.1.8].

For arrangements where the effective backing bracket is larger than the effective bracket in way of face plate, the shear span is to be taken as the mean distance between toes of the effective brackets as shown in item (f) of Figure 10.

1.1.8 Effective bracket definition

The effective bracket is defined as the maximum size of right angled triangular bracket with a length to height ratio of 1.5 that fits inside the fitted bracket. See Figure 9 for examples.

1.2 Spacing and load supporting breadth

1.2.1 Stiffeners

Stiffeners spacing, *s*, in mm, for the calculation of the effective attached plating of stiffeners is to be taken as the mean spacing between stiffeners and taken equal to, see Figure 11.

$$s = \frac{b_1 + b_2 + b_3 + b_4}{4}$$

where:

b_1, b_2, b_3, b_4: Spacings between stiffeners at ends, in mm.

In general, the loading breadth supported by stiffener is to be taken equal to *s*.

1.2.2 Primary supporting member

Primary supporting member spacing, *S*, for the calculation of the effective attached plating of primary supporting members is to be taken as the mean spacing between adjacent primary supporting members, and taken equal to, see Figure 11.

$$s = \frac{b_1 + b_2 + b_3 + b_4}{4}$$

where:

b_1, b_2, b_3, b_4: Spacings between primary supporting members at ends.

In general, the loading breadth supported by a primary supporting member is to be taken equal to *S*.

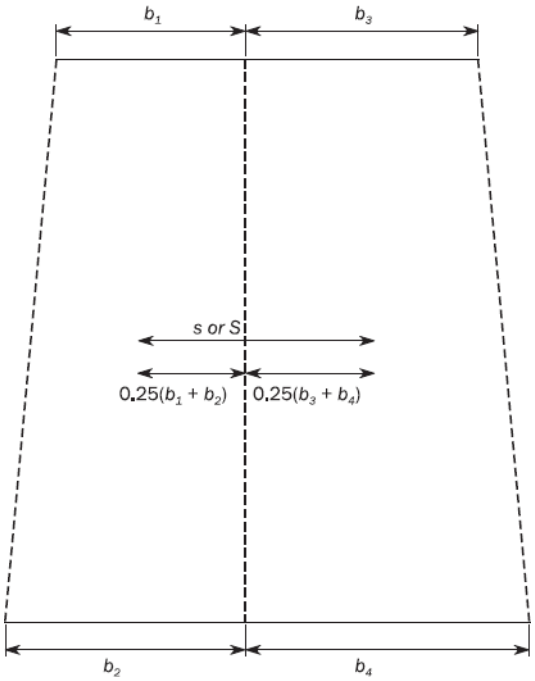


Figure 11 Spacing of plating

1.2.3 Spacing of curved plating

For curved plating, the stiffener spacing, *s* or the primary supporting member spacing, *S* is to be measured on the mean chord between members.

1.3 Effective breadth

1.3.1 Stiffeners

The effective breadth, b_{eff}, in mm, of the attached plating to be considered in the actual net section modulus for the yielding check of stiffeners is to be obtained from the following formulae:

- Where the plating extends on both sides of the stiffener:
  $b_{eff} = 200l$, or
  $b_{eff} = s$
  Whichever is lesser.
- Where the plating extends on one side of the stiffener (i.e. stiffeners bounding openings):
  $b_{eff} = 100l$, or
  $b_{eff} = 0.5\ s$
  Whichever is lesser.

However, where the attached plate net thickness is less than 8 mm, the effective breadth is not to be taken greater than 600 mm.

The effective breadth, b_{eff}, in mm, of the attached plating to be considered for the buckling check of stiffeners is given in Ch8, Sec 5, [2.3.5].

1.3.2 Primary supporting members

The effective breadth of attached plating, b_{eff}, in m, for calculating the section modulus and/or moment of inertia of a primary supporting member is to be taken as:

$$b_{eff} = S \min\left[\frac{1.12}{1+\frac{1.75}{\left(\frac{l_{bdg}}{S\sqrt{3}}\right)^{1.6}}};1.0\right] \quad \text{for } \frac{l_{bdg}}{S\sqrt{3}} \geq 1$$

$$b_{eff} = 0.407\frac{l_{bdg}}{\sqrt{3}} \quad \text{for } \frac{l_{bdg}}{S\sqrt{3}} < 1$$

1.3.3 Effective area of curved face plate and attached plating of primary supporting members

The effective net area given in a) and b) is only applicable to curved face plates and curved attached plating of primary supporting members. This is not applicable for the area of web stiffeners parallel to the face plate.

The effective net area is applicable to primary supporting members for the following calculations:

- Actual net section modulus used for comparison with the scantling requirements in Ch6.
- Actual effective net area of curved face plates, modelled by beam elements, used in Ch7.

a) The effective net area, $A_{eff\text{-}n50}$, in mm^2, is to be taken as:
$A_{eff\text{-}n50} = C_f\, t_{f\text{-}n50}\, b_f$

where:
C_f : Flange efficiency coefficient is to be obtained from the following formula but not to be greater than 1.0:

$$C_f = C_{f1}\frac{1.285}{\beta k_1} \text{ for symmetrical face plate}$$

$$C_f = 0.18 + \frac{0.08}{\beta^2}$$ for unsymmetrical face plate

$$C_f = C_{f1}\frac{1.285}{\beta k_1}$$ for attached plating of box girders

C_{f1} : Coefficient taken equal to:

- For symmetrical face plates,

$$C_{f1} = \frac{(\sinh k_1\beta \cosh k_1\beta + \sin k_1\beta \cos k_1\beta)}{(\cos hk_1\beta)^2 + (\cos k_1\beta)^2}$$

- For attached plating of box girders with two webs,

$$C_{f1} = \frac{0.78\ (\sinh\beta + \sin\beta)(\cosh\beta - \cos\beta)}{\sinh^2\beta + \sin^2\beta}$$

- For attached plating of box girders with multiple webs,

$$C_{f1} = \frac{1.56\ (\cosh\beta - \cos\beta)}{\sinh\beta + \sin\beta}$$

k_1 : Coefficient calculated as:

$k_1 = 1.4 + 1.25(1.4 - \beta)^3$ for $\beta < 1.4$

$k_1 = 1.4$ for $\beta \geq 1.4$

β : Coefficient calculated as:

$$\beta = \frac{1.285\ b_1}{\sqrt{r_f\ t_{f-n50}}}$$, in rad.

b_1 : Breadth, in mm, to be taken equal to:

- For symmetrical face plates, $b_1 = 0.5\ (b_f - t_w\text{-}n_{50})$
- For unsymmetrical face plates, $b_1 = b_f$
- For attached plating of box girders, $b_1 = s_w - t_w\text{-}n_{50}$

s_w : Spacing of supporting webs for box girders, in mm.

$t_{f\text{-}n50}$: Net flange thickness, in mm. For calculation of C_f and β of unsymmetrical face plates, $t_{f\text{-}n50}$ is not to be taken greater than $t_{w\text{-}n50}$.

$t_{w\text{-}n50}$: Net web plate thickness, in mm.

r_f : Radius of curved face plate or attached plating, in mm, see Figure 12 at mid thickness.

b_f : Breadth of face plate or attached plating, in mm, see Figure 12.

b) The effective net area, in mm^2, of curved face plates supported by radial brackets, or attached plating supported by cylindrical stiffeners, is given by:

$$A_{eff-n50} = \left(\frac{3r_f t_{f-n50} + C_f s_r^2}{3r_f t_{f-n50} + s_r^2}\right) t_{f-n50} b_f$$

where:

s_r : Spacing of tripping brackets or web stiffeners or stiffeners normal to the web plating, in mm, see Figure 12.

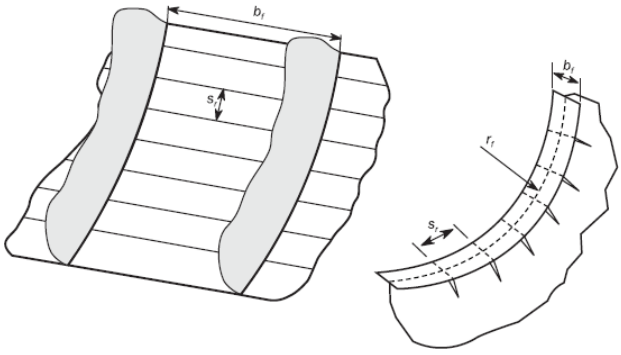


Figure 12 Curved shell panel and face plate

1.4 Geometrical properties of stiffeners and primary supporting members

1.4.1 Stiffener profile with a bulb section

The properties of bulb profile sections are to be determined by direct calculations.

Where direct calculation of properties is not possible, a bulb section may be taken equivalent to a built-up section. The net dimensions of the equivalent built-up section are to be obtained, in mm, from the following formulae.

$$h_w = h'_w - \frac{h'_w}{9.2} + 2$$

$$b_f = \alpha\left(t'_w + \frac{h'_w}{6.7} - 2\right)$$

$$t_f = \frac{h'_w}{9.2} - 2$$

$$t_w = t'_w$$

where:

h'_w, t'_w : Net height and thickness of a bulb section, in mm, as shown in Figure 13.

α : Coefficient equal to:

$$\alpha = 1.1 + \frac{(120 - h'_w)^2}{3000} \quad \text{for } h'_w \leqslant 120$$

α=1.0 for $h'_w > 120$

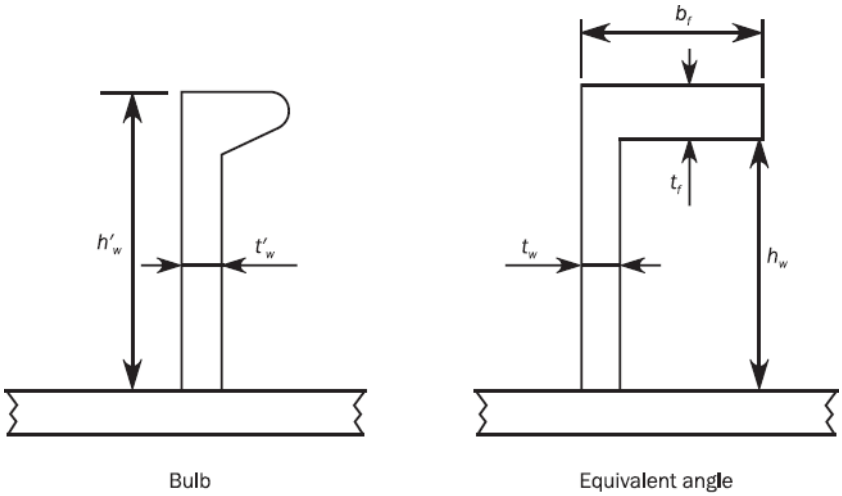


Figure 13 Dimensions of stiffeners

1.4.2 Net elastic shear area of stiffeners

The net elastic shear area, A_{shr}, in cm^2, of stiffeners is to be taken as:

$$A_{sh} = d_{shr}\, t_w 10^{-2}$$

d_{shr} : Effective shear depth of stiffener, in mm, as defined in [1.4.3].

t_w : Net web thickness of the stiffener, in mm, as defined in Ch 3, Sec 2, Figure 2.

1.4.3 Effective shear depth of stiffeners

The effective shear depth of stiffeners, d_{shr}, in mm, is to be taken as:

$$d_{shr} = (h_{stf} - 0.5t_{c\text{-}stf} + t_p + 0.5t_{c\text{-}pl})\sin\varphi_w$$

where:

h_{stf}: Height of stiffener, in mm, as defined in Ch 3, Sec 2, Figure 2.

t_p : Net thickness of the stiffener attached plating, in mm, as defined in Ch 3, Sec 2, Figure 2.

t_{c_stf} :Corrosion addition, in mm, of considered stiffener as given in Ch 3, Sec 3.

t_{c_pl} : Corrosion addition, in mm, of attached plate of the stiffener considered as given in Ch 3, Sec 3.

1.4.4 Elastic net section modulus and net moment of inertia of stiffeners

The elastic net section modulus, Z , in cm^3 and the net moment of inertia, I, in cm^4 of stiffeners, is to be taken as:

$Z = Z_{stf} \sin \varphi_w$

$I = I_{st} \sin^2 \varphi_w$

where:

Z_{stf} : Net section modulus of the stiffener, in cm^3, considered perpendicular to its attached plate, i.e. with φ_w = 90 deg.

I_{st}: Net moment of inertia of the stiffener, in cm^4, considered perpendicular to its attached plate, i.e. with φ_w = 90 deg.

Figure 14 Angle between stiffener web and attached plating

1.4.5 Effective net plastic shear area of stiffeners

The net plastic shear area, $A_{shr\text{-}pl}$, of stiffeners, in cm^2, which is used for assessment against impact loads is to be taken as:

$A_{shr\text{-}pl} = A_{shr}$

where:

A_{shr} : Net elastic shear area, in cm^2, as defined in [1.4.2].

1.4.6 Effective net plastic section modulus of stiffeners

The effective net plastic section modulus, Z_{pl}, of stiffeners, in cm^3, which is used for assessment against impact loads, is to be taken as:

$$Z_{pl} = \frac{f_w h_w^{\,2} t_w}{2000} + \frac{(2\gamma - 1) A_f h_{f-ctr}}{1000} \quad \text{for } 75^\circ \leqslant \varphi_w \leqslant 105^\circ$$

$$Z_{pl} = \frac{f_w h_w^{\,2} t_w \sin\phi_w}{2000} + \frac{(2\gamma - 1) A_f \left(h_{f-ctr} \sin\phi_w - b_{f-ctr} |\cos\phi_w|\right)}{1000} \quad \text{for } \varphi_w < 75^\circ \text{ or } \varphi_w > 105^\circ$$

where:

f_w : Web shear stress factor, taken equal to:

- For flanged profile cross sections with n = 1 or 2, f_w = 0.75.
- For flanged profile cross sections with n = 0, f_w = 1.0.
- For flat bar stiffeners, f_w = 1.0.

n : Number of plastic hinges at end supports of each member, taken equal to: 0, 1 or 2.

A plastic hinge at end support may be considered where:

- The stiffener is continuous at the support.
- The stiffener passes through the support plate while it is connected at its termination point by a carling (or equivalent) to adjacent stiffeners.
- The stiffener is attached to an abutting stiffener effective in bending (not a buckling stiffener).
- The stiffener is attached to a bracket effective in bending. The bracket is assumed to be effective in bending when it is attached to another stiffener (not a buckling stiffener).

h_w: Depth of stiffener web, in mm, taken equal to:

- For T, L (rolled and built-up) profiles and flat bar, as defined in Ch 3, Sec 2, Figure 2

- For L2 profile as defined in Ch 3, Sec 2, Figure 3,
- For bulb profiles, to be taken as defined in [1.4.1].

γ : Coefficient equal to:

$$\gamma = \frac{1+\sqrt{3+12\beta}}{4}$$

β : Coefficient equal to:

- $\beta = \frac{t_w^2 f_b l_{shr}^{\ 2}}{80 b_f^2 t_f h_{f-ctr}} 10^6 + \frac{t_w}{2b_f}$ for L profiles without a mid-span tripping bracket,but not to be taken greater than 0.5.
- β= 0.5 for other cases.

A_f :Net cross sectional area of flange, in mm^2:

- A_f = 0 for flat bar stiffeners.
- $A_f = b_f t_f$ for other stiffeners.

$b_{f\text{-}ctr}$: Distance from mid thickness of stiffener web to the centre of the flange area:

- $b_{f\text{-}ctr} = 0.5\ (b_f - t_w)$ for rolled angle profiles and bulb profiles.
- $b_{f\text{-}ctr}$ = 0 for T profiles.

$h_{f\text{-}ctr}$: Height of stiffener measured to the mid thickness of the flange:

- $h_{f\text{-}ctr} = h_w + 0.5t_f$ for profiles with flange of rectangular shape and for bulb profiles.

f_b : Coefficient taken equal to:

- f_b = 0.8 for flanges continuous through the primary supporting member, with end bracket(s).
- f_b= 0.7 for flanges sniped at the primary supporting member or terminated at the support without aligned structure on the other side of the support, and with end bracket(s).
- f_b = 1.0 for other stiffeners.

t_f : Net flange thickness, in mm.

- t_f = 0 for flat bar stiffeners.
- For bulb profiles t_f is defined in [1.4.1].

1.4.7 Primary supporting member web not perpendicular to attached plating

Where the primary supporting member web is not perpendicular to the attached plating, the actual net shear area, in cm^2, and the actual net section modulus, in cm3, can be obtained from the following formulae:

- Actual net shear area:
  $A_{sh-n50} = A_{sh-0-n50}\sin\varphi_w$
- Actual net section modulus:
  $Z_{n50} = Z_{perp-n50}\sin\varphi_w$

where:

$A_{sh-0-n50}$: Actual net shear area, in cm^2, of the primary supporting member assumed to be perpendicular to the attached plating, to be taken equal to:

$$A_{sh-0-n50} = \left(h_{eff} + t_{f-n50} + t_{p-n50}\right) t_{w-n50} 10^{-2}$$

$Z_{perp-n50}$: Actual section modulus, in cm^3, with its attached plating of the primary supporting member assumed to be perpendicular to the attached plating.

1.4.8 Shear area of primary supporting members with web openings

The effective web height, h_{eff}, in mm, to be considered for calculating the effective net shear area, $A_{sh\text{-}n50}$ is to be taken as the lesser of:

$h_{eff} = h_w$

$h_{eff} = h_{w3} + h_{w4}$

$h_{eff} = h_{w1} + h_{w2} + h_{w4}$

where:

h_w : Web height of primary supporting member, in mm.

h_{w1}, h_{w2}, h_{w3}, h_{w4} : Dimensions as shown in Figure 16.

Where an opening is located at a distance less than $h_w/3$ from the cross-section considered, h_{eff} is to be taken as the smaller of the net height and the net distance through the opening. See Figure 16.

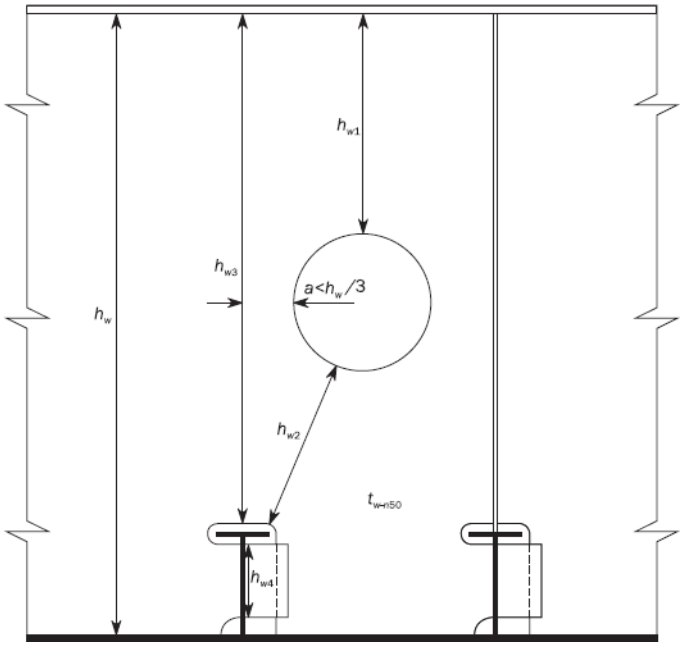


Figure 15 Effective shear area in way of web openings

1.4.9 Stiffener flange width

In case the stiffener flange thickness requirement in Ch 8, Sec 2, [3.1.1] b) is not fulfilled, the effective free flange outstand, used in strength assessment including the calculation of actual net section modulus, is to be taken as $b_{f\text{-}out\text{-}max}$ defined in Ch 8, Sec 2, [3.1.1].

2 PLATES

2.1 Idealisation of EPP

2.1.1 EPP

An elementary plate panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary supporting members. The plate panel length, *a*, and breadth, *b*, of the EPP are defined respectively as the longest and shortest plate edges, as shown in Figure 16.

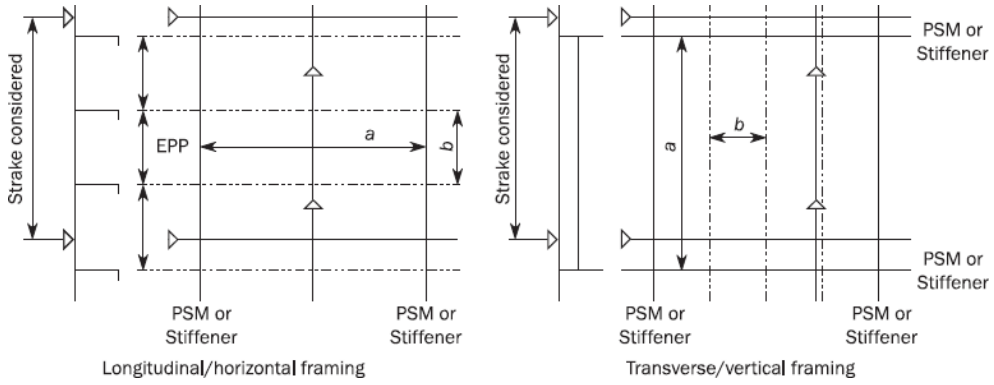


Figure 16 Elementary Plate Panel (EPP) definition

2.1.2 Strake required thickness

The required thickness of a plate strake is to be taken as the greatest value required for each EPP within that strake. The requirements given in Table 1 are to be applied for the selection of strakes to be considered as shown in Figure 17.

The maximum corrosion addition within a strake is to be applied according to Ch3, Sec 3, [1.2.4].

Strake considered in a given EPP **Table 1**

	$a/b>2$	$a/b\leqslant 2$
$a_1>b/2$	All strakes (St1, St2, St3, St4)	All strakes (St1, St2, St3, St4)

	$a/b>2$	$a/b\leqslant 2$
$a_1\leqslant b/2$	Strakes St2 and St4	All strakes (St1, St2, St3, St4)

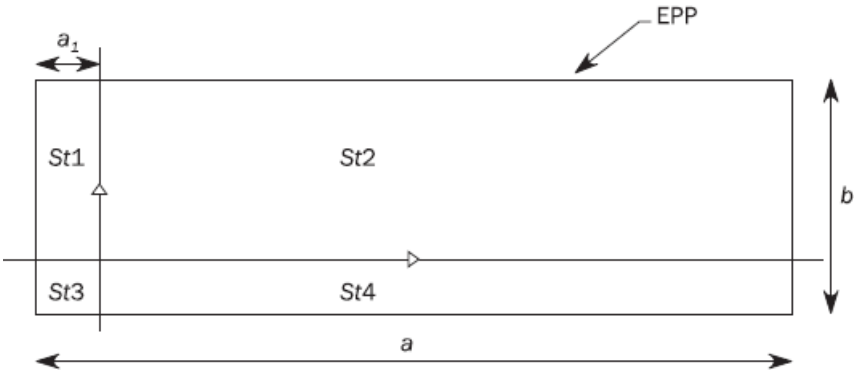


Figure 17 Strake considered in a given EPP

where:

a_1 : Distance, in mm, measured inside the considered strake in the direction of the long edge of the EPP, between the strake boundary weld seam and the EPP edge.

2.1.3

For direct strength assessment, the EPP is idealised with the mesh arrangement in the finite element model.

2.2 Load calculation point

2.2.1 Yielding

For the yielding check, the local pressure and hull girder stress, used for the calculation of the local scantling requirements are to be taken at the Load Calculation Point (LCP) having coordinates *x*, *y* and *z* as defined in Table 2.

LCP coordinates for yielding **Table 2**

LCP coordinates	General (1)		Horizontal plating		Vertical transverse structure and transverse stool plating	
	Longitudinal framing (Figure 18)	Transverse framing (Figure 19)	Longitudinal framing	Transverse framing	Horizontal framing (Figure 20)	Vertical framing (Figure 21)
x coordinate	Mid-length of the EPP		Mid-length of the EPP		Corresponding to y and z values	
y coordinate	Corresponding to *x* and *z* coordinates		Outboard y value of the EPP		Outboard y value of the EPP, taken at z level(2)	
z coordinate	Lower edge of the EPP	The greater of lower edge of the EPP or lower edge of the strake	Corresponding to x and y values		Lower edge of the EPP	The greater of lower edge of the EPP or lower edge of the strake

(1) All structures other than horizontal platings or vertical transverse structures.
(2) For transom plate, the y coordinate of the load calculation point is to be taken corresponding to y value at side shell at z level of the load calculation point, for the external dynamic pressure calculation.

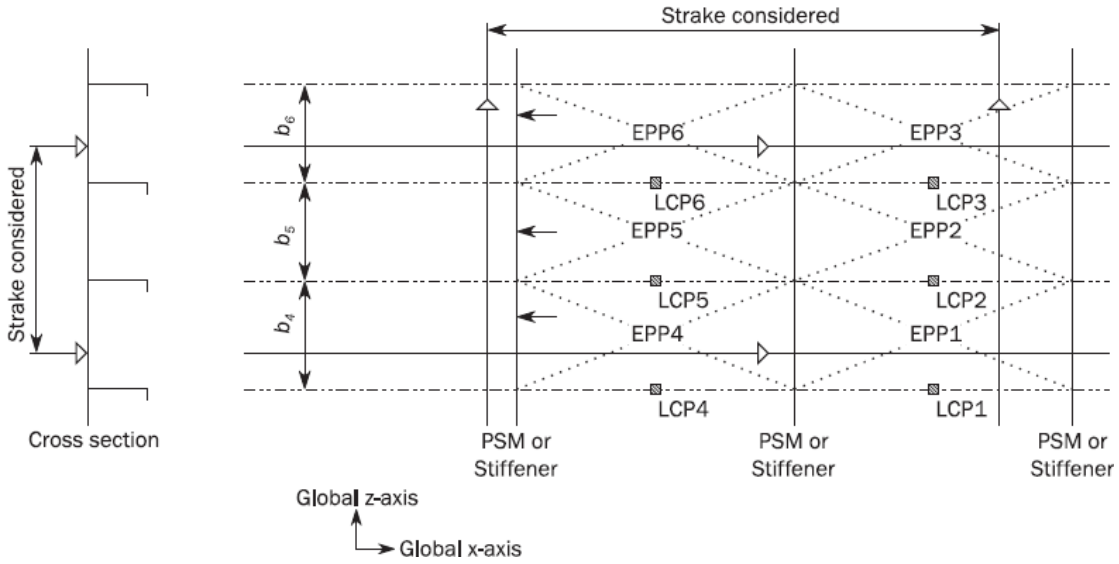


Figure 18 Load calculation point (LCP) for longitudinal framing

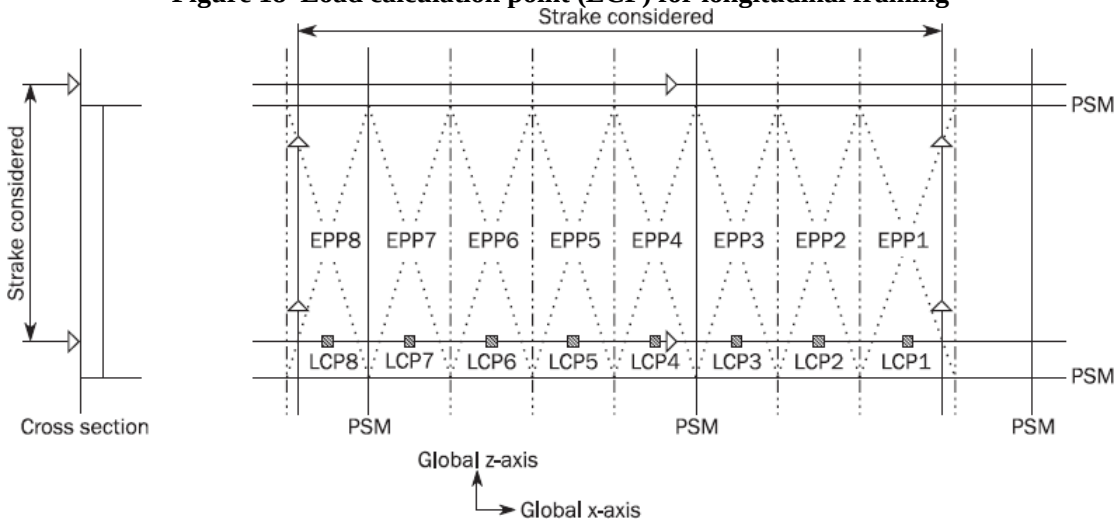


Figure 19 Load calculation point for transverse framing

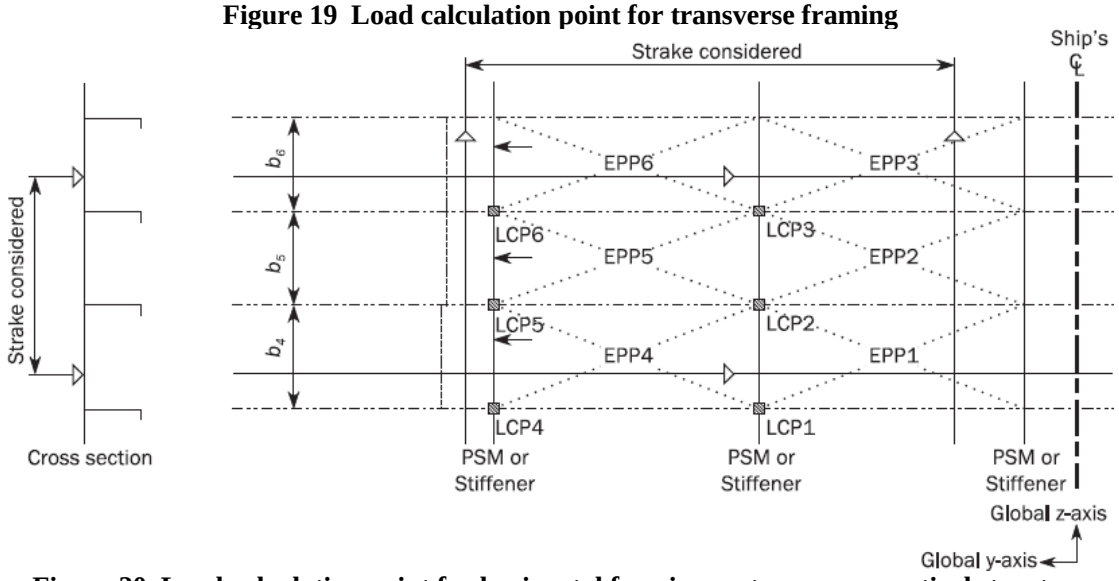


Figure 20 Load calculation point for horizontal framing on transverse vertical structure

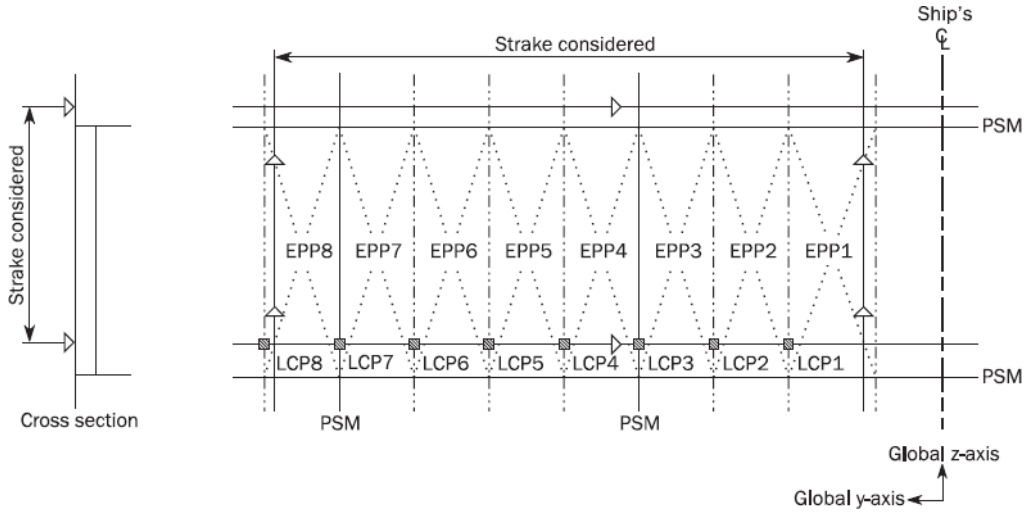


Figure 21 Load calculation point for vertical framing on transverse vertical structure

2.2.2 Buckling

For the prescriptive buckling check of the EPP according to Ch 8, Sec 3, the LCP for the pressure and for the hull girder stresses are defined in Table 3.

For the FE buckling check, Ch 8, Sec 4 is applicable.

LCP coordinates for plate buckling **Table 3**

LCP coordinates	LCP for pressure	LCP for hull girder stresses (Figure 22)		
		Bending stresses(1)		Shear stresses
		Non horizontal plate	Horizontal plate	
x coordinate	Same coordinates as LCP for yielding See Table 2	Mid-length of the EPP		
y coordinate		Corresponding to *x* and *z* values	Outboard and inboard ends of the EPP (points A1 and A2)	Mid-point of EPP (point B)
z coordinate		Both upper and lower ends of the EPP (points A1 and A2)	Corresponding to *x* and *y* values	

(1) The bending stress for curved plate panel is the mean value of the stresses calculated at points A1 and A2.

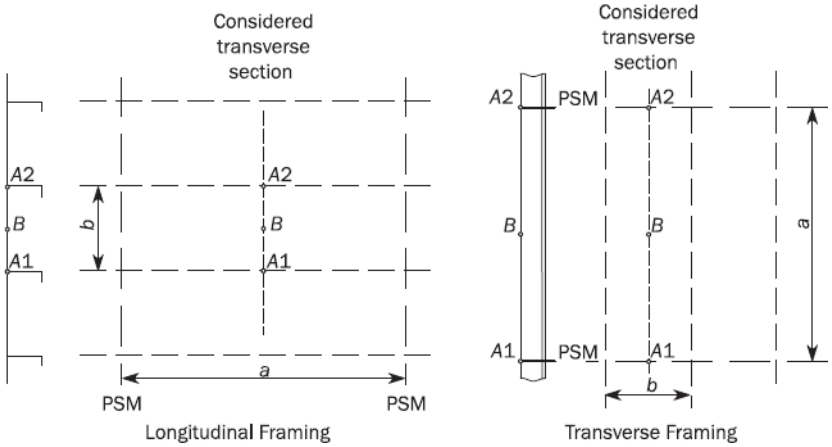


Figure 22 LCP for plate buckling – hull girder stresses

3 STIFFENERS

3.1 Reference point

3.1.1

The requirements of section modulus for stiffeners relate to the reference point giving the minimum section modulus. This reference point is generally located as shown in Figure 23 for typical profiles.

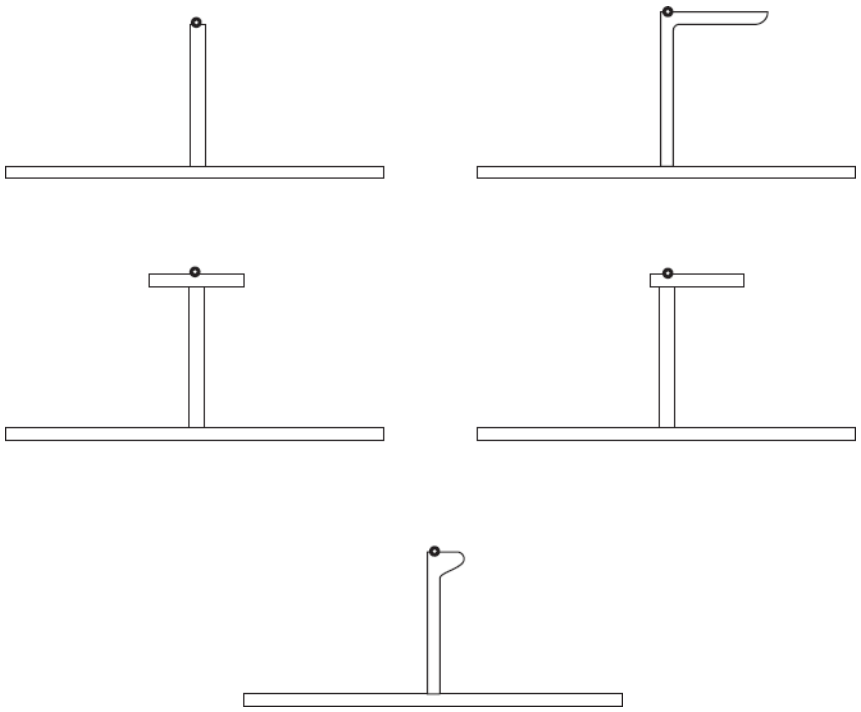


Figure 23 Reference point for calculation of section modulus and hull girder stress for local scantling assessment

3.2 Load calculation points

3.2.1 LCP for Pressure

The load calculation point for the pressure is located at:

- Middle of the full length, *l*, of the considered stiffener.
- The intersection point between the stiffener and its attached plate.

For stiffeners located on transom plate, the y coordinate of the load calculation point is to be taken corresponding to y value at side shell at z level of the load calculation point, for the external dynamic pressure calculation.

3.2.2 LCP for hull girder bending stress

The load calculation point for the hull girder bending stresses is defined as follows:

- For prescriptive yielding verification according to Ch 6 and Ch 10, Sec 4:
  - At the middle of the full length, l, of the considered stiffener.
  - At the reference point given in Figure 23.
- For prescriptive buckling requirements according to Ch 8:
  - At the middle of the full length, *l*, of the considered stiffener.
  - At the intersection point between the stiffener and its attached plate.

3.2.3 Non-horizontal stiffeners

The lateral pressure, *P* is to be calculated as the maximum between the value obtained at middle of the full length, *l*, and the value obtained from the following formulae:

$P = \frac{p_U + p_L}{2}$ when the upper end of the vertical stiffener is below the lowest zero pressure level.

$P = \frac{l_1}{l}\frac{p_L}{2}$ when the upper end of the vertical stiffener is at or above the lowest zero pressure

level, see Figure24.

where:

l_1 : Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level.

P_U, P_L : Lateral pressures at the upper and lower end of the vertical stiffener span l, respectively.

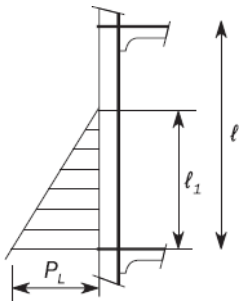


Figure 24 Definition of pressure for vertical stiffeners

4 PRIMARY SUPPORTING MEMBERS

4.1 Load calculation point

4.1.1

The load calculation point is located at the middle of the full length, *S*, at the attachment point of the primary supporting member with its attached plate. However, for primary supporting members in the cargo hold region the requirements in Pt 2, Ch 1, Sec 4, [4], as applicable, for bulk carriers and Pt 2, Ch 2, Sec 3, [1] for oil tankers are to be followed.

For primary supporting members located on transom plate, the y coordinate of the load calculation point is to be taken corresponding to y value at side shell at z level of load calculation point for the external dynamic pressure calculation.

Chapter 4 LOADS

Section 1 INTRODUCTION

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.
S : Static load case.
S+D: Static plus dynamic load case.

1 GENERAL
1.1 Application
1.1.1 Scope
This chapter provides the design load for strength and fatigue assessments.

The load combinations are to be derived for the design load scenarios specified in Ch4, Sec 7. This section uses the concept of design load scenarios to specify consistent design load sets which cover the appropriate operating modes of a bulk carrier or oil tanker.

1.1.2 Equivalent Design Wave EDW
The dynamic loads associated with each dynamic load case are based on the Equivalent Design Wave (EDW) concept. The EDW concept applies a consistent set of dynamic loads to the ship such that specified dominant load response is equivalent to the required long term response value.

1.1.3 Probability level for strength and fatigue assessments
In this chapter, the assessments are to be understood as follows:

- Strength assessment means the assessment for the strength criteria excluding fatigue, for the loads corresponding to the probability level of 10^{-8}, for the ballast water exchange, for harbour conditions and for flooded conditions.
- Fatigue assessment means the assessment for the fatigue criteria for the loads corresponding to the probability level of 10^{-2}.

1.1.4 Dynamic load components
All dynamic load components are to be concurrent values calculated for each dynamic load case.

1.1.5 Loads for strength assessment
The strength assessment is to be undertaken for all design load scenarios and the final assessment is to be made on the most onerous strength requirement.

Each design load scenario for strength assessment is composed of a Static (S) load case or a Static + Dynamic (S+D) load case, where the static and dynamic loads are dependent on the loading condition being considered.
The static loads are defined in the following sections:

- Still water hull girder loads in Ch4, Sec 4.
- External loads in Ch4, Sec 5.
- Internal loads in Ch4, Sec 6.

The EDWs for the strength assessment and the dynamic load combination factors for global loads are listed in Ch4, Sec 2, [2].

The dynamic load components are defined in the following sections:

- Dynamic hull girder load components in Ch4, Sec 4.
- External loads in Ch4, Sec 5.
- Internal loads in Ch4, Sec 6.

1.1.6 Loads for fatigue assessment

Each design load scenario for fatigue assessment is composed of a Static + Dynamic (S+D) load case, where the static and dynamic loads are dependent on the loading condition being considered. The static loads are defined in the following sections:

- Still water hull girder loads in Ch4, Sec 4.
- External loads in Ch4, Sec 5.
- Internal loads in Ch4, Sec 6.

The EDWs for the fatigue assessment are listed in Ch4, Sec 2, [3]. The dynamic load components are defined in the following sections:

- Dynamic hull girder load components in Ch 4, Sec 4.
- External loads in Ch4, Sec 5.
- Internal loads in Ch4, Sec 6.

1.2 Definitions

1.2.1 Coordinate system

The coordinate system is defined in Ch 1, Sec 4, [3.6.1].

1.2.2 Sign convention for ship motions

The ship motions are defined with respect to the ship's centre of gravity (COG) as shown in Figure 1, where:

- Positive surge is translation in the X-axis direction (positive forward).
- Positive sway is translation in the Y-axis direction (positive towards port side of ship).
- Positive heave is translation in the Z-axis direction (positive upwards).
- Positive roll motion is positive rotation about a longitudinal axis through the COG (starboard down and port up).
- Positive pitch motion is positive rotation about a transverse axis through the COG (bow down and stern up).
- Positive yaw motion is positive rotation about a vertical axis through the COG (bow moving to port and stern to starboard).

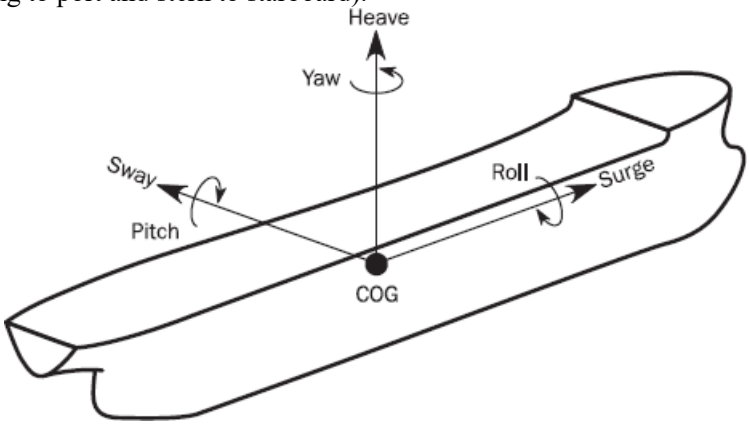


Figure 1 Definition of positive Motions

1.2.3 Sign convention for hull girder loads

The sign conventions of vertical bending moments, vertical shear forces, horizontal bending moments and torsional moments at any ship transverse section are as shown in Figure 2, namely:

- The vertical bending moments M_{sw} and M_{wv} are positive when they induce tensile stresses in the strength deck (hogging bending moment) and negative when they induce tensile stresses in the bottom (sagging bending moment).
- The vertical shear forces Q_{sw}, Q_{wv} are positive in the case of downward resulting forces acting aft of the transverse section and upward resulting forces acting forward of the transverse section under consideration.
- The horizontal bending moment M_{wh} is positive when it induces tensile stresses in the starboard side and negative when it induces tensile stresses in the port side.

- The torsional moment M_{wt} is positive in the case of resulting moment acting aft of the transverse section following negative rotation around the X-axis, and of resulting moment acting forward of the transverse section following positive rotation around the X-axis.

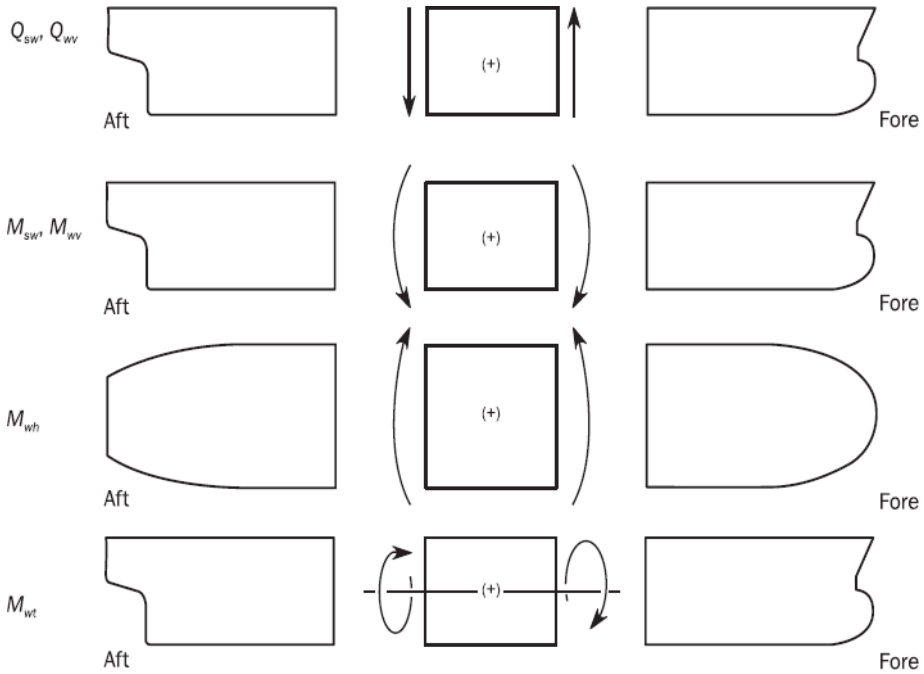


Figure 2 Sign conventions for shear forces Q_{sw}, Q_{wv} and bending moments M_{sw}, M_{wv}, M_{wh} and M_{wt}

Section 2 DYNAMIC LOAD CASES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

a_{surge}, $a_{pitch-x}$, a_{sway}, a_{roll-y}, a_{heave}, a_{roll-z}, $a_{pitch-z}$: Acceleration components, as defined in Ch 4, Sec 3.

f_{xL} : Ratio between X-coordinate of the load point and L, to be taken as:

$$f_{xL} = \frac{x}{L}$$, but not to be taken less than 0.0 or greater than 1.0.

f_T : Ratio between draught at a loading condition and scantling draught, as defined in Ch 4, Sec 3.

f_{lp} : Factor depending on longitudinal position along the ship, to be taken as:

$f_{lp} = 1.0$ for $x/L \leqslant 0.5$

$f_{lp} = -1.0$ for $0.5 < x/L$

$f_{lp\text{-}OST}$: Factor for the longitudinal distribution of the torsional moment for the OST load case, to be taken as:

$f_{lp\text{-}OST} = 5f_{xL}$ for $x/L < 0.2$

$f_{lp\text{-}OST} = 1.0$ for $0.2 \leqslant x/L < 0.4$

$f_{lp\text{-}OST} = -7.6f_{xL} + 4.04$ for $0.4 \leqslant x/L < 0.65$

$f_{lp\text{-}OST} = -0.9$ for $0.65 \leqslant x/L < 0.85$

$f_{lp\text{-}OST} = 6f_{xL} - 6$ for $0.85 \leqslant x/L$

$f_{lp\text{-}OSA}$: Factor for the longitudinal distribution of the torsional moment for the OSA load case, to be taken as:

$f_{lp\text{-}OSA} = -(0.2 + 0.3f_T)$ for $x/L < 0.4$

$f_{lp\text{-}OSA} = -(0.2 + 0.3f_T)(5.6 - 11.5f_{xL})$ for $0.4 \leqslant x/L < 0.6$

$f_{lp\text{-}OSA} = 1.3(0.2 + 0.3f_T)$ for $0.6 \leqslant x/L$

WS : Weather side, side of the ship exposed to the incoming waves.

LS : Lee side, sheltered side of the ship away from the incoming waves.

M_{WV} : Vertical wave bending moment, in kNm, defined in Ch 4, Sec 4.

Q_{WV} : Vertical wave shear force, in kN, defined in Ch 4, Sec 4.

M_{WH} : Horizontal wave bending moment, in kNm, defined in Ch 4, Sec 4.

M_{WT} : Torsional wave bending moment, in kNm, defined in Ch 4, Sec 4.

C_{WV} : Load combination factor to be applied to the vertical wave bending moment.

C_{QW} : Load combination factor to be applied to the vertical wave shear force.

C_{WH} : Load combination factor to be applied to the horizontal wave bending moment.

C_{WT} : Load combination factor to be applied to the wave torsional moment.

C_{XS} : Load combination factor to be applied to the surge acceleration.

C_{XP} : Load combination factor to be applied to the longitudinal acceleration due to pitch.

C_{XG} : Load combination factor to be applied to the longitudinal acceleration due to pitch motion.

C_{YS} : Load combination factor to be applied to the sway acceleration.

C_{YR} : Load combination factor to be applied to the transverse acceleration due to roll.

C_{YG} : Load combination factor to be applied to the transverse acceleration due to roll motion.

C_{ZH} : Load combination factor to be applied to the heave acceleration.

C_{ZR} : Load combination factor to be applied to the vertical acceleration due to roll.

C_{ZP} : Load combination factor to be applied to the vertical acceleration due to pitch.

θ : Roll angle, in deg, as defined in Ch 4, Sec 3, [2.1.1].

φ : Pitch angle, in deg, as defined in Ch 4, Sec 3, [2.1.2].

1 GENERAL

1.1 Definition of dynamic load cases

1.1.1

The following Equivalent Design Waves (EDW) are to be used to generate the dynamic load cases for structural assessment:

- HSM load cases:
  HSM-1 and HSM-2: Head sea EDWs that minimise and maximise the vertical wave

bending moment amidships respectively.

- HSA load cases:
  HSA-1 and HSA-2: Head sea EDWs that maximise and minimise the head sea vertical acceleration at FP respectively.
- FSM load cases:
  FSM-1 and FSM-2: Following sea EDWs that minimise and maximise the vertical wave bending moment amidships respectively.
- BSR load cases:
  BSR-1P and BSR-2P: Beam sea EDWs that minimise and maximise the roll motion downward and upward on the port side respectively with waves from the port side.
  BSR-1S and BSR-2S: beam Sea EDWs that maximise and minimise the roll motion downward and upward on the starboard side respectively with waves from the starboard side.
- BSP load cases:
  BSP-1P and BSP-2P: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the port side respectively.
  BSP-1S and BSP-2S: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the starboard side respectively.
- OST load cases:
  OST-1P and OST-2P: Oblique sea EDWs that minimise and maximise the torsional moment at 0.25L from the AE with waves from the port side respectively.
  OST-1S and OST-2S: Oblique sea EDWs that maximise and minimise the torsional moment at 0.25L from the AE with waves from the starboard side respectively.
- OSA load cases:
  OSA-1P and OSA-2P: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the port side respectively.
  OSA-1S and OSA-2S: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the starboard side respectively.

Note 1: 1 and 2 denote the maximum or the minimum dominate load component for each EDW.
Note 2: P and S denote that the weather side is on port side and on starboard side respectively.
HSA and OSA load cases are not to be used for fatigue assessment.

1.2 Application

1.2.1

The dynamic load cases described in this section are to be used for determining the dynamic loads required by the design load scenarios described in Ch 4, Sec 7. These dynamic load cases are to be applied to the following structural assessments:

a) Strength assessment:
   - For plating, ordinary stiffeners and primary supporting members by prescriptive methods.
   - For the direct strength method (FE analysis) assessment of structural members.

b) Fatigue assessment:
   - For structural details covered by simplified stress analysis.
   - For structural details covered by FE stress analysis.

2 DYNAMIC LOAD CASES FOR STRENGTH ASSESSMENT

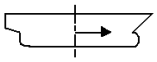
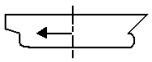
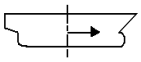
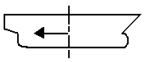
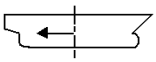
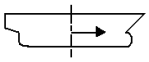
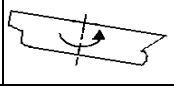
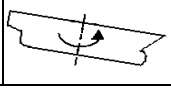
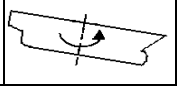
2.1 Description of dynamic load cases

2.1.1

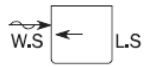
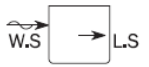
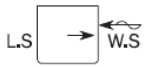
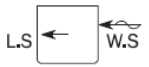
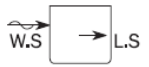
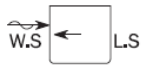
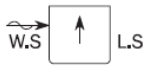
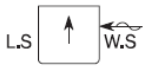
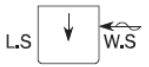
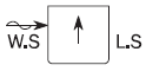
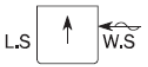
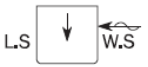
Table 1 to Table 3 describe the ship motions responses and the global loads corresponding to each dynamic load case to be considered for the strength assessment.

Ship responses for HSM, HSA and FSM load cases - Strength assessment Table 1

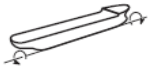
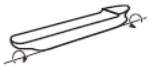
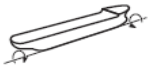
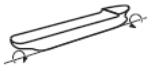
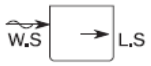
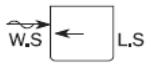
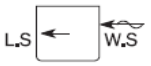
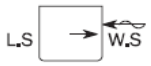
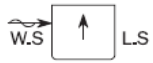
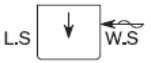
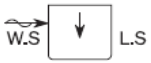
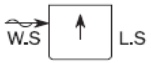
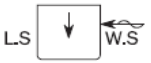
Loadcase	HSM-1	HSM-2	HSA-1	HSA-2	FSM-1	FSM-2
EDW	HSM		HSA		FSM	
Heading	Head		Head		Following	
Effect	Max. bending moment		Max. vertical acceleration		Max. bending moment	

Loadcase	HSM-1	HSM-2	HSA-1	HSA-2	FSM-1	FSM-2
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	-	-	-	-	-	-
TM	-	-	-	-	-	-
Surge	To stern	To bow	To stern	To bow	To bow	To stern
a_{surge}						
Sway	-	-	-	-	-	-
a_{sway}	-	-	-	-	-	-
Heave	Down	Up	Down	Up	-	-
a_{heave}					-	-
Roll	-	-	-	-	-	-
a_{roll}	-	-	-	-	-	-
Pitch	Bow down	Bow up	Bow down	Bow up	Bow up	Bow down
a_{pitch}						

Ship responses for BSR and BSP load cases - Strength assessment **Table 2**

Load case	BSR-1P	BSR-2P	BSR-1S	BSR-2S	BSP-1P	BSP-2P	BSP-1S	BSP-2S
EDW	BSR		BSR		BSP		BSP	
Heading	Beam				Beam			
Effect	Max. roll				Max. pressure at waterline			
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
HWBM	Stbd tensile	Port tensile	Port tensile	Stbd tensile	Stbd tensile	Port tensile	Port tensile	Stbd tensile
TM	-	-	-	-	-	-	-	-
Surge	-	-	-	-	-	-	-	-
a_{surge}	-	-	-	-	-	-	-	-
Sway	To starboard	To portside	To portside	To starboard	To portside	To starboard	To starboard	To portside
a_{sway}								
Heave	Down	Up	Down	Up	Down	Up	Down	Up
a_{heave}								
Roll	Portside down	Portside up	Starboard down	Starboard up	Portside down	Portside up	Starboard down	Starboard up
a_{roll}								
Pitch	-	-	-	-	Bow down	Bow up	Bow down	Bow up
a_{pitch}	-	-	-	-				

Ship responses for OST and OSA load cases - Strength assessment **Table 3**

Load case	OST-1P	OST-2P	OST-1S	OST-2S	OSA-1P	OSA-2P	OSA-1S	OSA-2S
EDW	OST				OSA			
Heading	Oblique				Oblique			
Effect	Max. torsional moment				Max. pitch acceleration			
VWBM	Sagging	Hogging	Sagging	Hogging	Hogging	Sagging	Hogging	Sagging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore
HWBM	Port tensile	Stbd tensile	Stbd tensile	Port tensile	Stbd tensile	Port tensile	Port tensile	Stbd tensile
TM								
Surge	To bow	To stern	To bow	To stern	To bow	To stern	To bow	To stern
a_{surge}								
Sway	-	-	-	-	To portside	To starboard	To starboard	To portside
a_{sway}	-	-	-	-				
Heave	Down	Up	Down	Up	Up	Down	Up	Down
a_{heave}								
Roll	Portside down	Portside up	Starboard down	Starboard up	Portside down	Portside up	Starboard down	Starboard up
a_{roll}								
Pitch	Bow up	Bow down	Bow up	Bow down	Bow up	Bow down	Bow up	Bow down
a_{pitch}								

2.2 Load combination factors

2.2.1

The load combinations factors, LCFs for the global loads and inertia load components for strength assessment are defined in:

Table 4 : LCFs for HSM, HSA and FSM load cases.

Table 5 : LCFs for BSR and BSP load cases.

Table 6 : LCFs for OST and OSA load cases.

Load combination factors, LCFs for HSM, HSA and FSM load cases - Strength assessment

Table 4

Load component		LCF	HSM-1	HSM-2	HAS-1	HAS-2	FSM-1	FSM-2
Hull girder loads	M_{WV}	C_{WV}	-1	1	-0.7	0.7	$-0.4f_T-0.6$	$0.4f_T+0.6$
	Q_{WV}	C_{QW}	$-1.0f_{lp}$	$1.0f_{lp}$	$-0.6f_{lp}$	$0.6f_{lp}$	$-1.0f_{lp}$	$1.0f_{lp}$
	M_{WH}	C_{WH}	0	0	0	0	0	0
	M_{WT}	C_{WT}	0	0	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	$0.3-0.2f_T$	$0.2f_T-0.3$	0.2	-0.2	$0.2-0.4f_T$	$0.4f_T-0.2$
	$a_{pitch-x}$	C_{XP}	-0.7	0.7	$-0.4f_T-0.4$	$0.4f_T+0.4$	0.15	-0.15
	$g\sin\varphi$	C_{XG}	0.6	-0.6	$0.4f_T+0.4$	$-0.4f_T-0.4$	-0.2	0.2
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0	0	0
	a_{roll-y}	C_{YR}	0	0	0	0	0	0
	$g\sin\theta$	C_{YG}	0	0	0	0	0	0
Vertical accelerations	a_{heave}	C_{ZH}	$0.5f_T-0.15$	$0.15-0.5f_T$	$0.4f_T-0.1$	$0.1-0.4f_T$	0	0
	a_{roll-z}	C_{ZR}	0	0	0	0	0	0
	$a_{pitch-z}$	C_{ZP}	-0.7	0.7	$-0.4f_T-0.4$	$0.4f_T+0.4$	0.15	-0.15

Load combination factors, LCFs for BSR and BSP load cases - Strength assessment

Table 5

Load component		LCF	BSR-1P	BSR-2P	BSR-1S	BSR-2S
Hull girder loads	M_{WV}	C_{WV}	$0.1-0.2f_T$	$0.2f_T-0.1$	$0.1-0.2f_T$	$0.2f_T-0.1$
	Q_{WV}	C_{QW}	$(0.1-0.2f_T)f_{lp}$	$(0.2f_T-0.1)f_{lp}$	$(0.1-0.2f_T)f_{lp}$	$(0.2f_T-0.1)f_{lp}$
	M_{WH}	C_{WH}	$1.2-1.1f_T$	$1.1f_T-1.2$	$1.1f_T-1.2$	$1.2-1.1f_T$
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	$g\sin\varphi$	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	$0.2-0.2f_T$	$0.2f_T-0.2$	$0.2f_T-0.2$	$0.2-0.2f_T$
	a_{roll-y}	C_{YR}	1	-1	-1	1
	$g\sin\theta$	C_{YG}	-1	1	1	-1
Vertical accelerations	a_{heave}	C_{ZH}	$0.7-0.4f_T$	$0.4f_T-0.7$	$0.7-0.4f_T$	$0.4f_T-0.7$
	a_{roll-z}	C_{ZR}	1	-1	1	-1
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Load component		LCF	BSP-1P	BSP-2P	BSP-1S	BSP-2S
Hull girder loads	M_{WV}	C_{WV}	0.3-0.8f_T	0.8f_T-0.3	0.3-0.8f_T	0.8f_T-0.3
	Q_{WV}	C_{QW}	(0.3-0.8f_T) f_{lp}	(0.8f_T-0.3) f_{lp}	(0.3-0.8f_T) f_{lp}	(0.8f_T-0.3) f_{lp}
	M_{WH}	C_{WH}	0.7- 0.7f_T	0.7f_T -0.7	0.7f_T -0.7	0.7- 0.7f_T
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0.1-0.3f_T	0.3f_T -0.1	0.3f_T -0.1	0.1-0.3f_T
	gsinφ	C_{XG}	0.3f_T -0.1	0.1-0.3f_T	0.3f_T -0.1	0.1-0.3f_T
Transverse accelerations	a_{sway}	C_{YS}	-0.9	0.9	0.9	-0.9
	a_{roll-y}	C_{YR}	0.3	-0.3	-0.3	0.3
	gsinθ	C_{YG}	-0.2	0.2	0.2	-0.2
Vertical accelerations	a_{heave}	C_{ZH}	1	-1	1	-1
	a_{roll-z}	C_{ZR}	0.3	-0.3	-0.3	0.3
	$a_{pitch-z}$	C_{ZP}	0.1-0.3f_T	0.3f_T-0.1	0.1-0.3f_T	0.3f_T-0.1

Load combination factors, LCFs for OST and OSA load cases - Strength assessment

Table 6

Load component		LCF	OST-1P	OST-2P	OST-1S	OST-2S
Hull girder loads	M_{WV}	C_{WV}	-0.3-0.2f_T	0.3+0.2f_T	-0.3-0.2f_T	0.3+0.2f_T
	Q_{WV}	C_{QW}	(-0.35-2f_T)f_{lp}	(0.35+0.2f_T)f_{lp}	(-0.35-0.2f_T)f_{lp}	(0.35+0.2f_T)f_{lp}
	M_{WH}	C_{WH}	-0.9	0.9	0.9	-0.9
	M_{WT}	C_{WT}	-f_{lp-OST}	f_{lp-OST}	f_{lp-OST}	-f_{lp-OST}
Longitudinal accelerations	a_{surge}	C_{XS}	0.1f_T -0.15	0.15-0.1f_T	0.1f_T -0.15	0.15-0.1f_T
	$a_{pitch-x}$	C_{XP}	0.7-0.3f_T	0.3f_T -0.7	0.7-0.3f_T	0.3f_T -0.7
	gsinφ	C_{XG}	0.2f_T-0.45	0.45-0.2f_T	0.2f_T-0.45	0.45-0.2f_T
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	a_{roll-y}	C_{YR}	0.4f_T-0.25	0.25-0.4f_T	0.25-0.4f_T	0.4f_T-0.25
	gsinθ	C_{YG}	0.1-0.2f_T	0.2f_T-0.1	0.2f_T-0.1	0.1-0.2f_T
Vertical accelerations	a_{heave}	C_{ZH}	0.2f_T-0.05	0.05-0.4f_T	0.2f_T-0.05	0.05-0.4f_T
	a_{roll-z}	C_{ZR}	0.4f_T-0.25	0.25-0.4f_T	0.25-0.4f_T	0.4f_T-0.25
	$a_{pitch-z}$	C_{ZP}	0.7-0.3f_T	0.3f_T-0.7	0.7-0.3f_T	0.3f_T-0.7

Load component		LCF	OSA-1P	OSA-2P	OSA-1S	OSA-2S
Hull girder loads	M_{WV}	C_{WV}	0.75-0.5f_T	-0.75+0.5f_T	0.75-0.5f_T	-0.75+0.5f_T
	Q_{WV}	C_{QW}	(0.6-0.4f_T) f_{lp}	(-0.6+0.4f_T) f_{lp}	(0.6-0.4f_T) f_{lp}	(-0.6+0.4f_T) f_{lp}
	M_{WH}	C_{WH}	0.55+0.2f_T	-0.55-0.2f_T	-0.55-0.2f_T	0.55+0.2f_T
	M_{WT}	C_{WT}	-f_{lp-OSA}	f_{lp-OSA}	f_{lp-OSA}	-f_{lp-OSA}
Longitudinal accelerations	a_{surge}	C_{XS}	0.1f_T -0.45	0.45-0.1f_T	0.1f_T -0.45	0.45-0.1f_T
	$a_{pitch-x}$	C_{XP}	1.0	-1.0	1.0	-1.0
	gsinφ	C_{XG}	-1.0	1.0	-1.0	1.0
Transverse	a_{sway}	C_{YS}	-0.2 -0.1f_T	0.2+0.1f_T	0.2+0.1f_T	-0.2 -0.1f_T

Load component		LCF	OSA-1P	OSA-2P	OSA-1S	OSA-2S
accelerations	a_{roll-y}	C_{YR}	0.3-0.2f_T	0.2f_T -0.3	0.2f_T -0.3	0.3-0.2f_T
	gsinθ	C_{YG}	0.1f_T-0.2	0.1-0.2f_T	0.2-0.1f_T	0.1f_T-0.2
Vertical accelerations	a_{heave}	C_{ZH}	-0.2f_T	0.2f_T	-0.2f_T	0.2f_T
	a_{roll-z}	C_{ZR}	0.3-0.2f_T	0.2f_T-0.3	0.2f_T-0.3	0.3-0.2f_T
	$a_{pitch-z}$	C_{ZP}	1.0	-1.0	1.0	-1.0

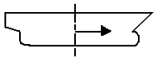
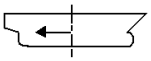
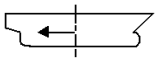
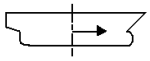
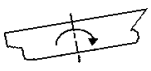
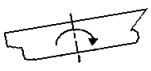
3 DYNAMIC LOAD CASES FOR FATIGUE ASSESSMENT

3.1 Description of dynamic load cases

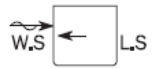
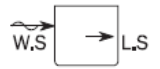
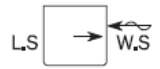
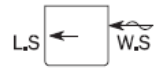
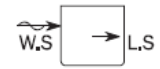
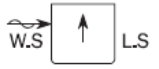
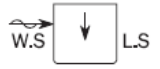
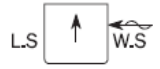
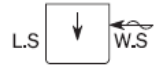
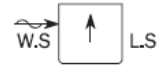
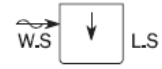
3.1.1

Table 7 to Table 9 define the ship motions responses and the global loads corresponding to each dynamic load case to be considered for fatigue assessment.

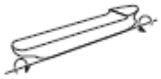
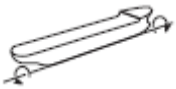
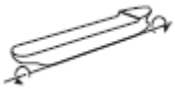
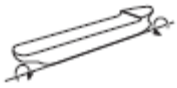
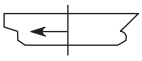
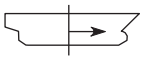
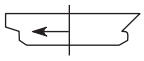
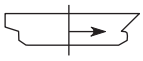
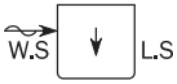
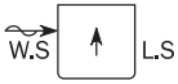
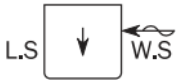
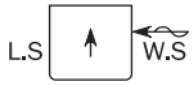
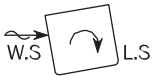
Ship responses for HSM and FSM load cases - Fatigue assessment Table 7

Load case	HSM-1	HSM-2	FSM-1	FSM-2
EDW	HSM		FSM	
Heading	Head		Following	
Effect	Max. bending moment		Max. bending moment	
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	-	-	-	-
TM	-	-	-	-
Surge	To stern	To bow	To bow	To stern
a_{surge}				
Sway	-	-	-	-
a_{sway}	-	-	-	-
Heave	Down	Up	-	-
a_{heave}			-	-
Roll	-	-	-	-
a_{roll}	-	-	-	-
Pitch	Bow down	Bow up	Bow up	Bow down
a_{pitch}				

Ship responses for BSR and BSP load cases - Fatigue assessment **Table 8**

Load case	BSR-1P	BSR-2P	BSR-1S	BSR-2S	BSP-1P	BSP-2P	BSP-1S	BSP-2S
EDW	BSR		BSR		BSP		BSP	
Heading	Beam				Beam			
Effect	Max. roll				Max. pressure at waterline			
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
HWBM	Stbd tensile	Port tensile	Port tensile	Stbd tensile	Stbd tensile	Port tensile	Port tensile	Stbd tensile
TM	-	-	-	-	-	-	-	-
Surge	-	-	-	-	-	-	-	-
a_{surge}	-	-	-	-	-	-	-	-
Sway	To starboard	To portside	To portside	To starboard	To portside	To starboard	To starboard	To portside
a_{sway}								
Heave	Down	Up	Down	Up	Down	Up	Down	Up
a_{heave}								
Roll	Portside down	Portside up	Starboard down	Starboard up	Portside down	Portside up	Starboard down	Starboard up
a_{roll}								
Pitch	-	-	-	-	-	-	-	-
a_{pitch}	-	-	-	-	-	-	-	-

Ship responses for OST load cases - Fatigue assessment **Table 9**

Load case	OST-1P	OST-2P	OST-1S	OST-2S
EDW	OST			
Heading	Oblique			
Effect	Max. torsional moment			
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	Port tensile	Stbd tensile	Stbd tensile	Port tensile
TM				
Surge	To bow	To stern	To bow	To stern
a_{surge}				
Sway	-	-	-	-
a_{sway}	-	-	-	-
Heave	Up	Down	Up	Down
a_{heave}				
Roll	Portside down	Portside up	Starboard down	Starboard up
a_{roll}				
Pitch	Bow up	Bow down	Bow up	Bow down
a_{pitch}				

3.2 Load combination factors

3.2.1

The load combinations factors, LCFs for the global loads and inertial load components for fatigue assessment are defined in:

Table 10: LCFs for HSM and FSM load cases. Table 11: LCFs for BSR and BSP load cases. Table 12: LCFs for OST load case.

Load combination factors, LCFs for HSM and FSM load cases - Fatigue assessment **Table 10**

Load component		LCF	HSM-1	HSM-2	FSM-1	FSM-2
Hull girder loads	M_{WV}	C_{WV}	-1	1	$-0.75-0.2f_T$	$0.75+0.2f_T$
	Q_{WV}	C_{QW}	$-1.0f_{lp}$	$1.0f_{lp}$	$(-0.75-.2f_T)f_{lp}$	$(0.75+0.2f_T)f_{lp}$
	M_{WH}	C_{WH}	0	0	0	0
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	$0.3-0.2f_T$	$0.2f_T-0.3$	$0.2-0.4f_T$	$0.4f_T-0.2$
	$a_{pitch-x}$	C_{XP}	-0.9	0.9	0.1	-0.1

Load component		LCF	HSM-1	HSM-2	FSM-1	FSM-2
	gsinφ	C_{XG}	$0.4f_T$+0.4	-0.4f_T-0.4	-0.15	0.15
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	a_{roll-y}	C_{YR}	0	0	0	0
	gsinθ	C_{YG}	0	0	0	0
Vertical accelerations	a_{heave}	C_{ZH}	$0.8f_T$-0.15	0.15-$0.8f_T$	0	0
	a_{roll-z}	C_{ZR}	0	0	0	0
	$a_{pitch-z}$	C_{ZP}	-0.9	0.9	0.1	-0.1

Load combination factors, LCFs for BSR and BSP load cases - Fatigue assessment

Table 11

Load component		LCF	BSR-1P	BSR-2P	BSR-1S	BSR-2S
Hull girder loads	M_{WV}	C_{WV}	0.1-$0.2f_T$	$0.2f_T$ -0.1	0.1-$0.2f_T$	$0.2f_T$ -0.1
	Q_{WV}	C_{QW}	(0.1-$0.2f_T$) f_{lp}	($0.2f_T$ -0.1) f_{lp}	(0.1-$0.2f_T$) f_{lp}	($0.2f_T$ -0.1) f_{lp}
	M_{WH}	C_{WH}	1.1- f_T	f_T -1.1	f_T -1.1	1.1- f_T
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	gsinφ	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	0.2-$0.2f_T$	$0.2f_T$ -0.2	$0.2f_T$ -0.2	0.2-$0.2f_T$
	a_{roll-y}	C_{YR}	1	-1	-1	1
	gsinθ	C_{YG}	-1	1	1	-1
Vertical accelerations	a_{heave}	C_{ZH}	0.7-$0.4f_T$	$0.4f_T$-0.7	0.7-$0.4f_T$	$0.4f_T$-0.7
	a_{roll-z}	C_{ZR}	1	-1	1	-1
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Load component		LCF	BSP-1P	BSP-2P	BSP-1S	BSP-2S
Hull girder loads	M_{WV}	C_{WV}	0.3-$0.8f_T$	$0.8f_T$-0.3	0.3-$0.8f_T$	$0.8f_T$-0.3
	Q_{WV}	C_{QW}	(0.3-$0.8f_T$) f_{lp}	($0.8f_T$-0.3) f_{lp}	(0.3-$0.8f_T$) f_{lp}	($0.8f_T$-0.3) f_{lp}
	M_{WH}	C_{WH}	0.6- $0.6f_T$	$0.6f_T$ -0.6	$0.6f_T$ -0.6	0.6- $0.6f_T$
	M_{WT}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	gsinφ	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	-0.95	0.95	0.95	-0.95
	a_{roll-y}	C_{YR}	0.3	-0.3	-0.3	0.3
	gsinθ	C_{YG}	-0.2	0.2	0.2	-0.2
Vertical accelerations	a_{heave}	C_{ZH}	1	-1	1	-1
	a_{roll-z}	C_{ZR}	0.3	-0.3	-0.3	0.3
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Load combination factors, LCFs for OST load cases Fatigue assessment Table 12

Load component		LCF	OST-1P	OST-2P	OST-1S	OST-2S
Hull girder loads	M_{WV}	C_{WV}	-0.4	0.4	-0.4	0.4
	Q_{WV}	C_{QW}	$-0.4f_{lp}$	$0.4f_{lp}$	$-0.4f_{lp}$	$0.4f_{lp}$
	M_{WH}	C_{WH}	-0.9	0.9	0.9	-0.9
	M_{WT}	C_{WT}	$-f_{lp\text{-}OST}$	$f_{lp\text{-}OST}$	$f_{lp\text{-}OST}$	$-f_{lp\text{-}OST}$
Longitudinal accelerations	a_{surge}	C_{XS}	$-0.25+0.2f_T$	$0.25-0.2f_T$	$-0.25+0.2f_T$	$0.25-0.2f_T$
	$a_{pitch\text{-}x}$	C_{XP}	$0.4-0.2f_T$	$-0.4+0.2f_T$	$0.4-0.2f_T$	$-0.4+0.2f_T$
	gsinφ	C_{XG}	$-0.4+0.2f_T$	$0.4-0.2f_T$	$-0.4+0.2f_T$	$0.4-0.2f_T$
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	$a_{roll\text{-}y}$	C_{YR}	$-0.4+0.6f_T$	$0.4-0.6f_T$	$0.4-0.6f_T$	$-0.4+0.6f_T$
	gsinθ	C_{YG}	$0.2-0.3f_T$	$-0.2+0.3f_T$	$-0.2+0.3f_T$	$0.2-0.3f_T$
Vertical accelerations	a_{heave}	C_{ZH}	-0.05	0.05	-0.05	0.05
	$a_{roll\text{-}z}$	C_{ZR}	$-0.4+0.6f_T$	$0.4-0.6f_T$	$0.4-0.6f_T$	$-0.4+0.6f_T$
	$a_{pitch\text{-}z}$	C_{ZP}	$0.4-0.2f_T$	$-0.4+0.2f_T$	$0.4-0.2f_T$	$-0.4+0.2f_T$

Section 3 SHIP MOTIONS AND ACCELERATIONS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

a_0 : Acceleration parameter, to be taken as:

$$a_0 = (1.58 - 0.47C_B)\left[\frac{2.4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2}\right]$$

T_θ : Roll period, in s, as defined in [2.1.1].

θ : Roll angle, in deg, as defined in [2.1.1].

T_φ : Pitch period, in s, as defined in [2.1.2].

φ : Pitch angle, in deg, as defined in [2.1.2].

R : Vertical coordinate, in m, of the ship rotation centre, to be taken as:

$$R = \min\left(\frac{D}{4} + \frac{T_{LC}}{2}, \frac{D}{2}\right)$$

C_{XG}, C_{XS}, C_{XP}, C_{YG}, C_{YS}, C_{YR}, C_{ZH}, C_{ZR}, *and* C_{ZP}: Load combination factors, as defined in Ch 4, Sec 2.

$a_{roll\text{-}y}$: Transverse acceleration due to roll, in m/s2, as defined in [3.3.2].

$a_{pitch\text{-}x}$: Longitudinal acceleration due to pitch, in m/s2, as defined in [3.3.1].

$a_{roll\text{-}z}$: Vertical acceleration due to roll, in m/s2, as defined in [3.3.3].

$a_{pitch\text{-}z}$: Vertical acceleration due to pitch, in m/s2, as defined in [3.3.3].

f_T : Ratio between draught at a loading condition and scantling draught, to be taken as:

$$f_T = \frac{T_{LC}}{T_{SC}} \text{ but is not to be taken less than 0.5}$$

T_{LC} : Draught, in m, amidships for the considered load case

x, y, z : X, Y and Z coordinates, in m, of the considered point with respect to the coordinate system, as defined in Ch 4, Sec 1, [1.2.1].

f_{ps} : Coefficient for strength assessments which is dependant on the applicable design load scenario specified in Ch 4, Sec 7, and to be taken as:

f_{ps} = 1.0 for extreme sea loads design load scenario.

f_{ps} = 0.8 for the ballast water exchange design load scenario.

f_{ps} = 0.8 for the accidental flooded design load scenario at sea.

f_{ps} = 0.4 for the harbour/sheltered water design load scenario.

f_{fa} : Fatigue coefficient to be taken as:

f_{fa} = 0.9

1 GENERAL

1.1 Definition

1.1.1

The ship motions and accelerations are assumed to be sinusoidal. The motion values defined by the formulae in this section are single amplitudes, i.e. half of the ‘crest to trough’ height.

2 SHIP MOTIONS AND ACCELERATIONS

2.1 Ship motions

2.1.1 Roll motion

The roll period T_θ, in s, to be taken as:

$$T_\theta = \frac{2.3\pi k_r}{\sqrt{gGM}}$$

The roll angle θ, in deg, to be taken as:

$$\theta = \frac{9000(1.25 - 0.025T_\theta) f_p f_{BK}}{(B + 75)\pi}$$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}(0.23-4f_TB\times10^{-4})$ for fatigue assessment.

f_{BK} : To be taken as:

f_{BK} = 1.2 for ships without bilge keel.

f_{BK} = 1.0 for ships with bilge keel.

k_r : Roll radius of gyration, in m, in the considered loading condition. The values in Table 1 or Table 2 are to be adopted.

GM : Metacentric height, in m, in the considered loading condition. The values in Table 1 or Table 2 are to be adopted.

k_r and GM values for oil tankers **Table 1**

Loading condition (1) (2)	T_{LC}	k_r	GM
Full load condition	T_{SC}	0.35B	0.12B
Optional conditions that have a draught greater than $0.9T_{SC}$	Actual draught but $\geqslant 0.9T_{SC}$	0.35B	0.12B
Partial load condition	$\leqslant 0.6T_{SC}$	0.40B	0.24B
Ballast condition	T_{BAL}	0.45B	0.33B

(1) For optional loading conditions or gale/emergency ballast conditions with draught between $0.6T_{SC}$ and $0.9T_{SC}$, the values of k_r and GM, unless provided in the loading manual, are to be obtained by linear interpolation between the optional condition at $0.9T_{SC}$ and the partial load condition at $0.6T_{SC}$ based on the actual draught.

(2) For flooded loading conditions, the values of k_r and GM, unless provided in the loading manual, are to be taken as those for the full load condition.

k_r and GM values for bulk carriers **Table 2**

Loading condition (1) (2) (4)		Application	T_{LC}	k_r	GM
Full load condition	Homogeneous loading	All bulk carriers	T_{SC}	0.35B	0.12B
	Alternate heavy cargo	BC-A		0.40B	0.20B
	Alternate light cargo	BC-A		0.35B	0.12B
	Homogeneous heavy cargo	BC-B, BC-A		0.42B	0.25B
Steel coil loading (3)		All bulk carriers designated for the carriage of steel products		0.42B	0.25B
Heavy ballast condition		All bulk carriers	T_{BAL-H}	0.40B	0.25B
Normal ballast condition		All bulk carriers	T_{BAL}	0.45B	0.33B

(1) For Multi-port (MP) loading conditions with draught greater than or equal to $0.9T_{SC}$, the values of kr and GM, unless provided in the loading manual, are to be taken as those from the most appropriate full load condition.
For Multi-port (MP) loading conditions with draught between T_{BAL-H} and $0.9T_{SC}$, the values of k_r and GM, unless provided in the loading manual, are to be obtained by linear interpolation, based on the draught, between the heavy ballast condition and the most appropriate full load condition.
For Multi-port (MP) loading conditions with a draught below T_{BAL-H}, the values of kr and GM for the heavy ballast condition are to be used.

(2) For flooded loading conditions, the values of k_r and GM, unless provided in the loading manual, are to be taken as those for the full load condition.

(3) When steel coil loading condition is provided by the designer according to Ch 1, Sec 2, [3.6] in the loading manual, this condition is to be assessed with draught, kr and GM values given in this table.

(4) Block Loading conditions are to be assessed with draught, k_r and GM values given in this table for Homogeneous heavy cargo loading condition.

2.1.2 Pitch motion

The pitch period T_φ, in s, is to be taken as:

$$T_\varphi = \sqrt{\frac{2\pi\lambda_\varphi}{g}}$$

where:

$\lambda_\varphi = 0.6(1+f_T)L$

The pitch angle φ, in deg, is to be taken as:

$$\varphi = 1350 f_p L^{-0.94} \left\{ 1.0 + \left(\frac{2.57}{\sqrt{gL}} \right)^{1.2} \right\}$$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}[(0.27\text{-}0.02f_T)\text{-}(13\text{-}5f_T)\ L\times10^{-5}]$ for fatigue assessment

2.2 Ship accelerations at the centre of gravity

2.2.1 Surge acceleration

The longitudinal acceleration due to surge, in m/s^2, is to be taken as:

$a_{surge} = 0.2 f_p a_0 g$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}[0.27\text{-}(15+4f_T)\ L\times10^{-5}]$ for fatigue assessment.

2.2.2 Sway acceleration

The transverse acceleration due to sway, in m/s^2, is to be taken as:

$a_{sway} = 0.3 f_p a_0 g$

where:

f_p： Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}[0.24\text{-}(6\text{-}2f_T)\ B\times10^{-4}]$ for fatigue assessment.

2.2.3 Heave acceleration

The vertical acceleration due to heave, in m/s^2, is to be taken as:

$a_{heave} = f_p a_0 g$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}[(0.27+0.02f_T)\ \text{-}17L\times10^{-5}]$ for fatigue assessment.

2.2.4 Roll acceleration

The roll acceleration, a_{roll}, in rad/s^2, is to be taken as:

$$a_{roll} = f_p \theta \frac{\pi}{180} \left(\frac{2\pi}{T_\theta} \right)^2$$

where:

θ : Roll angle using *fp* equal to 1.0.

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = f_{fa}[0.23\text{-}4f_T\ B\times10^{-4}]$ for fatigue assessment.

2.2.5 Pitch acceleration

The pitch acceleration, *apitch*, in rad/s2, is to be taken as:

$$a_{pitch} = f_p \theta \left(\frac{3.1}{\sqrt{gL}} + 1.0 \right) \varphi \frac{\pi}{180} \left(\frac{2\pi}{T_\varphi} \right)^2$$

where:

φ : Pitch angle using *fp* equal to 1.0.

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.
$f_p = f_{fa}[0.28-(5+6f_T)\ L\times10^{-5}]$ for fatigue assessment.

3 ACCELERATIONS AT ANY POSITION

3.1 General

3.1.1

The accelerations used to derive the inertial loads at any position are defined with respect to the ship fixed coordinate system. Hence the acceleration values defined in [3.2] and [3.3] include the gravitational acceleration components due to the instantaneous roll and pitch angles.

3.1.2

The accelerations to be applied for the dynamic load cases defined in Ch 4, Sec 2 are given in [3.2].

3.1.3

The envelope accelerations as defined in [3.3] are provided for advisory purposes and may be used for other design purpose when the maximum design acceleration values are required, for example, crane foundations, machinery foundations, etc.

3.2 Accelerations for dynamic load cases

3.2.1 General

The accelerations to be applied for the dynamic load cases defined in Ch 4, Sec 2 are given in [3.2.2] to [3.2.4].

3.2.2 Longitudinal acceleration

The longitudinal acceleration at any position for each dynamic load case, in m/s^2, is to be taken as:

$a_X = -C_{XG}g\sin\varphi + C_{XS}a_{surge} + C_{XP}a_{pitch}(z-R)$

3.2.3 Transverse acceleration

The transverse acceleration at any position for each dynamic load case, in m/s^2, is to be taken as:

$a_Y = -C_{YG}g\sin\theta + C_{YS}a_{sway} - C_{YR}a_{roll}(z-R)$

3.2.4 Vertical acceleration

The vertical acceleration at any position for each dynamic load case, in m/s^2, is to be taken as:

$a_Z = -C_{ZH}\,a_{heave} + C_{ZR}a_{roll}y - C_{ZP}a_{pitch}\,(x-0.45L)$

3.3 Envelope accelerations

3.3.1 Longitudinal acceleration

The envelope longitudinal acceleration, $a_{x\text{-}env}$, in m/s^2, at any position, is to be taken as:

$$a_{x-env} = 0.7\sqrt{a_{surge}^2 + \left[\frac{L}{325}(g\sin\varphi + a_{pitch-x})\right]^2}$$

where:

$a_{pitch\text{-}x}$: Longitudinal acceleration due to pitch, in m/s^2

$a_{pitch\text{-}x} = a_{pitch}\,(z-R)$

3.3.2 Transverse acceleration

The envelope transverse acceleration, $a_{y\text{-}env}$, in m/s^2, at any position, is to be taken as:

$$a_{y-env} = \sqrt{a_{sway}^2 + (g\sin\theta + a_{roll-y})^2}$$

where:

$a_{roll\text{-}y}$: Transverse acceleration due to roll, in m/s^2.

$a_{roll\text{-}y} = a_{roll}\,(z-R)$

3.3.3 Vertical acceleration

The envelope vertical acceleration, $a_{z\text{-}env}$, in m/s^2, at any position, is to be taken as:

$$a_{z-env} = \sqrt{a_{heave}^2 + \left[\left(0.3 + \frac{L}{325}\right) a_{pitch-z}\right]^2 + (1.2a_{roll-z})^2}$$

where:

$a_{picth-z}$: Vertical acceleration due to pitch, in m/s^2.

$a_{pitch-z} = a_{pitch}\,(x\text{-}0.45L)$

a_{roll-z} : Vertical acceleration due to roll, in m/s^2.

$a_{roll-z} = a_{roll} y$

Section 4 HULL GIRDER LOADS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

x : X coordinate, in m, of the calculation point with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

C_w : Wave coefficient, to be taken as:

$$C_w = 10.75 - \left(\frac{300 - L}{100}\right)^{1.5} \quad \text{for } 90\text{m} \leqslant L \leqslant 300\text{m}$$

$C_w = 10.75$ for $300\text{m} < L \leqslant 350\text{m}$

$$C_w = 10.75 - \left(\frac{L - 350}{150}\right)^{1.5} \quad \text{for } 350\text{m} < L \leqslant 500\text{m}$$

f_β : Heading correction factor, to be taken as:

- For strength assessment:

  f_β =1.05 for HSM and FSM load cases for the extreme sea loads design load scenario.

  f_β=0.8 for BSR and BSP load cases for the extreme sea loads design load scenario.

  f_β =1.0 for HSA, OST and OSA load cases for the extreme sea loads design load scenario.

  f_β =1.0 for ballast water exchange at sea, harbour/sheltered water and accidental flooded design load scenarios.

- For fatigue assessment:

  f_β= 1.0.

f_{ps} : Coefficient, as defined in Ch 4, Sec 3.

BSR, *BSP*, *HSM*, *HSA*, *FSM*, *OST*, *OSA*: Dynamic load cases, as defined in Ch 4, Sec 2.

1 APPLICATION

1.1 General

1.1.1

The hull girder loads for the static (S) design load scenarios is to be taken as the still water loads defined in [2].

1.1.2

The total hull girder loads for the static plus dynamic (S+D) design load scenarios are to be derived for each dynamic load case and are to be taken as the sum of the still water loads defined in [2] and the dynamic loads defined in [3.5].

2 VERTICAL STILL WATER HULL GIRDER LOADS

2.1 General

2.1.1 Seagoing and harbour/sheltered water conditions

The designer is to provide the permissible still water bending moment and shear force for seagoing and harbour/sheltered water operations.

The permissible still water hull girder loads are to be given at each transverse bulkhead in the cargo hold region, at the middle of cargo compartments, at the collision bulkhead, at the engine room forward bulkhead and at the mid-point between the forward and aft engine room bulkheads. The permissible hull girder bending moments and shear forces at any other position may be obtained by linear interpolation.

Note1: It is recommended that, for initial design, the permissible hull girder hogging and sagging still water bending moments are at least 5% above the maximum still water bending moment from loading conditions in the loading manual, and the permissible hull girder shear forces are at least 10% above the maximum still water shear force from loading condition in the loading manual, to account for growth and design margins during the design and construction phase of the ship.

2.1.2 Flooded condition

The designer is to provide the envelope of permissible still water bending moment and shear force in flooded condition.

2.1.3 Still water loads for the fatigue assessment

The still water bending moment and shear force values and distribution to be used for the fatigue assessment are to be taken as the most typical values applicable for the loading conditions that the ship will operate in for most of its life. Typically, these conditions will be the normal ballast condition and full homogeneously loaded condition for double hull oil tankers. For bulk carriers, these will be the normal ballast condition, heavy ballast condition, full homogeneously loaded condition and full alternate loaded condition; note the latter is only applicable to BC-A bulk carriers. The definition of loading conditions to use is specified in Ch9.

2.2 Vertical still water bending moment

2.2.1 Minimum still water bending moment

The minimum still water bending moment, $M_{sw\text{-}h\text{-}min}$ and $M_{sw\text{-}s\text{-}min}$, in kNm, in hogging and sagging condition, respectively is to be taken as:

Hogging conditions:

$M_{sw\text{-}h\text{-}min}=f_{sw}(171C_wL^2B(C_B+0.7)10^{-3}-M_{wv\text{-}h\text{-}mid})$

Sagging conditions:

$M_{sw\text{-}s\text{-}min}= - 0.85f_{sw}(171C_wL^2B(C_B+0.7)10^{-3}+M_{wv\text{-}s\text{-}mid})$

where:

$M_{wv\text{-}h\text{-}mid}$: Vertical wave bending moment for strength assessment in hogging condition, as defined in [3.1.1] using f_p and f_m equal to 1.0.

$M_{wv\text{-}s\text{-}mid}$: Vertical wave bending moment for strength assessment in sagging condition, as defined in [3.1.1] using f_p and f_m equal to 1.0.

f_{sw} : Distribution factor along the ship length. To be taken as, see Figure 1:

$f_{sw} = 0.0$ for $x \leqslant 0$

$f_{sw} = 0.15$ at $x = 0.1\ L$

$f_{sw} = 1.0$ for $0.3\ L \leqslant x \leqslant 0.7\ L$

$f_{sw} = 0.15$ at $x = 0.9\ L$

$f_{sw} = 0.0$ for $x \geqslant L$

Intermediate values of f_{sw} are to be obtained by linear interpolation.

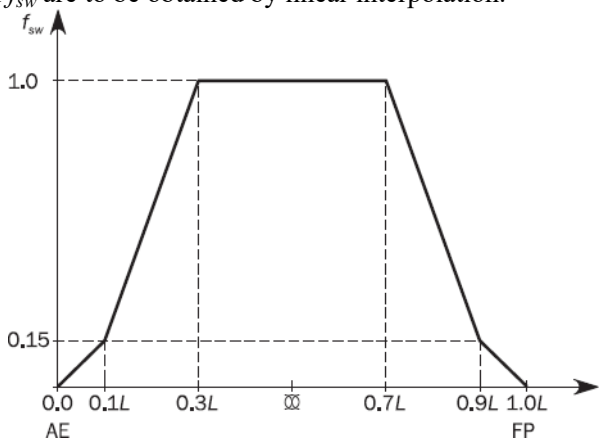


Figure 1 Distribution factor f_{sw}

2.2.2 Permissible vertical still water bending moment in seagoing condition

The permissible vertical still water bending moments, $M_{sw\text{-}h}$ and $M_{sw\text{-}s}$ in seagoing condition at any longitudinal position are to envelop:

- The most severe still water bending moments calculated, in hogging and sagging conditions, respectively, for the seagoing loading conditions defined in Ch 4, Sec 8.
- The most severe still water bending moments for the seagoing loading conditions defined in the loading manual.
- The minimum still water bending moment defined in [2.2.1]

2.2.3 Permissible vertical still water bending moment in harbour/sheltered water and tank testing condition

The permissible vertical still water bending moments in the harbour/sheltered water and tank testing condition $M_{sw\text{-}p\text{-}h}$ and $M_{sw\text{-}p\text{-}s}$ at any longitudinal position are to envelop:

- The most severe still water bending moments, in hogging and sagging conditions, respectively, for the harbour/sheltered water loading conditions defined in Ch 4, Sec 8.
- The most severe still water bending moments for the harbour/sheltered water loading conditions defined in the loading manual.
- The permissible still water bending moment defined in [2.2.2].
- The minimum still water bending moment defined in [2.2.1] increased by 25%.

2.2.4 Permissible vertical still water bending moment in flooded condition at sea

The permissible vertical still water bending moments in flooded condition $M_{sw\text{-}f}$ at any longitudinal position are to envelop:

- The most severe still water bending moments, in hogging and sagging conditions, respectively, for the intact and flooded seagoing loading conditions defined in Ch 4, Sec 8. Loading conditions encountered during ballast water exchange need not to be considered for the flooded condition.
- The most severe still water bending moments for the intact and flooded seagoing loading conditions defined in the loading manual.
- The permissible still water bending moment defined in [2.2.2] increased by 10%.

2.3 Vertical still water shear force

2.3.1 Minimum still water shear force in seagoing conditions for oil tankers

The minimum hull girder positive and negative vertical still water shear force, $Q_{sw\text{-}min}$ in kN, in way of transverse bulkheads between cargo tanks in the seagoing condition is to be taken as:

a) For oil tankers with three cargo tanks across the breadth of the ship:

$$Q_{sw-min} = \pm \max \begin{cases} 0.225\rho g B_{local} l_{tk} T_{SC} \\ 0.5\rho g[0.98(V_{CT} + 2V_{ST}) - 0.7 B_{local} l_{tk} T_{SC}] \end{cases}$$

and is to be taken as the maximum value of *Qsw-min* calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

b) For oil tankers with two cargo tanks across the breadth of the ship:

$Q_{sw\text{-}min} = \pm 0.4\rho g B_{local} l_{tk} T_{SC}$

and is to be taken as maximum value of *Qsw-min* calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

where:

B_{local} : Local breadth, in m, at T_{SC} at the middle length of the tank under consideration.

l_{tk} : Length of cargo tank under consideration, in m, taken at the forward or aft side of the transverse bulkhead under consideration, in m.

V_{CT} : Volume of centre cargo tank, in m_3, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration.

V_{ST} : Volume of side cargo tank, in m^3, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration.

2.3.2 Minimum still water shear force in harbour/sheltered water conditions for oil tankers

The minimum hull girder positive and negative vertical still water shear force, $Q_{sw\text{-}p\text{-}min}$ in kN in the harbour/sheltered water condition in way of transverse bulkheads between cargo tanks are to be taken as:

a) For oil tankers with three cargo tanks across the breadth of the ship:

$$Q_{sw-min} = \pm \max \begin{cases} 0.275\rho g B_{local} l_{tk} T_{SC} \\ 0.5\rho g[0.98(V_{CT} + 2V_{ST}) - 0.6 B_{local} l_{tk} T_{SC}] \end{cases}$$

and is to be taken as the maximum value of $Q_{sw\text{-}p\text{-}min}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

b) For oil tankers with two cargo tanks across the breadth of the ship:

$Q_{sw\text{-}p\text{-}min} = \pm 0.45\rho g B_{local} l_{tk} T_{SC}$

and is to be taken as maximum value of $Q_{sw\text{-}p\text{-}min}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead.

2.3.3 Permissible still water shear force in seagoing condition

The permissible vertical still water shear forces, Q_{sw} for oil tankers and bulk carriers, in seagoing condition at any longitudinal position are to envelop:

- The most severe still water shear forces, positive or negative, for the seagoing loading conditions defined in Ch 4, Sec 8 after shear force correction in case of bulk carrier.
- The most severe still water shear forces for the seagoing loading conditions defined in the loading manual after shear force correction in case of bulk carrier.
- For oil tankers, the minimum still water shear forces for seagoing conditions defined in [2.3.1].

2.3.4 Permissible still water shear force in harbour/sheltered water and tank testing condition

The permissible vertical still water shear forces, *Qsw-p* for oil tankers and bulk carriers, in the harbour/sheltered water and tank testing condition at any longitudinal position are to envelop:

- The most severe still water shear forces, positive or negative, for the harbour/sheltered water loading conditions defined in Ch 4, Sec 8 after shear force correction in case of bulk carrier.
- The most severe still water shear forces for the harbour/sheltered water loading conditions defined in the loading manual after shear force correction in case of bulk carrier.
- The permissible vertical still water shear force defined in [2.3.3].
- For oil tankers, the minimum still water shear forced for harbour/sheltered water conditions defined in [2.3.2].

The following value may be used as guidance at preliminary design stage:

$Q_{sw\text{-}p} = Q_{sw} + 0.6Q_{wv}$

where:

Q_{sw} : Permissible still water shear force Q_{sw}, as defined in [2.3.3].

Q_{wv} : Vertical wave shear force for strength assessment $Q_{wv\text{-}pos}$ and $Q_{wv\text{-}neg}$, as defined in [3.2.1] using f_p equal to 1.0.

2.3.5 Permissible still water shear force in flooded condition at sea

The permissible vertical still water shear forces, *Qsw-f* for oil tankers and bulk carriers, in flooded condition at any longitudinal position are to envelop:

- The most severe still water shear forces, positive or negative, for the flooded seagoing loading conditions defined in Ch 4, Sec 8 after shear force correction in case of bulk carrier. Loading conditions encountered during ballast water exchange need not be considered for the flooded condition.
- The most severe still water shear forces for the flooded seagoing loading conditions defined in the loading manual after shear force correction in case of bulk carrier.
- The permissible still water shear force is defined in [2.3.3].

3 DYNAMIC HULL GIRDER LOADS

3.1 Vertical wave bending moment

3.1.1

The vertical wave bending moments at any longitudinal position, in kNm, are to be taken as:

Hogging condition:

$M_{wv\text{-}h} = 0.19 f_{nl\text{-}vh} f_m f_p C_w L^2 B C_B$

Sagging condition:

$M_{wv\text{-}s} = -0.19 f_{nl\text{-}vs} f_m f_p C_w L^2 B C_B$

where:

$f_{nl\text{-}vh}$: Coefficient considering nonlinear effects applied to hogging, to be taken as:

$f_{nl\text{-}vh}$ =1.0 for strength and fatigue assessment.

$f_{nl\text{-}vs}$: Coefficient considering nonlinear effects applied to sagging, to be taken as:

$f_{nl-s} = 0.58\dfrac{(C_B + 0.7)}{C_B}$， for strength assessment.

f_{nl-s} = 1.0， for fatigue assessment.

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ ， for strength assessment.

$f_p = 0.9[0.27-(6+4f_T)L\times10^{-5}]$， for fatigue assessment.

f_m : Distribution factor for vertical wave bending moment along the ship's length, to be taken as:

$f_m = 0.0$ for $x \leqslant 0$

$f_m = 1.0$ for $0.4\,L \leqslant x \leqslant 0.65\,L$

$f_m = 0.0$ for $x \geqslant L$

Intermediate values of fm are to be obtained by linear interpolation (see Figure 2).

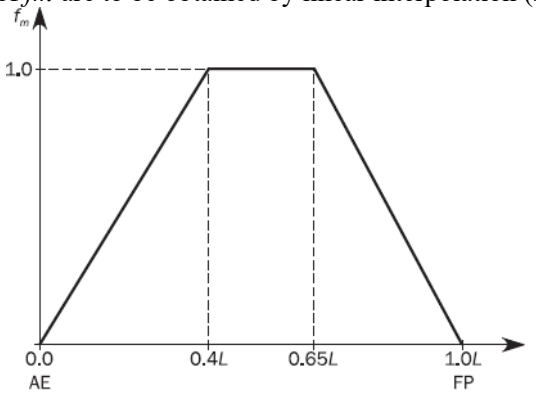


Figure 2 Distribution factor f_m

3.2 Vertical wave shear force

3.2.1

The vertical wave shear forces at any longitudinal position, in kN, are to be taken as:

$Q_{wv-pos}=0.52f_{q-pos}f_pC_wLBC_B$

$Q_{wv-neg}=-0.52f_{q-neg}f_pC_wLBC_B$

where:

f_p : Coefficient to be taken as:

$f_p = f_{ps}$,for strength assessment.

$f_p = 0.9[0.27-(17-8f_T)L\times10^{-5}]$, for fatigue assessment.

f_{q-pos} : Distribution factor along the ship length for positive wave shear force, to be taken as:

$f_{q-pos} = 0.0$ for $x \leqslant 0$

$f_{q-pos} = 0.92\,f_{nl-vh}$ for $0.2\,L \leqslant x \leqslant 0.3\,L$

$f_{q-pos} = 0.7$ for $0.4\,L \leqslant x \leqslant 0.6\,L$

$f_{q-pos} = 1.0f_{nl-vs}$ for $0.7\,L \leqslant x \leqslant 0.85\,L$

$f_{q-pos} = 0.0$ for $x \geqslant L$

Intermediate values of f_{q-pos} are to be obtained by linear interpolation (see Figure 3).

f_{q-neg}: Distribution factor along the ship length for negative wave shear force, to be taken as:

$f_{q-neg} = 0.0$ for $x \leqslant 0$

$f_{q-neg} = 0.92f_{nl-vs}$ for $0.2L \leqslant x \leqslant 0.3\,L$

$f_{q-neg} = 0.7$ for $0.4L \leqslant x \leqslant 0.6\,L$

$f_{q-neg} = 1.0f_{nl-vh}$ for $0.7L \leqslant x \leqslant 0.85\,L$

$f_{q-neg} = 0.0$ for $x \geqslant L$

Intermediate values of f_{q-neg} are to be obtained by linear interpolation, see Figure 4.

f_{nl-vh},f_{nl-vs}: Coefficient considering nonlinear effects defined in [3.1.1].

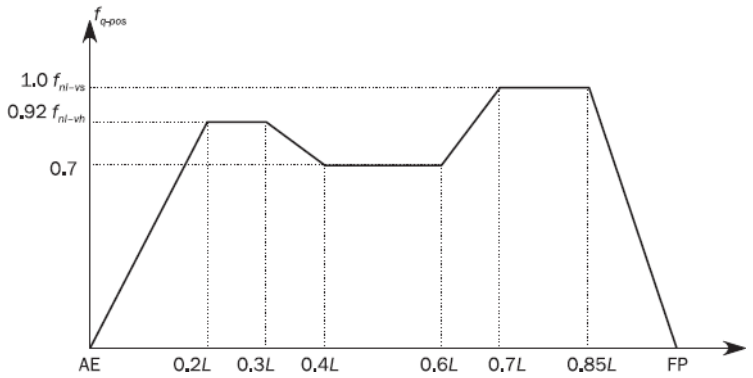


Figure 3 Distribution factor of positive vertical shear force $f_{q\text{-}pos}$

3.3 Horizontal wave bending moment

3.3.1

The horizontal wave bending moment at any longitudinal position, in kNm, is to be taken as:

$$M_{wh} = f_{nlh} f_p \left(0.31 + \frac{L}{2800}\right) f_m C_w L^2 T_{LC} C_B$$

where:

f_{nlh} : Coefficient considering nonlinear effect to be taken as:

f_{nlh} = 0.9 for strength assessment

f_{nlh} = 1.0 for fatigue assessment

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = 0.9[(0.2+0.04 f_T)+(11-8 f_T)L\times 10^{-5}]$ for fatigue assessment.

f_m : Distribution factor defined in [3.1.1].

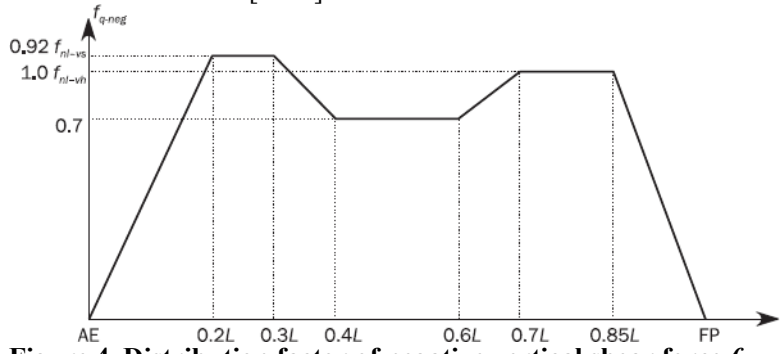


Figure 4 Distribution factor of negative vertical shear force $f_{q\text{-}neg}$

3.4 Wave torsional moment

3.4.1

The wave torsional moment at any longitudinal position with respect to the ship baseline, in kNm, is to be taken as:

$M_{wt}=f_p(M_{wt1}+M_{wt2})$

where:

$$M_{wt1} = 0.4 f_{t1} C_w \sqrt{\frac{L}{T_{LC}}} B^2 D C_B$$

$M_{wt2}=0.22 f_{t2} C_w L B^2 C_B$

f_{t1}, f_{t2} : Distribution factors, taken as:

$f_{t1}=0$ for $x<0$

$$f_{t1} = \left|\sin\left(\frac{2\pi x}{L}\right)\right| \text{ for } 0 \leqslant x \leqslant L$$

$f_{t1}=0$ for $x>L$

$f_{t2}=0$ for $x<0$

$$f_{t2} = \sin^2\left(\frac{\pi x}{L}\right) \quad \text{for } 0 \leqslant x \leqslant L$$

$f_{t2}=0$ for $x>L$

f_p : Coefficient to be taken as:

$f_p = f_{ps}$ for strength assessment.

$f_p = 0.9[0.2+(5f_T-4.25)B\times10^{-4}]$ for fatigue assessment

3.5 Hull girder loads for dynamic load cases

3.5.1 General

The dynamic hull girder loads to be applied for the dynamic load cases defined in Ch 4, Sec 2, are given in [3.5.2] to [3.5.5].

3.5.2 Vertical wave bending moment

The vertical wave bending moment, $M_{wv\text{-}LC}$, in kNm, to be used for each dynamic load case in Ch 4, Sec2, is defined in Table 1.

Vertical wave bending moment for dynamic load cases **Table 1**

Load combination factor	$M_{wv\text{-}LC}$
$C_{WV} \geqslant 0$	$f_\beta C_{WV} M_{wv-h}$
$C_{WV} < 0$	$f_\beta C_{WV} \lvert M_{wv-s} \rvert$

where:

C_{WV} : Load combination factor for vertical wave bending moment, to be taken as specified in Ch 4, Sec 2.

$M_{wv\text{-}h}$, $M_{wv\text{-}s}$: Hogging and sagging vertical wave bending moment taking account of the considered design load scenario, as defined in [3.1.1].

3.5.3 Vertical wave shear force

The vertical wave shear force, $Q_{wv\text{-}LC}$, in kN, to be used for each dynamic load case in Ch 4, Sec 2, is defined inTable 2.

Vertical wave shear force for dynamic load cases **Table 2**

Load combination factor	$Q_{wv\text{-}LC}$
$C_{QW} \geqslant 0$	$f_\beta C_{QW} Q_{wv-pos}$
$C_{QW} < 0$	$f_\beta C_{QW} \lvert Q_{wv-neg} \rvert$

where:

C_{QW} : Load combination factor for vertical wave shear force, to be taken as specified in Ch 4, Sec 2.

$Q_{wv\text{-}pos}$, $Q_{wv\text{-}neg}$: Positive and negative vertical wave shear force taking account of the considered design load scenario, as defined in [3.2.1].

3.5.4 Horizontal wave bending moment

The horizontal wave bending moment, $M_{wh\text{-}LC}$, in kNm, to be used for each dynamic load case defined in Ch4, Sec 2, is to be taken as:

$M_{wh\text{-}LC}=f_\beta C_{WH} M_{wh}$

where:

C_{WH} : Load combination factor for horizontal wave bending moment, to be taken as specified in Ch 4, Sec 2.

M_{wh} : Horizontal wave bending moment taking account of the appropriate design load scenario, as defined in [3.3.1].

3.5.5 Wave torsional moment

The wave torsional moment, $M_{wt\text{-}LC}$, in kNm, to be used for each dynamic load case defined in Ch 4, Sec 2, is to be taken as:

$M_{wt\text{-}LC}=f_\beta C_{WT} M_{wt}$

where:

C_{WT} : Load combination factor for wave torsional moment, to be taken as specified in Ch 4, Sec 2.
M_{wt} : Wave torsional moment taking account of the appropriate design load scenario, as defined in [3.4.1].

Section 5 EXTERNAL LOADS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

λ : Wave length, in m.

B_x : Moulded breadth at the waterline, in m, at the considered cross section.

x, y, z: *X*, *Y* and *Z* coordinates, in m, of the load point with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

f_{xL} : Ratio as defined in Ch 4, Sec 2.

f_{yB} : Ratio between *Y*-coordinate of the load point and B_x, to be taken as:

$$f_{yB} = \frac{|2y|}{B_x}, \text{ but not greater than 1.0,}$$

f_{yB} = 1.0 when B_x =0.

f_{yB1} : Ratio between *Y*-coordinate of the load point and *B*, to be taken as:

$$f_{yB} = \frac{|2y|}{B}, \text{ but not greater than 1.0}$$

C_w : Wave coefficient defined in Ch 4, Sec 4.

f_T : Ratio as defined in Ch 4, Sec 3.

$P_{W,WL}$: Wave pressure at the waterline, kN/m^2, for the considered dynamic load case.

$P_{W,WL}=P_W$ for $y=B_x/2$ and $z = T_{LC}$

h_W : Water head equivalent to the pressure at waterline, in m, to be taken as:

$$h_W = \frac{P_{W,WL}}{\rho g}$$

f_{ps} : Coefficient for strength assessment, as defined in Ch 4, Sec 3.

θ : Roll angle, in deg, as defined in Ch 4, Sec 3, [2.1.1].

T : Roll period, in s, as defined in Ch 4, Sec 3, [2.1.1].

f_{fa} : Coefficient defined in Ch 4, Sec 3.

f : Coefficient defined in Ch 4, Sec 4.

z_{SD} : Z coordinate, in m, of the midpoint of stiffener span, or of the middle of the elementary plate panel.

1 SEA PRESSURE

1.1 Total pressure

1.1.1

The external pressure P_{ex} at any load point of the hull, in kN/m^2, for the static (S) design load scenarios, is to be taken as:

$P_{ex} = P_S$,but not less than 0.

The total pressure P_{ex} at any load point of the hull for the static plus dynamic (S+D) design load scenarios, is to be derived from each dynamic load case and is to be taken as:

$P_{ex} = P_S + P_W$, but not less than 0.

where:

P_S : Hydrostatic pressure, in kN/m^2, defined in [1.2].

P_W : Wave pressure, in kN/m^2, is defined in [1.3].

1.2 Hydrostatic pressure

1.2.1

The hydrostatic pressure, P_S at any load point, in kN/m^2, is obtained from Table 1. See also Figure 1.

Hydrostatic pressure, P_S **Table 1**

Location	Hydrostatic Pressure, P_S, in kN/m^2
$z \leqslant T_{LC}$	$\rho g(T_{LC}-z)$
$z > T_{LC}$	0

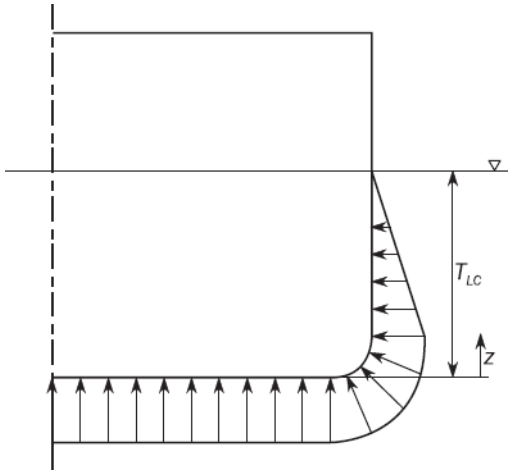


Figure 1 Hydrostatic pressure, P_S

1.3 External dynamic pressures for strength assessment

1.3.1 General

The hydrodynamic pressures for each dynamic load case defined in Ch4, Sec 2, [2] are defined in [1.3.2] to [1.3.8].

1.3.2 Hydrodynamic pressures for HSM load cases

The hydrodynamic pressures, *PW*, for HSM-1 and HSM-2 load cases, at any load point, in kN/m2, are to be obtained from Table 2. See also Figure 2 and Figure 3.

Hydrodynamic pressures for HSM load cases **Table 2**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant h_W + T_{LC}$	$z > h_W + T_{LC}$
HSM-1	$P_W = \max(-P_{HS}, \rho g(z-T_{LC}))$	$P_W = P_{W,WL} - g(z-T_{LC})$	$P_W = 0$
HSM-2	$P_W = \max(P_{HS}, \rho g(z-T_{LC}))$		

where:

$$P_{HS} = f_\beta f_{ps} f_{nl} f_h k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{nl} : Coefficient considering non-linear effects, to be taken as:

- For extreme sea loads design load scenario:
  f_{nl} = 0.7 at f_{XL}= 0.0
  f_{nl} = 0.9 at f_{XL}= 0.3
  f_{nl} = 0.9 at f_{XL}= 0.7
  f_{nl} = 0.6 at f_{XL}= 1.0
- For ballast water exchange design load scenario:
  f_{nl} = 0.85 at f_{XL}= 0.0
  f_{nl} = 0.95 at f_{XL}= 0.3
  f_{nl} = 0.95 at f_{XL}= 0.7
  f_{nl} = 0.80 at f_{XL}= 1.0
  Intermediate values are obtained by linear interpolation.

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:
f_h=3.0(1.21-0.66f_T)

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = (0.5 + f_T)\left\{(3 - 2\sqrt{f_{yB}}) - \frac{20}{9} f_{xL}(7 - 6\sqrt{f_{yB}})\right\} + \frac{2}{3}(1 - f_T) \quad \text{for} \quad f_{xL} < 0.15$$

k_a=1.0 for $0.15 \leqslant f_{xL} < 0.7$

$$k_a = 1+(f_{xL}-0.7)\left\{\left(\frac{40}{3}f_T-5\right)+2(1-f_{yB})\left[\frac{18}{C_B}f_T(f_{xL}-0.7)-0.25(2-f_T)\right]\right\} \text{ for } f_{xL}\geqslant 0.7$$

λ : Wave length of the dynamic load case, in m, to be taken as:

$\lambda=0.6(1+f_T)L$

k_p : Phase coefficient to be obtained from Table 3. Intermediate values are to be interpolated.

k_p values for HSM load cases **Table 3**

f_{xL}	0	0.3 – 0.1 f_T	0.35 – 0.1 f_T	0.8 – 0.2 f_T	0.9 – 0.2f_T	1.0
k_p	–0.25 f_T (1 + f_{yB})	-1	1	1	-1	-1

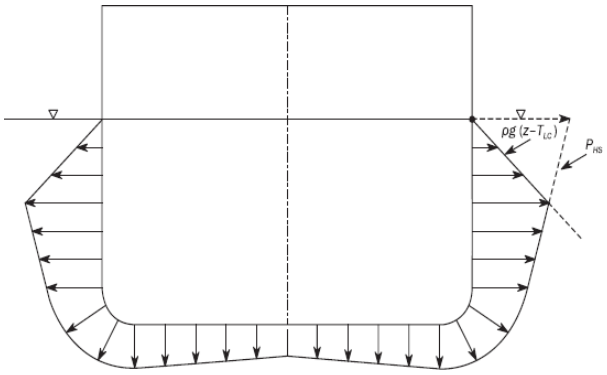


Figure 2 Transverse distribution amidships of dynamic pressure for HSM-1, HSA-1 and FSM-1 load cases

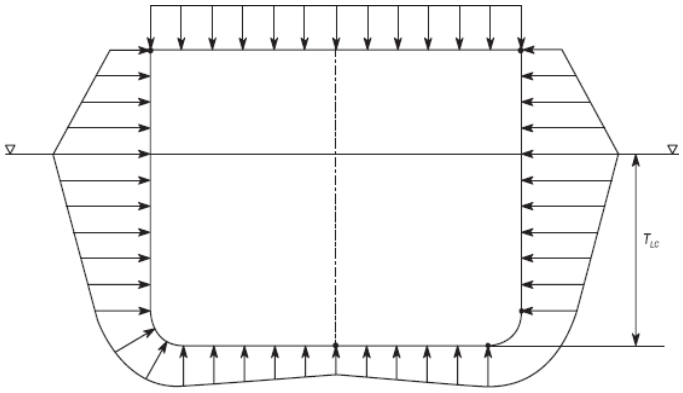


Figure 3 Transverse distribution amidships of dynamic pressure for HSM-2, HSA-2 and FSM-2 load cases

1.3.3 Hydrodynamic pressures for HSA load cases

The hydrodynamic pressures, P_W, for HSA-1 and HSA-2 load cases at any load point, in kN/m^2, are to be obtained from Table 4. See also Figure 2 and Figure 3.

Hydrodynamic pressures for HSA load cases **Table 4**

	Wave pressure, in kN/m^2		
Load case	$z\leqslant T_{LC}$	$T_{LC}<z\leqslant h_W+T_{LC}$	$z>h_W+T_{LC}$
HSA-1	$P_W=\max(-P_{HS}, \rho g(z-T_{LC}))$	$P_W=P_{W,WL}-g(z-T_{LC})$	$P_W=0$
HSA-2	$P_W=\max(P_{HS}, \rho g(z-T_{LC}))$		

where:

$$P_{HS} = f_{ps}f_{nl}f_h k_a k_p f_{yz} C_W \sqrt{\frac{L_0+\lambda-125}{L}}$$

f_{nl} : Coefficient considering non-linear effects, to be taken as defined in [1.3.2].

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:

f_h=2.4(1.21-0.66f_T)

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as defined in [1.3.2].

λ : Wave length of the dynamic load case, in m, to be taken as:
λ=0.6(1+f_T)L

k_p : Phase coefficient to be obtained from Table 5. Intermediate values are to be interpolated.

k_p values for HSA load cases **Table 5**

f_{xL}	0	0.3 – 0.1 f_T	0.5 – 0.2 f_T	0.8 – 0.2 f_T	0.9 – 0.2 f_T	1.0
k_p	1.5– f_T –0.5f_{yB}	-1	1	1	-1	-1

1.3.4 Hydrodynamic pressures for FSM load cases

The hydrodynamic pressures, P_W, for FSM-1 and FSM-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 6. See also Figure 2 and Figure 3.

Hydrodynamic pressures for FSM load cases **Table 6**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC}<z \leqslant h_W+T_{LC}$	$z>h_W+T_{LC}$
FSM-1	P_W= max(-P_{HS}, $\rho g(z-T_{LC})$)	$P_W = P_{W,WL}-g(z-T_{LC})$	P_W= 0
FSM-2	P_W= max(P_{HS}, $\rho g(z-T_{LC})$)		

where:

$$P_{FS} = f_\beta f_{ps} f_{nl} f_h k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{nl} : Coefficient considering non-linear effects, to be taken as:
f_{nl} = 0.9 for extreme sea loads design load scenario.
f_{nl} = 0.95 for ballast water exchange design load scenarios.

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:
f_h = 2.6

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as:
k_a = 1+(3.75-2f_T)(1-5f_{xL})(1-f_{yB}) for f_{xL}<0.2
k_a=1.0 for 0.2$\leqslant f_{xL}$<0.9
k_a = 1+20 (1-f_{yB}) (f_{xL}-0.9) for $f_{xL} \geqslant$0.9

λ : Wave length of the dynamic load case, in m, to be taken as:
λ=0.6(1+2/3f_T)L

k_p : Phase coefficient to be obtained from Table 7. Intermediate values are to be interpolated.

k_p values for FSM load cases **Table 7**

f_{xL}	0	0.35 – 0.1 f_T	0.5 – 0.2 f_T	0.75	0.8	1.0
k_p	– 0.75–0.25f_{yB}	-1	1	1	-1	– 0.75–0.25f_{yB}

1.3.5 Hydrodynamic pressures for BSR load cases

The wave pressures, P_W, for BSR-1 and BSR-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 8. See also Figure 4 and Figure 5.

Hydrodynamic pressures for BSR load cases **Table 8**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC}<z \leqslant h_W+T_{LC}$	$z>h_W+T_{LC}$
BSR-1P	P_W= max(P_{BSR}, $\rho g(z-T_{LC})$)	$P_W = P_{W,WL} - \rho g(z-T_{LC})$	P_W= 0
BSR-2P	P_W = max (-P_{BSR} , ρ $g(z-T_{LC})$)		
BSR-1S	P_W = max (P_{BSR} , $\rho g(z-T_{LC})$)		
BSR-2S	P_W = max (-P_{BSR} , $\rho g(z-T_{LC})$)		

where:

- For BSR-1P and BSR-2P load cases.

$$P_{BSR} = f_\beta f_{nl}\left(10y\sin\theta + 0.88 f_{ps} C_w \sqrt{\frac{L_0+\lambda-125}{L}}(f_{yB1}+1)\right)$$

- For BSR-1S and BSR-2S load cases.

$$P_{BSR} = f_\beta f_{nl}\left(-10y\sin\theta + 0.88 f_{ps} C_w \sqrt{\frac{L_0+\lambda-125}{L}}(f_{yB1}+1)\right)$$

f_{nl} : Coefficient considering non-linear effect, to be taken as:
f_{nl} = 1 for extreme sea loads design load scenario.
f_{nl} = 1 for ballast water exchange design load scenarios.

λ :Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = \frac{g}{2\pi}T_\theta^2$$

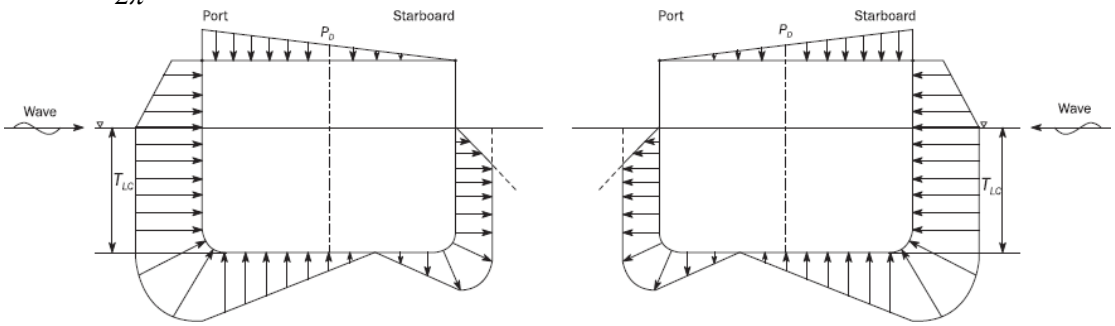


Figure 4 Transverse distribution of dynamic pressure for BSR-1P (left) and BSR-1S (right) load cases

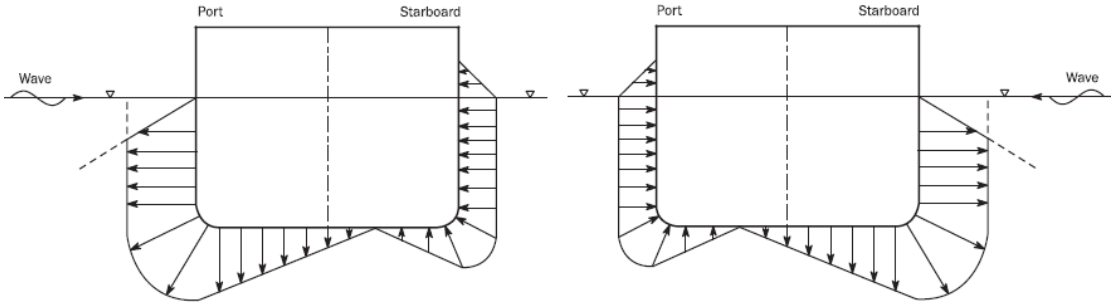


Figure 5 Transverse distribution of dynamic pressure for BSR-2P (left) and BSR-2S (right) load cases

1.3.6 Hydrodynamic pressures for BSP load cases

The wave pressures, *PW*, for BSP-1 and BSP-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 9. See also Figure 6 and Figure 7.

Hydrodynamic pressures for BSP load cases **Table 9**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$z \leqslant T_{LC}$	$z \leqslant T_{LC}$
BSP-1P	$P_W = \max(P_{BSP}, \rho g(z-T_{LC}))$	$P_W = P_{W,WL} - \rho g(z-T_{LC})$	$P_W = 0$
BSP-2P	$P_W = \max(-P_{BSP}, \rho g(z-T_{LC}))$		
BSP-1S	$P_W = \max(P_{BSP}, \rho g(z-T_{LC}))$		
BSP-2S	$P_W = \max(-P_{BSP}, \rho g(z-T_{LC}))$		

where:

$$P_{BSP} = 4.5 f_\beta f_{ps} f_{nl} f_{yz} C_w \sqrt{\frac{L_0+\lambda-125}{L}}$$

λ : Wave length of the dynamic load case, in m, to be taken as:
$\lambda = 0.2(1+2f_T)L$

f_{yz}: Girth distribution coefficient, to be obtained from Table 10.

Girth distribution coefficient, f_{yz} for BSP load cases **Table 10**

Transverse position	BSP-1P，BSP-2P	BSP-1S，BSP-2S
$y \geq 0$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5 f_{yB} + 0.5$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB} + 0.5$
$y < 0$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2} f_{yB} + 0.5$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5 f_{yB} + 0.5$

fnl : Coefficient considering non-linear effect, to be taken as:

- For extreme sea loads design load scenario:
  f_{nl} = 0.6 at f_{XL} = 0.0
  f_{nl} = 0.8 at f_{XL} = 0.3
  f_{nl} = 0.8 at f_{XL} = 0.7
  f_{nl} = 0.6 at f_{XL} = 1.0
- For ballast water exchange design load scenario:
  f_{nl} = 0.6 at f_{XL}= 0.0
  f_{nl} = 0.8 at f_{XL}= 0.3
  f_{nl} = 0.8 at f_{XL}= 0.7
  f_{nl} = 0.6 at f_{XL}= 1.0

Intermediate values are obtained by linear interpolation.

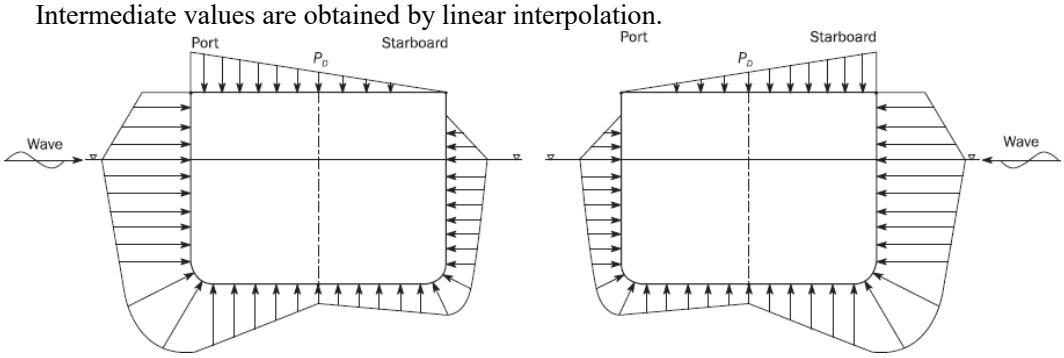


Figure 6 Transverse distribution of dynamic pressure for BSP-1P (left) and BSP-1S (right) load cases

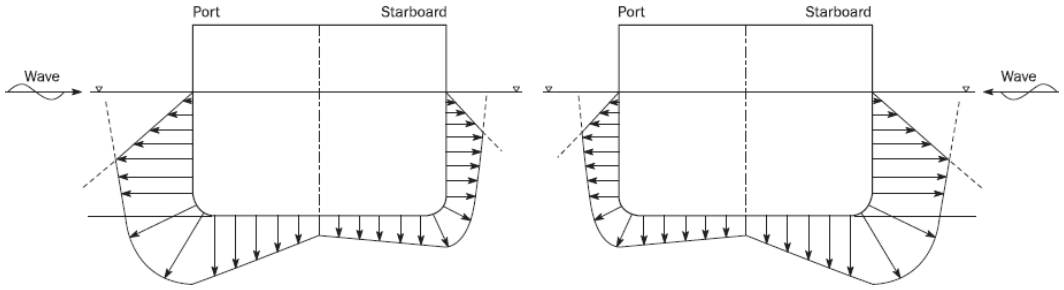


Figure 7 Transverse distribution of dynamic pressure for BSP-2P (left) and BSP-2S (right) load cases

1.3.7 Hydrodynamic pressures for OST load cases

The wave pressures, P_W, for OST-1 and OST-2 load cases, at any load point are to be obtained, in kN/m^2, from Table 11. See also Figure 8 and Figure 9.

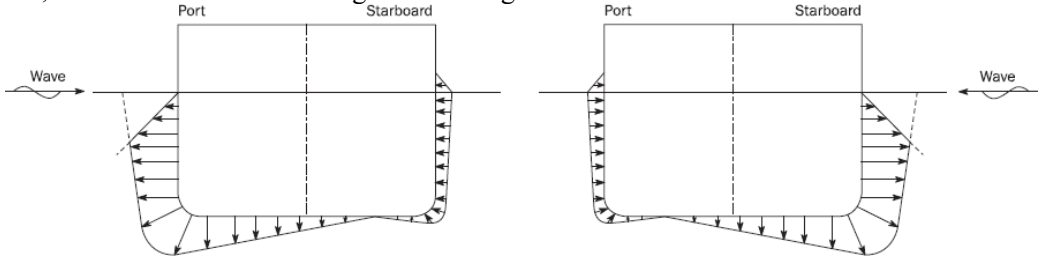


Figure 8 Transverse distribution of dynamic pressure amidships for OST-1P (left) and OST-1S (right) load cases

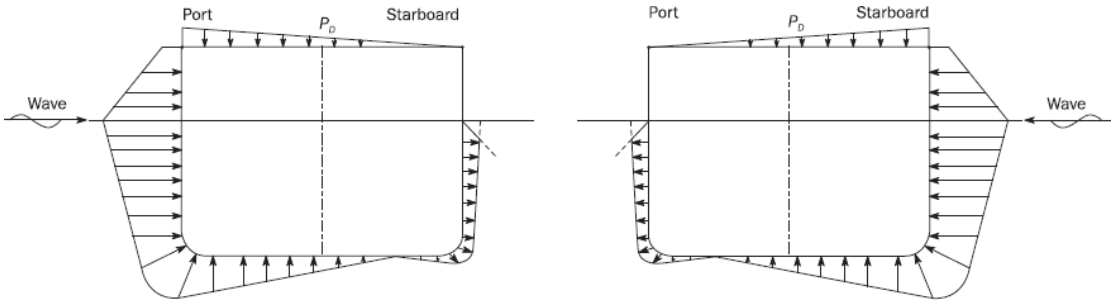


Figure 9 Transverse distribution of dynamic pressure amidships for OST-2P (left) and OST-2S (right) load cases

Hydrodynamic pressures for OST load cases **Table 11**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant h_W + T_{LC}$	$z > h_W + T_{LC}$
OST-1P	$P_W = \max(P_{OST}, \rho g(z-T_{LC}))$	$P_W = P_{W,WL} - \rho g(z-T_{LC})$	$P_W = 0$
OST-2P	$P_W = \max(-P_{OST}, \rho g(z-T_{LC}))$		
OST-1S	$P_W = \max(P_{OST}, \rho g(z-T_{LC}))$		
OST-2S	$P_W = \max(-P_{OST}, \rho g(z-T_{LC}))$		

where:

$$P_{OST} = 1.38 f_{ps} f_{nl} k_a k_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} : Girth distribution coefficient, to be obtained from Table 12.

f_{nl} : Coefficient considering non-linear effect, to be taken as:

f_{nl} = 0.8 for extreme sea loads design load scenario.

f_{nl} = 0.9 for ballast water exchange design load scenarios.

λ : Wave length of the dynamic load case, in m, to be taken as:

λ= 0.45 L

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 13.

k_p : Phase coefficient to be obtained from Table 14. Intermediate values are to be interpolated.

Girth distribution coefficient, f_{yz} for OST load cases **Table 12**

Transverse position	OST-1P，OST-2P	OST -1S，OST -2S
$y \geq 0$	$5\frac{z}{T_{LC}} + 3.5 f_{yB} + 1.5$	$1.5\frac{z}{T_{LC}} + 1.5$
$y < 0$	$1.5\frac{z}{T_{LC}} + 1.5$	$5\frac{z}{T_{LC}} + 3.5 f_{yB} + 1.5$

k_a values for OST load cases **Table 13**

Transverse position	Longitudinal Position	OST-1P - OST-2P	OST-1S - OST-2S
$y \geq 0$	$f_{xL} \leqslant 0.2$	$1.0+3.5(1-f_{yB})(1-5f_{xL})$	$1.0+[3.5-(4f_T-0.5)f_{yB}](1-5f_{xL})$
	$0.2 < f_{xL} \leqslant 0.8$	1.0	1.0
	$f_{xL} > 0.8$	1.0	$1.0+4(1-f_T)(5f_{xL}-4)f_{yB}$
$y < 0$	$f_{xL} \leqslant 0.2$	$1.0+[3.5-(4f_T-0.5)f_{yB}](1-5f_{xL})$	$1.0+3.5(1-f_{yB})(1-5f_{xL})$
	$0.2 < f_{xL} \leqslant 0.8$	1.0	1.0
	$f_{xL} > 0.8$	$1.0+4(1-f_T)(5f_{xL}-4)f_{yB}$	1.0

k_p values for OST load cases **Table 14**

Transverse position	f_{xL}	OST-1P - OST-2P	OST-1S - OST-2S
$y \geqslant 0$	0.0	1.0	1.0

Transverse position	f_{xL}	OST-1P - OST-2P	OST-1S - OST-2S
	0.2	1.0	$1.0+(0.75-1.5\,f_T)f_{yB}$
	0.4	-1.0	$-1.0+(1.75-0.5\,f_T)f_{yB}$
	0.5	-1.0	$1.0+(0.75-1.5\,f_T)f_{yB}$
	0.7	$-0.1+(1.6\,f_T-1.5)f_{yB}$	$-0.1+(0.25-0.3\,f_T)f_{yB}$
	0.9	$0.8+0.2f_{yB}$	$0.8-(0.9\,f_T+0.85)f_{yB}$
	1.0	$-1.0+f_{yB}$	$-1.0+(0.5-0.5\,f_T)f_{yB}$
$y<0$	0.0	1.0	1.0
	0.2	$1.0+(0.75-1.5\,f_T)f_{yB}$	1.0
	0.4	$-1.0+(1.75-0.5\,f_T)f_{yB}$	-1.0
	0.5	$-1.0+(1.75-0.5\,f_T)f_{yB}$	-1.0
	0.7	$-0.1+(0.25-0.3\,f_T)f_{yB}$	$-1.0+(1.6\,f_T-1.5)f_{yB}$
	0.9	$0.8-(0.9\,f_T+0.85)f_{yB}$	$0.8+0.2f_{yB}$
	1.0	$-1.0+(0.5-0.5\,f_T)f_{yB}$	$-1.0+f_{yB}$

1.3.8 Hydrodynamic pressures for OSA load cases

The wave pressures, P_W, for OSA-1 and OSA-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 15. See also Figure 10 and Figure 11.

Hydrodynamic pressures for OSA load cases **Table 15**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC}<z \leqslant h_W+T_{LC}$	$z>h_W+T_{LC}$
OSA-1P	$P_W = \max(P_{OSA}, \rho g(z-T_{LC}))$	$P_W = P_{W,WL} - \rho g(z-T_{LC})$	$P_W = 0$
OSA-2P	$P_W = \max(-P_{OSA}, \rho g(z-T_{LC}))$		
OSA-1S	$P_W = \max(P_{OSA}, \rho g(z-T_{LC}))$		
OSA-2S	$P_W = \max(-P_{OSA}, \rho g(z-T_{LC}))$		

where:

$$P_{OSA} = 0.8 f_{ps} f_{nl} k_a k_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}} (1 + 0.5 f_T)$$

λ : Wave length of the dynamic load case, in m, to be taken as:

$\lambda = 0.7L$

f_{nl} : Coefficient considering non-linear effect, to be taken as:

- For extreme sea loads design load scenario:
  $f_{nl} = 0.5$ at $f_{XL} = 0.0$
  $f_{nl} = 0.8$ at $f_{XL} = 0.3$
  $f_{nl} = 0.8$ at $f_{XL} = 0.7$
  $f_{nl} = 0.6$ at $f_{XL} = 1.0$
- For ballast water exchange design load scenario:
  $f_{nl} = 0.75$ at $f_{XL} = 0.0$
  $f_{nl} = 0.9$ at $f_{XL} = 0.3$
  $f_{nl} = 0.9$ at $f_{XL} = 0.7$
  $f_{nl} = 0.8$ at $f_{XL} = 1.0$

  Intermediate values are obtained by linear interpolation.

fyz : Girth distribution coefficient, to be obtained from Table 16.

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 17.

k_p : Phase coefficient to be obtained from Table 18. Intermediate values are to be interpolated.

Girth distribution coefficient, f_{yz} for OSA load cases **Table 16**

Transverse position	OSA-1P, OSA-2P	OSA -1S, OSA -2S
$y \geqslant 0$	$5.5\frac{z}{T_{LC}} + 5.3f_{yB} + 2.2$	$0.9\frac{z}{T_{LC}} + 0.4f_{yB} + 2.2$
$y<0$	$0.9\frac{z}{T_{LC}} + 0.4f_{yB} + 2.2$	$5.5\frac{z}{T_{LC}} + 5.3f_{yB} + 2.2$

k_a values for OSA load cases **Table 17**

Transverse position	Longitudinal position	OSA-1P - OSA-2P	OSA-1S - OSA-2S
$y \geqslant 0$	$f_{xL} \leqslant 0.2$	$1.0+3(2-f_T)(1-5f_{xL})(1-f_{yB})$	$1.0+3(2-f_T)(1-5f_{xL})+\{(28f_{xL}-5)+3f_T(1-5f_{xL})\}f_{yB}$
	$0.2<f_{xL} \leqslant 0.5$	1.0	$1.0+(1-2f_{xL})f_{yB}$
	$0.5<f_{xL} \leqslant 0.8$	1.0	$1.0+1.5(2f_{xL}-1)f_{yB}$
	$f_{xL} \geqslant 0.8$	$1.0+(f_{xL}-0.8)(1-f_{yB})A$	$1.0+\{1.5(2f_{xL}-1)-(f_{xL}-0.8)A)\}f_{yB}+(f_{xL}-0.8)A$
$y<0$	$f_{xL} \leqslant 0.2$	$1.0+3(2-f_T)(1-5f_{xL})+\{(28f_{xL}-5)+3f_T(1-5f_{xL})\}f_{yB}$	$1.0+3(2-f_T)(1-5f_{xL})(1-f_{yB})$
	$0.2<f_{xL} \leqslant 0.5$	$1.0+(1-2f_{xL})f_{yB}$	1.0
	$0.5<f_{xL} \leqslant 0.8$	$1.0+1.5(2f_{xL}-1)f_{yB}$	1.0
	$f_{xL} \geqslant 0.8$	$1.0+\{1.5(2f_{xL}-1)-(f_{xL}-0.8)A)\}f_{yB}+(f_{xL}-0.8)A$	$1.0+(f_{xL}-0.8)(1-f_{yB})A$
where: $A=22-15f_T+3[22(f_{xL}-0.8)-0.25(2-f_T)]$			

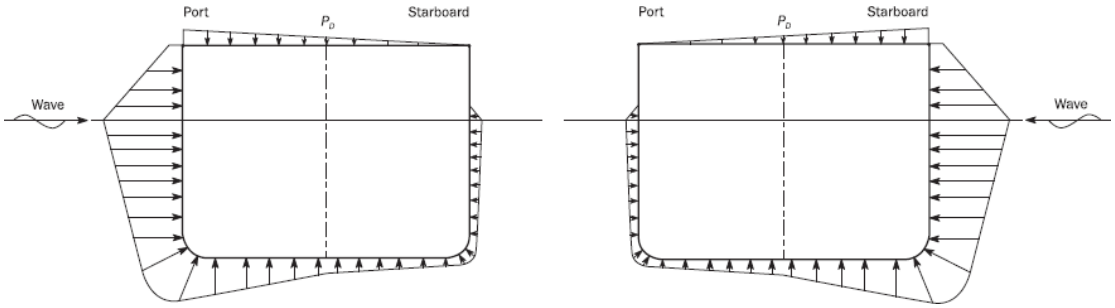


Figure 10 Transverse distribution of dynamic pressure amidships for OSA-1P (left) and OSA-1S (right) load cases

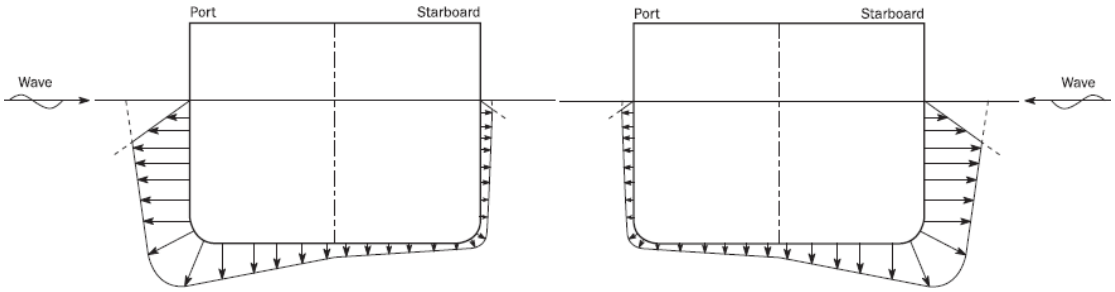


Figure 11 Transverse distribution of dynamic pressure amidships for OSA-2P (left) and OSA-2S (right) load cases

k_p values for OSA load cases **Table 18**

Transverse position	f_{xL}	OSA-1P; OSA-2P	OSA-1S; OSA-2S
$y \geqslant 0$	0.0	$0.75-f_{yB}$	0.75
	0.2	$f_T-0.25+(1.25-f_T)f_{yB}$	$f_T-0.25+(0.35f_T-0.47)f_{yB}$
	0.4	1.0	$1.0+(2.7f_T-3.2)f_{yB}$
	0.5	$1.25-0.5f_T+(0.5f_T-0.25)f_{yB}$	$1.25-0.5f_T+(2.7f_T-3.2)f_{yB}$
	0.6	$1.5-f_T+(f_T-1.07)f_{yB}$	$1.5-f_T+(2.68f_T-3.19)f_{yB}$
	0.85	$0.5f_T-1.25+(0.25-0.5f_T)f_{yB}$	$0.5f_T-1.25+(0.2-0.1f_T)f_{yB}$
	1.0	$0.5f_T-1.25+(0.25-0.5f_T)f_{yB}$	$0.5f_T-1.25+(0.2-0.1f_T)f_{yB}$
$y<0$	0.0	0.75	$0.75-0.5f_{yB}$
	0.2	$f_T-0.25+(0.35f_T-0.47)f_{yB}$	$f_T-0.25+(1.25-f_T)f_{yB}$
	0.4	$1.0+(2.7f_T-3.2)f_{yB}$	1.0
	0.5	$1.5-0.5f_T+(2.7f_T-3.2)f_{yB}$	$1.25-0.5f_T+(0.5f_T-0.25)f_{yB}$
	0.6	$1.5-f_T+(2.68f_T-3.19)f_{yB}$	$1.5-f_T+(f_T-1.07)f_{yB}$
	0.85	$0.5f_T-1.25+(0.2-0.1f_T)f_{yB}$	$0.5f_T-1.25+(0.25-0.5f_T)f_{yB}$
	1.0	$0.5f_T-1.25+(0.2-0.1f_T)f_{yB}$	$0.5f_T-1.25+(0.25-0.5f_T)f_{yB}$

1.3.9 Envelope of dynamic pressure

The envelope of dynamic pressure at any point, *Pex-max*, is to be taken as the greatest pressure obtained from any of the load cases determined by [1.3.2] to [1.3.8].

1.4 External dynamic pressures for fatigue assessments

1.4.1 General

The external pressure P_{ex} at any load point of the hull for the fatigue static plus dynamic (F:S+D) design load scenario, is to be derived for each fatigue dynamic load case and is to be taken as:

$P_{ex} = P_S + P_W$ but not less than 0.

where:

P_S : Hydrostatic pressure, in kN/m^2, defined in [1.2].

P_W : Hydrodynamic pressure, in kN/m^2, is defined in [1.4.2] to [1.4.6].

1.4.2 Hydrodynamic pressures for HSM load cases

The hydrodynamic pressures, P_W, for load cases HSM-1 and HSM-2, at any load point, in kN/m^2, are to be obtained from Table 19.

Hydrodynamic pressures for HSM load cases **Table 19**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC}<z \leqslant 2h_W+T_{LC}$	$z>2h_W+T_{LC}$
HSM-1	$P_W = \max(-P_{HS}, \rho g(z-T_{LC}))$	$P_W = P_{W,WL} - \frac{1}{2}\rho g(z-T_{LC})$	$P_W = 0$
HSM-2	$P_W = \max(P_{HS}, \rho g(z-T_{LC}))$		

where:

$$P_{HS} = f_p f_h k_a k_p f_{yz} C_w \sqrt{\frac{L_0+\lambda-125}{L}}$$

f_{yz}: Girth distribution coefficient, to be taken as:

$$f_{yz} = \frac{z}{T_{LC}} + f_{yB} + 1$$

f_h : Coefficient to be taken as:

f_h=2.75(1.21-0.66f_T)

f_p: Coefficient to be taken as:

$f_p=f_{fa}[(0.21+0.02f_T)+(6-4f_T)L\times10^{-5}]$

k_a: Amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$k_a=1+3f_T-(1+f_T)f_{yB}+[5(1+f_T)f_{yB}-15f_T]f_{xL}$ for $f_{xL}<0.2$

$k_a=1.0$ for $0.2\leqslant f_{xL}<0.6$

$k_a=1+(f_{xL}-0.6)[(13.5-3.5f_T)f_{yB}+(14.5f_T-17)+40(1-f_{yB})(f_{xL}-0.6)]$ for $f_{xL}\geqslant0.6$

λ: Wave length of the dynamic load case, in m, to be taken as:

$\lambda=0.6(1+f_T)L$

k_p : Phase coefficient to be obtained from Table 20. Intermediate values are to be interpolated.

k_p values for HSM load cases **Table 20**

f_{xL}	k_P
0	$(1.0-f_T)+(0.5-f_T)f_{yB}$
$0.3-0.1f_T$	-1
$0.5-0.2f_T$	1
$0.9-0.4f_T$	1
$0.9-0.2f_T$	-1
1.0	-1

1.4.3 Hydrodynamic pressures for FSM load cases

The hydrodynamic pressures, P_W, for FSM-1 and FSM-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 21.

Hydrodynamic pressures for FSM load cases **Table 21**

	Wave pressure, in kN/m^2		
Load case	$z\leqslant T_{LC}$	$T_{LC}<z\leqslant2h_W+T_{LC}$	$z>2h_W+T_{LC}$
FSM-1	$P_W=\max(-P_{FS},\rho g(z-T_{LC}))$	$P_W=P_{W,WL}-\frac{1}{2}\rho g(z-T_{LC})$	$P_W=0$
FSM-2	$P_W=\max(P_{FS},\rho g(z-T_{LC}))$		

where:

$$P_{FS}=f_p f_h k_a k_p f_{yz} C_w\sqrt{\frac{L_0+\lambda-125}{L}}$$

f_{yz} : Girth distribution coefficient, to be taken as:

$$f_{yz}=\frac{z}{T_{LC}}+f_{yB}+1$$

f_h : Coefficient to be taken as:

$f_h=2.6$

f_p : Coefficient to be taken as:

$f_p=f_{fa}[(0.21+0.02f_T)+(6-4f_T)L\times10^{-5}]$

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$k_a=1+(3.5-2f_T)(1-5f_{xL})(1-f_{yB})$ for $f_{xL}<0.2$

$k_a=1.0$ for $0.2\leqslant f_{xL}<0.9$

$k_a=1+15(1-f_{yB})(f_{xL}-0.9)$ for $f_{xL}\geqslant0.9$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda=0.6\left(1+\frac{2}{3}f_T\right)L$$

k_p : Phase coefficient to be obtained from Table 22. Intermediate values are to be interpolated.

k_p values for FSM load cases **Table 22**

f_{xL}	k_P
0	$-0.75-0.25f_{yB}$
$0.35-0.1f_T$	-1

f_{xL}	k_P
$0.5 - 0.2f_T$	1
0.75	1
$0.9 - 0.1f_T$	-1
1.0	$-0.5 - 0.5f_{yB}$

1.4.4 Hydrodynamic pressures for BSR load cases

The hydrodynamic pressures, P_W, for BSR-1 and BSR-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 23.

Hydrodynamic pressures for BSR load cases **Table 23**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant 2h_W + T_{LC}$	$z > 2h_W + T_{LC}$
BSR-1P	$P_W = \max(P_{BSR}, \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_W = 0$
BSR-2P	$P_W = \max(-P_{BSR}, \rho g(z - T_{LC}))$		
BSR-1S	$P_W = \max(P_{BSR}, \rho g(z - T_{LC}))$		
BSR-2S	$p_W = \max(-P_{BSR}, \rho g(z - T_{LC}))$		

where:

- For BSR-1P and BSR-2P load cases.

$$P_{BSR} = 10y\sin\theta + 0.88 f_p C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}(f_{yB} + 1)$$

- For BSR-1S and BSR-2S load cases.

$$P_{BSR} = -10y\sin\theta + 0.88 f_p C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}(f_{yB} + 1)$$

f_p : Coefficient to be taken as:
$f_p = f_{fa}[(0.21 + 0.04f_T) - (12f_T - 2)B \times 10^{-4}]$

λ : Wave length of the dynamic load case, in m, to be taken as:

$$\lambda = \frac{g}{2\pi} T_\theta^2$$

1.4.5 Hydrodynamic pressures for BSP load cases

The wave pressures, P_W, for BSP-1 and BSP-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 24.

Hydrodynamic pressures for BSP **Table 24**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC} < z \leqslant 2h_W + T_{LC}$	$z > 2h_W + T_{LC}$
BSP-1P	$P_W = \max(P_{BSP}, \rho g(z - T_{LC}))$	$P_W = P_{W,WL} - \frac{1}{2}\rho g(z - T_{LC})$	$P_W = 0$
BSP-2P	$P_W = \max(-P_{BSP}, \rho g(z - T_{LC}))$		
BSP-1S	$P_W = \max(P_{BSP}, \rho g(z - T_{LC}))$		
BSP-2S	$P_W = \max(-P_{BSP}, \rho g(z - T_{LC}))$		

where:

$$P_{BSP} = 0.45 f_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

λ : Wave length of the dynamic load case, in m, to be taken as:
$\lambda = 0.2(1 + 2f_T)L$

f_p : Coefficient to be taken as:
$f_p = f_{fa}[0.2 + (8 + 16f_T) \times 10^{-3}]$

f_{yz} : Girth distribution coefficient, to be obtained from Table 25.

Girth distribution coefficient, f_{yz} for BSP load case **Table25**

Transverse position	BSP-1P，BSP-2P	BSP-1S，BSP-2S
$y \geqslant 0$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5f_{yB} + 0.5$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2}f_{yB} + 0.5$
$y<0$	$f_{yz} = \frac{2}{3}\frac{z}{T_{LC}} + \frac{1}{2}f_{yB} + 0.5$	$f_{yz} = 2\frac{z}{T_{LC}} + 2.5f_{yB} + 0.5$

1.4.6 Hydrodynamic pressures for OST load cases

The wave pressures, P_W, for OST-1 and OST-2 load cases, at any load point, in kN/m^2, are to be obtained from Table 26.

Hydrodynamic pressures for OST load cases **Table 26**

	Wave pressure, in kN/m^2		
Load case	$z \leqslant T_{LC}$	$T_{LC}<z \leqslant 2h_W+T_{LC}$	$z>2h_W+T_{LC}$
OST-1P	P_W = max (P_{OST}, $\rho g(z-T_{LC})$)	$P_W = P_{W,WL} - \frac{1}{2}\rho g(z-T_{LC})$	$P_W = 0$
OST-2P	P_W = max (-P_{OST}, $\rho g(z-T_{LC})$)		
OST-1S	P_W = max (P_{OST}, $\rho g(z-T_{LC})$)		
OST-2S	P_W = max (-P_{OST}, $\rho g(z-T_{LC})$)		

where:

$$P_{OST} = 1.38 f_p k_a k_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

f_{yz} : Girth distribution coefficient, to be obtained from Table 27.

Girth distribution coefficient, f_{yz} for OST load cases **Table 27**

Transverse position	OST-1P - OST-2P	OST-1S - OST-2S
$y \geqslant 0$	$5\frac{z}{T_{LC}} + 3.3f_{yB} + 1.7$	$\frac{z}{T_{LC}} + 0.3f_{yB} + 1.7$
$y<0$	$\frac{z}{T_{LC}} + 0.3f_{yB} + 1.7$	$5\frac{z}{T_{LC}} + 3.3f_{yB} + 1.7$

f_p : Coefficient to be taken as:

$f_p = f_{fa}[(0.25-0.02f_T) + (12f_T-9)B\times10^{-4}]$

λ : Wave length of the dynamic load case, in m, to be taken as:

$\lambda = 0.45L$

k_a : Amplitude coefficient in the longitudinal direction of the ship, to be obtained from Table 28.

k_p : Phase coefficient to be obtained from Table 29. Intermediate values are to be interpolated.

k_a values for OST load cases **Table 28**

Transverse Position	Longitudinal Position	OST-1P - OST-2P	OST-1S - OST-2S
$y \geqslant 0$	$f_{xL} \leqslant 0.2$	$\frac{1.0 + \{(3.5-2f_T) + (10f_T - 17.5)\}}{f_{xL}(1-f_{yB})}$	$1.0+(3.5-2f_T-1.5f_{yB})+(10f_T-17.5+7.5f_{yB})f_{xL}$
	$0.2<f_{xL} \leqslant 0.8$	1.0	1.0
	$f_{xL}>0.8$	1.0	$1.0+2(1-f_T)(5f_{xL}-4)f_{yB}$
$y<0$	$f_{xL} \leqslant 0.2$	$1.0+(3.5-2f_T-1.5f_{yB})+(10f_T-17.5+7.5f_{yB})f_{xL}$	$\frac{1.0 + \{(3.5-2f_T) + (10f_T - 17.5)\}}{f_{xL}(1-f_{yB})}$
	$0.2<f_{xL} \leqslant 0.8$	1.0	1.0
	$f_{xL}>0.8$	$1.0+2(1-f_T)(5f_{xL}-4)f_{yB}$	1.0

k_p values for OST load cases **Table 29**

Transverse position	f_{xL}	OST-1P - OST-2P	OST-1S - OST-2S
$y \geqslant 0$	0.0	1.0	$1.0+(0.5-f_T)f_{yB}$
	0.2	1.0	$1.0+3(0.5-f_T)f_{yB}$
	0.4	-1.0	$(2.7-2.4f_T)f_{yB}-1$
	0.5	-1.0	$(2.8-2.6f_T)f_{yB}-1$
	0.7	$(f_T-0.62)f_{yB}-0.38$	$(2.38-3f_T)f_{yB}-0.38$
	0.9	$0.24+0.76\,f_{yB}$	$0.24-(0.24+f_T)f_{yB}$
	1.0	$-1.0+0.5f_{yB}$	-1.0
$y<0$	0.0	$1.0+(0.5-f_T)f_{yB}$	1.0
	0.2	$1.0+3(0.5-f_T)f_{yB}$	1.0
	0.4	$(2.7-2.4f_T)f_{yB}-1$	-1.0
	0.5	$(2.8-2.6f_T)f_{yB}-1$	-1.0
	0.7	$(2.38-3f_T)f_{yB}-0.38$	$(f_T-0.62)f_{yB}-0.38$
	0.9	$0.24-(0.24+f_T)f_{yB}$	$0.24+0.76\,f_{yB}$
	1.0	–1.0	$-1.0+0.5f_{yB}$

2 EXTERNAL PRESSURES ON EXPOSED DECKS

2.1 Application

2.1.1

The external pressures and forces on exposed decks are only to be applied for strength assessment.

2.1.2

The green sea pressures defined in [2.2] for exposed decks are to be considered independently of the pressures due to distributed cargo or other equipment loads and any concentrated forces due to cargo or other unit equipment loads, defined in [2.3.1] and [2.3.2] respectively.

2.2 Green sea loads

2.2.1 Pressure on exposed deck

The external dynamic pressure due to green sea loading, P_D, at any point of an exposed deck, in kN/m^2, for the static plus dynamic (S+D) design load scenarios is to be derived for each dynamic load case and is to be taken as defined in [2.2.3] to [2.2.4]

The external dynamic pressure due to green sea loading, P_D, at any point of an exposed deck for the static (S) design load scenarios is zero.

2.2.2

If a breakwater is fitted on the exposed deck, no reduction in the green sea pressure is allowed for the area of the exposed deck located aft of the breakwater.

2.2.3 HSM, HSA and FSM load cases

The external pressure, P_D, for HSM, HSA and FSM load cases, at any load point of an exposed deck is to be obtained, in kN/m^2, from the following formula, see Figure 2 and Figure 3:

$P_D=\chi P_W$

where:

$P_W = P_{W,D}$, but not to be taken less than $P_{D\text{-}min}$.

$P_{W,D}$: Pressure, in kN/m^2, obtained at side of the exposed deck for HSM, HSA and FSM load cases as defined in [1.3].

$P_{D\text{-}min}$: Minimum exposed deck pressure, in kN/m^2, to be taken as:

- For cargo hold analysis according to Ch 7: $P_{D\text{-}min} = 0$.

- For other cases: $P_{D\text{-}min}$ as defined in Table 30.

χ : Coefficient defined in Table 31.

Minimum pressures on exposed decks for HSM, HSA, FSM load cases Table 30

Location	Minimum pressure on exposed deck, $P_{D\text{-}min}$, in kN/m^2	
	$L_{LL} \geq 100$m	$L_{LL} < 100$m
$x_{LL}/L_{LL} \leqslant 0.75$	34.3	$14.9 + 0.195\ L_{LL}$
$x_{LL}/L_{LL} > 0.75$	$34.3 + (14.8 + a(L_{LL} - 100))\left(4\frac{x_{LL}}{L_{LL}} - 3\right)$	$12.2 + \frac{L_{LL}}{9}\left(5\frac{x_{LL}}{L_{LL}} - 2\right) + 3.6\frac{x_{LL}}{L_{LL}}$

Where
a : Coefficient taken equal to:
$a = 0.356$ for Type A, Type B-60 and Type B-100 freeboard ships
$a = 0.0726$ for Type B freeboard ships.
x_{LL} : X-coordinate of the load point measured from the aft end of the freeboard length L_{LL}.

Coefficient for pressure on exposed decks Table 31

Exposed deck location	χ
Freeboard deck	1.00
Superstructure deck including forecastle deck	0.75
1st tier of deckhouse	0.56
2nd tier of deckhouse	0.42
3rd tier of deckhouse	0.32
4th tier of deckhouse	0.25
5th tier of deckhouse	0.20
6th tier of deckhouse	0.15
7th tier of deckhouse and above	0.10

2.2.4 BSR, BSP, OST and OSA load cases

The external pressure, P_D, for BSR, BSP, OST and OSA load cases at any load point of an exposed deck is to be obtained, in kN/m^2, by linear interpolation between the pressures at the port and starboard deck edges (see also Figure 4, Figure 6, Figure 9 and Figure 10):

$P_{D,stb} = \chi P_{W,D\text{-}stb}$

$P_{D,pt} = \chi P_{W,D\text{-}pt}$

where:

$P_{W,D\text{-}stb}$: Pressure obtained at starboard deck edge for BSR, BSP, OST or OSA load cases as defined in [1.3], as appropriate.

$P_{W,D\text{-}pt}$: Pressure obtained at port deck edge for BSR, BSP, OST and OSA load cases as defined in [1.3], as appropriate.

χ : Coefficient defined in Table 31.

2.2.5 Envelope of dynamic pressures on exposed deck

The envelope of dynamic pressure at any point of an exposed deck, $P_{D\text{-}max}$, is to be taken as the greatest pressure obtained from any of the load cases determined by [2.2.3] and [2.2.4].

2.3 Load carried on exposed deck

2.3.1 Pressure due to distributed load

If a distributed load is carried on an exposed deck, for example deck cargo or other equipment, the static and dynamic pressures due to this distributed load are to be considered.

The total pressure, P_{dl}, in kN/m^2, due to this distributed load for the static (S) design load scenario is to be taken as:

$P_{dl} = P_{dl\text{-}s}$

The pressure P_{dl}, in kN/m^2, due to this distributed load for the static plus dynamic (S+D) design load scenario is to be derived for each dynamic load case and is to be taken as:

$P_{dl}=P_{dl\text{-}s}+P_{dl\text{-}d}$

where:

$P_{dl\text{-}s}$: Static pressure, in kN/m^2, due to the distributed load, to be defined by the Designer and, in general, but not less than 10kN/m^2.

$P_{dl\text{-}d}$: Dynamic pressure, in kN/m^2, due to the distributed load, in kN/m^2, to be taken as:

$$P_{dl-d} = f_\beta \frac{a_Z}{g} P_{dl-s}$$

a_Z : Vertical acceleration, in m/s^2, at the centre of gravity of the distributed load, for the considered load case, to be obtained according to Ch 4, Sec 3, [3.2.4].

2.3.2 Concentrated force due to unit load

If a unit load, for example deck cargo, is carried on an exposed deck, the static and dynamic forces due to the unit load carried are to be considered.

The force F_U, in kN, due to this concentrated load for the static (S) design load scenarios, is to be taken as:

$F_U=F_{U\text{-}s}$

The force F_U, in kN, due to this concentrated load for the static plus dynamic (S+D) design load scenarios is to be derived for each dynamic load case and is to be taken as:

$F_U=F_{U\text{-}s}+F_{U\text{-}d}$

where:

$F_{U\text{-}s}$: Static force, in kN, due to the unit load to be taken equal to:

$F_U=m_U g$

$F_{U\text{-}d}$: Dynamic force, in kN, due to unit load to be taken equal to:

$F_{U\text{-}d}=m_U f_\beta a_Z$

m_U : Mass of the unit load carried, in t.

a_Z : Vertical acceleration, in m/s^2, at the centre of gravity of the unit load carried for the considered load case, to be obtained according to Ch 4, Sec 3, [3.2.4].

3 EXTERNAL IMPACT PRESSURES FOR THE BOW AREA

3.1 Application

3.1.1

The impact pressures for the bow area are only to be applied for strength assessment.

3.2 Bottom slamming pressure

3.2.1

The bottom slamming pressure P_{SL}, in kN/m^2, for the bottom slamming design load scenario is to be evaluated for the following two cases:

Case 1: An empty ballast tank or a void space in way of the bottom shell.

$P_{SL} = 10g\sqrt{L} f_{SL} c_{SL-et}$ for $L < 170$ m

$P_{SL} = 130 g f_{SL} c_{SL-et} e^{c1}$ for $L \geqslant 170$ m

Case 2: A full ballast tank in way of the bottom shell.

$P_{SL} = 10g\sqrt{L} f_{SL} c_{SL-ft} - 1.25\rho g(z_{top} - z)$ for $L < 170$ m

$P_{SL} = 130 g f_{SL} c_{SL-ft} e^{c1} - 1.25\rho g(z_{top} - z)$ for $L \geqslant 170$ m

where:

c_1 : Coefficient to be taken as:

$c_1=0$ for $L \leqslant 180$m

$c_1=-0.0125(L-180)^{0.705}$ for $L > 180$ m

$c_{SL\text{-}et}$: Slamming coefficient for case with an empty ballast tank or void space:

$$c_{SL-et} = 5.95 - 10.5\left(\frac{T_{F-e}}{L}\right)^{0.2}$$

c_{SL-ft} : Slamming coefficient for case with a full ballast tank:

$$c_{SL-ef} = 5.95 - 10.5\left(\frac{T_{F-f}}{L}\right)^{0.2}$$

f_{SL} : Longitudinal slamming distribution factor, to be taken as:

f_{SL}=0 for $x/L \leqslant 0.5$

f_{SL}=1.0 for x/L=0.5+c_2

f_{SL}=1.0 for x/L=0.65+c_2

f_{SL}=0.5 for $x/L \geqslant 1.0$

Intermediate values of f_{SL} are to be obtained by linear interpolation.

c_2 : Coefficient to be taken as:

$$c_2 = 0.33C_B + \frac{L}{2500}$$ but not to be taken greater than 0.35

TF-e : Design slamming draught at the FP to be provided by the Designer. T_{F-e} is not to be greater than the minimum draught at the FP indicated in the loading manual for all seagoing conditions where any of the ballast tanks within the bottom slamming region are empty. This includes all loading conditions with tanks inside the bottom slamming region that use the 'sequential' ballast water exchange method, if relevant.

T_{F-f} : Design slamming draught at the FP to be provided by the Designer. T_{F-f} is not to be greater than the minimum draught at the FP indicated in the loading manual for all seagoing conditions where all ballast tanks within the bottom slamming region are full. This includes all loading conditions with tanks inside the bottom slamming region that use the 'flow-through' ballast water exchange method, if relevant.

z_{top} : Z-coordinate of the highest point of the tank, excluding small hatchways, in m.

For strength assessment of double bottom floors and girders, z_{top} is not to be taken greater than the double bottom height.

3.2.2 Loading manual information

The loading guidance information is to clearly state the design slamming draughts and the ballast water exchange method used for each ballast tank, if any.

3.3 Bow impact pressure

3.3.1 Design pressures

The bow impact pressure P_{FB}, in kN/m^2, to be considered for the bow impact design load scenario is to be taken as:

P_{FB}=1.025$f_{FB}c_{FB}V^2_{im}$sinγwl

where:

f_{FB} : Longitudinal bow flare impact pressure distribution factor. To be taken as:

f_{FB}=0.55 for $x/L \leqslant 0.9$

f_{FB}=4(x/L-0.9)+0.55 for $0.9 < x/L \leqslant 0.9875$

f_{FB}=8(x/L-0.9875)+0.9 for $0.9875 < x/L \leqslant 1.0$

f_{FB}=1.0 for $x/L > 1.0$

V_{im} : Impact speed, in knots, to be taken as:

$$V_{im} = 0.514V_{ref}\sin\alpha_{wl} + \sqrt{L}$$

V_{ref} : Forward speed, in knots, to be taken as:

V_{ref}=0.75V, but not less than 10.

α_{wl} : Local waterline angle, in deg, at the considered position, but not less than 35 deg. See Figure 12.

γ_{wl} : Local bow impact angle, in deg, measured in a vertical plane containing the normal to the shell, from the horizontal to the tangent line at the considered position but not less than 50 deg, as shown in Figure 12. Where this value is not available, it may be taken as:

$$\gamma_{wl} = \tan^{-1}\left(\frac{\tan\beta_{pl}}{\cos\alpha_{wl}}\right)$$

For ships with bow impact angle less than 50 deg, the impact pressure is to be individually considered by the Society. The resulting scantling individually considered by the Society is in no case to be less than the scantling calculated in accordance with [3.3.1] for local bow impact angle equal to 50 deg.

β_{pl} : Local body plan angle, in deg, at the considered position from the horizontal to the tangent line, but not less than 35 deg.

c_{FB} : Coefficient to be taken as:

c_{FB}=1.0 for positions between draughts T_{BAL} and T_{SC}

$$c_{FB} = \sqrt{1.0 + \cos^2\left[90\frac{(h_{fb} - 2h_0)}{h_{fb}}\right]}$$ for positions above draughts T_{SC}

h_{fb} : Vertical distance, in m, from the waterline at the draught T_{SC} to the highest deck at side. See Figure12.

h_0 : Vertical distance, in m, from the waterline at the draught T_{SC} to the considered position. See Figure 12.

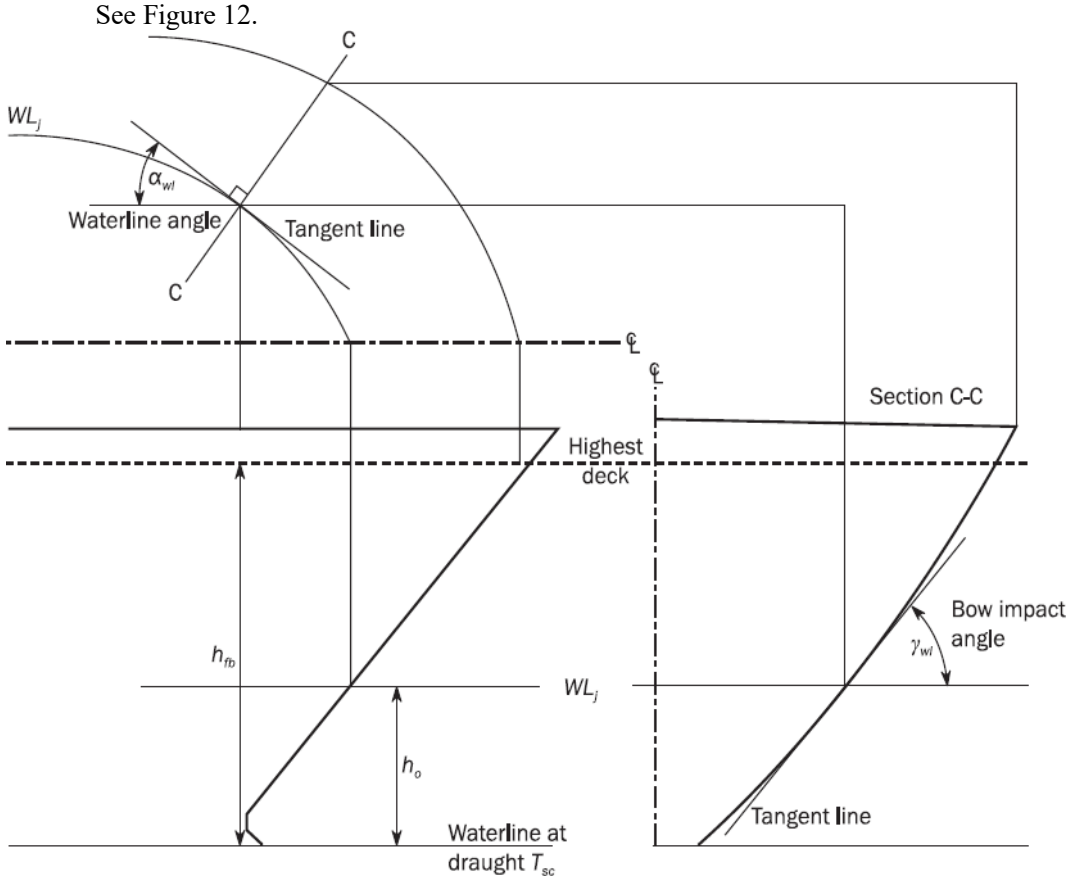


Figure 12 Definition of bow geometry

CCS 3.3.1a For ships with impact angle, γ_{wl}, less than 50 deg, in addition to [3.3.1], the requirements given in Ch 6, Sec 7, [3.3] of CCS Rules for Structures of Container Ships are to be complied also.

4 EXTERNAL PRESSURES ON SUPERSTRUCTURE AND DECKHOUSES

4.1 Application

4.1.1

The external pressures on superstructure and deckhouses are only to be applied for strength assessment. These pressures are to be considered as dynamic pressures and are to be applied to the appropriate structure without any static pressure load component.

4.1.2

The dynamic load case concept is not to be applied for external pressures on

superstructures and deckhouses.

4.2 Exposed wheel house tops

4.2.1

The lateral pressure for exposed wheel house tops, P_D, in kN/m^2, is to be taken as:

P_D=12.5

4.3 Sides of superstructures

4.3.1

The design pressure for the external sides of superstructures, P_{SI}, in kN/m^2, is to be taken as:

$$P_{SI} = 2.1 C_w c_F (C_B + 0.7) \frac{20}{10 + z_{SD} - T_{SC}}$$

where:

c_F : Distribution factor according to Table 32.

Distribution factor c_F **Table32**

Location	c_F
$x/L < 0.2$	$1.0 + \frac{5}{C_B}\left(0.2 - \frac{x}{L}\right)$ without taking x/L less than 0.1
$x/L \geqslant 0.2$	1.0

4.4 End bulkheads of superstructures and deckhouse walls

4.4.1

The external pressure for the aft and forward external bulkheads of superstructures and deckhouse walls, in kN/m^2, is to be taken as:

$P_A = f_n f_c [f_b f_d - (z_{SD} - T_{SC})]$

but is not to be less than $P_{A\text{-}min}$.

where:

f_n : Coefficient defined in Table 33.

f_c : Coefficient, to be taken as:

$$f_c = 0.3 + 0.7 \frac{b_1}{B_1}, \text{ but not less than } 0.475$$

For exposed parts of machinery casings, f_c is not to be taken less than 1.0.

f_d : Coefficient, to be taken as:

$$f_d = \frac{L}{10} e^{-(L/300)} - \left(1 - \left(\frac{L}{150}\right)^2\right) \text{ for } L < 150 \text{ m}$$

$$f_d = \frac{L}{10} e^{-(L/300)} \text{ for } 150 \text{ m} \leqslant L < 300 \text{ m}$$

f_d = 11.03 for $L \geqslant$ 300 m

b_1 : Breadth of deckhouse at the position considered.

B_1 : Actual breadth of ship on the exposed weather deck at the position considered.

f_b : Coefficient defined in Table 34.

$P_{A\text{-}min}$: Minimum lateral pressure, in kN/m^2, as defined in Table 35.

5 EXTERNAL PRESSURES ON HATCH COVERS

5.1 Application

5.1.1

The external pressures on hatch covers are only to be applied for strength assessment.

5.2 Green sea loads

5.2.1

The green sea loads at any load point of a hatch cover, *PHC*, in kN/mm2, is to be taken as follows:

- For cargo hold analysis according to Ch 7:
  $P_{HC} = P_D - \rho g (z_{HC} - D)$, without being less than 0

- For other cases: $P_{HC} = P_{D,min}$ as defined in Table 30.

P_D : Green sea pressure, in kN/mm^2, on the deck in way of the hatch cover obtained according to [2.2], considering χ equal to 1.0.

z_{HC} : z coordinate of the top of the hatch cover, in m.

5.3 Load carried on hatch covers

5.3.1

If a distributed load or a unit load is carried on a hatch cover, the pressure is to be obtained according to [2.3].

Coefficient f_n **Table33**

Type of bulkhead	Location	f_n
Unprotected front bulkhead (1)	Lowest tier (2)	$20+\frac{L_2}{12}$
	Second tier	$10+\frac{L_2}{12}$
	Third tier and above	$5+\frac{L_2}{15}$
Protected front bulkhead (1)	All tiers	$5+\frac{L_2}{15}$
Side bulkheads	All tiers	$5+\frac{L_2}{15}$
Aft end bulkheads	Abaft amidships	$7+\frac{L_2}{100}-8\frac{x}{L_2}$
	Forward of amidships	$5+\frac{L_2}{100}-4\frac{x}{L_2}$

(1) The front bulkhead of a superstructure or deckhouse may be considered as protected when it is located less than Bx behind another superstructure or deckhouse, and the width of the front bulkhead being considered is less than the width of the aft bulkhead of the superstructure or deckhouse forward of it. B_x is the local breadth of the ship at the front bulkhead.

(2) The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the moulded depth D is measured. However, when (D - T_{SC}) exceeds the minimum non-corrected tabular freeboard (according to ICLL as amended) by at least one standard superstructure height (as defined in Ch 1, Sec 4, [3.3]), then this tier may be defined as the 2nd tier and the tier above as the 3rd tier.

Coefficient f_b **Table 34**

Location of bulkhead (1)	f_b
$\frac{x}{L}<0.45$	$1.0+\left(\frac{x/L-0.45}{C_{B1}+0.2}\right)^2$
$\frac{x}{L}\geq 0.45$	$1.0+1.5\left(\frac{x/L-0.45}{C_{B1}+0.2}\right)^2$

where:

C_{B1} : Block coefficient, but not less than 0.60 nor greater than 0.80. For aft deckhouse bulkheads located forward of amidships, C_{B1} may be taken as 0.80.

(1) For deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0.15L each, and x is to be taken as the X-coordinate of the centre of each part considered.

Minimum lateral pressure, $P_{A\text{-}min}$ **Table 35**

	$P_{A\text{-}min}$, kN/m^2	
L	Lowest tier of unprotected fronts	Elsewhere (1)
$90<L\leq 250$	$25+\frac{L}{10}$	$12.5+\frac{L}{20}$
L>250	50	25

(1) For the 4th tier and above, $P_{A\text{-}min}$ is to be taken equal to 12.5 kN/m^2.

Section 6 INTERNAL LOADS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4

a_X, a_Y, a_Z: Longitudinal, transverse and vertical accelerations, in m/s^2, at x_G, y_G, z_G, as defined in Ch 4, Sec 3, [3.2].

B_H : Breadth of the cargo hold, in m, measured at mid-length of the cargo hold and at the mid height between the top of hopper tank and the bottom of topside tank, see Figure 2.

B_{IB} : Breadth of inner bottom, in m, measured at mid-length of the cargo hold, see Figure 2.

D_1 : Distance, in m, from the baseline to the freeboard deck at side amidships.

d_{sc} : Diameter, in m, of a steel coil.

f_{cd} : Factor for joint probability of occurrence of liquid cargo density and maximum sea state in 25 years design life, to be taken as:

- For strength assessment with FE analysis of cargo tanks filled with liquid cargo:
  f_{cd} = 1.0 for ρ_L > 1.025 t/m^3.
  f_{cd} = 0.88 for ρ_L = 1.025t/m^3.
- For other cases:
  f_{cd} = 1.0.

f_{dc} : Dry cargo factor taken as:
f_{dc} = 1.0 for strength assessment,
f_{dc} = 0.5 for fatigue assessment.

f_β : Coefficient defined in Ch 4, Sec 4.

h_{air} : Height of air pipe or overflow pipe above the top of the tank, in m.

h_C : Height of bulk cargo, in m, from the inner bottom to the upper surface of bulk cargo, as defined in[2.3.1] or [2.3.2].

h_{DB} : Height, in m, of the double bottom at the centreline, measured at mid-length of the cargo hold, see Figure 2.

h_{HPL} :Vertical distance, in m, from the inner bottom at centreline to the upper intersection of hopper tank and side shell or inner side for double side bulk carriers, determined at mid length of the considered cargo hold, as shown in Figure 2.
h_{HPL} = 0 if there is no hopper tank.

h_{HPU} : Vertical distance, in m, from the inner bottom at centreline to the lower intersection of topside tank and side shell or inner side for double side bulk carriers, determined at mid length of the cargo hold at midship, as shown in Figure 2.

h_{LS} : Mean height, in m, of the lower stool, measured from the inner bottom.

h_{max} : Maximum permissible filling level, in m, taken as:
For ballast tanks: maximum tank height,

- For cargo tanks with cargo density equal to ρ_L: maximum tank height
- For cargo tanks with heavy liquid cargo density equal to ρ_{part} associated with a partially filled cargo tank: hpart as defined in Ch 10, Sec 4, [1.2.1].

K_C : Coefficient taken equal to:

$K_C = \cos^2\alpha + (1-\sin\Psi)\sin^2\alpha$	for $\alpha \leqslant 90°$
$K_C = (1-\sin\Psi)\sin^2\alpha$	for $90° < \alpha \leqslant 120°$
$K_C = 0.75(1-\sin\Psi)[1-(\alpha-120)/(60-\Psi)]$	for $\alpha > 120°$ and $\alpha + \Psi < 180°$
$K_C = 0$	when $\alpha + \Psi \geqslant 180°$

$K_{C\text{-}f}$: Coefficient taken equal to:

$$K_{C-f} = \tan^2\left(45 - \frac{\Psi}{2}\right)$$

l : Distance, in m, between floors.

l_H : Length of the cargo hold, in m, at the centreline between the transverse bulkheads. This is to be measured to the mid-depth of the corrugated bulkhead(s) if fitted.

l_{lp} : Distance, in m, between outermost dunnage per EPP in the ship X direction, see Figure 11.

l_{st} : Length, in m, of a steel coil.

M : Mass, in t, of the bulk cargo being considered.

M_{Full} : Cargo mass, in t, in a cargo hold corresponding to the volume up to the top of the hatch

coaming with a density of the greater of M_H/V_{Full} or 1.0 t/m^3.
M_{Full}=1.0V_{Full} but not less than M_H.

M_H : Cargo mass, in t, in a cargo hold that corresponds to the homogeneously loaded condition at maximum draught with 50% consumables.

M_{HD} : Maximum allowable cargo mass, in t, in a cargo hold according to design loading conditions with specified holds empty at maximum draught with 50% consumables. and all ballast water tanks in cargo hold region empty.

$M_{sc\text{-}ib}$: Equivalent mass of a steel coil, in t, on inner bottom, as defined in [4.3.1]

$M_{sc\text{-}hs}$: Equivalent mass of a steel coil, in t, on hopper side, as defined in [4.3.2].

n_1 : Number of tiers of steel coils.

n_2 : Number of load points per EPP of the inner bottom, see [4.1.3].

n_3 : Number of dunnages supporting one row of steel coils.

P_{drop} : Overpressure, in kN/m^2, due to sustained liquid flow through air pipe or overflow pipe in case of overfilling or filling during flow through ballast water exchange. It is to be defined by the designer, but not to be less than 25 kN/m^2.

P_{PV} : Design vapour pressure, in kN/m^2, but not less than 25 kN/m^2.

perm : Permeability of cargo, to be taken as:
perm = 0.3 for iron ore, coal cargoes and cement.
perm = 0 for steel coils and steel packed products.

R : Vertical coordinate of the ship rotation centre, defined in Ch 4, Sec 3.

s_C : Spacing of corrugations, in m, as defined in Ch 3, Sec 6, [10.4.2].

T_θ : Roll period, in s, as defined in Ch 4, Sec 3, [2.1.1].

V_{Full} : Volume, in m^3, of cargo hold up to top of the hatch coaming, taken as:
$V_{Full} = V_H + V_{HC}$.

V_H :Volume, in m^3, of cargo hold up to level of the intersection of the main deck with the hatch coaming excluding the volume enclosed by hatch coaming, see Figure 2.

V_{HC} : Volume, in m^3, of the hatch coaming, from the level of the intersection of the main deck with the hatch side coaming to the top of the hatch coaming, determined for the cargo hold at midship, as shown in Figure 2.

V_{TS} : Total volume, in m^3, of the portion of the lower bulkhead stools within the cargo hold length l_H and inboard of the hopper tanks.

W : Mass, in t, of a steel coil.

x, y, z : X, Y and Z coordinates, in m, of the load point with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

x_G, y_G, z_G: X, Y and Z coordinates, in m, of the volumetric centre of gravity of the tank or fully filled cargo hold, i.e. V_{Full}, considered with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2].
In case of partially filled cargo hold, x_G, y_G, z_G to be taken as follows:
x_G, y_G: Volumetric centre of gravity of the cargo hold.
$z_G = h_{DB} + h_{C\text{-}cl} / 2$

z_{top} : Z coordinate of the highest point of tank, excluding small hatchways, in m.

z_C : Height of the upper surface of the cargo above the baseline in way of the load point, in m, to be taken as:
$z_C = h_{DB} + h_C$

α : Angle, in deg, between panel considered and the horizontal plane. The angle is to be measured inward and upward from horizontal plane outside cargo hold, between 0 and 180 deg, as shown in Figure 1.

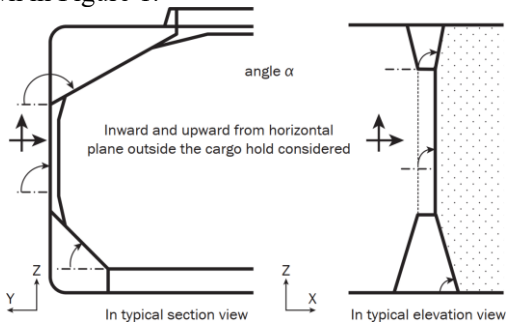


Figure 1 Measurement of angle α

φ : Pitch angle, in deg, defined in Ch 4, Sec 3, [2.1.2].

Ψ : Assumed angle of repose, in deg, of bulk cargo (considered drained and removed); to be taken as:
Ψ= 30° in general.
Ψ= 35° for iron ore.
Ψ= 25° for cement.

ρc : Density of bulk cargo, in t/m^3, as defined in [2.3.3].

ρ_L : Density of liquid in the tank and ballast hold, in t/m^3, but not less than:
- For strength assessment:

ρ_L = 1.025 for all liquids including oil cargoes. If a tank filled at 98% is intended to carry heavier liquid cargoes than 1.025 (i.e. $\rho_{max\text{-}LM} > 1.025$), then $\rho_L = \rho_{max\text{-}LM}$.
- For fatigue assessment:

ρ_L = 0.9 for liquid cargoes.
ρ_L= 1.025 for all other liquids.

$\rho_{max\text{-}LM}$: Maximum liquid cargo density in t/m^3, associated with a full tank at 98%, from any loading condition in the ship's loading manual or value specified by the designer.

ρ_{part} : Maximum permissible high liquid cargo density, in t/m^3, associated with a partially filled cargo tank but not taken less than ρ_L considered for strength assessment.

ρ_{slh} : Liquid density, in t/m^3, to be used for sloshing assessment, taken as:
$\rho_{slh}=\rho_{part}$, for heavy liquid cargo density associated with partial filling of cargo
$\rho_{slh}=\rho_L$, for all other cases

ρ_{ST} : Density of steel, in t/m^3, to be taken as 7.85.

Θ : Roll angle, in deg, defined in Ch 4, Sec 3, [2.1.1].

θ_h : Angle, in deg, between inner bottom plate and hopper sloping plate. in general θ_h is such that:

$$\tan\theta_h = \frac{2h_{HPL}}{B_H - B_{IB}}$$

1 PRESSURES DUE TO LIQUIDS

1.1 Application

1.1.1 Pressures for the strength and fatigue assessments of intact conditions

The internal pressure due to liquid acting on any load point of a tank and ballast hold boundary, in kN/m^2, for the static (S) design load scenarios, given in Ch 4, Sec 7, is to be taken as:

$P_{in}=P_{ls}$ but not less than 0.

The internal pressure due to liquid acting on any load point of a tank and ballast hold boundary, in kN/m^2, for the static plus dynamic (S+D) design load scenarios is to be derived for each dynamic load case and is to be taken as:

$P_{in}=P_{ls}+P_{ld}$ but not less than 0.

where:

P_{ls} : Static pressure due to liquid in tanks and ballast holds, in kN/m^2, as defined in [1.2].

P_{ld} : Dynamic inertial pressure due to liquid in tanks and ballast holds, in kN/m^2, as defined in [1.3].

1.1.2 Pressures for the strength assessments of flooded conditions

The internal pressure in flooded condition, in kN/m^2, acting on any load point of the watertight boundary of a hold, tank or other space for the flooded static (S) design load scenarios, given in Ch 4, Sec 7, is to be taken as:

$P_{in}=P_{fs}$ but not less than $\rho g d_0$

The internal pressure in flooded condition, in kN/m^2, acting on any load point of the watertight boundary of a hold, tank or other space for the flooded static plus dynamic (S+D) design load scenarios, is to be derived for each dynamic load case and is to be taken as:

$P_{in}=P_{fs}+P_{fd}$ but not less than $gd0$where:

P_{fs} : Static pressure of seawater in flooded condition in the compartment, in kN/m^2, as defined in [1.4].

P_{fd} : Dynamic inertial pressure of seawater in flooded condition in the compartment, in kN/m^2, as defined in [1.5].

d_0 : Distance, in m, to be taken as:

d_0=0.02L， form

d_0=2.4， for m

For corrugations of vertically corrugated bulkheads of bulk carrier cargo holds, the flooded pressures and forces specified in [3] for bulk cargoes are to be applied.

1.2 Static liquid pressure

1.2.1 Normal operations at sea

The static pressure due to liquid in tanks and ballast holds, P_{ls} during normal operations at sea, in kN/m^2, is to be taken as:

$P_{ls}=f_{cd}\rho_L g(z_{top}-z)+P_{PV}$, for cargo tanks filled with liquid cargo.

$P_{ls}=\rho_L g(z_{top}-z+0.5h_{air})$, for other cases

1.2.2 Harbour/sheltered water operations

The static pressure, P_{ls} due to liquid in tanks and ballast holds for harbour/sheltered water operations, in kN/m^2, is to be taken as:

$P_{ls}=\rho_L g(z_{top}-z+h_{air})+P_{drop}$ for ballast tanks

$P_{ls}=\rho_L g(z_{top}-z)+P_{PV}$ for cargo tanks filled with liquid cargo

$P_{ls}=\rho_L g(z_{top}-z+0.5h_{air})$ for ballast holds with h_{air} = 0 and for other cases

1.2.3 Sequential ballast water exchange

The static pressure, P_{ls} due to liquid in ballast tanks associated with sequential ballast water exchange operations, in kN/m^2, is to be taken as:

$P_{ls}=\rho Lg(z_{top}$-z+0.5$h_{air})$

1.2.4 Flow through ballast water exchange

The static pressure, P_{ls} due to liquid in ballast tanks associated with flow through ballast water exchange operations, in kN/m^2, is to be taken as:

$P_{ls}=\rho_L g(z_{top}-z+h_{air})+P_{drop}$

1.2.5 Ballasting using ballast water treatment system

The static pressure, P_{ls} due to liquid in tanks and ballast holds associated with ballasting operations using a ballast water treatment system is to be taken as defined for sequential ballast exchange in [1.2.3]. The ship designer has to inform the Society if the ballast water treatment system implies additional pressure to be considered as P_{drop}, etc in addition to the pressure defined in [1.2.3].

1.2.6 Static liquid pressure for the fatigue assessment

The static pressure due to liquid in tanks and ballast holds, P_{ls} to be used for the fatigue assessment, in kN/m^2, is to be taken as:

$P_{ls}=\rho_L g(z_{top}-z)$ for all tanks (cargo and water ballast tanks, ballast hold and other tanks).

1.3 Dynamic liquid pressure

1.3.1

The dynamic pressure, *Pld* due to liquid in tanks and ballast holds, in kN/m2 is to be taken as:

$P_{ld} = f_\beta f_{cd}\,\rho_L\,[a_Z\,(z_0 - z) + f_{ull\text{-}l}\,a_X\,(x_0 - x) + f_{ull\text{-}t}\,a_Y\,(y_0 - y)]$

where:

$f_{ull\text{-}l}$: Longitudinal acceleration correction factor for the ullage space above the liquid in tanks and ballast holds, taken as:

- For strength assessment:
  $f_{ull\text{-}l}$ = 0.62 for cargo tanks filled with any liquids including water ballast.
  $f_{ull\text{-}l}$ = 1.0 for other cases.
- For fatigue assessment

$$f_{ull-l} = 0.5 + \frac{|z_0 - z|}{l_{fs}} \frac{180}{\varphi\pi}$$ for cargo tanks and ballast holds

f_{ull-l} = 1.0 for other cases.

f_{ull-l} is not to be less than 0.0 nor greater than 1.0

l_{fs} : Cargo tank length at the top of the tank or length of the ballast hold hatch coaming, in m.

f_{ull-t} : Transverse acceleration correction factor to account for the ullage space above the liquid in tanks and ballast holds, taken as:

- For strength assessment:

  f_{ull-t} = 0.67 for cargo tanks filled with any liquids including water ballast.

  f_{ull-t} = 1.0 for other cases.
- For fatigue assessment

$$f_{ull-t} = 0.5 + \frac{|z_0 - z|}{b_{top}} \frac{180}{\theta\pi}$$ for cargo tanks and ballast holds.

f_{ull-t} = 1.0 for other cases.

f_{ull-t} is not to be less than 0.0 nor greater than 1.0

b_{top} : Cargo tank breadth at the top of the tank or breadth of the ballast hold hatch coaming, in m, determined at mid length of the tank or ballast hold hatch coaming.

x_0 : X coordinate, in m, of the reference point.

y_0 : Y coordinate, in m, of the reference point.

z_0 : Z coordinate, in m, of the reference point.

The reference point is to be taken as the point with the highest value of V_j, calculated for all points that define the upper boundary of the tank or ballast hold as follows:

$V_j = a_X(x_j - x_G) + a_Y(y_j - y_G) + (a_z + g)(z_j - z_G)$

where:

x_j : X coordinate, in m, of the point j on the upper boundary of the tank or ballast hold.

y_j : Y coordinate, in m, of the point j on the upper boundary of the tank or ballast hold.

z_j : Z coordinate, in m, of the point j on the upper boundary of the tank or ballast hold.

1.4 Static pressure in flooded conditions

1.4.1 Static pressure in flooded compartments

The static pressure, P_{fs} in kN/m^2, for watertight boundaries of flooded compartments is to be taken as:

$P_{fs} = \rho g(z_{FD} - z)$ but not less than 0.

where:

z_{FD} : Z coordinate, in m, of the freeboard deck at side in way of the transverse section considered or the deepest equilibrium waterline in the damaged condition whichever is the greater.

1.5 Dynamic pressure in flooded conditions

1.5.1 Dynamic pressure in flooded compartments

The dynamic pressure, P_{fd}, in kN/m^2, for watertight boundaries of flooded compartments is to be taken as:

$$P_{fd} = f_\beta \rho \left[a_Z (z_{0FD} - z) + f_{ull-l} a_X (x_0 - x) + f_{ull-t} a_Y (y_0 - y)\right]$$

where:

z_{0FD} : Z coordinate of the effective reference point, in m, for a flooded compartment taken as:

When $z_{FD} > z_0$, $z_{0FD} = z_0$

When $z_{FD} \leqslant z_0$, $z_{0FD} = z_{FD}$

f_{ull-l}, f_{ull-t} : Longitudinal and transverse acceleration correction factors:

When $z_{FD} \leqslant z_0$, f_{ull-l} and f_{ull-t} are to be taken as defined in [1.3.1].

When $z_{FD} > z_0$, f_{ull-l} = 1.0 and f_{ull-t} = 1.0.

2 PRESSURES AND FORCES DUE TO DRY BULK CARGO

2.1 Application

2.1.1

The pressures and forces due to dry cargo in bulk in a cargo hold are to be determined both for fully and partially filled cargo holds according to [2.4] and [2.5].

2.2 Hold definitions

2.2.1 Geometrical characteristics

Figure 2 gives the main geometrical elements of a bulk carrier cargo hold.

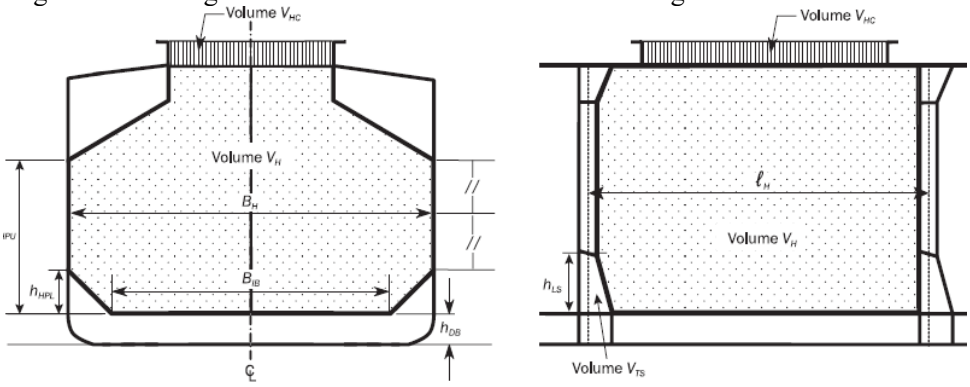


Figure 2 Definition of cargo hold parameters for bulk carrier

2.2.2 Fully and partially filled cargo holds

The definitions of a fully and partially filled dry bulk cargo holds are as follow:

a) Fully filled hold:
The dry bulk cargo density is such that the cargo hold is filled up to the top of the hatch coaming, as shown in Figure 3.
The upper surface of the cargo and its effective height in the hold h_C are to be determined in accordance with [2.3.1].

b) Partially filled hold:
The cargo density is such that the cargo hold is not filled up to the top of the hatch coaming, as shown in Figure 4 or Figure 5.
The upper surface of the cargo and its effective height in the hold h_C are to be determined in accordance with [2.3.2].

2.3 Dry cargo characteristics

2.3.1 Definition of the upper surface of dry bulk cargo for full cargo holds

For a fully filled cargo hold as defined in [2.2.2], including non-prismatic holds, the effective upper surface of the cargo is an equivalent horizontal surface at h_C, in m, above inner bottom at centreline as shown in Figure 3.

The value of h_C is to be calculated at mid length of the cargo hold at the midship, is to be kept constant over the cargo hold region area and is determined as follows:

$h_C = h_{HPU} + h_0$

where:

$$h_0 = \frac{S_A}{B_H}$$

$$S_A = S_0 + \frac{V_{HC}}{l_H}$$

S_0: Shaded area, in m^2, above the lower intersection of topside tank and side shell or inner side, as the case may be, and up to the level of the intersection of the main deck with the hatch coaming, determined for the cargo hold at the midship as shown in Figure 3.

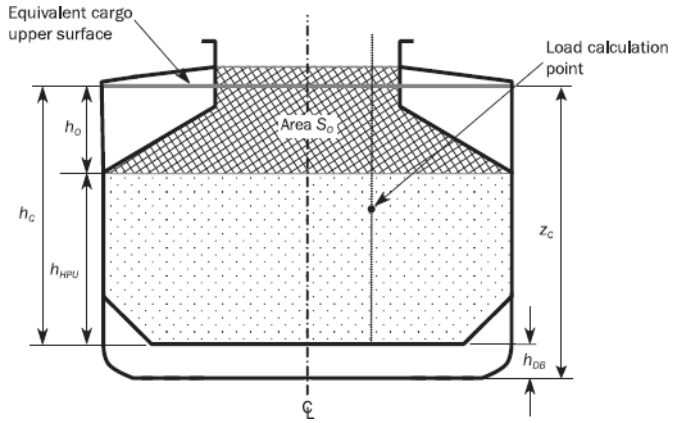


Figure 3 Definition of effective upper surface of cargo for a full cargo hold

2.3.2 Definition of upper surface of dry bulk cargo for partially filled cargo holds

For any partially filled cargo hold, as defined in [2.2.2], including non-prismatic holds, the effective upper surface of the cargo is to be made of three parts:

- One central horizontal surface of breadth $B_H/2$, in m, at a height $h_{C\text{-}CL}$, in m, above the inner bottom
- A sloped surface at each side with an angle $\psi/2$, in degrees, between the central horizontal surface, and the side shell or inner hull, as shown in Figure 4, or the hopper plating, as shown in Figure 5, as the case may be.

The height of cargo surface h_C, in m, is to be calculated at mid length of the considered cargo hold and is to be taken as constant over the length of the hold as follows:

For $|y| \le \frac{B_H}{4}$: $h_C = h_{C_CL}$

For $\frac{B_H}{4} < |y| \le \frac{B_2}{2}$: $h_C = h_{C_CL} - \left(|y| - \frac{B_H}{2}\right)\tan\left(\frac{\varphi}{2}\right)$

For $|y| > \frac{B_2}{2}$: $h_C = 0$

where:

h_1 : Height, in m, to be taken as:

$$h_1 = \frac{M}{\rho c \cdot B_H l_H} - \left(\frac{B_H + B_{IB}}{2B_H}\right)h_{HPL} - \frac{3}{16}B_H \tan\frac{\psi}{2} + \frac{V_{TS}}{B_H l_H}$$

- For $h_1 \geqslant 0$ as shown in Figure 4:

  $h_{C_CL} = h_{HPL} + h_1 + h_2$

  $$h_2 = \frac{B_H}{4}\tan\frac{\psi}{2}$$

  $B_2 = B_H$

- For $h_1 < 0$ as shown in Figure 5

  $h_{C_CL} = h_{11} + h_{22}$

  $$h_{11} = h_{HPL}\left(\frac{B_2 - B_{IB}}{B_H - B_{IB}}\right)$$

  $$h_{22} = \left(\frac{B_2}{2} - \frac{B_H}{4}\right)\tan\frac{\psi}{2}$$

  $$B_2 = \sqrt{\frac{\frac{1}{l_H}\left(\frac{M}{\rho_C} + V_{TS}\right) + \frac{1}{2}\left(\frac{h_{HPL} \cdot B_{IB}^2}{B_H - B_{IB}}\right) + \frac{B_H^2}{16}\tan\frac{\psi}{2}}{\frac{1}{2}\left[\left(\frac{h_{HPL}}{B_H - B_{IB}}\right) + \frac{1}{2}\tan\frac{\psi}{2}\right]}}$$

$h_{C\text{-}CL}$: Height, in m, of the cargo surface at the centreline, as shown in Figure 4 and Figure 5

B_2 : Maximum breadth of the cargo, in m, as shown in Figure 4 and Figure 5

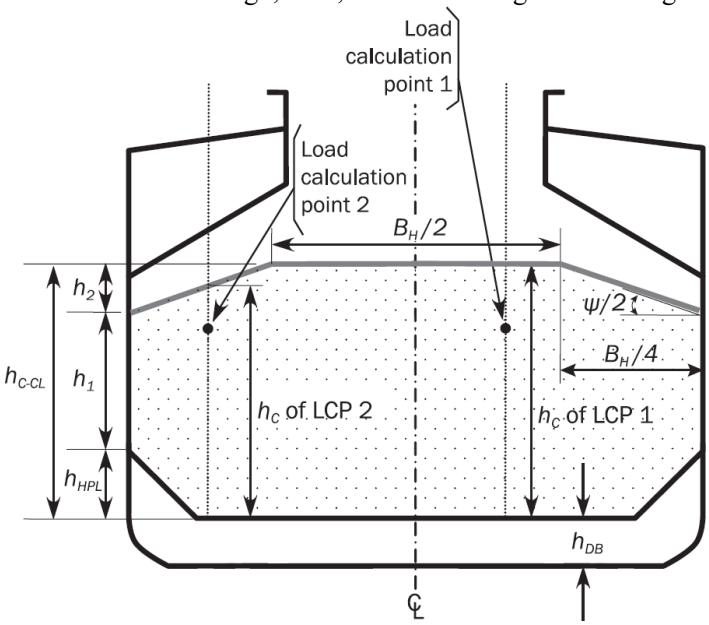


Figure 4 Definition of the effective upper surface of cargo for a partially filled cargo hold when $h_1 \geq 0$

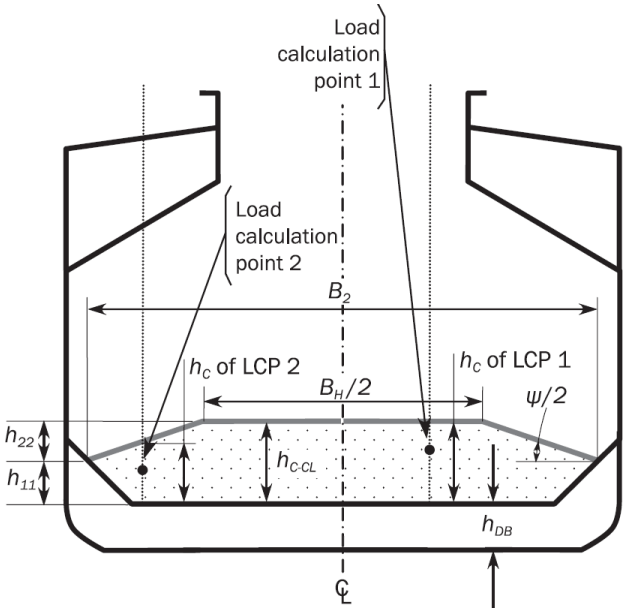


Figure 5 Definition of the effective upper surface of cargo for a partially filled cargo hold when $h_1 < 0$

2.3.3 Mass and density

The dry cargo mass and the density of the cargo are to be taken as follows:

- For strength assessment in intact condition: the values defined in Table 1
- For fatigue assessment: the values defined in Table 2
- For strength assessment in flooded condition: the values defined in Table 3

Dry bulk cargo mass and density for strength assessment in intact condition Table1

Ship type	Cargo mass Cargo density	Homogeneous loading condition		Alternate loading condition	
		Fully filled hold	Partially filled hold	Fully filled hold	Partially filled hold
No BC notation	M	$M = M_{Full}$	N/A	N/A	
	ρ_C	Maximum value specified in the loading manual			
BC-C	M	$M = M_{Full}$	N/A	N/A	
	ρ_C	$\rho_C = \left(\frac{M_{Full}}{V_{Full}}\right)$ but not less than			
BC-B	M	$M = M_{Full}$	$M = M_H$	N/A	
	ρ_C	$\rho_C = \left(\frac{M_{Full}}{V_{Full}}\right)$ but not less than	$\rho_C = 3.0$ (1)		
BC-A	M	$M = M_{Full}$	$M = M_H$	$M = M_{HD} + 0.1M_H$	$M = M_{HD} + 0.1M_H$
	ρ_C	$\rho_C = \left(\frac{M_{Full}}{V_{Full}}\right)$ but not less than	$\rho_C = 3.0$ (1)	$\rho_C = \frac{M_{HD} + 0.1M_H}{V_{Full}}$	$\rho_C = 3.0$ (1)
(1) To be taken as 3.0 unless an alternative maximum cargo density is specified in the loading manual.					

Dry bulk cargo mass and density for fatigue assessment Table 2

Ship type	Cargo mass Cargo density	Homogeneous loading condition (Fully filled hold)	Alternate loading condition (Partially filled hold)
No BC notation	M	$M = M_H$	N/A
	ρ_C	ρ_C = maximum value specified in the loading manual	
BC-C	M	$M = M_H$	
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	
BC-B	M	$M = M_H$	
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	
BC-A	M	$M = M_H$	$M = M_{HD}$
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	$\rho_C = 3.0$ (1)
(1) To be taken as 3.0 unless an alternative maximum cargo density is specified in the loading manual.			

Dry bulk cargo mass and density for strength assessment in flooded condition Table 3

Ship type	Cargo mass Cargo density	Homogeneous loading condition		Alternate loading condition		
		Fully filled hold	Partially filled hold	Fully filled hold	Partially filled hold	Hold loaded with ρ_C=1.78 t/m^3(2)
No BC notation	M	$M = M_H$		N/A		
	ρ_C	ρ_C = maximum value specified in the loading manual				
BC-C	M	$M = M_H$		N/A		
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$				
BC-B	M	$M = M_H$	$M = M_H$	N/A		
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	$\rho_C = 3.0$ (1)			
BC-A	M	$M = M_H$	$M = M_H$	$M = M_{HD}$	$M = M_{HD}$	$M = M_{HD}$
	ρ_C	$\rho_C = \left(\frac{M_H}{V_{Full}}\right)$	$\rho_C = 3.0$ (1)	$\rho_C = \left(\frac{M_{HD}}{V_{Full}}\right)$	ρ_C=3.0 (1)	$\rho_C = 1.78$

(1) To be taken as 3.0 unless an alternative maximum cargo density is specified in the loading manual.
(2) To be applied for bulk carriers that are required to carry cargoes with a density less than or equal to 1.78 t/m^3.

2.3.4 FE application

The following process is to be applied for the bulk cargo pressure loads used in FE analysis:

a) Determine h_c according to [2.3.1] for fully filled cargo hold or [2.3.2] for partially filled cargo hold.
b) Determine the corresponding static pressure as defined in [2.4.2] and static shear pressure as defined in ρ_C [2.5.2] using and apply them in the FE model.
c) Calculate the actual mass of cargo, M_{actual}, in t.
d) Determine the effective cargo density, in t/m^3:

$$\rho_{eff} = \frac{M}{M_{actual}}\rho_C$$

e) Calculate the final pressure distribution and shear load using ρ_{eff} instead of ρ_C.

2.4 Dry bulk cargo pressures

2.4.1 Total pressure

The total pressure due to dry bulk cargo acting on any load point of a cargo hold boundary, in kN/m^2, is to be taken as:

$P_{in}=P_{bs}$ For strength assessment of intact conditions for static (S) design load scenarios, given in Ch 4, Sec 7

$P_{in}=P_{bs}+P_{bd}$ For strength assessment of intact conditions and fatigue assessment for static plus dynamic (S+D) design load scenarios, given in Ch 4, Sec 7

but not less than 0.

where:

P_{bs} : Static pressure due to dry bulk cargo, in kN/m^2, as defined in [2.4.2].

P_{bd} : Dynamic inertial pressure due to dry bulk cargo in cargo holds, in kN/m^2, as defined in [2.4.3].

Static and dynamic pressures as defined in [2.4.2] and [2.4.3] for FE analysis are to be determined using ρ_{eff} instead of ρ_C.

2.4.2 Static pressure

The dry bulk cargo static pressure P_{bs}, in kN/m^2, is to be taken as:

$P_{bs}=\rho_C g K_C(z_C-z)$ but not less than 0.

2.4.3 Dynamic pressure

The dry bulk cargo dynamic pressure P_{bd}, in kN/m^2, for each load case is to be taken as:

$P_{bd}=f_\beta\rho_C[0.25a_X(x_G-x)+ 0.25a_Y(y_G-y)+f_{dc}K_Ca_Z(z_C-z)]$ for $z\leqslant z_C$

$P_{bd}=0.0$ for $z>z_C$

2.5 Shear load

2.5.1 Application

For FE strength assessment and FE fatigue assessment, the following shear load pressures are to be considered in addition to the dry bulk cargo pressures defined in [2.4] when the load point elevation, z, is lower or equal to z_c:

- For static (S) design load scenarios, given in Ch 4, Sec 7: Static shear load, $P_{bs\text{-}s}$, due to gravitational forces acting on hopper tanks and lower stools plating, as defined in [2.5.2].
- For static plus dynamic (S+D) design load scenarios, given in Ch 4, Sec 7: The following dynamic shear load pressures:
  $P_{bs\text{-}s} + P_{bs\text{-}d}$ for the hopper tank and the lower stool plating, as defined in [2.5.3].
  $P_{bs\text{-}dx}$ for the inner bottom plating in the longitudinal direction, as defined in [2.5.4].
  $P_{bs\text{-}dy}$ for the inner bottom plating in the transverse direction, as defined in [2.5.4].

Shear loads as defined in [2.5.2] to [2.5.4] for FE analysis are to be determined using ρ_{eff} instead of ρ_c.

2.5.2 Static shear load on the hopper tank and lower stool plating

The static shear load pressure, $P_{bs\text{-}s}$ (positive downward to the plating) due to dry bulk cargo gravitational forces acting on hopper tank and lower stool plating, in kN/m^2, is to be taken as:

$$P_{bs-s} = \rho_C g \frac{(1-K_C)(z_C-z)}{\tan\alpha}$$

2.5.3 Dynamic shear load on the hopper tank and lower stool plating

The dynamic shear load pressure, $P_{bs\text{-}d}$ (positive downward to the plating) due to dry bulk cargo forces on the hopper tank and lower stool plating, in kN/m^2, for each dynamic load case is to be taken as:

$$P_{bs-d} = f_\beta\rho_C a_Z \frac{(1-K_C)(z_C-z)}{\tan\alpha}$$

2.5.4 Dynamic shear load along the inner bottom plating for FE analyses

The dynamic shear load pressures, $P_{bs\text{-}dx}$ in the longitudinal direction (positive to bow) due to dry bulk cargo forces acting along the inner bottom plating, in kN/m^2, for each dynamic load case is to be taken respectively as:

$P_{bs\text{-}dx}= -0.75f_\beta\rho_C a_X h_C$

The dynamic shear load pressures, $P_{bs\text{-}dy}$ in the transverse direction (positive to port) due to dry bulk cargo forces acting along the inner bottom plating, in kN/m^2, for each dynamic load case is to be taken respectively as

$P_{bs\text{-}dy}= -0.75f_\beta\rho_C a_Y h_C$

The dynamic shear load pressures $P_{bs\text{-}dx}$ and $P_{bs\text{-}dy}$ are only used for FE strength assessment.

3 PRESSURES AND FORCES DUE TO DRY CARGOES IN FLOODED CONDITIONS

3.1 Vertically corrugated transverse watertight bulkheads

3.1.1 Application

The pressure defined in this sub-article applies to vertically corrugated transverse watertight bulkheads of the cargo holds of bulk carriers for the assessment in flooded conditions.

Each cargo hold is to be considered individually flooded, see Figure 6, Figure 7 and Figure 8.

3.1.2 General

The loads to be considered as acting on each bulkhead are those given by the combination of loads induced by cargo loads with those induced by the flooded loads of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooded loads without cargo is also to be considered.

The most severe combinations of cargo induced loads and flooded loads are to be used for the check of the scantlings of each bulkhead, depending on the loading conditions included in the loading manual considering the individual flooded condition of both loaded and empty holds:

- Homogeneous loading conditions;
- Non-homogeneous loading conditions;

For the purpose of this article, the following items are defined as:

- Design load limits:
  The specified design load limits for the cargo holds are to be represented by loading conditions defined by the designer in the loading manual.
- Maximum cargo mass to consider:
  Unless the ship is intended to carry, in non-homogeneous conditions, only iron ore or cargo having bulk density equal to or greater than 1.78 t/m^3, the maximum mass of cargo which may be carried in the hold is also to be considered to fill that hold up to the top of the hatch coaming.
- Homogeneous loading conditions:
  Homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling level, evaluated for each hold, does not exceed 1.20, to be corrected for different cargo densities.
- Packed cargoes:
  Holds carrying packed cargoes (such as steel mill products) are to be considered as empty.
- Unconsidered loading conditions:
  Non-homogeneous part loading conditions associated with multi-port loading and unloading operations for homogeneous loading conditions do not need to be considered for the verification of these requirements.

3.1.3 Flooded level

The flooded level z_F is the distance, in m, measured vertically from the baseline with the ship in the upright position, and obtained from Table 4.

Flooded level z_F, in m, for vertically corrugated transverse bulkheads Table 4

Bulk carrier type	Loading Condition	Vertically corrugated transverse bulkhead position	
		Foremost	Others
Bulk carriers less than 50,000 t deadweight with Type B freeboard	Non-homogeneous loading conditions with cargo density less than 1.78 t/m^3	z_F=0.9D_1	z_F=0.8D_1
	Other cases	z_F = 0.95D_1	z_F = 0.85D_1
Other bulk carriers	Non-homogeneous loading conditions with cargo density less than 1.78 t/m^3	z_F=0.95D_1	z_F=0.85D_1
	Other cases	z_F=D_1	z_F=0.9D_1

3.1.4 Flooded patterns

Three different flooded patterns are to be considered:

- The flooded level is below the upper surface of the cargo, (see Figure 6: $z_C > z_F$)
- The flooded level is above the upper surface of the cargo, (see Figure 7: $z_C \leqslant z_F$)
- The flooded hold is empty, (see Figure 8: $z_C = h_{DB}$)

3.1.5 Pressures and forces on vertically corrugated transverse bulkheads of flooded cargo holds

The static pressure $P_{bf\text{-}s}$, in kN/m^2, at any point of the vertically corrugated transverse bulkhead located at a level z from the baseline is given in Table 5 for each flooded pattern defined in [3.1.4].

The force $F_{bf\text{-}s}$, in kN, acting on a corrugation of a transverse bulkhead is given by Table 6 for each flooded pattern defined in [3.1.4].

where:

$P_{bf\text{-}s\text{-}LE}$: Static pressure calculated according to Table 5 for $z = h_{LS}+h_{DB}$

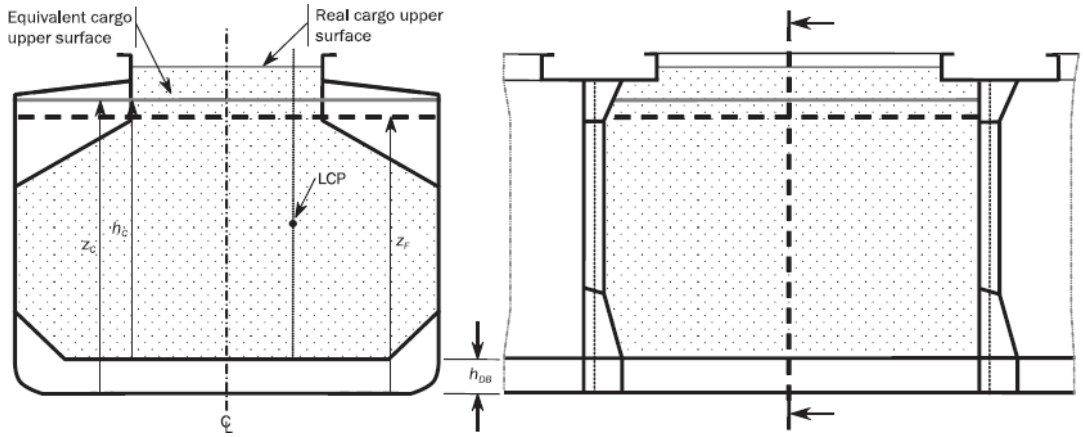


Figure 6 Flooded level below upper surface of bulk cargo

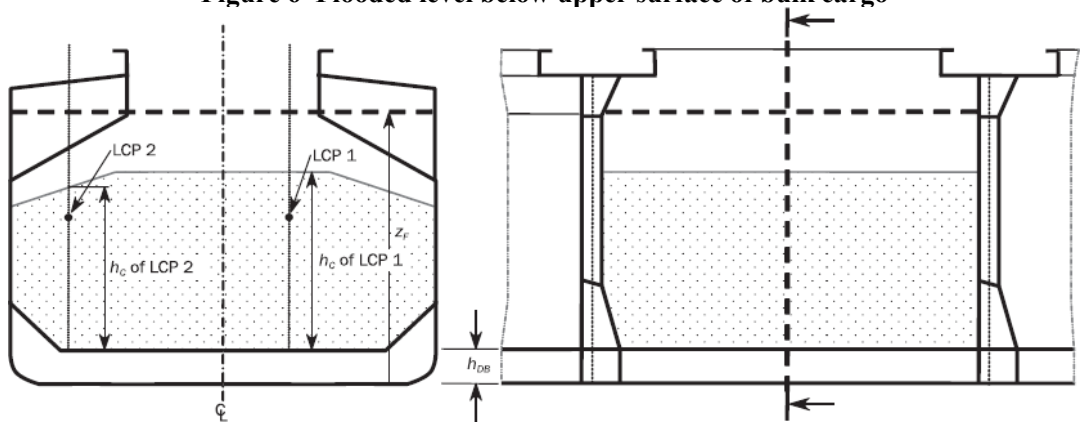


Figure 7 Flooded level above upper surface of bulk cargo

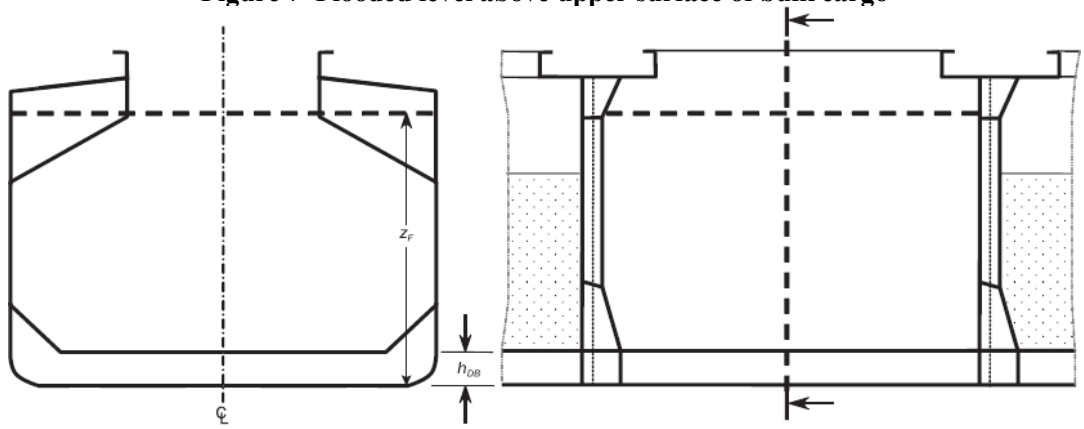


Figure 8 Flooded cargo hold without cargo

Static pressure on vertically corrugated transverse bulkhead of a flooded cargo hold $P_{bf\text{-}s}$

Table 5

Flooded case	Load point position	Pressure $p_{bf\text{-}s}$, in kN/m^2
$z_C > z_F$	$z > z_C$	$P_{bf\text{-}s}=0$
	$z_C \geqslant z \geqslant z_F$	$P_{bf\text{-}s}=\rho_C g(z_C-z)K_{C\text{-}f}$
	$z_F \geqslant z \geqslant h_{DB}$	$P_{bf\text{-}s}=\rho g(z_F-z)+[\ \rho_C(z_C-z) - \rho(1\text{-}perm)\ (z_F-z)]gK_{C\text{-}f}$
$h_{db} \leqslant z_C \leqslant z_F$	$z > z_F$	$P_{bf\text{-}s}=0$
	$z_F \geqslant z \geqslant z_C$	$P_{bf\text{-}s}=g\ (z_F - z)$
	$z_C \geqslant z \geqslant h_{DB}$	$P_{bf\text{-}s}=\rho g(z_F-z) + [\ \rho_C - \rho(1\text{-}perm)]g(z_C-z\ )K_{C\text{-}f}$

Force acting on a corrugation in the flooded cargo holds F_{bf-s} Table 6

Flooded case	Force F_{bf-s}, in kN
$z_C > z_F$	$F_{bf-s} = s_C \left\{ \rho_C g \frac{(z_C - z_F)^2}{2} K_{C-f} + \left[\frac{\rho_C g (z_C - z_F) K_{C-f} + p_{bf-s-LE}}{2} \right] (z_F - h_{DB} - h_{LS}) \right\}$
$z_F \geqslant z_C$	$F_{bf-s} = s_C \left\{ \rho g \frac{(z_C - z_F)^2}{2} + \left[\frac{\rho g (z_F - z_C) + p_{bf-s-LE}}{2} \right] (z_C - h_{DB} - h_{LS}) \right\}$

3.1.6 Pressures and forces on vertically corrugated transverse bulkheads of non-flooded cargo holds

The static pressure P_{bs}, in kN/m^2, at a point of the vertically corrugated transverse bulkhead located, located at the level z from the baseline, due to dry bulk cargo of a non-flooded cargo hold acting on the intact side of the transverse bulkhead which is flooded on the other side is to be taken as:

$P_{bs}=\rho_C g K_{C\text{-}f}(z_C - z)$, but not less than 0.

The resultant force F_{bs}, in kN, acting on a corrugation is to be taken as:

$$F_{bs} = \rho_C g s_C \frac{(z_C - h_{DB} - h_{LS})^2}{2} K_C$$

3.1.7 Resultant pressures and forces on vertically corrugated transverse bulkheads of flooded cargo holds

The resultant pressure P_R, in kN/m^2, at each point of the bulkhead, and the resultant force F_R, in kN, acting on a corrugation, given in Table 7, are to be considered for the assessment in flooded conditions of vertically corrugated transverse bulkhead structures, where:

$P_{bf\text{-}s}$: Pressure in the flooded cargo holds, in kN/m^2, as defined in [3.1.5].

P_{bs}: Pressure in the non-flooded cargo holds, in kN/m^2, as defined in [3.1.6].

$F_{bf\text{-}s}$: Force acting on a corrugation in the flooded cargo holds, in kN, as defined in [3.1.5].

F_{bs} : Force acting on a corrugation in the non-flooded cargo holds, in kN, as defined in [3.1.6].

Resultant pressure P_R and resultant force F_R on vertically corrugated transverse bulkhead in flooded condition Table 7

Loading condition	Resultant pressure P_R, in kN/m^2	Resultant force F_R, in kN	Application
Homogeneous	$P_R = P_{bf\text{-}s} - 0.8\, P_{bs}$	$F_R = F_{bf\text{-}s} - 0.8\, F_{bs}$	All bulk carriers
Alternate	$P_R = P_{bf\text{-}s}$	$F_R = F_{bf\text{-}s}$	BC-A bulk carriers

3.2 Double bottom in cargo hold region of bulk carrier in flooded conditions

3.2.1 Application

Each cargo hold is to be considered individually flooded.

3.2.2 General

The loads to be considered as acting on the double bottom are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of the hold to which the double bottom belongs.

The most severe combinations of cargo induced loads and flooded loads are to be used, depending on the loading conditions included in the loading manual:

- Homogeneous loading conditions.
- Non-homogeneous loading conditions.
- Packed cargo conditions (such as in the case of steel mill products).

For each loading condition, the maximum dry bulk cargo density to be carried is to be considered in calculating the allowable hold loading.

3.2.3 Flooded level

The flooded level z_F is the distance, in m, measured vertically from the baseline with the ship in the upright position, and obtained from Table 8.

Flooded level z_F, for double bottom in cargo hold region of bulk carrier Table 8

Bulk carrier type	Cargo hold	
	Foremost	Others
Bulk carriers less than 50,000 t deadweight with Type-B freeboard	$z_F = 0.95\ D_1$	$z_F = 0.85\ D_1$
Other bulk carriers	$z_F = D_1$	$z_F = 0.9\ D_1$

4 STEEL COIL LOADS IN CARGO HOLDS OF BULK CARRIERS

4.1 General

4.1.1 Application

The provision is determined by assuming Figure 9 as the standard means of securing steel coils loaded on wooden dunnage.

It is assumed that all the steel coils have the same characteristics.

In cases where steel coils are lined up in two or more tiers, formulae in [4.1.3] and [4.2] can be applied assuming that only the lowest tier of steel coils is in contact with hopper sloping plate or inner side plate. In other cases, scantling requirements are to be determined on a case-by-case basis.

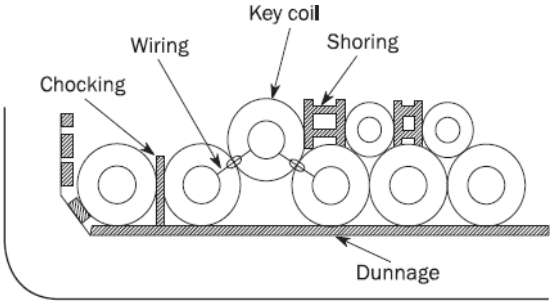


Figure 9 Inner bottom loaded by steel coils

4.1.2 Arrangement of steel coils on inner bottom

The two following arrangements of steel coils on the inner bottom are considered:

- The steel coils are positioned without respect to the location of the inner bottom floors, as shown in Figure 10.
- The steel coils are positioned with respect to the location of the inner bottom floors, as shown in Figure 11.

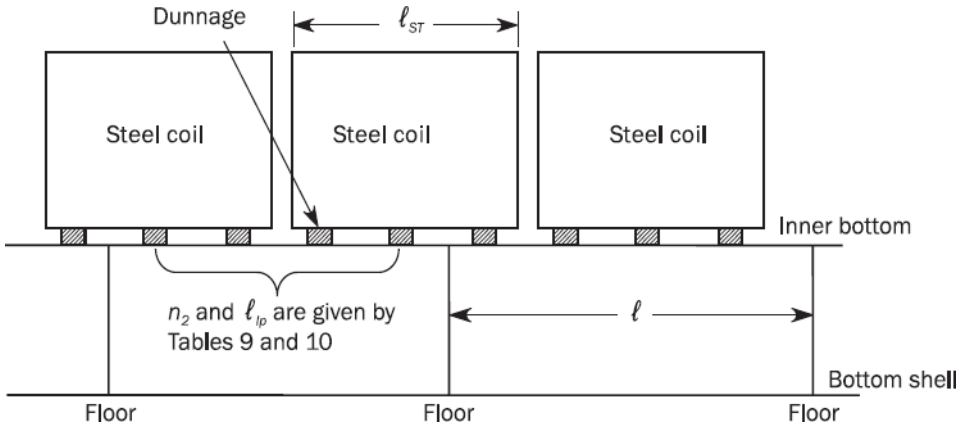


Figure 10 Steel coils loaded independently of inner bottom floors locations

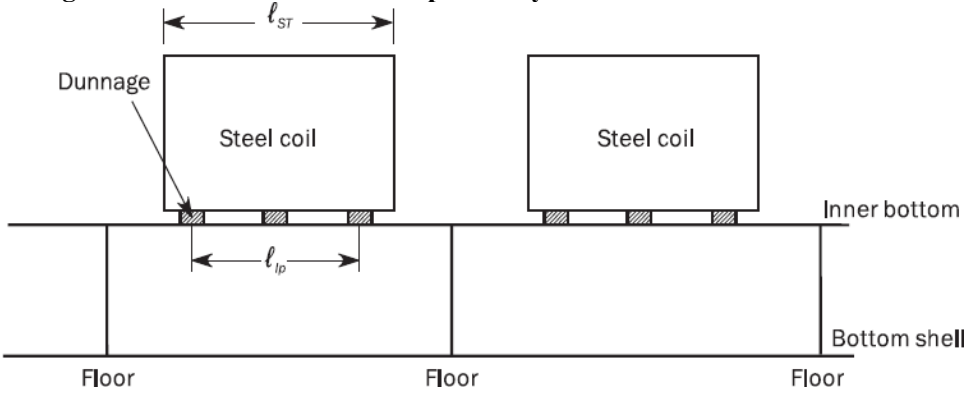


Figure 11 Steel coils loaded between inner bottom floors

4.1.3 Arrangement of steel coils independently of the floor locations

For steel coils loaded without respect to the location of floors in the inner bottom, see Figure 10:

The number n_2 of load point dunnages per elementary plate panels is to be found in comply with Table 9.

The distance l_{lp}, in m, between outermost load point dunnages per elementary plate panel is to be found in comply with Table 10.

Number n_2 of load point dunnages per elementary plate panel **Table 9**

n_2 (1) (2)	n_3 (3)				
	2	3	4	5	6
1	$0 < \frac{l}{l_{st}} \le 0.5$	$0 < \frac{l}{l_{st}} \le 0.33$	$0 < \frac{l}{l_{st}} \le 0.25$	$0 < \frac{l}{l_{st}} \le 0.2$	$0 < \frac{l}{l_{st}} \le 0.17$
2	$0.5 < \frac{l}{l_{st}} \le 1.2$	$0.33 < \frac{l}{l_{st}} \le 0.67$	$0.25 < \frac{l}{l_{st}} \le 0.5$	$0.2 < \frac{l}{l_{st}} \le 0.4$	$0.17 < \frac{l}{l_{st}} \le 0.33$
3	$1.2 < \frac{l}{l_{st}} \le 1.7$	$0.67 < \frac{l}{l_{st}} \le 1.2$	$0.5 < \frac{l}{l_{st}} \le 0.75$	$0.4 < \frac{l}{l_{st}} \le 0.6$	$0.33 < \frac{l}{l_{st}} \le 0.5$
4	$1.7 < \frac{l}{l_{st}} \le 2.4$	$1.2 < \frac{l}{l_{st}} \le 1.53$	$0.75 < \frac{l}{l_{st}} \le 1.2$	$0.6 < \frac{l}{l_{st}} \le 0.8$	$0.5 < \frac{l}{l_{st}} \le 0.67$
5	$2.4 < \frac{l}{l_{st}} \le 2.9$	$1.53 < \frac{l}{l_{st}} \le 1.87$	$1.2 < \frac{l}{l_{st}} \le 1.45$	$0.8 < \frac{l}{l_{st}} \le 1.2$	$0.67 < \frac{l}{l_{st}} \le 0.83$
6	$2.9 < \frac{l}{l_{st}} \le 3.6$	$1.87 < \frac{l}{l_{st}} \le 2.4$	$1.45 < \frac{l}{l_{st}} \le 1.7$	$1.2 < \frac{l}{l_{st}} \le 1.4$	$0.83 < \frac{l}{l_{st}} \le 1.2$
7	$3.6 < \frac{l}{l_{st}} \le 4.1$	$2.4 < \frac{l}{l_{st}} \le 2.73$	$1.7 < \frac{l}{l_{st}} \le 1.95$	$1.4 < \frac{l}{l_{st}} \le 1.6$	$1.2 < \frac{l}{l_{st}} \le 1.37$

n_2 (1) (2)	n_3 (3)				
	2	3	4	5	6
8	$4.1 < \frac{l}{l_{st}} \le 4.8$	$2.73 < \frac{l}{l_{st}} \le 3.07$	$1.95 < \frac{l}{l_{st}} \le 2.4$	$1.6 < \frac{l}{l_{st}} \le 1.8$	$1.37 < \frac{l}{l_{st}} \le 1.53$
9	$4.8 < \frac{l}{l_{st}} \le 5.3$	$3.07 < \frac{l}{l_{st}} \le 3.6$	$2.4 < \frac{l}{l_{st}} \le 2.65$	$1.8 < \frac{l}{l_{st}} \le 2.0$	$1.53 < \frac{l}{l_{st}} \le 1.7$
10	$5.3 < \frac{l}{l_{st}} \le 6.0$	$3.6 < \frac{l}{l_{st}} \le 3.93$	$2.65 < \frac{l}{l_{st}} \le 2.9$	$2.0 < \frac{l}{l_{st}} \le 2.4$	$1.7 < \frac{l}{l_{st}} \le 1.87$

(1) In case l/l_{st} is greater than the value given in Table 9, n_2 is to be considered as greater than 10.
(2) For plating, n_2 is to be based on l. For stiffener, n_2 is to be derived with l replaced by l_{bdg}.
(3) The number of dunnages, n_3, considered at the design stage is to reflect the intended operation conditions. Unusual arrangements with 5 or more dunnages per row of steel coil need to be carefully considered by the designer and ship owner.

Distance between outermost load point dunnages per elementary plate panel, l_{lp}, in m

Table 10

n_2 (1)	n_3				
	2	3	4	5	6
1	Actual breadth of dunnages				
2	0.5 l_{st}	0.33 l_{st}	0.25 l_{st}	0.2 l_{st}	0.17 l_{st}
3	1.2 l_{st}	0.67 l_{st}	0.50 l_{st}	0.4 l_{st}	0.33 l_{st}
4	1.7 l_{st}	1.20 l_{st}	0.75 l_{st}	0.6 l_{st}	0.5 l_{st}
5	2.4 l_{st}	1.53 l_{st}	1.20 l_{st}	0.8 l_{st}	0.67 l_{st}
6	2.9 l_{st}	1.87 l_{st}	1.45 l_{st}	1.2 l_{st}	0.83 l_{st}
7	3.6 l_{st}	2.40 l_{st}	1.70 l_{st}	1.4 l_{st}	1.2 l_{st}
8	4.1 l_{st}	2.73 l_{st}	1.95 l_{st}	1.6 l_{st}	1.37 l_{st}
9	4.8 l_{st}	3.07 l_{st}	2.40 l_{st}	1.8 l_{st}	1.53 l_{st}
10	5.3 l_{st}	3.60 l_{st}	2.65 l_{st}	2.0 l_{st}	1.7 l_{st}

(1) When $n_2 > 10$, l_{lp} is to be taken equal to l.

4.1.4 Arrangement of steel coils between floors

For steel coils loaded with respect to the locations of floors in the inner bottom, see Figure 11:

- The number n_2 of load point dunnages per elementary plate panels is to be taken as: $n_2 = n_3$
- The distance l_{lp} between outermost load point dunnages per elementary plate panel is to be taken as the distance between the outermost dunnage supporting one row of steel coils.

4.1.5 Centre of gravity of steel coil cargo

The centre of gravity of the steel coil cargo of the considered cargo hold is to be taken at the following position:

a) Longitudinal position

x_{Gsc} is the X coordinate, in m, of the volumetric centre of gravity of the considered cargo hold with respect to the reference coordinate system defined in Ch 4, Sec 1, [1.2.1].

b) Transverse position

$$y_{Gsc} = \varepsilon \frac{B_H}{4}$$

c) Vertical position

$$z_{Gsc} = h_{DB} + \left\{1 + (n_1 - 1)\frac{\sqrt{3}}{2}\right\}\frac{d_{sc}}{2}$$

where:

ε : Coefficient to be taken as:

ε=1.0 when a port side structural member is assessed.

ε= -1.0 when a starboard side structural member is assessed.

4.2 Total loads

4.2.1 Total load on the inner bottom

The total load $F_{sc\text{-}ib}$, in kN, due to steel coil cargoes on the inner bottom is to be taken as:

$F_{sc\text{-}ib}$=cos ($C_{XG}\cdot\varphi$) ·cos ($C_{YG}\cdot\theta$) ·$F_{sc\text{-}ib\text{-}s}$ + $F_{sc\text{-}ib\text{-}d}$, but not less than 0

where:

$F_{sc\text{-}ib\text{-}s}$: Static load, in kN, on the inner bottom, given in [4.3.1].

$F_{sc\text{-}ib\text{-}d}$: Dynamic load, in kN, on the inner bottom, given in [4.4.2].

C_{XG}, C_{YG}: Load combination factors, as defined in Ch 4, Sec 2, [2.2].

4.2.2 Total load on the hopper side

The total load $F_{sc\text{-}hs}$, in kN, due to steel coil cargoes on the hopper side is to be taken as:

$$F_{sc-ib} = \frac{\cos(C_{XG}\cdot\varphi)\cdot\cos(C_{YG}\cdot\theta)}{\cos\theta_h}\cdot F_{sc-hs-s} + F_{sc-hs-d}$$ but not less than 0

where:

$F_{sc\text{-}hs\text{-}s}$: Static load, in kN, on the hopper side, given in [4.3.2].

$F_{sc\text{-}hs\text{-}d}$: Dynamic load, in kN, on the hopper, given in [4.4.3].

C_{XG}, C_{YG}: Load combination factors, as defined in Ch 4, Sec 2, [2.2].

4.3 Static loads

4.3.1 Static loads on the inner bottom

The static load $F_{sc\text{-}ib\text{-}s}$, in kN, on the inner bottom due to steel coils is to be taken as:

$F_{sc\text{-}ib\text{-}s} = M_{sc\text{-}ib}\cdot g$

where:

$M_{sc\text{-}ib}$: Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-ib} = K_S W \frac{n_1 n_2}{n_3} \quad \text{for } n_2 \leqslant 10$$

$$M_{sc-ib} = K_S W n_1 \frac{l}{l_{st}} \quad \text{for } n_2 > 10, \text{ for plating}$$

$$M_{sc-ib} = K_S W n_1 \frac{l_{bdg}}{l_{st}} \quad \text{for } n_2 > 10, \text{ for stiffener}$$

K_S : Coefficient to be taken as:

K_S = 1.4 when steel coils are lined up in one tier with a key coil.

K_S = 1.0 in other cases.

4.3.2 Static load on the hopper side

The static load $F_{sc\text{-}hs\text{-}s}$, in kN, on the hopper side due to steel coils is to be taken as:

$F_{sc\text{-}hs\text{-}s}$=cos$\theta_h$ $M_{sc\text{-}hs}$ ·g

where:

$M_{sc\text{-}hs}$: Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-hs} = C_k W \frac{n_2}{n_3} \quad \text{for } n_2 \leqslant 10$$

$$M_{sc-hs} = C_k W \frac{l}{l_{st}} \qquad \text{for } n_2>10, \text{ for plating}$$

$$M_{sc-hs} = C_K W \frac{l_{bdg}}{l_{st}} \qquad \text{for } n_2>10, \text{ for stiffener}$$

C_k : Coefficient to be taken as:
C_k = 3.2 when steel coils are lined up two or more tiers, or when steel coils are lined up one tier and key coil is located second or 3rd from hopper sloping plate or inner hull plate.
C_k = 2.0 for other cases.

4.4 Dynamic loads

4.4.1 Tangential roll acceleration

The tangential roll acceleration a_R, in m/s^2, is to be taken as:

$$a_R = \theta \cdot \frac{\pi}{180} \cdot \left(\frac{2\pi}{T_\theta}\right)^2 \cdot \sqrt{y_{Gsc}^2 + (R - z_{Gsc})^2}$$

where:
y_{Gsc} : Y coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].
z_{Gsc} : Z coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

4.4.2 Dynamic load on the inner bottom

The dynamic load $F_{sc\text{-}ib\text{-}d}$, in kN, on the inner bottom due to steel coils is to be taken as:
$F_{sc\text{-}ib\text{-}d} = M_{sc\text{-}ib} \cdot a_z$
where:
a_z : Vertical acceleration, in m/s^2, as defined in Ch 4, Sec 3, [3.2.4], calculated at the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

4.4.3 Dynamic load on the hopper side

The dynamic load $F_{sc\text{-}hs\text{-}d}$, in kN, on the hopper side due to steel coils is to be taken as:

$$F_{sc-hs-d} = \varepsilon M_{sc-hs} \left[C_{YR} a_R \sin\left(\tan^{-1} \left| \frac{y_{Gsc}}{R - z_{Gsc}} \right| - \theta_h \right) - C_{YS} a_{sway} \sin\theta_h \right]$$

where:
C_{YS}, C_{YR} : Load combination factors, defined in Ch 4, Sec 2, [2.2].
a_{sway} : Sway acceleration, in m/s^2, as defined in Ch 4, Sec 3, [2.2.2].
a_R : Tangential acceleration, in m/s^2, as defined in [4.4.1].
y_{Gsc} : Y coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].
z_{Gsc} : Z coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [4.1.5].

5 LOADS ON NON-EXPOSED DECKS AND PLATFORMS

5.1 Application

5.1.1 General

The loads defined in [5.2] and [5.3] are applicable to non-exposed decks, accommodation decks and platforms.

5.2 Pressure due to distributed load

5.2.1

If a distributed load is carried on a deck, the static and dynamic pressures due to this distributed load are to be considered.
The static distributed load is to be defined by the designer without being less than 3kN/m^2 for accommodation decks and 10kN/m^2 for other decks and platforms.
The pressure P_{dl}, in kN/m^2, due to this distributed load for the static (S) design load scenarios,

given in Ch 4, Sec 7, is to be taken as:

$P_{dl}=P_{dl\text{-}s}$

The pressure P_{dl}, in kN/m^2, due to this distributed load for the static plus dynamic (S+D) design load scenarios, is to be derived for the envelope of dynamic load cases and is to be taken as:

$P_{dl}=P_{dl\text{-}s}+P_{dl\text{-}d}$ but not less than 0.

where:

$P_{dl\text{-}s}$: Static pressure, in kN/m^2, due to the distributed load.

$P_{dl\text{-}d}$: Dynamic pressure, in kN/m^2, due to the distributed load, in kN/m^2, to be taken as:

$$P_{dl-d} = f_\beta \frac{a_{Z-env}}{g} P_{dl-s}$$

$a_{z\text{-}env}$: Envelope of vertical acceleration, in m/s^2, at the load position being considered, for the dynamic load cases, given in Ch 4, Sec 3, [3.3.3].

5.3 Concentrated force due to unit load

5.3.1

If a unit load is carried on an internal deck, the static and dynamic forces due to the unit load carried are to be considered when a direct analysis is applied for stiffeners or primary supporting members such as in Pt 1, Ch6, Sec 5, [1.2] or Pt 1, Ch 6, Sec 6, [3.3] respectively.

The force F_U, in kN, due to this concentrated load for the static (S) design load scenarios, given in Ch 4, Sec 7, is to be taken as:

$F_U=F_{U\text{-}s}$

The force F_U, in kN, due to this concentrated load for the static plus dynamic (S+D) design load scenarios, is to be derived for the envelope of dynamic load cases and is to be taken as:

$F_U=F_{U\text{-}s}+F_{U\text{-}d}$ but not less than 0.

where:

$F_{U\text{-}s}$: Static force, in kN, due to the unit load to be taken as:

$$F_{U-s} = m_U g$$

$F_{U\text{-}d}$: Dynamic force, in kN, due to unit load to be taken as:

$$F_{U-d} = m_U f_\beta a_{z-env}$$

m_U : Mass of the unit load carried, in t.

$a_{z\text{-}env}$: Envelope of vertical acceleration, in m/s^2, at the centre of gravity of the unit load carried for the dynamic load cases, given in Ch 4, Sec 3, [3.3.3].

6 SLOSHING PRESSURES IN TANKS

6.1 General

6.1.1 Application

This article applies to all liquid cargo, ballast tanks and other tanks with volume exceeding 100 m^3, but does not apply to the water ballast cargo hold of bulk carriers.

6.1.2

The sloshing pressures defined in this article do not include the effect of impact pressures due to high velocity impacts with tank boundaries or internal structures. For tanks with a maximum effective sloshing breadth, b_{slh}, see [6.4.2], greater than $0.56B$ or a maximum effective sloshing length, l_{slh}, see [6.3.2], greater than $0.13L$ at any filling level from $0.05h_{max}$ to $0.95h_{max}$, see [6.3.3], a separate impact assessment is to be carried out in accordance with the Society procedures.

CCS 6.1.2a Where $l_s>0.13L$ or $b_s>0.56B$ for the tank, level 3 sloshing impact loads are to be calculated in accordance with relevant requirements of Section 2 of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantlings of Tanks.

6.1.3 Sloshing pressure on tank boundaries and internal divisions

The sloshing pressure due to liquid motions in a tank P_{slh} acting on any load point of a tank boundary or internal divisions, in kN/m^2, for the sloshing design load scenario, given in Ch4, Sec 7, is to be taken as follows, without being less than $P_{slh\text{-}min}$, as given in [6.2]:

- $P_{slh} = P_{slh\text{-}lng}$ for transverse bulkheads, as defined in [6.3.3].
- $P_{slh} = P_{slh\text{-}wf}$ for web frames and transverse stringers, as defined in [6.3.4].
- $P_{slh} = P_{slh\text{-}t}$ for longitudinal bulkheads, as defined in [6.4.3].

- $P_{slh} = P_{slh\text{-}grd}$ for longitudinal girders and stringers, see [6.4.4].

6.2 Minimum sloshing pressure

6.2.1

The minimum sloshing pressure, $P_{slh\text{-}min}$, for tanks of cellular construction, i.e. double hull construction with internal structures restricting the fluid motion, is to be taken as 12 kN/m^2.
The minimum sloshing pressure, $P_{slh\text{-}min}$, for cargo and all other tanks is to be taken as 20 kN/m^2.

6.3 Sloshing pressure due to longitudinal liquid motion

6.3.1 Application

The sloshing pressure due to longitudinal liquid motion, $P_{slh\text{-}lng}$, is to be taken as a constant value over the full tank depth and is to be taken as the greater of the sloshing pressures calculated for filling levels from 0.05 h_{max} to 0.95h_{max}, in 0.05h_{max} increments.

6.3.2 Effective sloshing length

The effective sloshing length, l_{slh}, in m, is to be taken as defined in Table11.

Effective sloshing length l_{slh} **Table 11**

Type of transverse bulkhead	l_{slh}
Transverse tight bulkheads	$l_{slh} = \frac{(1+n_{WT}\alpha_{WT})(1+f_{wf}\alpha_{wf})l_{tk-h}}{(1+n_{WT})(1+f_{wf})}$
Transverse wash bulkheads	$l_{slh} = \frac{[1+(n_{WT}-1)\alpha_{WT}](1+f_{wf}\alpha_{wf})l_{tk-h}}{(1+n_{WT})(1+f_{wf})}$

where:

n_{WT} : Number of transverse wash bulkheads in the tank.

α_{WT} : Transverse wash bulkhead coefficient, to be taken as (see Figure 12):

$$\alpha_{WT} = \frac{A_{OWT}}{A_{tk-t-h}}$$

For tanks with changing shape along the length and/or with wash bulkhead of different shape the transverse wash bulkhead coefficient, α_{WT}, may be taken as the weighted average of all wash bulkhead locations in the tank given as:

$$\alpha_{WT} = \frac{\sum_{i=1}^{n_{WT}} \frac{A_{OWT_i}}{A_{tk-t-h_i}}}{n_{WT}}$$

α_{wf} : Transverse web frame coefficient, to be taken as (see Figure 13):

$$\alpha_{wf} = \frac{A_{O-wf-h}}{A_{tk-t-h}}$$

For tanks with changing shape along the length and/or with web frames of different shape the transverse web frame coefficient, α_{wf}, may be taken as the weighted average of all web frame locations in the tank given as:

$$\alpha_{wf} = \frac{\sum_{i=1}^{n_{wf}} \frac{A_{o-wf-h_i}}{A_{tk-t-h_i}}}{n_{wf}}$$

A_{OWT} : Total area of openings, in m^2, in the transverse section in way of the wash bulkhead below the considered filling height.

$A_{tk\text{-}t\text{-}h}$: Total transverse cross sectional area, in m^2, of the tank below the considered filling height.

$A_{O\text{-}wf\text{-}h}$: Total area of openings, in m^2, in the transverse section in way of the web frame below the considered filling height.

f_{wf} : Factor to account for number of transverse web frames and transverse wash bulkheads in the tank, to be taken as:

$$f_{wf} = \frac{n_{wf}}{1+n_{WT}}$$

n_{wf} : Number of transverse web frames, excluding wash bulkheads, in the tank.

$l_{tk\text{-}h}$: Length of cargo tank, in m, at considered filling height.

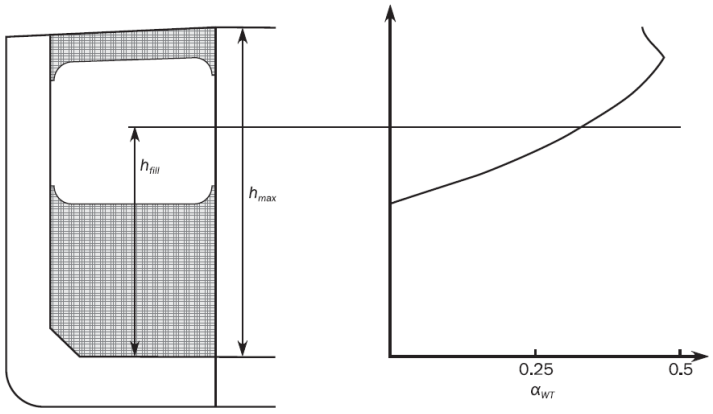


Figure 12 Transverse wash bulkhead coefficient

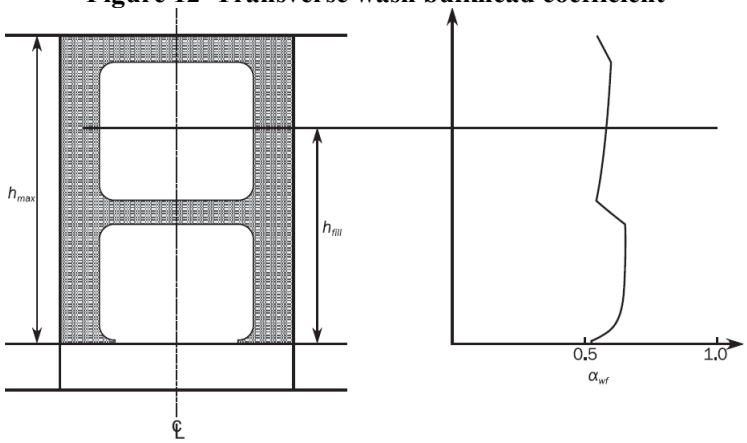


Figure 13 Transverse web frame coefficient

6.3.3 Sloshing pressure in way of transverse bulkheads

The sloshing pressure in way of transverse bulkheads including wash bulkheads due to longitudinal liquid motion, $P_{slh\text{-}lng}$, in kN/m^2, for a particular filling level, is to be taken as:

$$P_{slh-lng} = \rho_{slh} g l_{slh} \left[0.4 - \left(0.39 - \frac{1.7 l_{slh}}{L} \right) \frac{L}{350} \right]$$

where:

l_{slh} : Effective sloshing length, in m, as defined in [6.3.2].

f_{slh} : Coefficient taken as:

$$f_{slh} = 1 - 2\left(0.7 - \frac{h_{fill}}{h_{max}} \right)^2$$

h_{fill} : Filling height, measured from tank bottom, in m, see Figure 12.

6.3.4 Sloshing pressure on internal web frames or transverse stringers adjacent to a transverse bulkhead

For tanks with internal web frames the sloshing pressure acting on a web frame or transverse stringer adjacent to transverse bulkheads or transverse wash bulkheads due to longitudinal liquid motion, $P_{slh\text{-}wf}$, in kN/m^2, provided it is located within $0.25 l_{slh}$ from the bulkhead, is to be taken as:

$$P_{slh-wf} = P_{slh-lng} \left(1 - \frac{s_{wf}}{l_{slh}} \right)^2$$

where:

l_{slh} : Effective sloshing length, in m, as defined in [6.3.2].

$P_{slh\text{-}lng}$: Sloshing pressure due to longitudinal liquid motion acting on transverse bulkhead, as defined in [6.3.3].

s_{wf} : Distance from transverse bulkhead to web frame under consideration, in m.

The distribution of pressure across web frames and transverse stringers is given in Figure 14.

6.4 Sloshing pressure due to transverse liquid motion

6.4.1 Application

The sloshing pressure due to transverse liquid motion, *Pslh-t*, is to be taken constant as a constant value over the full tank depth and is to be taken as the greater of the sloshing pressures calculated for filling levels from 0.05 h_{max} to 0.95h_{max}, in 0.05h_{max} increments.

6.4.2 Effective sloshing breadth

The effective sloshing breadth, b_{slh}, in m, is to be taken as in Table 12, but not less than 0.3B.

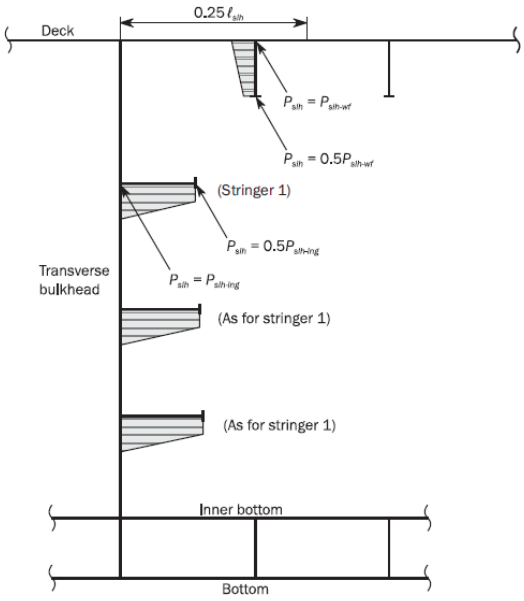


Figure 14 Sloshing pressure distribution on transverse stringers and web frames

Effective sloshing breadth b_{slh} **Table 12**

Type of longitudinal bulkhead	b_{slh}
Longitudinal tight bulkheads	$b_{slh} = \dfrac{(1+n_{WL}\alpha_{WL})(1+f_{grd}\alpha_{grd})b_{tk-h}}{(1+n_{WL})(1+f_{grd})}$
Longitudinal wash bulkheads	$b_{slh} = \dfrac{[1+(n_{WL}-1)\alpha_{WL}](1+f_{grd}\alpha_{grd})b_{tk-h}}{(1+n_{WL})(1+f_{grd})}$

where:

n_{WL} : Number of longitudinal wash bulkheads in the tank.

α_{WL} : Longitudinal wash bulkhead coefficient:

$$\alpha_{WL} = \frac{A_{OWL}}{A_{tk-L-h}}$$

For tanks with changing shape along the breadth and/or with wash bulkhead of different shape the longitudinal wash bulkhead coefficient, α_{WL}, may be taken as the weighted average of all wash bulkhead locations in the tank given as:

$$\alpha_{WT} = \frac{\sum_{i=1}^{n_{WL}} \frac{A_{OWL_i}}{A_{tk-L-h_i}}}{n_{WL}}$$

α_{grd} : Girder coefficient, to be taken as:

$$\alpha_{grd} = \frac{A_{O-grd-h}}{A_{tk-L-h}}$$

For tanks with changing shape along the breadth and/or with girder of different shape the girder coefficient, α_{grd}, may be taken as the weighted average of all girder locations in the tank given as:

$$\alpha_{grd} = \frac{\sum_{i=1}^{n_{grd}} \frac{A_{O-grd-h_i}}{A_{tk-L-h_i}}}{n_{grd}}$$

A_{OWL} : Total area of openings, in m^2, in the longitudinal section in way of the wash bulkhead below the considered filling height.

$A_{tk\text{-}L\text{-}h}$: Total longitudinal cross sectional area, in m^2, of the tank below the considered filling height.

$A_{O\text{-}grd\text{-}h}$: Total area of openings, in m^2, in the longitudinal section in way of the web frame below the considered filling height.

f_{grd} : Factor to account for number of longitudinal girders and longitudinal wash bulkheads in the tank, to be taken as:

$$f_{grd} = \frac{n_{grd}}{1 + n_{WL}}$$

n_{grd} : Number of longitudinal girders, excluding longitudinal wash bulkheads, in the tank.

$b_{tk\text{-}h}$: Breadth of cargo tank, in m, at considered filling height.

6.4.3 Sloshing pressure in way of longitudinal bulkheads

The sloshing pressure in way of longitudinal bulkheads including wash bulkheads due to transverse liquid motion, $P_{slh\text{-}t}$, in kN/m^2, for a particular filling level, is to be taken as:

$$P_{slh-t} = 7\rho_{slh} g f_{slh} \left(\frac{b_{slh}}{B} - 0.3 \right) GM^{0.75}$$

where:

b_{slh} : Effective sloshing breadth defined in [6.4.2].

GM : Metacentric height, given in Ch 4, Sec 3, [2.1.1].

For the calculation of sloshing pressure in ballast tanks the 'ballast condition' is to be used for oil tankers and the 'normal ballast condition' for bulk carriers.

For the calculations of sloshing pressure in cargo tanks of oil tankers, the 'partial load condition' is to be used.

f_{slh} : Coefficient defined in [6.3.3].

6.4.4 Sloshing pressure on internal girders or longitudinal stringers adjacent to longitudinal bulkheads

For tanks with internal girders or stringers, the sloshing pressure acting on the girder/web frame adjacent to longitudinal bulkheads and longitudinal wash bulkhead, $P_{slh\text{-}grd}$, in kN/m^2, provided it is located within 0.25 b_{slh} from the bulkhead, is to be taken as:

$$P_{slh-grd} = P_{slh-t} \left(1 - \frac{s_{grd}}{b_{slh}} \right)^2$$

where:

b_{slh} : Effective sloshing breadth defined in [6.4.2].

$P_{slh\text{-}t}$: Sloshing pressure due to transverse liquid motion acting on longitudinal bulkhead, as defined in [6.4.3].

s_{grd} : Distance from longitudinal bulkhead to girder under consideration, in m.

The distribution of pressure across stringers is given in Figure 15. The distribution of pressure across longitudinal girders is similar to the deck web frame shown in Figure 14.

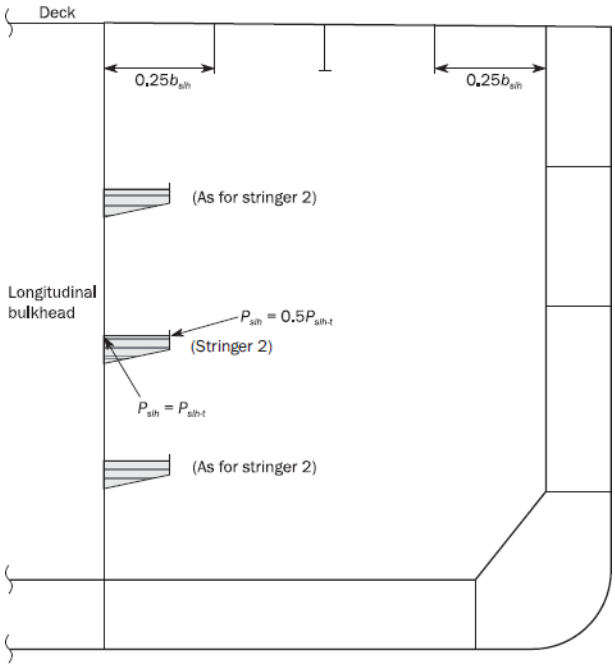


Figure 15 Sloshing pressure distribution on longitudinal stringers and girders

7 DESIGN PRESSURE FOR TANK TESTING

7.1 Definition

7.1.1

The actual strength testing is to be carried out in accordance with Ch1, Sec 2, [3.8.4]. In order to assess the structure, static design pressures are to be applied.

The design pressure for tank testing, P_{ST}, in kN/m^2, is to be taken as:

P_{ST}=10(z_{ST}-z)

where:

z_{ST}: Design testing load height, in m, as defined in Table 13.

Design testing load height z_{ST} **Table 13**

Compartment	z_{ST}
Double bottom tanks (1)	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{bd}$
Hopper side tanks, topside tanks, double side tanks, fore and aft peaks used as tank	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{top} + 2.4$
Tank bulkheads, deep tanks, fuel oil bunkers	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{top} + 2.4$ $z_{ST} = z_{top} + 0.1P_{PV}$
Ballast hold	$z_{ST} = z_h + 0.9$
Chain locker	$z_{ST} = z_c$
Independent tanks	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{top} + 0.9$
Ballast ducts	Testing load height corresponding to ballast pump maximum pressure

Compartment	z_{ST}
where: z_{bd} : Z coordinate, in m, of the bulkhead deck. z_h : Z coordinate, in m, of the top of hatch coaming. z_c : Z coordinate, in m, of the top of the chain pipe. (1) For double bottom tanks connected with hopper side tanks, topside tanks or double side tanks, z_{ST} corresponding to "Hopper side tanks, topside tanks, double side tanks, fore and aft peaks used as tank, cofferdams" is applicable.	

Section 7 DESIGN LOAD SCENARIOS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

V_{BM} : Design vertical bending moment, in kNm.

M_{sw} : Permissible hull girder hogging and sagging still water bending moment for seagoing operation, in kNm, as defined in Ch 4, Sec 4, [2.2.2].

$M_{sw\text{-}p}$: Permissible hull girder hogging and sagging still water bending moment for harbour/sheltered water operation, in kNm, as defined in Ch 4, Sec 4, [2.2.3].

$M_{sw\text{-}f}$: Permissible hull girder hogging or sagging still water bending moment $M_{sw\text{-}f}$ for seagoing operation in the flooded condition, in kNm, as defined in Ch 4, Sec 4, [2.2.4].

$M_{wv\text{-}LC}$: Vertical wave bending moment for a considered dynamic load case, in kNm, as defined in Ch 4, Sec4, [3.5.2].

HBM : Design horizontal bending moment, in kNm.

$M_{wh\text{-}LC}$: Horizontal wave bending moment for a considered dynamic load case, in kNm, as defined in Ch4, Sec 4, [3.5.4].

TM : Design torsional moment, in kNm.

$M_{wt\text{-}LC}$: Wave torsional moment for a considered dynamic load case, in kNm, as defined in Ch 4, Sec 4, [3.5.5].

VSF : Design vertical shear force, in kN.

Q_{sw} : Permissible hull girder positive and negative still water shear force limits for seagoing operation, in kN, as defined in Ch 4, Sec 4, [2.3.1] or Ch 4, Sec 4, [2.3.3].

$Q_{sw\text{-}p}$: Permissible hull girder positive and negative still water shear force limits for harbour/sheltered water operation, in kN, as defined in Ch 4, Sec 4, [2.3.2] or Ch 4, Sec 4, [2.3.4].

$Q_{sw\text{-}f}$: Permissible hull girder positive and negative still water shear force for seagoing operation in the flooded condition, in kN, as defined in Ch 4, Sec 4, [2.3.5].

$Q_{wv\text{-}LC}$: Vertical wave shear force for a considered dynamic load case, in kN, as defined in Ch 4, Sec 4, [3.5.3].

P_{ex} : Design external pressure, in kN/m^2.

P_S : Static sea pressure at considered draught, in kN/m^2, as defined in Ch 4, Sec 5, [1.2.1].

P_W : Dynamic pressure for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 5, [1.3.2] to Ch 4, Sec 5, [1.3.8].

P_D : Green sea load for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 5, [2.2.3] and Ch 4, Sec 5, [2.2.4].

P_{in} : Design internal pressure, in kN/m^2.

P_{ST} : Tank testing pressure, in kN/m^2, see Ch 4, Sec 6, [7.1.1].

P_{ls} : Static liquid pressure in tank, in kN/m^2, as defined in Ch 4, Sec 6, [1.2].

P_{ld} : Dynamic liquid pressure in tank for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 6, [1.3].

P_{bs} : Dry bulk cargo static pressure, in kN/m^2, as defined in Ch 4, Sec 6, [2.5.2].

P_{bd} : Dry bulk cargo dynamic pressure for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 6, [2.5.3].

P_{fs} : Static pressure in compartments and tanks in flooded condition, in kN/m^2, as defined in Ch 4, Sec 6, [1.4.1].

P_{fd} : Dynamic pressure in compartments and tanks in flooded condition, in kN/m², as defined in Ch 4, Sec 6, [1.5.1]

$P_{dl\text{-}s}$: Static pressure on non-exposed decks and platforms, in kN/m^2, as defined in Ch 4, Sec 6, [5.2.1].

$P_{dl\text{-}d}$: Dynamic pressure on non-exposed decks and platforms for a considered dynamic load case, in kN/m^2, as defined in Ch 4, Sec 6, [5.2.1]

$F_{U\text{-}s}$: Static load acting on supporting structures and securing systems for heavy units or cargo, equipment or structural components, in kN, as defined in Ch 4, Sec 5, [2.3.2].

$F_{U\text{-}d}$: Dynamic load acting on supporting structures and securing systems for heavy units of cargo equipment or structural components, in kN, as defined in Ch 4, Sec 5, [2.3.2].

P_{SL} : Bottom slamming pressure, in kN/m^2, as defined in Ch 4, Sec 5, [3.2].

P_{FB} : Bow impact pressure, in kN/m², as defined in Ch 4, Sec 5, [3.3].
P_{slh} : Sloshing pressure, in kN/m², as defined in Ch 4, Sec 6, [6].

1 GENERAL

1.1 Application

1.1.1

This section gives the design load scenarios that are to be used for:

- Strength assessment by prescriptive and direct analysis (Finite Element Method, FEM) methods, as given in [2].
- Fatigue assessment by prescriptive and direct analysis (FEM) methods, as given in [3].

1.1.2

For the strength assessment, the principal design load scenarios consist of either S (Static) loads or S+D (Static + Dynamic) loads. In some cases, the letter 'A' prefixes the S or S+D to denote that this is an accidental design load scenario. There are some additional design load scenarios to be considered which relate to impact (I) loads, sloshing (SL) loads and fatigue (F) load.

2 DESIGN LOAD SCENARIOS FOR STRENGTH ASSESSMENT

2.1 Principal design load scenarios

2.1.1

The principal design load scenarios are given in Table 1.

Principal design load scenarios **Table 1**

Design load scenario			Harbour and sheltered water and testing	Seagoing conditions With extreme sea loads	Ballast water exchange (4)	Accidental flooded conditions (4)	
Load components			Static (S)	Static +Dynamic (S+D)	Static + Dynamic (S+D)	Static (S)	Static + Dynamic (A : S+D)
Hull Girder	*VBM*		M_{sw-p}	$M_{sw} + M_{wv-LC}$	$M_{sw} + M_{wv-LC}$	M_{sw-f}(2)	$M_{sw-f} + M_{wv-LC}$(3)
	HBM		-	M_{wh-LC}	M_{wh-LC}	-	M_{wh-LC}(3)
	VSF		Q_{sw-p}	$Q_{sw} + Q_{wv-LC}$	$Q_{sw} + Q_{wv-LC}$	-	$Q_{sw-f} + Q_{wv-LC}$(3)
	TM		-	M_{wt-LC}	M_{wt-LC}	-	-
Local Loads	P_{ex}	External deck for green sea	-	P_D	-	-	-
		Hull envelope	P_S	$P_S + P_W$	$P_S + P_W$	-	-
	P_{in}	Ballast tanks (1)	$Max(P_{ls}, P_{ST})$	$P_{ls} + P_{ld}$	$P_{ls} + P_{ld}$	-	-
		Liquid cargo tanks			-	-	
		Other tanks			-	-	
		Watertight boundaries	-	-	-	P_{fs}	$P_{fs} + P_{fd}$
		Cargo holds	P_{bs}	$P_{bs} + P_{bd}$	-		
	P_{dk}	Internal decks for dry spaces	P_{dl-s}	$P_{dl-s} + P_{dl-d}$	-	-	-
		External deck for distributed loads	P_{dl-s}	$P_{dl-s} + P_{dl-d}$	-	-	-
		External deck for heavy units	F_{U-s}	$F_{U-s} + F_{U-d}$	-	-	-

Design load scenario	Harbour and sheltered water and testing	Seagoing conditions With extreme sea loads	Ballast water exchange (4)	Accidental flooded conditions (4)	
Load components	Static (S)	Static +Dynamic (S+D)	Static + Dynamic (S+D)	Static (S)	Static + Dynamic (A : S+D)

(1) WB cargo hold is considered as ballast tank except for design load scenario 'ballast water exchange'.
(2) M_{swf} used for hull local scantling of watertight bulkhead
(3) Hull girder strength check is performed according to Ch 5, Sec 1 for bulk carriers having a freeboard length L_{LL} of 150 m or above
(4) Applicable to prescriptive assessment only

2.2 Additional design load scenarios

2.2.1

The design load scenarios to be considered for sloshing, bottom slamming and bow impact are given in Table 2.

Design load scenarios for impact and sloshing conditions Table 2

Design load scenario / Load components			Bow impact Impact (I)	Bottom Slamming Impact (I)	Sloshing Sloshing (SL)
Hull Girder		VBM	-	-	M_{sw}
		HBM	-	-	-
		VSF	-	-	-
		TM	-	-	-
Local Loads	P_{ex}	External deck for green sea	-	-	-
		Hull envelope	P_{FB}	P_{SL}	-
	P_{in}	Ballast tanks	-	-	P_{slh}
		Liquid cargo tanks			
		Other tanks			
		Watertight boundaries		-	-
		Cargo holds(1)	-	-	-
	P_{dk}	Internal decks for dry spaces	-	-	-
		External deck for distributed loads	-	-	-
		External deck for heavy units	-	-	-

(1) Sloshing assessment is not to be considered for water ballast cargo holds of bulk carriers.

3 DESIGN LOAD SCENARIOS FOR FATIGUE ASSESSMENT

3.1 Design load scenarios

3.1.1

The design load scenarios for fatigue assessment are given in Table 3.

Design load scenarios for fatigue assessment Table 3

Design load scenario / Load components		Fatigue: Static + Dynamic (F: S+D)
Hull Girder	VBM	$M_{sw} + M_{wv\text{-}LC}$
	HBM	$M_{wh\text{-}LC}$
	VSF	$Q_{sw} + Q_{wv\text{-}LC}$

Design load scenario			Fatigue: Static + Dynamic (F: S+D)
Load components			
	TM		$M_{wt\text{-}LC}$
Local Loads	P_{ex}	External deck for green sea	-
		Hull envelope	$P_S + P_W$
	P_{in}	Ballast tanks (1)	$P_{ls} + P_{ld}$
		Liquid cargo tanks	
		Other tanks	
		Watertight boundaries	-
		Cargo holds	$P_{bs} + P_{bd}$
	P_{dk}	Internal decks for dry spaces	-
		External deck for distributed loads	-
		External deck for heavy units	-

(1) WB cargo hold is considered as ballast tank except for design load scenario ‘ballast water exchange’.

Section 8 LOADINGCONDITIONS

SYMBOLS

For symbols not defined in this section, refer to Ch1, Sec 4.

l : Distance from propeller centreline to the waterline, in m.

D_p : Propeller diameter, in m.

M_{Full} : Cargo mass, in t, as defined in Ch4, Sec 6.

M_H : Cargo mass, in t, as defined in Ch4, Sec 6.

M_{HD} : Cargo mass, in t, as defined in Ch4, Sec 6.

M_{BLK} : Maximum cargo mass in cargo holds in block loading conditions, in t, as defined in Ch4, App 1.

$C_{BM\text{-}LC}$: Coefficient taken as the percentage of permissible SWBM, defined in Table 2 to Table 9 and Table 12 to Table 21.

$C_{SF\text{-}LC}$: Coefficient taken as the percentage of permissible SWSF, defined in Table 2 to Table 9 and Table 12 to Table 21.

$x_{b\text{-}aft}$, $x_{b\text{-}fwd}$:Longitudinal position, in m, of respectively the aft and forward bulkhead of the mid-hold of the FE model.

EA : Empty hold in alternate loading condition.

FA : Full hold in alternate loading condition.

T_{H1}, T_{H2}, T_{H3}, T_{H4}: Minimum permissible draught, in m, in harbour condition as defined in Ch 4, App 1.

1 APPLICATION

1.1 Ships having a freeboard length L_{LL} of 150m or above

1.1.1

The requirements in [2] to [5] are applicable to ships having a freeboard length L_{LL} of 150 m or above.

1.1.2 Design loading conditions for strength assessment

Design loading conditions for strength assessment are given in [2] to [4]. The design loading conditions common to both oil tankers and bulk carriers are given in [2]. Specific design loading conditions for oil tankers and bulk carriers are given in [3] and [4] respectively.

Unless otherwise specified, each of the design seagoing conditions is to be investigated for the arrival and departure conditions.

1.1.3

These requirements are not intended to prevent conditions to be included in the loading manual for which calculations are to be submitted. It is not intended to replace in any way the required loading manual/instrument.

1.1.4

Loading conditions from the loading manual, which are not covered in [2] to [4], if any, are to be considered.

1.1.5 Standard design load conditions for fatigue assessment

The standard design loading conditions for fatigue assessment are given in [5].

1.2 Bulk carriers having a freeboard length L_{LL} less than 150 m

1.2.1

The severest loading condition from the loading manual, midship section drawing or otherwise specified by the Designer are to be considered for the longitudinal strength given in Ch5 and for local strength check of plating, ordinary stiffeners and primary supporting members given in Ch6 and Pt 2, Ch1, Sec 3 and Pt 2, Ch1, Sec 4.

The requirements in [2] are applicable to ships having a freeboard length L_{LL} less than 150 m.

1.3 Dynamic load cases

1.3.1 Seagoing conditions

Unless otherwise specified, each of the design seagoing conditions are to be investigated for all dynamic load cases.

1.3.2 Beam and oblique sea dynamic load cases

For FE load analysis, the beam sea and oblique sea dynamic load cases calculated for port and starboard sides are to be applied on the model to obtain the results for both model sides.

For ship with structure symmetrical about the centreline, the beam sea and oblique sea dynamic load cases calculated for portside may be applied only to the model (i.e. dynamic load cases on starboard side may be omitted) provided the results (yield and buckling) are mirrored.

2 COMMON DESIGN LOADING CONDITIONS

2.1 Definitions

2.1.1

In general, the design cargo and ballast loading conditions, based on the amount of bunker, fresh water and stores at departure and arrival, are to be considered for the still water bending moment and shear force calculations. Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting are to be submitted and included in the loading manual.

2.1.2 Departure conditions

The departure conditions are to be based on bunker tanks not taken less than 95% full and other consumables taken at 100% capacity. In case of liquefied gas fuel tank, the filling level is to be based on the definition in International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IGF code) 6.8.

2.1.3 Arrival conditions

The arrival conditions are to be based on 10% of the maximum capacity of bunker, fresh water and stores.

2.2 Partially filled ballast tanks

2.2.1 Partially filled ballast tanks in ballast loading conditions

Ballast loading conditions involving partially filled peak and/or other ballast tanks in any departure, arrival or intermediate condition are not permitted to be used as design loading conditions unless:

- Longitudinal strength of hull girder given in Ch 5, Sec 1 and Ch 8, Sec 3 is to comply with loading conditions with the considered tanks full, empty and partially filled at intended level in any departure, arrival or intermediate condition.
- For bulk carriers having a freeboard length L_{LL} of 150 m or above, longitudinal strength of hull girder in flooded condition given in Ch 5, Sec 1 is to comply with loading conditions with the considered tanks full, empty and partially filled at intended level in any departure, arrival or intermediate condition.

The corresponding full, empty and partially filled tank conditions are to be considered as design conditions for calculation of the still water bending moment and shear force, but these do not need to comply with propeller immersion and trim requirements as specified in [2.3.1], [3.1.1] or [4.1.1].

Where multiple tanks are intended to be partially filled, all combinations of empty, full and partially filled at intended levels for those tanks are to be investigated. These requirements are not applicable to ballast water exchange using the sequential method.

2.2.2 Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirement in [2.2] applies to peak ballast tanks only.

2.3 Seagoing conditions

2.3.1

The following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Homogeneous cargo loading condition including a condition at the scantling draught. Homogeneous loading conditions are to not include filling of ballast tanks in departure conditions.

b) Ballast condition where the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in [2.2.1] are to be complied with. All cargo tanks/holds are to be empty including cargo tanks/holds suitable for the carriage of water ballast at sea. The propeller is to be fully immersed. The trim is to be by the stern and is not to exceed 0.015 L_{LL}.

c) Conditions covering ballast water exchange procedures, if any, with the calculations of intermediate conditions just before and just after ballasting and/or deballasting any ballast tank.

2.4 Harbour and sheltered water conditions

2.4.1

The following harbour and sheltered water conditions are to be included in the loading manual:

a) Conditions representing typical complete loading and unloading operations.

b) Docking condition afloat.

c) Propellers inspection afloat condition, in which the propeller shaft centreline is at least $D_p/4$ above the waterline in way of the propeller. Ships with podded propulsion system arrangements are to be individually considered by the Society.

CCS 2.4.1a The afloat condition for podded propulsion system inspection is to be included in the loading manual. Consideration may be given to inspection requirements of equipment supplier for the system.

2.5 Loading conditions

2.5.1 Alternative design

For structural arrangement not covered by this section, the loading conditions, including loading pattern, corresponding draught, still water bending moment and shear forces are to be agreed by the Society.

CCS 2.5.1a Where the hull structural arrangement is different from that covered by the Rules, for load conditions used for FE analysis, they are to be determined according to CCS Appendix B of this PART.

3 OIL TANKERS

3.1 Specific design loading conditions

3.1.1 Seagoing conditions

The following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Heavy ballast condition where the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in [2.2.1] are to be complied with. The fore peak water ballast tank is to be full, if fitted. If upper and lower fore peak tanks are fitted, the lower is required to be full and the upper tank may be full, partially full or empty. All the cargo tanks are to be empty including cargo tanks suitable for the carriage of water ballast at sea. The draught at the forward perpendicular is not to be less than that for the normal ballast condition. The propeller is to be fully immersed. The trim is to be by the stern and is not to exceed 0.015 L_{LL}.

b) Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions.

c) Any specified non-uniform distribution of loading.

d) Conditions with high density cargo including the maximum design cargo density, when applicable.

e) Design ballast condition in which all segregated ballast tanks in the cargo tank region are full and all other tanks are empty including fuel oil and fresh water tanks. This design condition is for assessment of hull strength and is not intended for ship operation.

3.1.2 Additional loading conditions

The following additional loading conditions are to be included in the loading manual if the ship is specifically approved and intended to be operated in such conditions:

a) Seagoing ballast conditions including water ballast carried in one or more cargo tanks which are intended for use in emergency situations as allowed by MARPOL Reg. 18.

b) Seagoing loading conditions where the net static upward load on the double bottom exceeds that given with the combination of an empty cargo tank and a mean ship's draught of 0.9 T_{SC}.

c) Seagoing loading conditions with cargo tanks less than 25% full with the combination of mean ship's draught greater than 0.9 T_{SC}.

d) Seagoing loading conditions where the net static downward load on the double bottom exceeds that given with the combination of a full cargo tank at a cargo density of 1.025 t/m^3 or greater and a mean ship's draught of 0.6T_{SC}.

e) For ships arranged with cross ties in the centre cargo tank, seagoing loading conditions showing a non-symmetric loading pattern where the difference in filling level between corresponding port an starboard wing cargo tanks exceeds 25% of the filling height in the wing cargo tank.

3.2 Design load combinations for direct strength analysis

3.2.1

The design load combinations for FE analysis are given in Table 1 as follows:

Design load combination for oil tankers **Table 1**

	Midship cargo hold region	Outside midship cargo hold region	Foremost cargo tanks	Aftmost cargo tanks
Tankers with two oil-tight bulkheads	Table 2	Table 4	Table 6	Table 8
Tankers with one centreline oil-tight bulkhead	Table 3	Table 5	Table 7	Table 9
Note 1: Outside midship cargo hold region means the forward or aft cargo hold region except the foremost and aftmost cargo holds				

3.2.2

For tankers with two oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.15 L, the draughts given in Table 2, Table 4, Table 6 and Table 8 are subject to special consideration by the Society.

CCS 3.2.2a For tankers with two oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.15L, the draughts corresponding to the load conditions are determined according to CCS Appendix B of this PART.

3.2.3

For tankers with one centreline oil-tight longitudinal bulkhead, where the cargo tank length is less than 0.11 L, the draughts given in Table 3, Table 5, Table 7 and Table 9 are subject to special consideration by the Society.

CCS 3.2.3a For tankers with one oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.11L, the draughts corresponding to the load conditions are determined according to CCS Appendix B of PART9-1.

3.2.4

For seagoing conditions, the dynamic load cases required to be investigated for each loading pattern are indicated in Table 2 to Table 9. Dynamic load cases are defined in Ch 4, Sec 2.

3.2.5 Ships with structure symmetrical about centreline

For ships with structure symmetrical about the centreline, the loading pattern mirrored about centreline of another pattern may be omitted provided the results (yield and buckling) are mirrored, e.g. Table 2 A7b, A12b.

3.2.6 Tankers with two oil-tight longitudinal bulkheads except with a cross tie arrangement in the wing cargo tanks

For tankers with two oil-tight longitudinal bulkheads except with a cross tie arrangement in the wing cargo tanks, loading patterns A7 in Table 2, Table 4, Table 6 and Table 8 is to be examined for the possibility that unequal filling levels in transversely paired wing cargo tanks would result in a more onerous stress response. Loading pattern A7 is required to be analysed only if such a non-symmetric seagoing loading condition is included in the ship loading manual. The actual loading pattern, draught, GM and k_r from the loading manual are to be used in the FE analysis. Where the GM and k_r are not given in the ship's loading manual, GM and k_r are to be determined in accordance with Ch4, Sec 3.

If loading pattern A7 is not considered, an operational restriction describing that the difference in filling level between corresponding port and starboard wing cargo tanks is not to exceed 25% of the filling height in the wing cargo tank, is to be added in the loading manual.

Loading pattern A7 needs not be examined for tankers with a cross tie arrangement in the wing cargo tanks.

3.2.7

For tankers with two oil-tight longitudinal bulkheads, seagoing loading pattern A3 and harbour loading pattern A13, with all cargo tanks abreast empty, in Table 2, Table 4, Table 6 and Table 8 are to be analysed with a ship draught of $0.65T_{SC}$ and $0.7T_{SC}$ respectively. If conditions in the ship loading manual specify greater draughts for loading pattern A3 or A13, then the maximum specified draught in the ship's loading manual for the loading pattern is to be used.

3.2.8

For tankers with two oil-tight longitudinal bulkheads, seagoing loading pattern A5 and harbour loading pattern A11, with all cargo tanks abreast fully loaded, in Table 2, Table 4, Table 6 and Table 8 are to be analysed with a ship draught of $0.65T_{SC}$ and $0.6T_{SC}$ respectively. If conditions in the ship loading manual specify lesser draughts for loading pattern A5 or A11, then the minimum specified draught in the ship's loading manual for the loading pattern is to be used.

3.2.9

For loading patterns A1, A2, B1, B2 and B3, with cargo tank(s) empty, in Table 2 to Table 9, a minimum ship draught of $0.9T_{SC}$ is to be used in the analysis. If conditions in the ship loading manual specify greater draughts for loading patterns with empty cargo tank(s), then the maximum specified draught for the actual condition is to be used.

3.2.10 Ballast conditions

Where a ballast condition is specified in the ship loading manual with ballast water filled in one or more cargo tanks, loading patterns A8 or B7 in Table 2 or Table 3 are to be examined.

If the actual loading pattern as specified in the loading manual is different from load pattern A8 or B7 then:

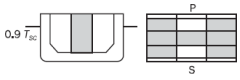
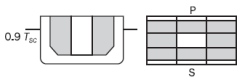
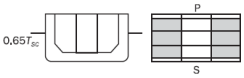
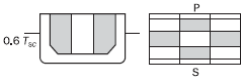
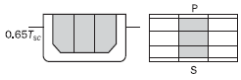
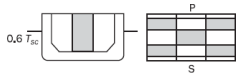
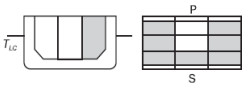
a) The actual loading patterns are to be substituted for the loading pattern A8 or B7 with the following calculation conditions:
   - Draught to be taken as $T_{BAL\text{-}E}$,
   - $C_{BM\text{-}LC}$ = 100% (sag.),
   - $C_{SF\text{-}LC}$ = 100%,
   - 100% filling of the considered tanks carrying ballast water.

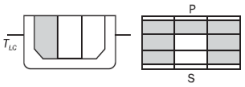
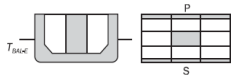
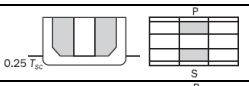
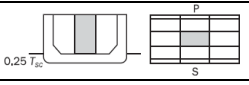
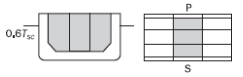
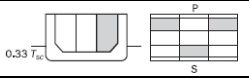
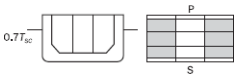
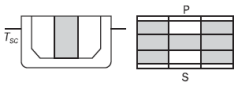
b) The strength assessment is to be carried out for all the dynamic load cases as defined in Ch 4, Sec 2.

c) An operational restriction corresponding to the analysed condition is to be added in the loading manual.

The actual loading pattern, draught, GM and k_r from the loading manual are to be used in the FE analysis. Where the GM and k_r are not given in the ship's loading manual, GM and k_r are to be determined in accordance with Ch 4, Sec 3.

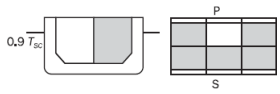
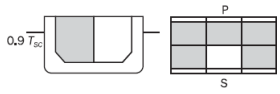
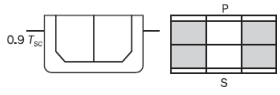
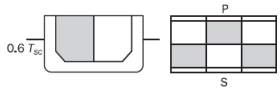
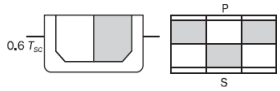
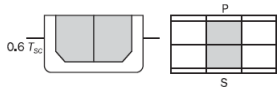
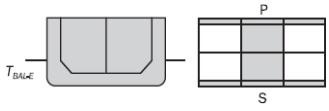
Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable tomidship cargo hold region **Table 2**

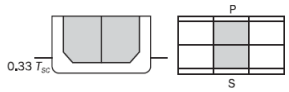
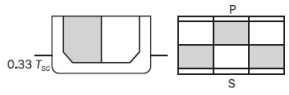
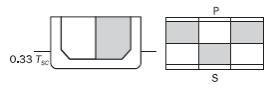
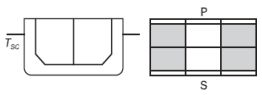
No.	Loading pattern	Still water loads			Dynamic load cases		
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Midship cargo region		
Seagoing conditions							
A1		0.9 T_{SC}	100% (sagging)	100%	HSM-1	BSP-1P/S	N/A
			100% (hog.)	100%	HSM-2 FSM-2	BSP-1P/S	OST-2P/S OSA-1P/S
A2		0.9 T_{SC}	100% (sagging)	100%	HSM-1	BSR-1P /S BSP-1P/S	N/A
			100% (hogging)	100%	HSM-2 FSM-2	BSR-1P/S BSP-1P/S	N/A
A3		0.65 T_{SC}	100% (hogging)	100% (4) Max SFLC	HSM-2	N/A	N/A
				100% (5) Max SFLC	HSM-2	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
			0%	100% (6) Max SFLC	HSM-1	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
A4		0.6 T_{SC}	100% (sagging)	100%	HSM-1	BSR-1P/S BSP-1P/S	OSA-2P/S
5		0.65 T_{SC}	100% (sagging)	100% (4) Max SFLC	HSM-1	N/A	N/A
				100% (5) Max SFLC	HSA-1	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
			0%	100% (6) Max SFLC	HSM-2	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
A6		0.6 T_{SC}	100% (hogging)	100%	HSM-2	BSR-1P/S BSP-1P/S	OSA-1P/S
A7a		T_{LC}	100% (hogging)	100%	HSM-2 FSM-2	BSR-1P/S BSP-1P/S	OST-2P/S OSA-1P/S OSA-2P/S

No.	Loading pattern	Still water loads			Dynamic load cases		
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Midship cargo region		
A7b		T_{LC}	100% (hogging)	100%	HSM-2 FSM-2	BSR-1P/S BSP-1P/S	OST-2P/S OSA-1P/S OSA-2P/S
A8		$T_{BAL\text{-}E}$	100% (sagging)	100%	HSM-1	BSR-1P/S BSP-1P/S	OSA-2P/S
Harbour and testing conditions							
A9		$0.25T_{SC}$	100% (sagging)	100%	N/A		
A10		$0.25T_{SC}$	100% (sagging)	100%	N/A		
A11		$0.6T_{SC}$	100% (sagging)	100% (2) Max SFLC	N/A		
				100% (3) Max SFLC	N/A		
A12a (1)		$0.33T_{SC}$	N/A	N/A	N/A		
A12b (1)		$0.33T_{SC}$	N/A	N/A	N/A		
A13		$0.7T_{SC}$	100% (hogging)	100% (2) Max SFLC	N/A		
				100% (3) Max SFLC	N/A		
A14		T_{SC}	100% (hogging)	100%	N/A		

(1) The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.
(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(4) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid- hold.
(5) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(6) This load combination is to be considered only for the mid-hold where $x_{b\text{-}aft} > 0.5L$ or $x_{b\text{-}fwd} < 0.5L$

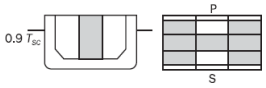
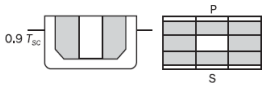
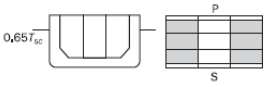
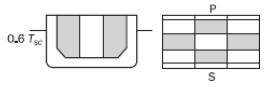
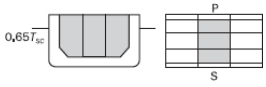
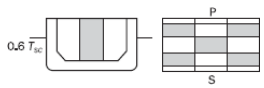
Load combinations for FE analysis for one centreline oil-tight bulkheads oil tankers applicable to midship cargo region **Table3**

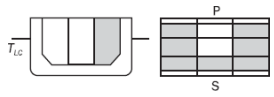
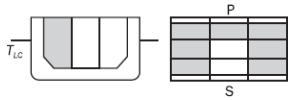
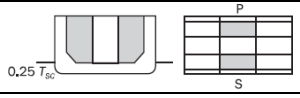
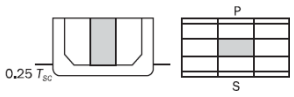
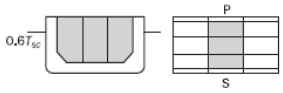
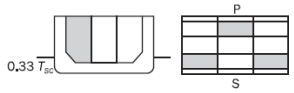
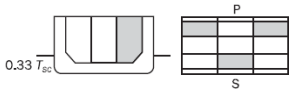
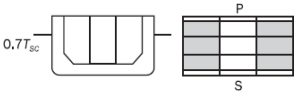
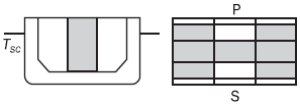
No.	Loading pattern	Still water loads			Dynamic load cases		
		Draught	C_{BM-LC} :% of perm. SWBM	C_{SF-LC}:% of perm. SWSF	Midship cargo region		
Seagoing conditions							
B1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 HSA-1	BSP-1P/S	N/A
			100% (hogging)	100%	HSM-2 FSM-2	BSP-1P BSR-1P	OST-2P
B2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 HSA-1	BSP-1P/S	N/A
			100% (hogging)	100%	HSM-2 FSM-2	BSR-1S BSP-1S	OST-2S
B3		$0.9T_{SC}$	100% (hogging)	100% (2) Max SFLC	HSM-2 FSM-2	N/A	N/A
				100% (2) Max SFLC	HSM-2 FSM-2	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
			0%	100% (2) Max SFLC	HSM-1 FSM-1	N/A	N/A
B4		$0.6T_{SC}$	100% (sagging)	75%	HSM-1	BSP-1P	OSA-2P/S
B5		$0.6T_{SC}$	100% (sagging)	75%	HSM-1	BSP-1S	OSA-2P/S
B6		$0.6T_{SC}$	100% (sagging)	100% (2) Max SFLC	HSM-1	N/A	N/A
				100% (2) Max SFLC	HSM-1	N/A	N/A
				100%	N/A	BSP-1P/S	N/A
			0%	100% (2) Max SFLC	HSM-2	N/A	N/A
B7		T_{BAL-E}	100% (sagging)	100%	HSM-1	BSP-1P/S	N/A
Harbour and testing conditions							

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Midship cargo region
B8		$0.33T_{SC}$	100% (sagging)	100% (1) Max SFLC	N/A
				100% (2) Max SFLC	N/A
B9		$0.33T_{SC}$	100% (sagging)	75%	N/A
B10		$0.33T_{SC}$	100% (sagging)	75%	N/A
B11		T_{SC}	100% (hogging)	100% (1) Max SFLC	N/A
				100% (2) Max SFLC	N/A

(1) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(2) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(3) For the mid-hold where $x_{b\text{-}aft} \leqslant 0.5L$ and $x_{b\text{-}fwd} \geqslant 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid- hold.
(4) For the mid-hold where $x_{b\text{-}aft} \leqslant 0.5L$ and $x_{b\text{-}fwd} \geqslant 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(5) This load combination is to be considered only For the mid-hold where $x_{b\text{-}aft} > 0.5L$ or $x_{b\text{-}fwd} < 0.5L$.

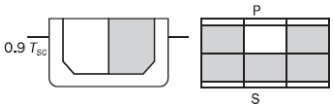
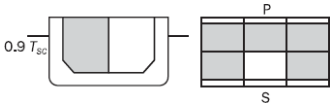
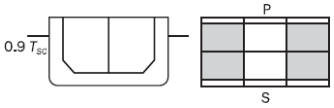
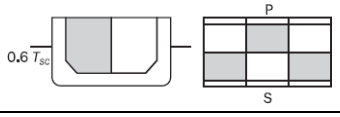
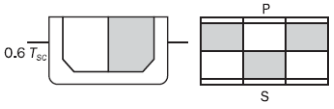
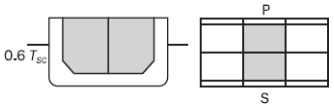
Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable to outside midship cargo hold region **Table 4**

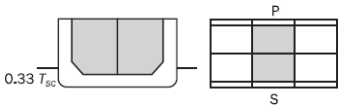
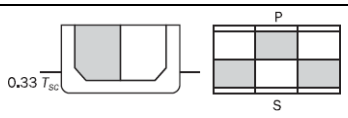
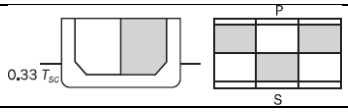
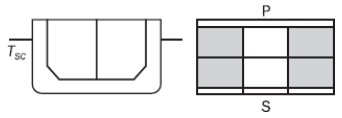
No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aft region	Forward region
Seagoing conditions						
A1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S,	HSM-1, BSP-1P/S,
			100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S, OST-2P/S, OSA-1P/S,	HSM-2, FSM-2 BSP-1P/S,
A2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S,	HSM-1, FSM-1 BSP-1P/S, OSA-2P/S,
			100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S, OSA-1P/S	HSM-2, BSP-1P/S,
A3		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2	HSM-2 FSM-2
				100%	BSP-1P/S,	BSP-1P/S, OSA-2P/S,
			0%	100% Max SFLC	HSM-1	HSM-1
				100%	N/A	BSP-1P/S, OSA-2P/S,
A4		$0.6T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S, BSR-1P/S,	HSM-1 BSP-1P/S, BSR-1P/S, OSA-2P/S,
A5		$0.65T_{SC}$	100% (sagging)	100% Max SFLC	HSM-1 FSM-1	HSM-1
				100%	BSP-1P/S,	BSP-1P/S, OSA-2P/S
			0%	100% Max SFLC	HSM-2	HSM-2
				100%	BSP-1P/S,	BSP-1P/S, OSA-2P/S
A6		$0.6T_{SC}$	100% (hogging)	100%	HSM-2 BSP-1P/S BSR-1P/S	HSM-2, BSP-1P/S BSR-1P/S OSA-2P/S

No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aft region	Forward region
A7a		T_{LC}	100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S BSR-1P, BSR-2S OSA-1P/S OSA-2P/S, OST-2P	HSM-2, FSM-2 BSP-1P/S BSR-1P, BSR-2S OSA-2P/S
A7b		T_{LC}	100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S BSR-2P, BSR-1S OSA-1P/S OSA-2P/S, OST-2S	HSM-2, FSM-2 BSP-1P/S BSR-2P, BSR-1S OSA-2P/S
Harbour and testing conditions						
A9		$0.25T_{SC}$	100% (sagging)	100%	N/A	
A10		$0.25T_{SC}$	100% (sagging)	100%	N/A	
A11		$0.6T_{SC}$	100% (sagging)	100%(2) Max SFLC	N/A	
				100%(3) Max SFLC	N/A	
A12a (1)		$0.33T_{SC}$	N/A	N/A	N/A	
A12b (1)		$0.33T_{SC}$	N/A	N/A	N/A	
A13		$0.7T_{SC}$	100% (hogging)	100%(2) Max SFLC	N/A	
				100%(3) Max SFLC	N/A	
A14		T_{SC}	100% (hogging)	100%	N/A	

(1) The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.
(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

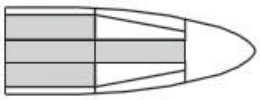
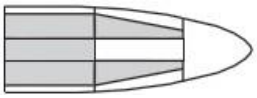
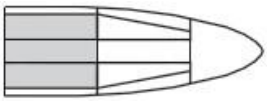
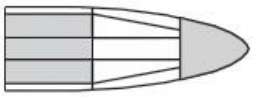
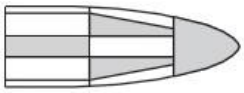
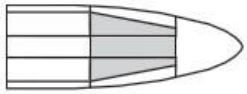
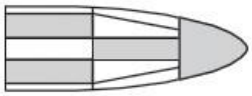
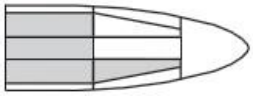
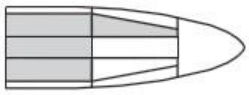
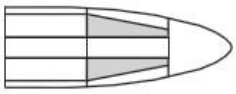
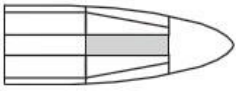
Load combinations for FE analysis for one centreline oil-tight bulkheads oil tankers pplicable to outside midship cargo hold region **Table 5**

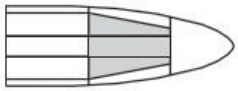
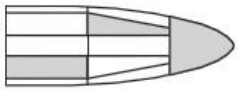
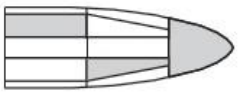
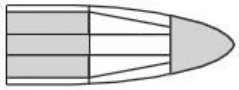
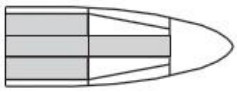
No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Aft region	Forward region
Seagoing conditions						
B1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-2 BSP-1P/S OSA-1S	HSM-1 BSP-1P/S OSA-2S
			100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S OSA-1P OST-2P/S	HSM-2, FSM-2 BSP-1P/S OSA-2S
B2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S OAS-1P	HSM-1 BSP-1P/S OSA-2P
			100% (hogging)	100%	HSM-2, FSM-2 BSP-1P/S OSA-1S OST-2P/S	HSM-2, FSM-2 BSP-1P/S OSA-2P
B3		$0.9T_{SC}$	100% (hogging)	100% (1) Max SFLC	HSM-2 FSM-2	HSM-2 FSM-2
				100%	BSR-1P/S BSR-1P/S	BSR-1P/S
			0%	100% (1) Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
				100%	BSP-1P/S	BSP-1P/S
B4		$0.6T_{SC}$	100% (sagging)	75%	HSM-1 BSR-1P/S	HSM-1 BSP-1P/S OSA-2P/S
B5		$0.6T_{SC}$	100% (sagging)	75%	HSM-1 BSR-1P/S	HSM-1 BSP-1P/S OSA-2P/S
B6		$0.6T_{SC}$	100% (sagging)	100% (1) Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
				100% (2) Max SFLC	OST-1P/S	OSA-2P/S

No.	Loading pattern	Still water loads			Dynamic load cases	
		Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Aft region	Forward region
			0%	100% (1) Max SFLC	HSM-2 FSM-2	HSM-2 FSM-2
				100% (2) Max SFLC	OSA-2P/S	OSA-2P/S
Harbour and testing conditions						
B8		$0.33T_{SC}$	100% (sagging)	100% (1) Max SFLC	N/A	
				100% (2) Max SFLC	N/A	
B9		$0.33T_{SC}$	100% (sagging)	100% (2) Max SFLC	N/A	
B10		$0.33T_{SC}$	100% (sagging)	75%	N/A	
B11		T_{SC}	100% (hogging)	100% (1) Max FLC	N/A	
				100% (2) Max SFLC	N/A	

(1) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(2) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

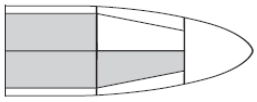
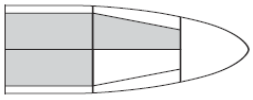
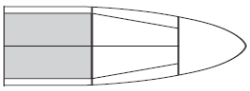
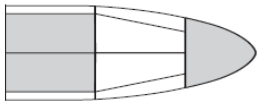
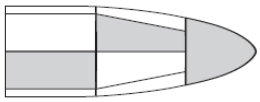
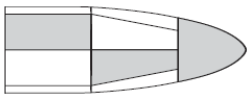
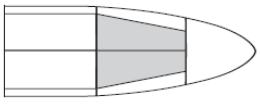
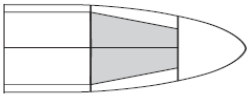
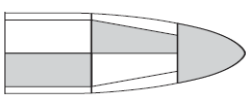
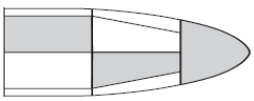
Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable for foremost cargo hold **Table 6**

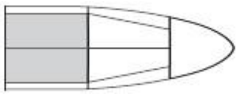
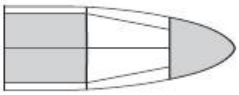
No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Foremost cargo hold
Seagoing conditions					
A1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S, BSR-1P/S OSA-2P/S, OST-1P/S
A2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, OSA-2P/S
A3-1		$0.65T_{SC}$	100% (sagging)	100%	HSM-1, OSA-2P/S
A3-2 (1)		$0.65T_{SC}$	0%	100% Max SFLC	HSM-2
				100%	BSP-1P/S, OSA-2P/S
			100% (sagging)	100% Max SFLC	HSM-1
				100%	OSA-2P/S
A4 (1)		$0.6T_{SC}$	50% (hogging)	100%	FSM-1,BSP-1P/S, OSA-2P/S
A5		$0.65T_{SC}$	0%	100% Max SFLC	HSM-1
			100% (hogging)	100% Max SFLC	HSM-2
				100%	BSP-1P/S
A6 (1)		$0.6T_{SC}$	50% (hogging)	100%	OSA-2P/S
A7a		T_{LC}	100% (sagging)	100%	HSM-1, HSA-1, FSM-1,BSP-1P/S, BSR-1P/S,OST-1P/S, OSA-2P/S
A7b		T_{LC}	100% (sagging)	100%	HSM-1, HSA-1, FSM-1,BSP-1P/S, BSR-1P/S, OST-1P/S, OSA-2P/S
Harbour and testing conditions					
A9		$0.25T_{SC}$	100% (hogging)	100%	N/A
A10		$0.25T_{SC}$	100% (hogging)	100%	N/A

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Foremost cargo hold
A11		$0.6T_{SC}$	100% (hogging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A
A12-a(1) (4)		$0.33T_{SC}$	N/A	N/A	N/A
A12-b(1) (4)		$0.33T_{SC}$	N/A	N/A	N/A
A13 (1)		$0.7T_{SC}$	100% (sagging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A
A14		T_{SC}	100% (sagging)	100%	N/A

(1) 100% filling of all fore peak water ballast tanks.
(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(4) The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.

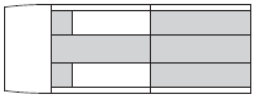
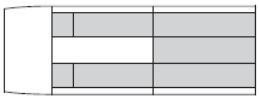
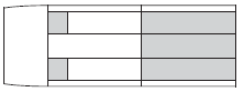
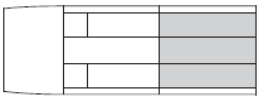
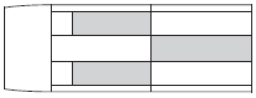
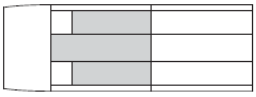
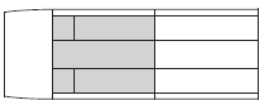
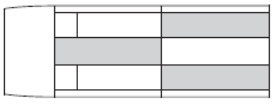
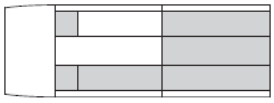
Load combination for FE analysis for one centreline oil-tight bulkheads oil tankers applicable for foremost cargo hold **Table 7**

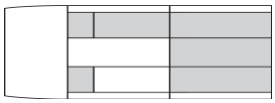
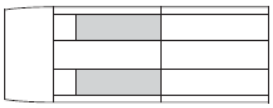
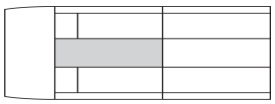
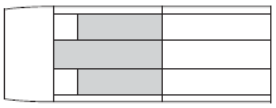
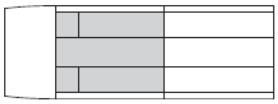
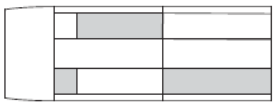
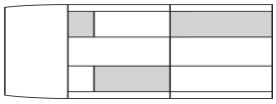
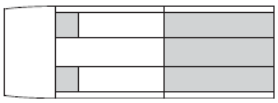
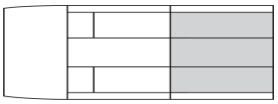
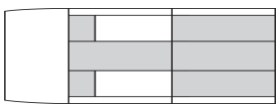
No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Foremost cargo hold
Seagoing conditions					
B1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S OSA-2P/S
B2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1P/S OSA-2P/S
B3-1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1 BSP-1S/P, OSA-2S/P,
B3-2 (1)		$0.9T_{SC}$	0%	100% Max SFLC	HSM-2,
				100%	BSP-1S/P, OSA-2S/P,
			100% (sagging)	100% Max SFLC	HSM-1, FMS-1
				100%	BSP-1S/P, OST-1S/P, OSA-2P/S
B4 (1)		$0.6T_{SC}$	100% (hogging)	75%	BSP-1P/S, OSA-2P/S
B5 (1)		$0.6T_{SC}$	100% (hogging)	75%	BSP-1P/S, OSA-2P/S
B6		$0.6T_{SC}$	0%	100% Max SFLC	HSM-1
				100%	OSA-2P/S
			100% (hogging)	100% Max SFLC	HSM-2, FSM-2,
				100%	OSA-2P/S
Harbour and testing conditions					
B8		$0.33T_{SC}$	100% (hogging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A
B9 (1)		$0.33T_{SC}$	100% (hogging)	75%	N/A
B10 (1)		$0.33T_{SC}$	100% (hogging)	75%	N/A

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Foremost cargo hold
B11-1		T_{SC}	100% (sagging)	100%	N/A
B11-2 (2)		T_{SC}	100% (sagging)	100% (2) Max SFLC	N/A
				100% (3) Max SFLC	N/A

(1) 100% filling of all fore end water ballast tanks.
(2) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(3) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

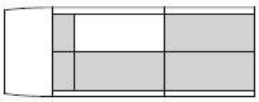
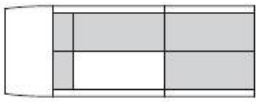
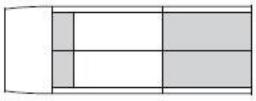
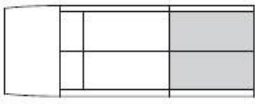
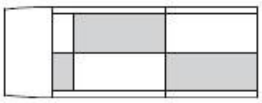
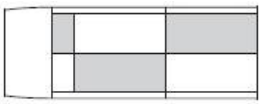
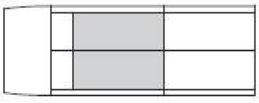
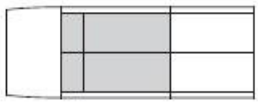
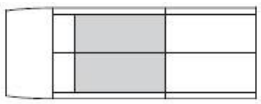
Load combinations for FE analysis for two oil-tight bulkheads oil tankers applicable for aftmost cargo hold **Table 8**

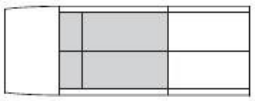
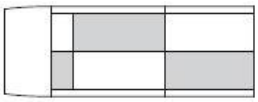
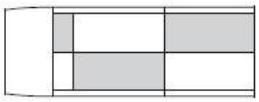
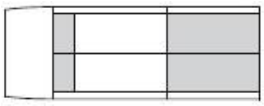
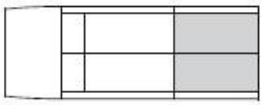
No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
Seagoing conditions					
A1		$0.9T_{SC}$	100% (sagging)	100%	FSM-1, HSM-1, BSP-1P/S
			100% (hogging)	100%	HSM-2, OSA-1P/S BSP-1P/S, BSR-1P/S
A2		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSR-1P/S,OST-1P/S
			100% (hogging)	100%	HSM-2, FSM-1, FSM-2,OSA-1P/S
A3-1 (1) (2)		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2,FSM-2
			100% (sagging)	100% Max SFLC	HSM-1, FSM-1
				100%	BSP-1P/S
A3-2 (1) (3)		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2
				100%	BSP-1P/S, OSA-1P/S
			100% (sagging)	100% Max SFLC	HSM-1, FSM-1
				100%	BSP-1P/S, OST-1P/S
A4		$0.6T_{SC}$	100% (sagging)	100%	HSM-1, BSP-1P/S
			100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, OSA-1P/S, OSA-2P/S
A5-1 (2)		$0.65T_{SC}$	0%	100% Max SFLC	HSM-1, HSM-2, FSM-1
			100% (hogging)	100% Max SFLC	HSM-2, FSM-1
				100%	BSP-1P/S
A5-2 (3)		$0.65T_{SC}$	0%	100% Max SFLC	HSM-1, HSM-2
				100%	BSP-1P/S, BSR-1P/S
			100% (hogging)	100%	HSM-2, FSM-2
A6		$0.6T_{SC}$	100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, BSR-1P/S, OSA-1P/S
A7a		T_{LC}	100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, BSR-1P/S OSA-1P/S

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
A7b		T_{LC}	100% (hogging)	100%	HSM-2, FSM-1, BSP-1P/S, BSR-1P/S, OSA-1P/S
Harbour and testing conditions					
A9		$0.25T_{SC}$	100% (hogging)	100%	N/A
A10		$0.25T_{SC}$	100% (hogging)	100%	N/A
A11-1 (2)		$0.6T_{SC}$	100% (hogging)	100%(5) Max SFLC	N/A
A11-2 (3)		$0.6T_{SC}$	100% (hogging)	100%(5) Max SFLC	N/A
				100%(6) Max SFLC	N/A
A-12a (4)		$0.33T_{SC}$	N/A	N/A	N/A
A-12b (4)		$0.33T_{SC}$	N/A	N/A	N/A
A13-1 (1)(2)		$0.7T_{SC}$	100% (hogging)	100%(5) Max SFLC	N/A
A13-2 (1) (3)		$0.7T_{SC}$	100% (hogging)	100%(5) Max SFLC	N/A
				100%(6) Max SFLC	N/A
		$0.7T_{SC}$	100% (sagging)	100%(5) Max SFLC	N/A
				100%(6) Max SFLC	N/A
A14		T_{SC}	100% (hogging)	100%	N/A
			100% (sagging)	100%	N/A

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
(1) 100% filling of fuel and water ballast tanks in engine room, with tank boundaries at the forward engine room bulkhead. (2) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward slop tank bulkhead. (3) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward machinery space bulkhead. (4) The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied. (5) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold. (6) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.					

Load combination for FE analysis for one centreline oil-tight bulkheads oil tankers applicable for the aftmost cargo hold **Table 9**

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
Seagoing conditions					
B1		$0.9T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S, BSR-1P/S
			100% (hogging)	100%	HSM-2 BSP-1P/S, OSA-1P/S
B2		$0.9\ T_{SC}$	100% (sagging)	100%	HSM-1, FSM-1 BSP-1P/S, BSR-1P/S
			100% (hogging)	100%	HSM-2 BSP-1P/S, OSA-1P/S
B3-1[(1)] [(2)]		$0.9\ T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2
				100%	BSP-1P/S
			100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	BSP-1P/S
B3-2[(1)] [(3)]		$0.9T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2, FSM-2
				100%	BSP-1P/S, OSA-1P/S
			100% (sagging)	100% Max SFLC	HSM-1, FSM-1
				100%	BSP-1P/S
B4		$0.6T_{SC}$	100% (hogging)	75%	HSM-2, BSP-1P/S, OSA-1P/S
B5		$0.6T_{SC}$	100% (hogging)	75%	HSM-2, BSP-1P/S, OSA-1P/S
B6-1[(2)]		$0.6\ T_{SC}$	0%	100% Max SFLC	HSM-1
			100% (hogging)	100% Max SFLC	HSM-2
B6-2[(3)]		$0.6\ T_{SC}$	0%	100% Max SFLC	HSM-1
			100% (hogging)	100% Max SFLC	HSM-2
				100%	HSA-2, BSR-1P/S,
Harbour and testing conditions					
B8-1[(2)]		$0.33T_{SC}$	100% (hogging)	100%[(4)] Max SFLC	N/A

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Aftmost cargo hold
B8-2 (3)		$0.33T_{SC}$	100% (hogging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A
			100% (sagging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A
B9		$0.33T_{SC}$	100% (hogging)	75%	N/A
B10		$0.33T_{SC}$	100% (hogging)	75%	N/A
B11-1 (1)(2)		T_{SC}	100% (hogging)	100% (4) Max SFLC	N/A
			100% (sagging)	100% (4) Max SFLC	N/A
B11-2 (1)(3)		T_{SC}	100% (hogging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A
			100% (sagging)	100% (4) Max SFLC	N/A
				100% (5) Max SFLC	N/A

(1) 100% filling of fuel and water ballast tanks in engine room, with tank boundaries at the forward engine room bulkhead.
(2) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward slop tank bulkhead.
(3) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward machinery space bulkhead.
(4) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(5) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

4 BULK CARRIERS

4.1 Specific design loading condition

4.1.1 Seagoing conditions

The following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Cargo loading conditions as defined in [4.1.2] to [4.1.4].

b) Heavy ballast condition where the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in [2.2.1] are to be complied with. The propeller immersion l/D_p is to be at least 60%. The trim is to be by the stern and is not to exceed 0.01 5 L_{LL}. The moulded forward draught is not to be taken less than the smaller of 0.03 L_{LL} or 8 m.

4.1.2 Cargo loading condition for BC-C

Homogeneous cargo loaded condition is to be included in the loading manual where the cargo density corresponds to all cargo holds, including hatchways, being 100% full at scantling draught with all ballast tanks empty.

4.1.3 Cargo loading condition for BC-B

As required for BC-C, plus:

Homogeneous cargo loaded condition is to be included in the loading manual where the cargo density is taken equal to 3.0 t/m^3, and all cargo holds are taken with the same filling ratio (cargo mass/hold cubic capacity) in all cargo holds at scantling draught with all ballast tanks empty.

In cases where the cargo density applied for this design loading condition is different from 3.0t/m^3, the maximum density of the cargo that the ship is allowed to carry is to be indicated in the loading manual. If the maximum density is less than 3.0t/m^3 then the additional service feature {maximum cargo density *x.y* t/m^3} is to be indicated as defined in Ch 1, Sec 1, [3.2.1].

4.1.4 Cargo loading condition for BC-A

As required for BC-B, plus:

At least one cargo loaded condition with specified holds empty, with cargo density 3.0t/m^3, and the same filling ratio (cargo mass/hold cubic capacity) in all loaded cargo holds at scantling draught with all ballast tanks empty.

The combination of specified empty holds is to be indicated with the additional service feature {Holds *a*, *b*, …may be empty}.

In such cases where the design cargo density applied is different from 3.0t/m^3, the maximum density of the cargo that the ship is allowed to carry is to be indicated in the loading manual. If the maximum density is less than 3.0 t/m^3 then the additional service feature {Holds *a*, *b*, … may be empty with maximum cargo density *x.y* t/m^3} is to be indicated as defined in Ch1, Sec 1, [3.2.1].

4.1.5 Additional ballast conditions

The following ballast conditions are to be included in the loading manual for longitudinal strength assessment:

- Ballast conditions with all ballast tanks 100% full,
- Heavy ballast conditions with all ballast tanks 100% full and one cargo hold adapted and designated for the carriage of water ballast at sea, where provided, 100% full.
  Where more than one hold is adapted and designated for the carriage of water ballast at sea, it is not required that two or more holds be assumed 100% full simultaneously in the longitudinal strength assessment, unless such conditions are expected in the heavy ballast condition. Unless each hold is individually investigated, the designated heavy ballast hold and any/all restrictions for the use of other ballast hold(s) are to be indicated in the loading manual.

4.1.6 Steel coils or heavy cargoes

The following note is to be included in the loading manual:

"Where the ship engages in a service carrying such cargoes as steel coils or heavy cargoes that may have an adverse effect on the local strength of the double bottom and which is not described as cargo in the loading manual, the maximum permissible and the minimum required mass of cargo are to be considered specially."

4.2 Design load combinations for direct strength analysis

4.2.1 Applicable general loading patterns

The following loading patterns are to be applied:

a) Any cargo hold carrying M_{Full} with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at scantling draught.

b) Any cargo hold carrying minimum 50% of M_H, with all double bottom tanks and all fuel oil tanks in way of the cargo hold being empty, at scantling draught.

c) Any cargo hold taken empty, with all double bottom tanks and all fuel oil tanks in way of the cargo hold being empty, at the deepest ballast draught. Where a topside and double bottom tank are permanently connected as a common tank, the following conditions are to be considered:
- The topside and double bottom tank empty,
- The topside and double bottom tank full.

4.2.2 Multiport conditions

The following multiport conditions are applicable to all types of bulk carriers except when the service feature {no MP} is assigned:

a) Any cargo hold carrying M_{Full} with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of scantling draught.

b) Any cargo hold taken empty with all double bottom tanks and all fuel oil tanks in way of the cargo hold being empty, at 83% of scantling draught.

c) Any two adjacent cargo holds carrying M_{Full} with the next holds being empty, with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of the scantling draught. This requirement to the mass of the cargo and fuel oil tanks in way of the cargo hold applies also to the condition where the adjacent hold is filled with ballast.

d) Any two adjacent cargo holds being empty with the next holds being full, with all double bottom tanks and fuel oil tank in way of the cargo hold being empty, at 75% of scantling draught.

4.2.3 Alternate conditions

The following alternate conditions are applicable to BC-A only:

a) Cargo holds which are intended to be empty at scantling draught, being empty with all double bottom tanks and fuel oil tanks in way of the cargo hold also being empty.

b) Cargo holds which are intended to be loaded with high density cargo, carrying M_{HD} plus 10% of M_H, in the partially filled condition with highest density according to Ch 4, Sec 6, Table 1. The fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty in way of the cargo hold, at scantling draught.

c) Cargo holds which are intended to be loaded with high density cargo, carrying M_{HD} plus 10% of M_H in the full condition with lowest density according to Ch 4, Sec 6, Table 1. The fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty in way of the cargo hold, at scantling draught.

d) If the ship is intended to operate in alternate block load condition, any two adjacent cargo holds are to be loaded with the next holds being empty, carrying 10% of M_H in each hold in addition to the maximum cargo load according to that design loading condition, with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at scantling draught. In operation the maximum allowable mass is to be limited to the maximum cargo load according to the design loading conditions.

4.2.4 Heavy ballast condition

The following condition applies to ballast holds only:

- Cargo holds which are designed as ballast water holds, being 100% full of ballast water including hatchways, with all double bottom tanks and fuel oil tanks in way of the cargo hold being 100% full, at any heavy ballast draught. For ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper, stool, and double bottom tanks are empty

4.2.5 Additional harbour condition for all bulk carriers

The following additional harbour conditions apply to all bulk carriers:

a) At reduced draught during loading and unloading in harbour, the maximum allowable mass in a cargo hold may be increased by 15% of the maximum mass allowed at the scantling draught in seagoing condition, but is not to exceed the mass allowed at scantling draught in the seagoing condition. The minimum required mass may be reduced by the same amount.

b) Any single cargo hold holding the maximum allowable seagoing mass at 67% of scantling draught, in harbour condition with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty.

c) Any two adjacent cargo holds carrying M_{Full} with the next holds being empty, with fuel oil tanks in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of scantling draught, in harbour condition.

4.2.6 Design load combinations for direct strength analysis

The loading patterns to be considered in the direct strength analysis of bulk carriers are summarised in Table 10. Load combinations providing the calculations details for each loading pattern are given in Table 12 to Table 21.

Applicable loading patterns according to additional service features Table 10

Loading pattern	Requirement	BC-			BC- {no MP}		
		A	B	C	A	B	C
Full load in homogeneous condition	[4.2.1] item a	×	×	×	×	×	×
Slack load	[4.2.1] item b	×	×	×	×	×	×
Deepest ballast	[4.2.1] item c	×	×	×	×	×	×
Multiport-1	[4.2.2] item a	×	×	×			
Multiport-2	[4.2.2] item b	×	×	×			
Multiport-3	[4.2.2] item c	×	×	×			
Multiport-4	[4.2.2] item d	×	×	×			
Alternate load partial	[4.2.3] items a & b	×			×		
Alternate load full	[4.2.3] items a & c	×			×		
Alternate block load	[4.2.3] item d	×			×		
Heavy ballast	[4.2.4]	×	×	×	×	×	×
Harbour condition	[4.2.5]	×	×	×	×	×	×

4.2.7

The design load combinations for FE analysis are given as follows:

Design load combinations for Bulk Carriers Table 11

	Midship cargo hold region	Outside midship cargo hold region	Aftmost cargo hold	Foremost cargo hold
BC-A – EA	Table 12	Table 15	N/A	N/A
BC-A – FA	Table 13	Table 16	Table 18	Table 20
BC- B & BC-C	Table 14	Table 17	Table 19	Table 21
Note 1: Outside midship cargo hold region means the forward or aft cargo hold region except the foremost and aftmost cargo holds				

4.3 Hold mass curves

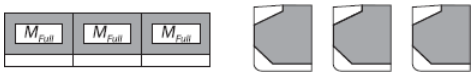
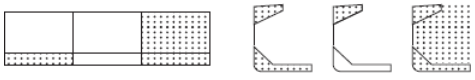
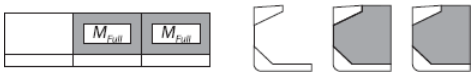
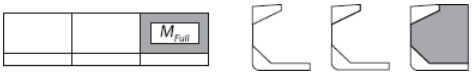
4.3.1

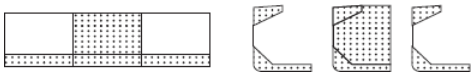
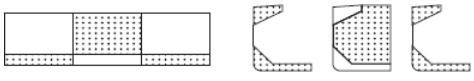
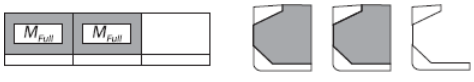
Based on the design loading criteria, as given in [4.2.1] to [4.2.5] except [4.2.4], hold mass curves for each single hold, as well as for any two adjacent holds are to be included in the loading manual and the loading instrument. The maximum allowable or minimum required cargo mass in a cargo

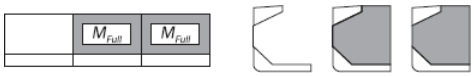
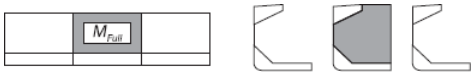
hold, or in two adjacent loaded holds is related to the net load on the double bottom. The net load on the double bottom is a function of draught, cargo mass in the cargo hold, as well as the mass of fuel oil and ballast water contained in double bottom tanks.

4.3.2
Hold mass curves are to be calculated according to Ch 4, App 1 showing maximum allowable and minimum required masses as a function of draught in seagoing condition as well as during loading and unloading in harbour.

FE Load combinations applicable to empty hold in alternate condition of BC-A (EA) - midship cargo hold region **Table 12**

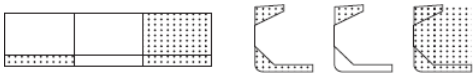
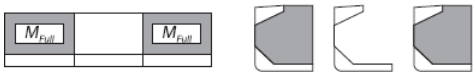
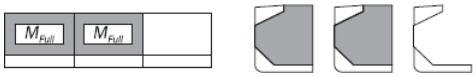
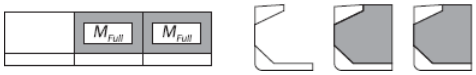
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
Seagoing conditions						
1(2)	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
2(1)	Full load [4.2.1]a		T_{SC}	50% (sag.)	100%	BSP-1P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
4	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
5(3)(4)	Deepest ballast [4.2.1] item c		$T_{Bal\text{-}H}$	100% (hog.)	100%	FSM-2 BSR-1P/S OST-2P/S
				100% (hog.)	100%	BSP-1P/S BSR-1P/S OST-1S/S
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	HSM-1 OST-1P/S
7	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	HSM-1 OST-1P/S
8	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1S/S
9	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1S/S
10(2)	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100%(8) Max SFLC	FSM-2
					100%(9) Max SFLC	FSM-2
					100%	OST-2P/S
				0%	100%	BSP-1P/S OST-1P/S

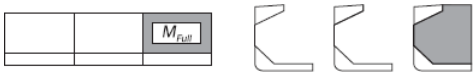
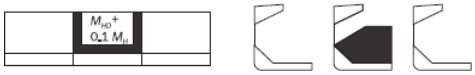
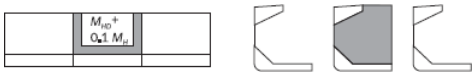
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
					100%[10] Max SFLC	HSM-1
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (hog.)	100%[8] Max SFLC	FSM-2 HSM-2
					100%[9] Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				0%	100%	BSP-1P/S
					100%[10] Max SFLC	HSM-1
12[2][5][6][13]	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S
13[2][5][6][13]	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S
14[7]	Heavy ballast [4.2.4]		$T_{BAL\text{-}H}$	0%	100%[10] Max SFLC	FSM-2 HSM-2
					100%	BSR-1P/S
				100% (sag.)	100%[8] Max SFLC	HSM-1
					100%[9] Max SFLC	HSM-1
					100%	BSR-1P/S
15[7]	Heavy ballast [4.2.4]		$T_{BAL\text{-}H}$	0%	100%	BSR-1P/S
				100% (sag.)	100%	BSR-1P/S
Harbour conditions						
16	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

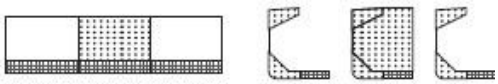
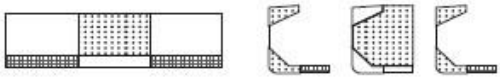
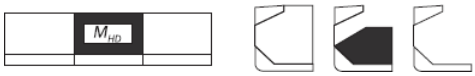
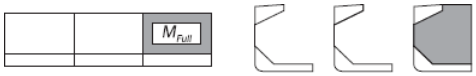
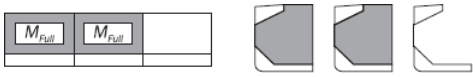
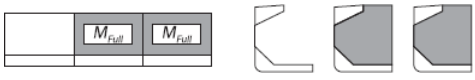
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
17	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
18	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100% (12) Max SFLC	N/A
					100% (13) Max SFLC	N/A
				100% (sag.)	100% (12) Max SFLC	N/A
					100% (13) Max SFLC	N/A
19(13)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
20(13)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

(1) Loading pattern No. 1 with the cargo mass MFull and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming MSW = 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is only required when this loading condition is included in the loading manual.
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(7) This condition is to be considered for the empty hold which is assigned as ballast hold, if any.
(8) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(9) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the midhold.
(10) This load combination is to be considered only for the mid-hold where $x_{b\text{-}aft} > 0.5L$ or $x_{b\text{-}fwd} < 0.5L$.
(11) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(12) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(13) This condition is only required when block loading condition is included in the loading manual.

FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) - midship cargo hold region **Table13**

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
Seagoing conditions						
1	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
2(1)	Full load [4.2.1]a		T_{SC}	50% (sag.)	100%	BSP-1P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
4(3)(4)	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	FSM-2, BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	100% (hog.)	100%(8) Max SFLC	FSM-2 HSM-2
					100%(9) Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				100% (sag.)	100%(10) Max SFLC	HSM-1
					100%	HSM-1
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S OST-1P/S
7	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S OST-1P/S
8	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	FSM-2, HSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S

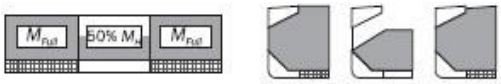
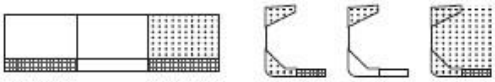
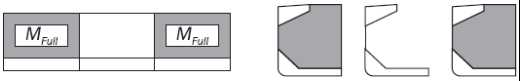
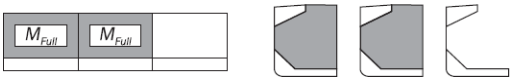
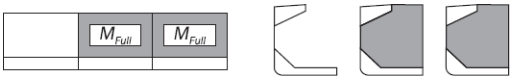
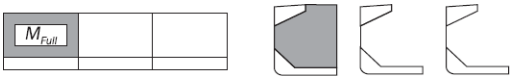
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
9	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	FSM-2, HSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
$10^{(2)}$	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100%(10) Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				0%	100%(10) Max SFLC	FSM-1 HSM-1
					100%(10) Max SFLC	FSM-1 HSM-1
					100%	BSP-1P/S OST-1P/S
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (sag.)	100%(10) Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				0%	100%(8) Max SFLC	HSM-1
					100%(9) Max SFLC	HSM-1
					100%	BSP-1P/S
$12^{(2)(5)(6)(13)}$	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 HSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S
$13^{(2)(5)(6)(13)}$	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 HSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S

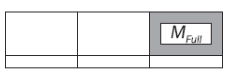
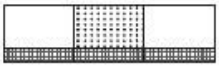
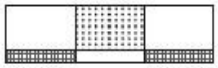
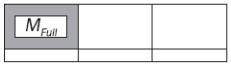
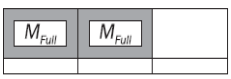
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
14[7]	Heavy ballast [4.2.4]		$T_{BAL\text{-}H}$	0%	100%[10] Max SFLC	FSM-2 HSM-2
					100%	BSR-1P/S
				100% (sag.)	100%[8] Max SFLC	HSM-1
					100%[9] Max SFLC	HSM-1
					100%	BSR-1P/S
15[7]	Heavy ballast [4.2.4]		$T_{BAL\text{-}H}$	0%	100%	BSR-1P/S
				100% (sag.)	100%	BSR-1P/S
Harbour conditions						
16[2]	Harbour condition [4.2.5] items a and b		T_{H4}	100% (hog.)	100%[11] Max SFLC	N/A
					100%[12] Max SFLC	N/A
				100% (sag.)	100%[11] Max SFLC	N/A
					100%[12] Max SFLC	N/A
17	Harbour condition [4.2.5] items a		$0.67T_{SC}$	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
18	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
19	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
20	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

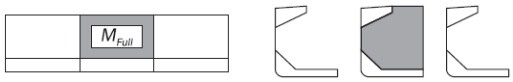
No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
21(13)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A
22(13)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A
				100% (sag.)	100%	N/A

(1) Loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW} =100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is only required when block loading condition is included in the loading manual.
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(7) This condition is to be considered for the heavy cargo hold which is assigned as ballast hold, if any.
(8) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(9) For the mid-hold, where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the mid- hold.
(10) This load combination is to be considered only for the mid-hold, where $x_{b\text{-}aft} > 0.5L$ or $x_{b\text{-}fwd} < 0.5L$.
(11) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(12) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(13) This condition is only required when block loading condition is included in the loading manual.

FE Load combinations applicable for BC-B & BC-C - midship cargo hold region Table 14

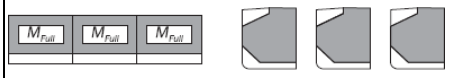
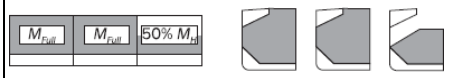
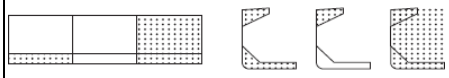
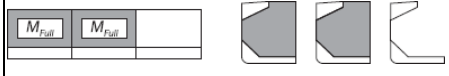
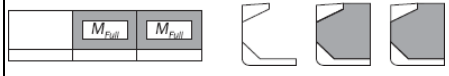
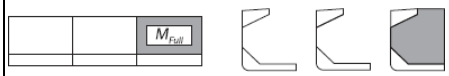
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
Seagoing conditions						
1(1)(3)	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
2(2)	Full load [4.2.1]a		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/S
4(4)(5)	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	FSM-2, BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	100% (hog.)	100%(7) Max SFLC	FSM-2 HSM-2,
					100%(8) Max SFLC	FSM-2 HSM-2
					100%	OST-2P/S
				100% (sag.)	100%(9) Max SFLC	HSM-1
					100%	BSP-1P/S OST-1P/S
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S OST-1P/S
7	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S OST-1P/S
8	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	FSM-2 HSM-2 BSR-1P/S OST-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S

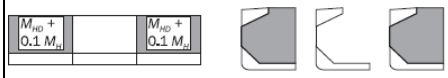
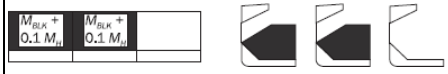
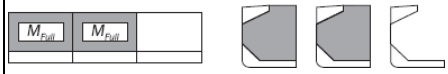
No.	Description Req^{t} ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
9	Multiport 4 [4.2.2] item d					$0.75T_S$	100% (hog.)	100%	FSM-2 HSM-2 BSR-1P/S OST-2P/S
							100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
10	Heavy ballast [4.2.4]					$T_{BAL\text{-}H}$	0%	100%$^{(9)}$ Max SFLC	FSM-2 HSM-2
								100%	BSR-1P/S
							100% (sag.)	100%$^{(7)}$ Max SFLC	HSM-1
								100%$^{(8)}$ Max SFLC	HSM-1
								100%	BSR-1P/S
11$^{(6)}$	Heavy ballast [4.2.4]a					$T_{BAL\text{-}H}$	0%	100%	BSR-1P/S
							100% (sag.)	100%	BSR-1P/S
Harbour conditions									
12	Harbour condition [4.2.5] items a					$0.67T_{SC}$	100% (hog.)	100%	N/A
							100% (sag.)	100%	N/A
13	Harbour condition [4.2.5] item a					$0.67T_{SC}$	100% (hog.)	100%	N/A
							100% (sag.)	100%	N/A
14	Harbour condition [4.2.5] items a and c					T_{H1}	100% (hog.)	100%	N/A
							100% (sag.)	100%	N/A
15	Harbour condition [4.2.5] items a and c					T_{H1}	100% (hog.)	100%	N/A
							100% (sag.)	100%	N/A

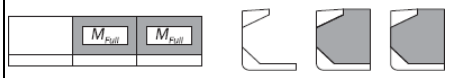
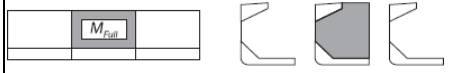
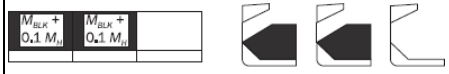
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
16	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100%(10) Max SFLC	N/A
					100%(11) Max SFLC	N/A
				100% (sag.)	100%(10) Max SFLC	N/A
					100%(11) Max SFLC	N/A

(1) Applicable to BC-B only.
(2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3] can be analysed in lieu of this loading pattern.
(3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure.
(4) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.
(5) Position of ballast hold is to be adjusted as appropriate.
(6) This condition is to be considered for the cargo hold which is assigned as ballast hold, if any.
(7) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(8) For the mid-hold where $x_{b\text{-}aft} \leq 0.5L$ and $x_{b\text{-}fwd} \geq 0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(9) This load combination is to be considered only for the mid-hold where $x_{b\text{-}aft} > 0.5L$ or $x_{b\text{-}fwd} < 0.5L$.
(10) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(11) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

FE Load combinations applicable to empty hold in alternate condition of BC-A (EA) - outside midship cargo hold region **Table15**

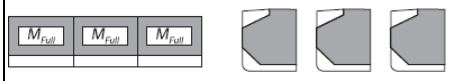
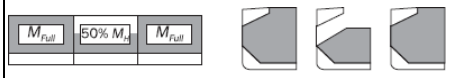
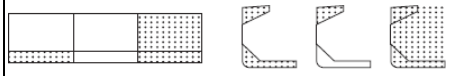
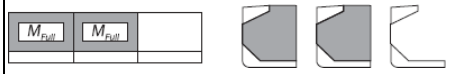
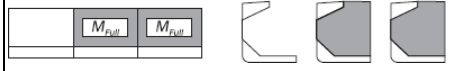
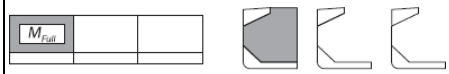
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
						aft region	forward region
Seagoing conditions							
1[2]	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	BSP-1P/1S OST-1P/1S OSA-1P/1S	HSM-1 BSP-1P/1S OST-1P/1S OSA-2P/S
2[1]	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	BSP-1P/1S	BSP-1P/1S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/1S	BSP-1P/1S
4	Slack load [4.2.1] item b		T_{SC}	0%	100%	BSP-1P/1S	BSP-1P/1S
5[3][4]	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-2 HSA-2 BSR-1P/1S OST-2P/S	FSM-2 BSP-1P/1S BSR-1P/1S OSA-2P/S
				100% (sag.) [10]	100%	HSM-1 BSP-1P/1S	HSM-1 BSP-1P/1S BSR-1P/1S OSA-2P
6[5]	Multiport 3 [4.2.2] item c		0.67 T_{SC}	100% (sag.)	100%	HSM-1 OST-1P/1S	HSM-1 OST-1P/1S
7[5]	Multiport 3 [4.2.2] item c		0.67T_{SC}	100% (sag.)	100%	HSM-1 OST-1P/1S	BSP-1P/1S OSA-2P/S
8[5]	Multiport 4 [4.2.2] item d		0.75 T_{SC}	100% (hog.)	100%	HSM-2 OST-2P/S	HSM-2 BSR-1P/1S OST-2P/S
				100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/1S OST-1P/1S	HSM-1 BSP-1P/1S OST-1P/1S
9[5]	Multiport 4 [4.2.2] item d		0.75T_{SC}	100% (hog.)	100%	HSM-2 OST-2P/S	HSM-2 OST-2P/S
				100% (sag.)	100%	HSM-1 FSM-1 BSP-	HSM-1 BSP-1P/1S BSR-1P/1S

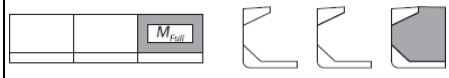
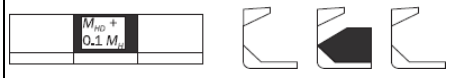
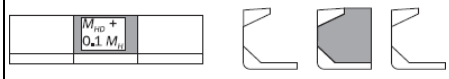
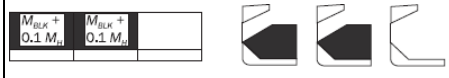
No.	Description Req^{t} ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
						aft region	forward region
						1P/1S OST-1P/1S	OST-1P/1S
10(2)	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100% Max SFLC	FSM-2, HSM-2	FSM-2, HSM-2
					100%	BSP-1P/1S OST-2P/S OSA-1P/1S	BSP-1P/1S BSR-1P/1S OST-2P/S OSA-2P/S
				0%	100%	BSP-1P/1S OST-2P/S OSA-1P/1S	BSP-1P/1S OST-2P/S
					100% Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (hog.)	100% Max SFLC	HSM-2 FSM-2	HSM-2 FSM-2
					100%	BSP-1P/S OST-2P/S	BSP-1P/S BSR-1P/S OST-2P/S OSA-2P/S
				0%	100%	BSP-P/1S	HSA-1 BSP-1P/S
					100% Max SFLC	HSM-1 FSM-1	HSM-1 FSM-1
12(2) (6)(7) (11)	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 BSP-1P/S OST-2P/S	FSM-2 BSP-1P/S OSA-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S	HSM-1 BSP-1P/S OSA-2P/S
13(2) (6)(7) (11)	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 BSP-1P/S OST-2P/S	FSM-2 BSP-1P/S OSA-2P/S OST-1P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S	HSM-1 BSP-1P/S OSA-2P/S
Harbour conditions							
14	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A

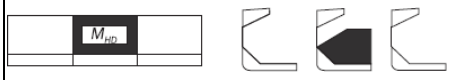
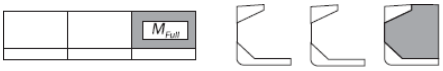
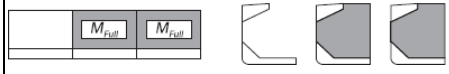
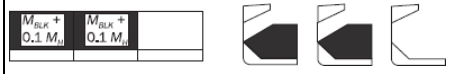
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
						aft region	forward region
15	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
16	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100%(8) Max SFLC	N/A	N/A
					100%(9) Max SFLC	N/A	N/A
				100% (sag.)	100%(8) Max SFLC	N/A	N/A
					100%(9) Max SFLC	N/A	N/A
17(11)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
18(11)	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A

(1) Loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is not required when {no MP} notation is assigned.
(6) This condition is only required when this loading condition is included in the loading manual.
(7) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(8) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(9) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(10) This loading condition is required only when the ballast hold is located inside the cargo hold model.
(11) This condition is only required when block loading condition is included in the loading manual.

FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) - outside midship cargo hold region **Table 16**

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case	
						Aft Region	Forward region
Seagoing conditions							
1	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	HSM-1 HSA-1 BSP-1P/S OSA-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
2(1)	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	N/A	BSP-1P/S OSA-2P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	HSM-2 HSA-1 BSP-1P/S OSA-1P/S	HSM-1 HSA-1 FSM-2 BSP-1P/S
4(3) (4)	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-2 FSM-2 OST-2P/S	HSM-2
				100% (sag.)	100%	HSM-1 FSM-1 OST-1P/S OSA-2P/S	HSM-1 HSA-1 FSM-1 BSP-1P/S OSA-2P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	100% (hog.)	100% Max SFLC	HSM-2	N/A
					100%	BSP-1P/S	BSP-1P/S
				100% (sag.)	100%	BSP-1P/S	HSA-1 BSR-1P/S
					100% Max SFLC	HSM-1	N/A
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S BSR-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
7	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S	HSM-1
8	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 FSM-2 BSR-1P/S BSP-1P/S OSA-1P/S OST-2P/S	FSM-2 BSR-2P/S OSA-2P/S
				100% (sag.)	100%	BSR-1P/S BSP-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S

No.	Description Req[1] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case	
						Aft Region	Forward region
9	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 BSR-1P/S OST-2P/S	FSM-2 BSR-1P/S BSR-2P/S
				100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S BSR-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S BSR-2P/S OST-1P/S
10(2)	Alternate load partial [4.2.3] items a and b		T_{SC}	100% (hog.)	100%	HSA-2 BSP-1P/S OSA-1P/S OST-2P/S	BSP-1P/S OSA-2P/S OST-2P/S
					100% Max SFLC	HSM-2 FSM-2	FSM-2
				0%	100% Max SFLC	HSM-1 FSM-1	HSM-1
					100%	BSP-1P/S OSA-1P/S	BSP-1P/S BSR-2P/S OSA-1P/S OSA-2P/S
11	Alternate load full [4.2.3] items a and c		T_{SC}	100% (hog.)	100%	HSA-2 BSP-1P/S OSA-1P/S	OSA-1P/S OSA-2P/S
					100% Max SFLC	N/A	FSM-2, HSM-2
				0%	100% Max SFLC	HSM-1	HSM-1
					100%	BSP-1P/S OSA-1P/S	OSA-1P/S OST-2P/S
12(2) (5)(6) (9)	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	HSA-2 FSM-2 BSP-1P/S OSA-1P/S OST-2P/S	HSM-2 FSM-2 BSP-1P/S OSA-2P/S
				100% (sag.)	100%	HSM-1 BSP-1P/S OSA-1P/S OST-1P/S	HSM-1 BSP-1P/S OSA-2P/S

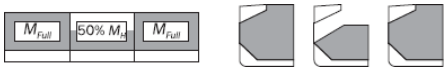
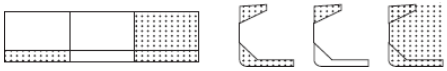
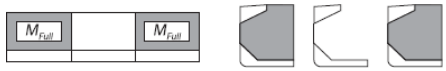
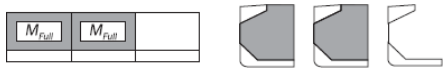
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case	
						Aft Region	Forward region
13[(2)(5)(6)(9)]	Alt-block load [4.2.3] item d		T_{SC}	100% (hog.)	100%	FSM-2 BSP-1P/S	HSM-2 FSM-2 BSP-1P/S OSA-2P/S OST-2P/S
				100% (sag.)	100%	HSM-1 HSA-1 FSM-1 BSP-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
Harbour conditions							
14[(2)]	Harbour condition [4.2.5] items a and b		T_{H4}	100% (hog.)	100%[(7)] Max SFLC	N/A	N/A
					100%[(8)]Max SFLC	N/A	N/A
				100% (sag.)	100% Max SFLC	N/A	N/A
					100%[(8)]Max SFLC	N/A	N/A
15	Harbour condition [4.2.5] item a		0.67 T_{SC}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
16	Harbour condition [4.2.5] item a		0.67 T_{SC}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
17	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
18	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
19[(9)]	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
20[(9)]	Alt-block harbour condition [4.2.3] item d		T_{H3}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A

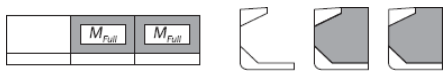
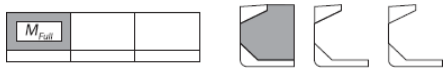
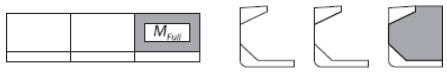
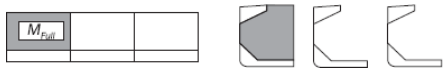
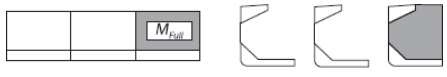
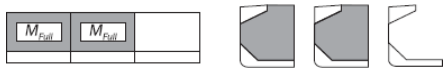
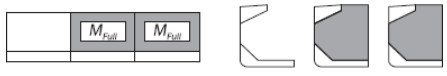
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case	
						Aft Region	Forward region

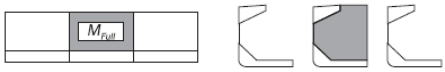
(1) Loading pattern No. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is only required when this loading condition is included in the loading manual.
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(7) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(8) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(9) This condition is only required when block loading condition is included in the loading manual.

FE Load combinations applicable for BC-B & BC-C - outside midship cargo hold region

Table 17

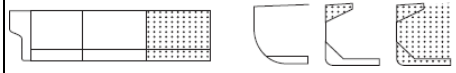
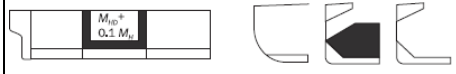
No.	Description Req^{t} ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
						Aft Region	Aft Region
Seagoing conditions							
1[(1)(3)]	Full load [4.1.3]		T_{SC}	50% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S OSA-1P/S OST-1P/S OST-2P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
2[(2)]	Full load [4.2.1] item a		T_{SC}	50% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S OSA-1P/S OST-1P/S OST-2P/S	HSM-1 HSA-1 FSM-2 BSP-1P/S OST-2P/S
3	Slack load [4.2.1] item b		T_{SC}	0%	100%	HSM-1 HSM-2 HSA-1 FSM-2 BSP-1P/S OSA-1P/S OST-2P/S	HSM-1 HSA-1 FSM-2 BSP-1P/S OST-2P/S
4[(4)(5)]	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-2 FSM-2 OST-2P/S	HSM-2
				100% (sag.)	100%	HSM-1 FSM-1 OSA-2P/S OST-1P/S	HSM-1 HSA-1 FSM-1 BSP-1P/S OSA-2P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	100% (hog.)	100% Max SFLC	HSM-2	N/A
					100%	BSP-1P/S	BSP-1P/S
				100% (sag.)	100%	BSP-1P/S	HSA-1 BSR-1P/S
					100% Max SFLC	HSM-1	N/A
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	BSP-1P/S BSR-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S

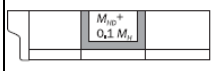
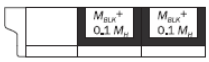
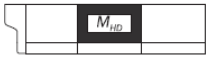
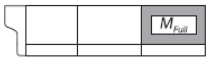
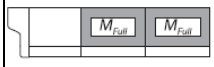
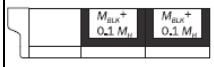
No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
						Aft Region	Aft Region
7	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S OST-1P/S	HSM-1 BSP-1P/S
8	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 FSM-2 BSP-1P/S BSR-1P/S OSA-1P/S OST-2P/S	HSM-2 FSM-2 BSR-2P/S OSA-2P/S
				100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S OSA-2P/S
9	Multiport 4 [4.2.2] item d		$0.75T_{SC}$	100% (hog.)	100%	HSM-2 BSR-1P/S OST-2P/S	FSM-2 BSR-1P/S BSR-2P/S
				100% (sag.)	100%	HSM-1 FSM-1 BSP-1P/S BSR-1P/S OST-1P/S	HSM-1 HSA-1 BSP-1P/S BSR-2P/S OST-1P/S
Harbour conditions							
10	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
11	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
12	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A
13	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%	N/A	N/A
				100% (sag.)	100%	N/A	N/A

No.	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case	
						Aft Region	Aft Region
14	Harbour condition [4.2.5] items a and c		T_{H1}	100% (hog.)	100%(6) Max SFLC	N/A	N/A
					100%(7) Max SFLC	N/A	N/A
				100% (sag.)	100%(6) Max SFLC	N/A	N/A
					100%(7) Max SFLC	N/A	N/A

(1) Applicable to BC-B only.
(2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3] can be analysed in lieu of this loading pattern.
(3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure.
(4) In case of no ballast hold, normal ballast condition with assuming M_{SW} = 100% (hog.) is to be analysed.
(5) Position of ballast hold is to be adjusted as appropriate.
(6) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

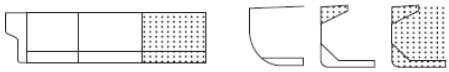
FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) – aftmost cargo hold **Table 18**

No.	Description Req[t] ref	Loading patten Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic [7] load case
Seagoing conditions						
1[2]	Full load [4.1.3]		T_{SC}	80% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
2[1]	Full load [4.2.1] item a		T_{SC}	80% (sag.)	100%	FSM-1
3	Slack load [4.2.1] item c		T_{SC}	100% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
4[3] [4]	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-2, FSM-1 BSP-1P/S BSR-1P/S OST-1P/S OST-2P/S OSA-1P/S
5	Multiport 2 [4.2.2] item b		$0.83T_{SC}$	30% (hog.)	100%	FSM-1, OSA-1P/S
				30% (sag.)	100%	FSM-1 BSP-1P/S
6	Multiport 3 [4.2.2] item c		$0.67T_{SC}$	50% (sag.)	100%	BSP-1P/S OST-1P/S
7[2]	Alternate load partial [4.2.3] items a and b		T_{SC}	50% (hog.)	100% Max SFLC	HSM-2
					100%	BSP-1P/S OSA-1P/S
				0%	100% Max SFLC	FSM-1
					100%	BSP-1P/S OST-1P/S OSA-1P/S

No.	Description Req[t] ref	Loading patten	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic (7) load case
8	Alternate load full [4.2.3] items a and c					T_{SC}	50% (hog.)	100% Max SFLC	HSM-2, FSM-2
								100%	BSP-1P/S, OSA-1P/S
							0%	100% Max SFLC	HSM-1
								100%	BSP-1P/S OST-1P/S OSA-1P/S
9(2) (5) (6)	Alt-block load [4.2.3] item d					T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
Harbour conditions									
10	Harbour condition [4.2.5] items a and b					T_{H4}	100% (hog.)	100%	N/A
							50% (hog.)	100%(7)Max SFLC	N/A
								100%(8)Max SFLC	N/A
11	Harbour condition [4.2.5] item a					$0.67T_{SC}$	50% (hog.)	100%	N/A
							100% (sag.)	100%	N/A
12	Harbour condition [4.2.5] items a and c					T_{H1}	50% (hog.)	100%	N/A
							50% (sag.)	100%	N/A
13(9)	Alt-block harbour condition [4.2.3] item d					T_{H3}	50% (hog.)	100%	N/A
							50% (sag.)	100%	N/A

(1) Loading pattern no. 1 with the cargo mass M_H and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW}= 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is only required when this loading condition is included in the loading manual.
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(7) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(8) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(9) This condition is only required when block loading condition is included in the loading manual.

FE Load combinations applicable for BC-B & BC-C - aftmost cargo hold Table 19

No	Description Req[t]ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
Seagoing conditions						
1(1)(3)	Full load [4.1.3]		T_{SC}	80% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S OSA-1P/S
2(2)	Full load [4.2.1] item a		T_{SC}	80% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
3	Slack load [4.2.1]b		T_{SC}	100% (sag.)	100%	FSM-1 BSP-1P/S OST-1P/S
4(4)(5)	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-2, FSM-1 BSP-1P/S BSR-1P/S OST-1P/S OST-2P/S OSA-1P/S
5	Multiport 2 [4.2.2] item b		0.83T_{SC}	30% (sag.)	100%	FSM-1 BSR-1P/S OSA-1P/S
				30% (hog.)	100%	FSM-1, OST-1P/S
6	Multiport 3 [4.2.2] item a		0.67T_{SC}	60% (hog.)	100%	BSP-1P/S
					100% Max SFLC	HSM-2
				0%	100% Max SFLC	HSM-1
7	Multiport 3 [4.2.2] item c		0.67T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
Harbour conditions						
8	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100%	N/A
				50% (hog.)	100%(6) Max SFLC	N/A
					100%(7) Max SFLC	N/A
9	Harbour condition [4.2.5] items a		0.67T_{SC}	50% (hog.)	100%	N/A
				50% (sag.)	100%	N/A
10	Harbour condition [4.2.5] items a and c		T_{H1}	50% (hog.)	100%	N/A
				50% (sag.)	100%	N/A

No	Description Req^{t}ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
(1) Applicable to BC-B only. (2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3] can be analysed in lieu of this loading pattern. (3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure. (4) In case of no ballast hold, normal ballast condition with assuming M_{SW}= 100% (hog.) is to be analysed. (5) Position of ballast hold is to be adjusted as appropriate. (6) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold. (7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold									

FE Load combinations applicable to loaded hold in alternate condition of BC-A (FA) – foremost cargo hold **Table 20**

No	Description Req[t] ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic[(7)] load case
Seagoing conditions						
1[(2)]	Full load [4.1.3]		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S OSA-2P/S
2[(1)]	Full load [4.2.1] item a		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
3	Slack load [4.2.1] item b		T_{SC}	100% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
4[(3)(4)]	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-1, HSM-2 BSP-1P/S BSR-1P/S OSA-2P/S
5	Multiport2 [4.2.2] item b		$0.83T_{SC}$	60% (sag.)	100%	HSM-1, FSM-1 BSP-1P/S OSA-2P/S
6	Multiport3 [4.2.2] item c		$0.67T_{SC}$	60% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
7	Multiport3 [4.2.2] item a		$0.67T_{SC}$	60% (hog.)	100%	FSM-2
(2)	Alternate load partial [4.2.3] items a and b		T_{SC}	60% (hog.)	100%	BSP-1P/S OST-2P/S OSA-2P/S
					100%Max SFLC	HSM-2
				0%	100%Max SFLC	HSM-1
					100%	BSP-1P/S OSA-2P/S
9	Alternate load full [4.2.3] items a and c		T_{SC}	60% (hog.)	100%	BSP-1P/S OST-2P/S OSA-2P/S
					100%Max SFLC	HSM-2
				0%	100%Max SFLC	HSM-1
					100%	BSP-1P/S OSA-2P/S

No	Description Req't ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic(7) load case
10(2)(5)(6)(9)	Alt-block load [4.2.3] item d		T_{SC}	50% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
Harbour conditions						
11(2)	Harbour condition [4.2.5] items a and b		T_{H4}	100% (hog.)	100%	N/A
				50% (sag.)	100%(7) Max SFLC	N/A
					100%(8) Max SFLC	N/A
12	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (sag.)	100%	N/A
13	Harbour condition [4.2.5] items a and c		T_{H1}	50% (hog.)	100%	N/A
14(9)	Alt-block harbour condition [4.2.3] item d		T_{H3}	50% (hog.)	100%	N/A

(1) Loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.4] can be analysed in lieu of this loading pattern.
(2) Maximum cargo density as defined in [4.1.4] is to be used for calculation of dry cargo pressure.
(3) In case of no ballast hold, normal ballast condition with assuming M_{SW}= 100% (hog.) is to be analysed.
(4) Position of ballast hold is to be adjusted as appropriate.
(5) This condition is only required when this loading condition is included in the loading manual.
(6) Actual still water vertical bending moment, as given in the loading manual, may be used instead of design value.
(7) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(8) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(9) This condition is only required when block loading condition is included in the loading manual.

FE Load combinations applicable for BC-B & BC-C - foremost cargo hold Table 21

No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
Seagoing conditions						
1(1)(3)	Full load [4.1.3]		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S OSA-2P/S
2(2)	Full load [4.2.1] item a		T_{SC}	60% (sag.)	100%	HSM-1 BSP-1P/S OST-1P/S OSA-2P/S
3	Slack load [4.2.1] item b		T_{SC}	100% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
4(4)(5)	Deepest ballast [4.2.1] item c		$T_{BAL\text{-}H}$	100% (hog.)	100%	HSM-1, HSM-2 BSP-1P/S BSR-1P/S OSA-2P/S
5	Multiport2 [4.2.2] item b		$0.83T_{SC}$	60% (sag.)	100%	HSM-1, FSM-1 BSP-1P/S OSA-2P/S
6	Multiport3 [4.2.2] item c		$0.67T_{SC}$	60% (sag.)	100%	HSM-1 BSP-1P/S OSA-2P/S
7	Multiport3 [4.2.2] item a		$0.67T_{SC}$	60% (hog.)	100%	BSP-1P/S OST-2P/S OSA-2P/S
					100% Max SFLC	HSM-2
				0%	100% Max SFLC	HSM-1
Harbour conditions						
8	Harbour condition [4.2.5] items a and b		T_{H2}	100% (hog.)	100%	N/A
				50% (hog.)	100%(6) Max SFLC	N/A
					100%(7) Max SFLC	N/A

No.	Description Req^t ref	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF	Dynamic load case
Seagoing conditions						
9	Harbour condition [4.2.5] item a		$0.67T_{SC}$	100% (sag.)	100%	N/A
10	Harbour condition [4.2.5] items a and c		T_{H1}	50% (hog.)	100%	N/A

(1) Applicable to BC-B only.
(2) For BC-B ships, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in [4.1.3] can be analysed in lieu of this loading pattern.
(3) Maximum cargo density as defined in [4.1.3] is to be used for calculation of dry cargo pressure.
(4) In case of no ballast hold, normal ballast condition with assuming M_{Sw} = 100% (hog.) is to be analysed.
(5) Position of ballast hold is to be adjusted as appropriate.
(6) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

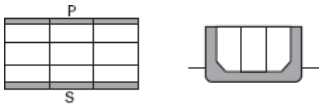
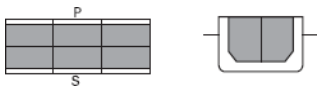
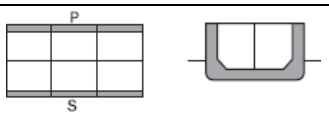
5 STANDARD LOADING CONDITIONS FOR FATIGUE ASSESSMENT

5.1 Oil tanker

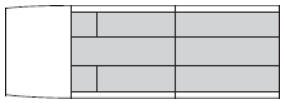
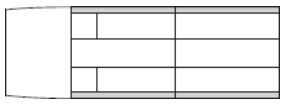
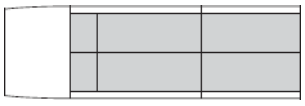
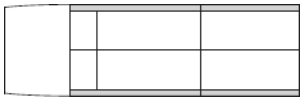
5.1.1

The standard loading conditions to be applied to oil tankers for fatigue assessment as required in Ch 9, Sec 1, [6.2], are defined in Table 22 to Table 24. Where fuel oil tanks, other oil tanks or fresh water tanks are arranged in way of the cargo hold region, the filling level of them are to be taken as full for both simplified stress analysis according to Ch 9, Sec 4 and direct strength analysis according to Ch 7 and Ch 9, Sec 5.

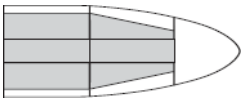
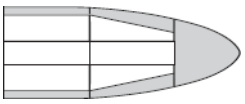
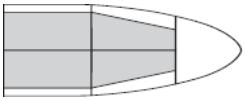
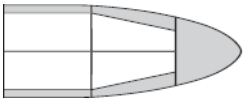
Standard design FE loading conditions for fatigue assessment of oil tankers except for foremost and aftmost cargo holds **Table 22**

No.	Description	Loading pattern	Still water loads			Dynamic load cases
			Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	
Oil tankers with two oil-tight bulkheads						
A1-F	Full load		T_{SC}	60% (sag.)		All
A2-F	Normal ballast		T_{BAL}	80% (hog.)		All
Oil tankers with centreline oil-tight bulkhead						
B1-F	Full load		T_{SC}	60% (sag.)		All
B2-F	Normal ballast		T_{BAL}	80% (hog.)		All
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.						

Standard design FE loading conditions for fatigue assessment of oil tankers for aftmost cargo hold **Table 23**

No.	Description	Loading pattern	Still water loads			Dynamic load cases
			Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	
Oil tankers with two oil-tight bulkheads						
A1-F	Full load		T_{SC}	60% (sag.)		All
A2-F	Normal ballast		T_{BAL}	80% (hog.)		All
Oil tankers with centreline oil-tight bulkhead						
B1-F	Full load		T_{SC}	60% (sag.)		All
B2-F	Normal ballast		T_{BAL}	80% (hog.)		All
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.						

Standard design FE loading conditions for fatigue assessment of oil tankers for foremost cargo hold **Table 24**

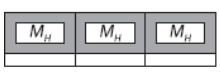
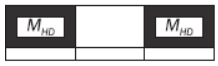
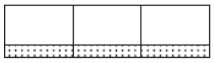
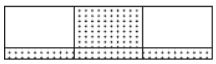
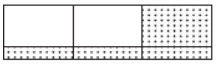
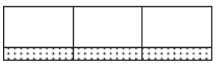
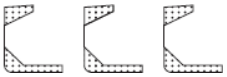
No.	Description	Loading pattern	Still water loads			Dynamic load cases
			Draught	$C_{BM\text{-}LC}$: % of perm. SWBM	$C_{SF\text{-}LC}$: % of perm. SWSF (1)	
Oil tankers with two oil-tight bulkheads						
A1-F	Full load		T_{SC}	60% (sag.)		All
A2-F	Normal ballast		T_{BAL}	80% (hog.)		All
Oil tankers with centreline oil-tight bulkhead						
B1-F	Full load		T_{SC}	60% (sag.)		All
B2-F	Normal ballast		T_{BAL}	80% (hog.)		All
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.						

5.2 Bulk carriers

5.2.1

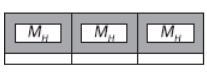
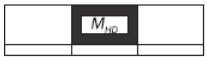
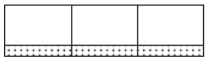
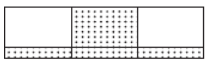
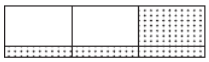
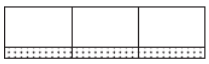
The standard loading conditions to be applied to bulk carriers for fatigue assessment as required in Ch 9, Sec 1, [6.3] are defined in Table 25, to Table 31 according to their additional service feature notations and the location of the assessed details. Where fuel oil tanks, other oil tanks or fresh water tanks are arranged in way of the cargo hold region, the filling level of them are to be taken as full for both simplified stress analysis according to Ch 9, Sec 4 and direct strength analysis according to Ch 7 and Ch 9, Sec 5.

Standard design FE Load combinations for fatigue assessment applicable to empty hold of BC-A in alternate condition (EA) - cargo hold region except aftmost and foremost cargo Holds **Table 25**

No.	Description Req^{t} ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous					T_{SC}	40% （sag.）		All
2-F(2)	Full load alternate					T_{SC}	75% （hog.）	100%	All
3-F(1)	Normal ballast					T_{BAL}	80% （hog.）		All
4-F (2) (3)	Heavy ballast					$T_{BAL\text{-}H}$	75% （sag.）	100%	All
5-F (2) (4)						$T_{BAL\text{-}H}$	45% （hog.）	100%	All
6-F (1) (5)						$T_{BAL\text{-}H}$	45% （hog.）		All

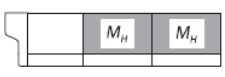
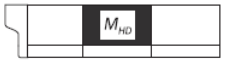
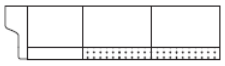
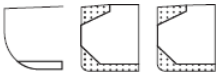
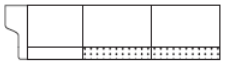
(1) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.
Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is to be considered for empty cargo hold which is assigned as ballast hold, if any
(4) This condition is applicable when the WB hold corresponds to the forward or aft hold of the 3 hold model.
(5) This condition is applicable when the WB hold is located outside the 3 cargo hold model

Standard design FE Load combinations for fatigue assessment applicable to loaded hold of BC-A in alternate condition (FA) - cargo hold region except aftmost and foremost cargo Holds **Table 26**

No.	Description Reqt ref	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous					T_{SC}	40% （sag.）		All
2-F(2)	Full load alternate					T_{SC}	75% （hog.）	100%	All
3-F(1)	Normal ballast					T_{BAL}	80% （hog.）		All
4-F (2) (3)	Heavy ballast					$T_{BAL\text{-}H}$	75% （sag.）	100%	All
5-F (2) (4)						$T_{BAL\text{-}H}$	45% （hog.）	100%	All
6-F (1) (5)						$T_{BAL\text{-}H}$	45% （hog.）		All

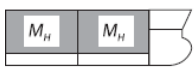
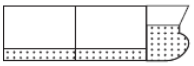
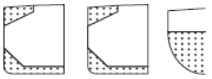
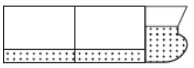
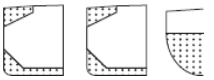
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used. Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is to be considered for loaded cargo hold which is assigned as ballast hold, if any
(4) This condition is applicable when the WB hold corresponds to the forward or aft hold of the 3 hold model.
(5) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

Standard design FE Load combinations for fatigue assessment applicable to loaded hold of BC-A in alternate condition (FA) - Aftmost cargo hold Table 27

No.	Description	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous					T_{SC}	40% (sag.)		All
2-F(2)	Full load alternate					T_{SC}	75% (hog.)	100%	All
3-F(1)	Normal ballast					T_{BAL}	80% (hog.)		All
4-F(1)(3)	Heavy ballast					$T_{BAL\text{-}H}$	45% (hog.)		All

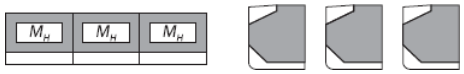
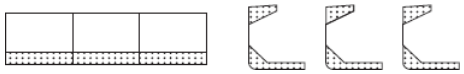
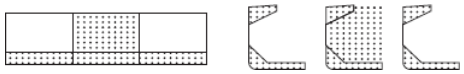
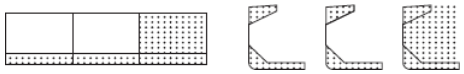
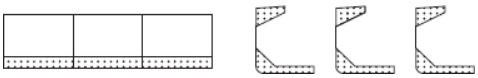
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

Standard design FE Load combinations for fatigue assessment applicable to loaded hold of BC-A in alternate condition (FA) - Foremost cargo hold Table 28

No.	Description	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous					T_{SC}	40% （sag.）		All
2-F(2)	Full load alternate					T_{SC}	75% （hog.）	100%	All
3-F(1)	Normal ballast					T_{BAL}	80% （hog.）		All
4-F(1)(3)	Heavy ballast					$T_{BAL\text{-}H}$	45% （hog.）		All

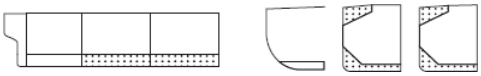
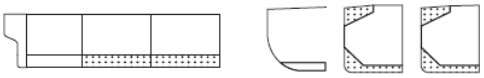
(1) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used. Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

Standard design FE load combinations for fatigue assessment of BC-B, BC-C bulk carriers – cargo hold region except aftmost and foremost cargo holds Table 29

No.	Description	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous		T_{SC}	40% （sag.）		All
2-F(2)	Normal ballast		T_{BAL}	80% （hog.）		All
-F(2)(3)	Heavy ballast		$T_{BAL\text{-}H}$	75% （sag.）	100%	All
4-F(2)(4)			$T_{BAL\text{-}H}$	45% （hog.）	100%	All
5-F(1)(2)			$T_{BAL\text{-}H}$	45% （hog.）		All

(1) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.
(2) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.
Where this shear force exceeds the target value, the correction of vertical loads is to be applied to adjust the shear force down to the target value.
(3) This condition is to be considered for cargo hold which is assigned as ballast hold, if any.
(4) This condition is applicable when the WB hold corresponds to the forward or aft hold of the 3 hold model.
(5) This condition is applicable when the WB hold is located outside the 3 cargo hold model.

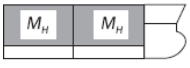
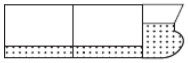
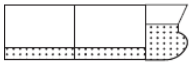
Standard design FE load combinations for fatigue assessment of BC-B, BC-C bulk carriers – Aftmost cargo hold Table 30

No.	Description	Loading pattern Aft Mid Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F (1)	Full load homogeneous		T_{SC}	40% (sag.)		All
2-F (1)	Normal ballast		T_{BAL}	80% (hog.)		All
3-F (1)	Heavy ballast		$T_{BAL\text{-}H}$	45% (hog.)		All

(1) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.

Standard design FE load combinations for fatigue assessment of BC-B, BC-C bulk carriers

Foremost cargo hold **Table 31**

No.	Description	Loading pattern	Aft	Mid	Fore	Draught	$C_{BM\text{-}LC}$:% of perm. SWBM	$C_{SF\text{-}LC}$:% of perm. SWSF	Dynamic load case
1-F(1)	Full load homogeneous					T_{SC}	40% (sag.)		All
2-F(1)	Normal ballast					T_{BAL}	80% (hog.)		All
3-F(1)	Heavy ballast					$T_{BAL\text{-}H}$	45% (hog.)		All

(1) The actual shear force curve that results from the application of static and dynamic local loads to the FE model are to be used.

Appendix 1 HOLD MASS CURVES

SYMBOLS

h : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline, in m.

h_a : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the aft cargo hold of two adjacent cargo holds, in m.

h_f : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the fore cargo hold of two adjacent cargo holds, in m.

M_H : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_{Full} : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_{HD} : Cargo mass, in t, as defined in Ch 4, Sec 6.

M_{BLK} : The maximum cargo mass in a cargo hold of two adjacent cargo holds according to the block loading condition in the loading manual, in t.

T_i : In loading condition No. i, draught, in m, at mid-hold position of single cargo hold length or at mid- length of the two adjacent cargo holds considered.

T_{min} : $0.75T_{SC}$ or draught in ballast conditions with the two adjacent cargo holds empty, whichever is greater, in m.

T_{H1} : Minimum permissible draught, in m, in harbour condition with M_{Full} in each of the two adjacent holds to be taken as:

- For ships having {No MP} notation assigned:

$$T_{H1} = \min \begin{cases} 0.67T_{SC} \\ T_{SC} - \dfrac{0.15\sum M_{Full}}{1.025\left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right)} \end{cases}$$

- For ships not having {No MP} notation assigned:

$$T_{H1} = 0.67T_{SC} - \frac{0.15\sum M_{Full}}{1.025\left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right)}$$

T_{H2} : Minimum permissible draught, in m, in harbour condition with M_{Full} in EA holds of BC-A ships or with M_{Full} in any holds of BC-B and BC-C ships to be taken as:

- For ships having {No MP} notation assigned:

$$T_{H2} = \min \begin{cases} 0.67T_{SC} \\ T_{SC} - \dfrac{0.15M_{Full}}{1.025\dfrac{V_H}{h}} \end{cases}$$

- For ships not having {No MP} notation assigned:

$$T_{H2} = 0.67T_{SC} - \frac{0.15M_{Full}}{1.025\dfrac{V_H}{h}}$$

T_{H3} : Minimum permissible draught, in m, in harbour condition in case of block loading with M_{BLK} in each of the two adjacent holds of BC-A ships to be taken as:

$$T_{H3} = T_{SC} - \frac{\sum\left(0.15M_{BLK} + 0.1M_H\right)}{1.025\left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right)}$$

T_{H4} : Minimum permissible draught, in m, in harbour condition with M_{HD} in FA holds of BC-A ships to be taken as:

$$T_{H4} = \min \begin{cases} 0.67T_{SC} \\ T_{SC} - \dfrac{0.15M_{HD} + 0.1M_H}{1.025\dfrac{V_H}{h}} \end{cases}$$

V_H : Volume in m^3, as defined in Ch 4, Sec 6.

V_a : Volume of the after cargo hold of two adjacent cargo holds excluding volume of the hatchway part, in m^3.

V_f : Volume of the forward cargo hold of two adjacent cargo holds excluding volume of the hatchway part, in m^3.

Σ : The sum of masses of two adjacent cargo holds.

E_A : Empty hold in alternate loading condition.

F_A : Full hold in alternate loading condition.

1 GENERAL

1.1 Application

1.1.1

The requirements of this appendix apply to bulk carriers having a freeboard length L_{LL} of 150 m or above.

1.1.2

This appendix describes the procedure to be used for determination of:

- The maximum and minimum mass of cargo in each cargo hold as a function of the draught at mid-hold position of cargo hold.
- The maximum and minimum mass of cargo in any two adjacent holds as a function of the draught at mid-length of these two adjacent cargo holds.

1.1.3 General

The cargo mass curves of single cargo hold or of two adjacent cargo holds in seagoing and harbour conditions as defined in [2] and [3] are based on the loading conditions considered in Ch 4, Sec 8, [4.2]. However if the ship structure is checked for more severe loading conditions than the ones considered in Ch 4, Sec 8, [4.2.7], the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

1.1.4 Loading/unloading conditions in harbour

For any bulk carrier, the maximum permissible cargo mass and the minimum required cargo mass of single cargo hold or of two adjacent cargo holds, corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in seagoing condition. However, maximum permissible mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

1.1.5 Maximum and minimum permissible mass expression

The maximum and minimum permissible mass in seagoing conditions, ($W_{maxS}(T_i)$, $W_{minS}(T_i)$) and in harbour condition (($W_{maxH}(T_i)$, $W_{minH}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae given in tables of [2] and [3] for the followings:

- BC-A ship not having {No MP} notation assigned,
- BC-A ship having {No MP} notation assigned,
- BC-B and BC-C ships not having {No MP} notation assigned,
- BC-B and BC-C ships having {No MP} notation assigned,

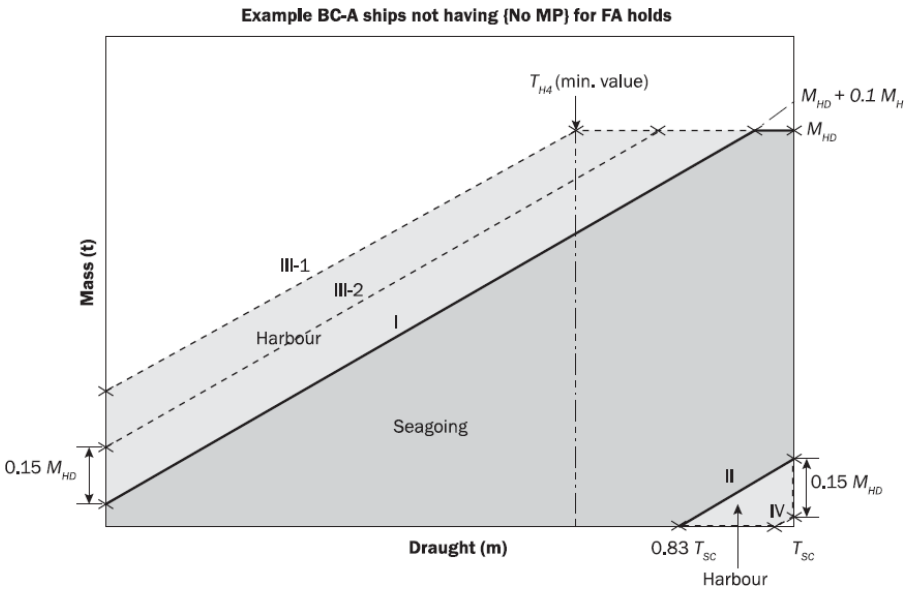
Examples for mass curve of loaded cargo holds and cargo hold which can be empty at the maximum draught for BC-A ships not having {No MP} assigned are shown in figures of the above mentioned tables.

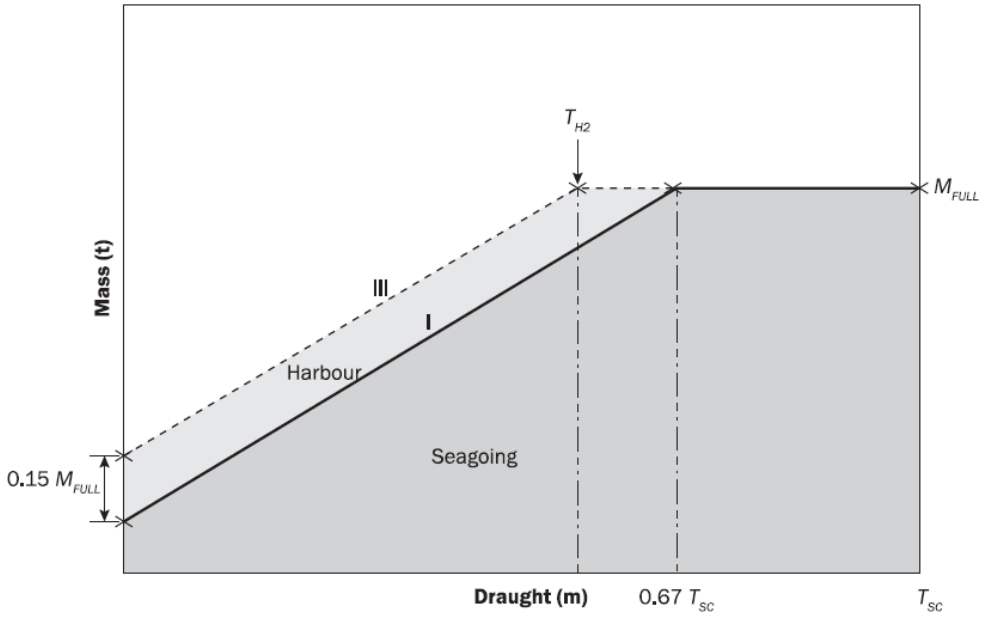
2 MAXIMUM AND MINIMUM MASSES OF CARGO IN EACH HOLD

2.1 Maximum permissible mass and minimum required mass of single cargo hold

2.1.1 BC-A ship not having {No MP} notation assigned

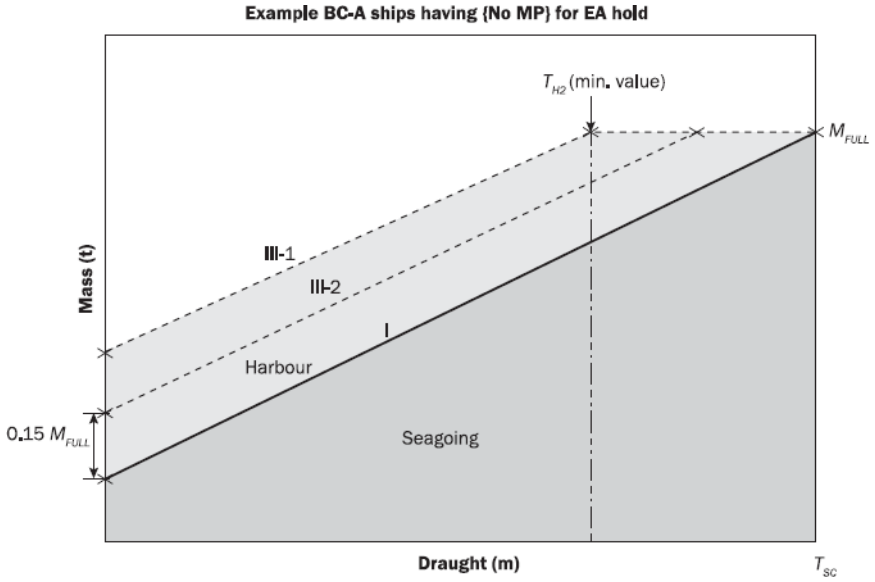
BC-A ship not having {No MP} notation assigned **Table 1**

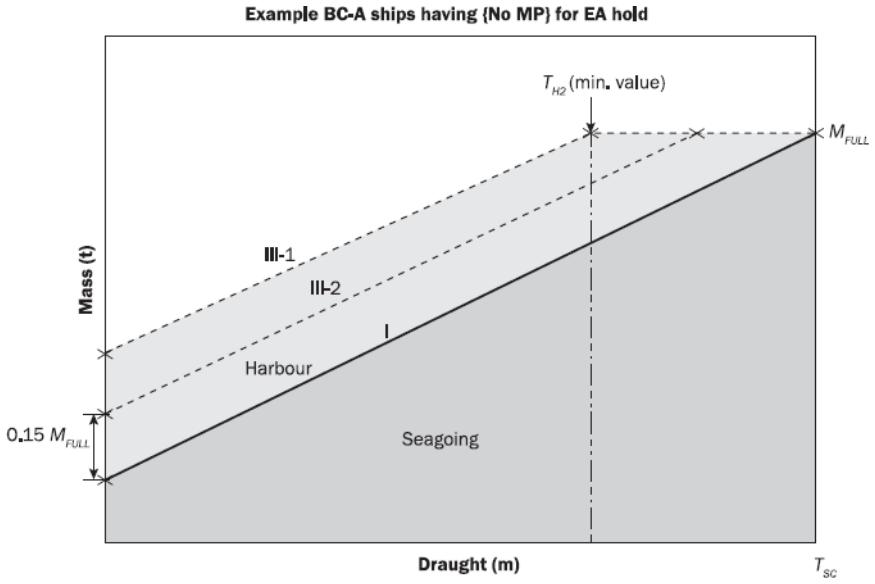
Hold	Loading conditions	Max / Min curves	Curve	Ref
FA	Seagoing	Maximum: $W_{maxS}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \frac{(T_{SC} - T_i)}{h} \le M_{MD}$	I	Ch 4, Sec 8, [4.2.3] b & c
		Minimum: $W_{minS}(T_i) = 1.025V_H \frac{(T_i - 0.83T_{SC})}{h} \ge 0$	II	Ch 4, Sec 8, [4.2.2] b
	Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{cases} M_{HD} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \le M_{HD} \\ W_{maxS}(T_i) + 0.15M_{MD} \le M_{MD} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch4, Sec8, [4.2.5]
		Minimum: $W_{min(Ti)} = W_{minS}(T_i) - 0.15M_{HD} \ge 0$	IV	Ch4,Sec, [4.2.5]
				

<table>
<tr><td rowspan="5">EA</td><td rowspan="2">Seagoing</td><td>Maximum：
$W_{maxS}(T_i) = M_{Full} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \le M_{Full}$</td><td>I</td><td>Ch 4, Sec 8, [4.2.2] a</td></tr>
<tr><td>Minimum：
$W_{minS}(T_i) = 1.025V_H \frac{(T_i - T_{SC})}{h} \ge 0$</td><td>II</td><td>Ch 4, Sec 8, [4.2.3] a</td></tr>
<tr><td rowspan="2">Harbour</td><td>Maximum：
$W_{max(Ti)} = W_{maxS}(T_i) + 0.15M_{Full} \geqslant M_{Full}$</td><td>III</td><td>Ch 4, Sec 8, [4.2.5]</td></tr>
<tr><td>Minimum：
$W_{min(Ti)} = W_{minS}(T_i) - 0.15M_{Full} \geqslant 0$</td><td>IV</td><td>Ch 4, Sec 8, [4.2.2] a</td></tr>
<tr><td colspan="4">Example BC-A ships not having (No MP) for EA hold
 
</td></tr>
</table>

2.1.2 BC-A ship having {No MP} notation assigned

BC-A ship having {No MP} notation assigned **Table 2**

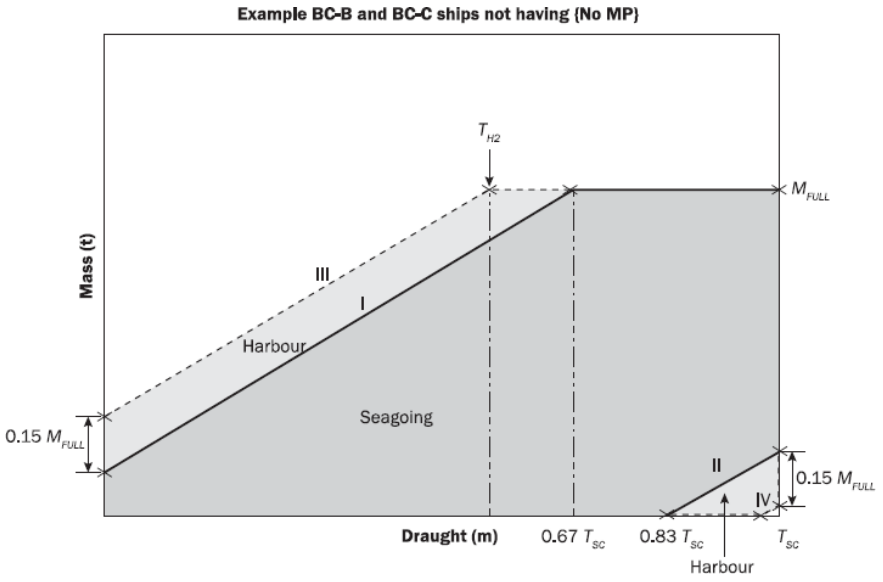
Hold	Loading conditions	Max / Min curves	Curve	Ref
FA	Seagoing	Maximum: $W_{maxS}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \frac{(T_{SC} - T_i)}{h} \le M_{HD}$	I	Ch 4, Sec 8, [4.2.3] b & c
		Minimum: $W_{minS}(T_i) = \min \begin{cases} 1.025V_H \frac{(T_i - T_{BAL-H})}{h} \ge 0 \\ 0.5M_H - 1.025V_H \frac{(T_{SC} - T_i)}{h} \ge 0 \end{cases}$	II-1 II-2	Ch 4, Sec 8, [4.2.1] c Ch 4, Sec 8, [4.2.1] b
	Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{cases} M_{HD} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \le M_{HD} \\ W_{maxS}(T_i) + 0.15M_{HD} \le M_{HD} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch 4, Sec 8, [4.2.5]
		Minimum: $W_{minH(Ti)} = W_{minS}(T_i) - 0.15M_{HD} \ge 0$	IV	Ch 4, Sec 8, [4.2.5]
				

<table>
<tr><td rowspan="4">EA</td><td rowspan="2">Seagoing</td><td>Maximum：
$W_{maxS}(T_i) = M_{Full} - 1.025V_H \frac{(T_{SC} - T_i)}{h} \le M_{Full}$</td><td>I</td><td>Ch 4, Sec 8, [4.2.1] a</td></tr>
<tr><td>Minimum：
$W_{minS}(T_i) = 1.025V_H \frac{(T_i - T_{SC})}{h} \ge 0$</td><td>II</td><td>Ch 4, Sec 8, [4.2.3] a</td></tr>
<tr><td rowspan="2">Harbour</td><td>Maximum：
$W_{maxH}(T_i) = \max \begin{cases} M_{Full} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \le M_{Full} \\ W_{maxS}(T_i) + 0.15M_{Full} \le M_{Full} \end{cases}$</td><td>III-1
III-2</td><td>Ch 4, Sec 8, [4.2.6] a
Ch 4, Sec 8, [4.2.5]</td></tr>
<tr><td>Minimum：
$W_{minH(Ti)} = W_{minS}(T_i) - 0.15M_{Full} \ge 0$</td><td>IV</td><td>Ch 4, Sec 8, [4.2.5]</td></tr>
<tr><td colspan="4"> 
</td></tr>
</table>

2.1.3 BC-B and BC-C ships not having {No MP} notation assigned

BC-B and BC-C ships not having {No MP} notation assigned **Table 3**

Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = M_{Full} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \le M_{Full}$	I	Ch 4, Sec 8, [4.2.2] a
	Minimum: $W_{minS}(T_i) = 1.025V_H \frac{(T_i - 0.83T_{SC})}{h} \ge 0$	II	Ch 4, Sec 8, [4.2.2] b
Harbour	Maximum: $W_{maxH}(T_i) = W_{maxS}(T_i) + 0.15M_{Full} \le M_{Full}$	III	Ch 4, Sec 8, [4.2.5]
	Minimum: $W_{minH(Ti)} = W_{minS}(T_i) - 0.15M_{Full} \ge 0$	IV	Ch 4, Sec 8, [4.2.5]

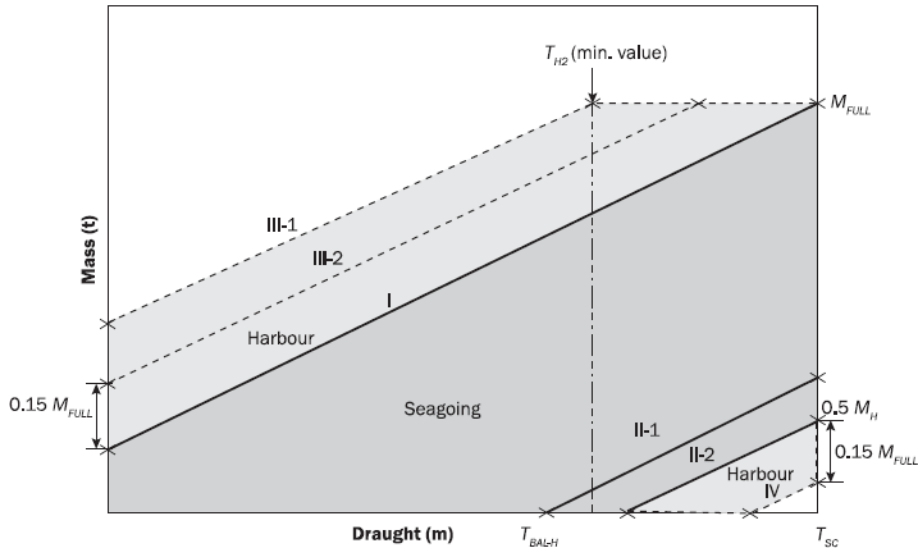


2.1.4 BC-B and BC-C ships having {No MP} notation assigned

BC-B and BC-C ships having {No MP} notation assigned Table 4

Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = M_{Full} - 1.025V_H \frac{(T_{SC} - T_i)}{h} \le M_{Full}$	I	Ch 4, Sec 8, [4.2.1] a
	Minimum: $W_{minS}(T_i) = \min \begin{cases} 1.025V_H \frac{(T_i - T_{BAL-H})}{h} \ge 0 \\ 0.5M_H - 1.025V_H \frac{(T_{SC} - T_i)}{h} \ge 0 \end{cases}$	II-1 II-2	Ch 4, Sec 8, [4.2.1] c Ch 4, Sec 8, [4.2.1] b
Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{cases} M_{Full} - 1.025V_H \frac{(0.67T_{SC} - T_i)}{h} \le M_{Full} \\ W_{maxS}(T_i) + 0.15M_{Full} \le M_{Full} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch4,Sec8, [4.2.5]
	Minimum: $W_{minH(Ti)} = W_{minS}(T_i) - 0.15M_{Full} \ge 0$	IV	Ch4,Sec8, [4.2.5]

Example BC-B and BC-C ships having {No MP}



3 MAXIMUM AND MINIMUM MASSES OF CARGO OF TWO ADJACENT HOLDS

3.1 Maximum permissible mass and minimum required mass of two adjacent holds

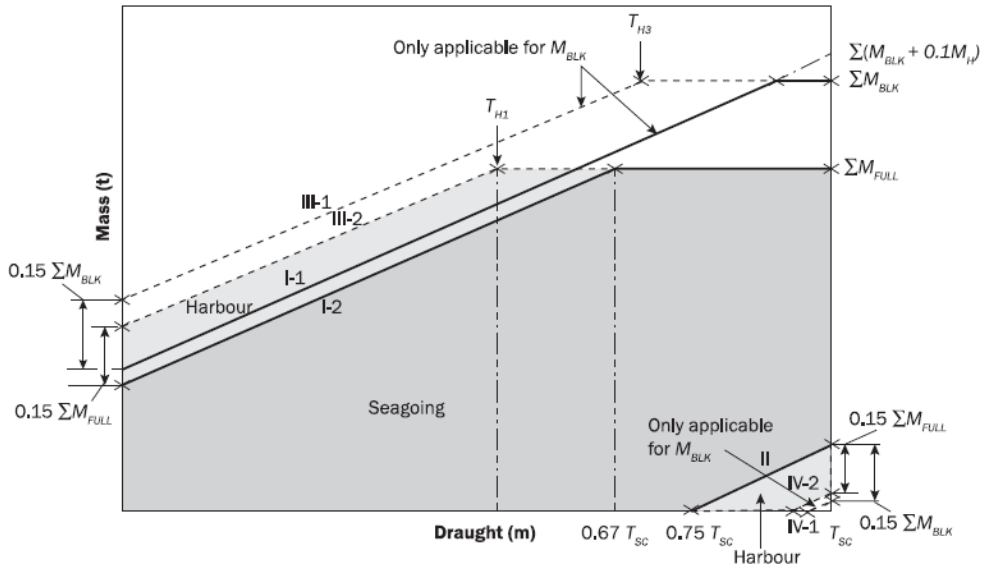
3.1.1 BC-A ships not having {No MP} notation assigned

BC-A ship not having {No MP} notation assigned **Table 5**

Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = \max \begin{cases} \sum(M_{BLK} + 0.1M_H) - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \le M_{BLK} \\ \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_{SC} - T_i) \le M_{Full} \end{cases}$	Ⅰ-1(1) Ⅰ-2	Ch 4,Sec8, [4.2.3]d Ch 4, Sec 8, [4.2.2]c
	Minimum: $W_{minS}(T_i) = 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - 0.75T_{SC}) \ge 0$	Ⅱ	Ch 4, Sec8, [4.2.2]d
Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{cases} W_{maxS}(T_i) + 0.15\sum M_{BLK} \le M_{BLK} \\ W_{maxS}(T_i) + 0.15\sum M_{Full} \le M_{Full} \end{cases}$	Ⅲ-1(1) Ⅲ-2	Ch 4,Sec8, [4.2.5] Ch 4,Sec8, [4.2.5]
	Minimum: $W_{minH}(T_i) = \min \begin{cases} W_{minS}(T_i) - 0.15\sum M_{BLK} \le 0 \\ W_{minS}(T_i) - 0.15\sum M_{Full} \le 0 \end{cases}$	Ⅳ-1(1) Ⅳ-2	Ch 4,Sec8, [4.2.5] Ch 4,Sec8, [4.2.5]

(1) This limit curve is only applicable when block loading condition is included in the loading manual.

Example BC-A ships not having {No MP} for two adjacent holds



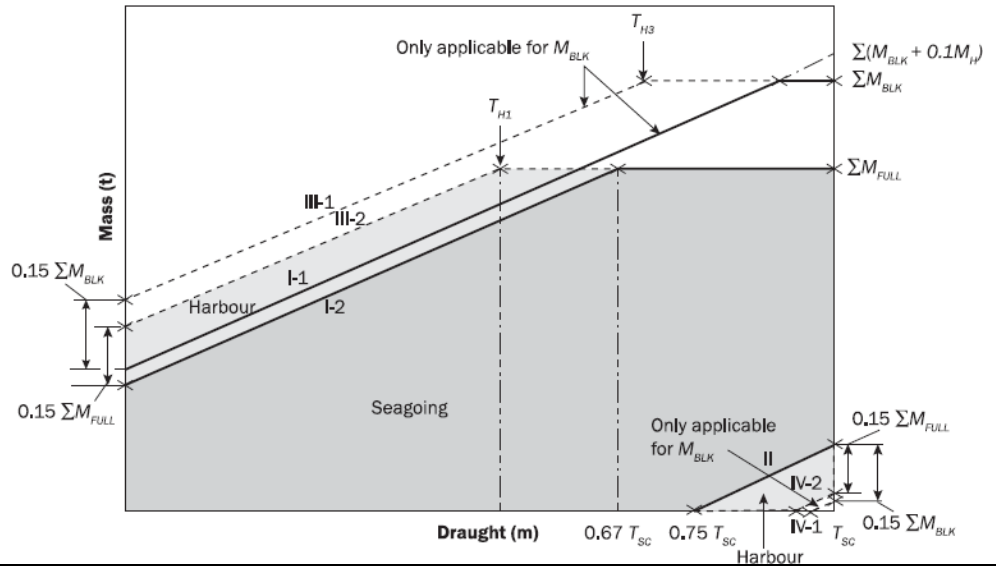
3.1.2 BC-A ships having {No MP} notation assigned

BC-A ship having {No MP} notation assigned **Table 6**

Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = \max \begin{cases} \sum (M_{BLK} + 0.1M_H) - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \le M_{BLK} \\ \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \le M_{Full} \end{cases}$	Ⅰ-1(1) Ⅰ-2	Ch 4, Sec 8, [4.2.3] d Ch 4, Sec 8, [4.2.2] a
	Minimum: $W_{minS}(T_i) = \max \begin{cases} 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - T_{BAL-H}) \ge 0 \\ 0.5\sum M_H - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \ge 0 \end{cases}$	Ⅱ-1 Ⅱ-2	Ch 4, Sec 8, [4.2.2] c Ch 4, Sec 8, [4.2.2] b
Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{cases} W_{maxS}(T_i) + 0.15\sum M_{BLK} \le M_{BLK} \\ \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_{SC} - T_i) \le \sum M_{Full} \\ W_{maxS}(T_i) + 0.15\sum M_{Full} \le M_{Full} \end{cases}$	Ⅲ-1(1) Ⅲ-2 Ⅲ-3	Ch 4, Sec 8, [4.2.5] Ch 4, Sec 8, [4.2.6] b Ch 4, Sec 8, [4.2.5]
	Minimum: $W_{minH}(T_i) = \min \begin{cases} W_{minS}(T_i) - 0.15\sum M_{BLK} \ge 0 \\ W_{minS}(T_i) - 0.15\sum M_{Full} \ge 0 \end{cases}$	Ⅳ-1(1) Ⅳ-2	Ch 4, Sec 8, [4.2.5] Ch 4, Sec 8, [4.2.5]

(1) This limit curve is only applicable when block loading condition is included in the loading manual.

Example BC-A ships not having {No MP} for two adjacent holds

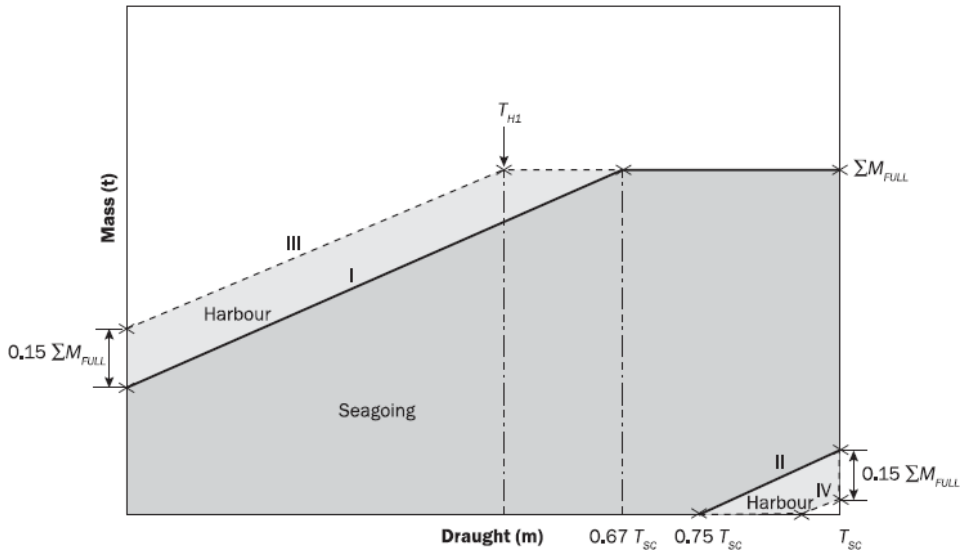


3.1.3 BC-B, BC-C ships, not having {No MP} notation assigned

BC-B and BC-C ships not having {No MP} notation assigned **Table 7**

Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = \sum M_{Full} - 1.025 V_H \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (0.67 T_{SC} - T_i) \le M_{Full}$	I	Ch 4, Sec 8, [4.2.2] c
	Minimum: $W_{minS}(T_i) = 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_i - 0.75 T_{SC}) \ge 0$	II	Ch 4, Sec 8, [4.2.2] d
Harbour	Maximum: $W_{maxH}(T_i) = W_{maxS}(T_i) + 0.15 \sum M_{Full} \le \sum M_{Full}$	III	Ch4, Sec8, [4.2.5]
	Minimum: $W_{minH}(T_i) = W_{minS}(T_i) - 0.15 \sum M_{Full} \ge 0$	IV	Ch4, Sec8, [4.2.5]

Example BC-B and BC-C ships not having {No MP} for two adjacent holds

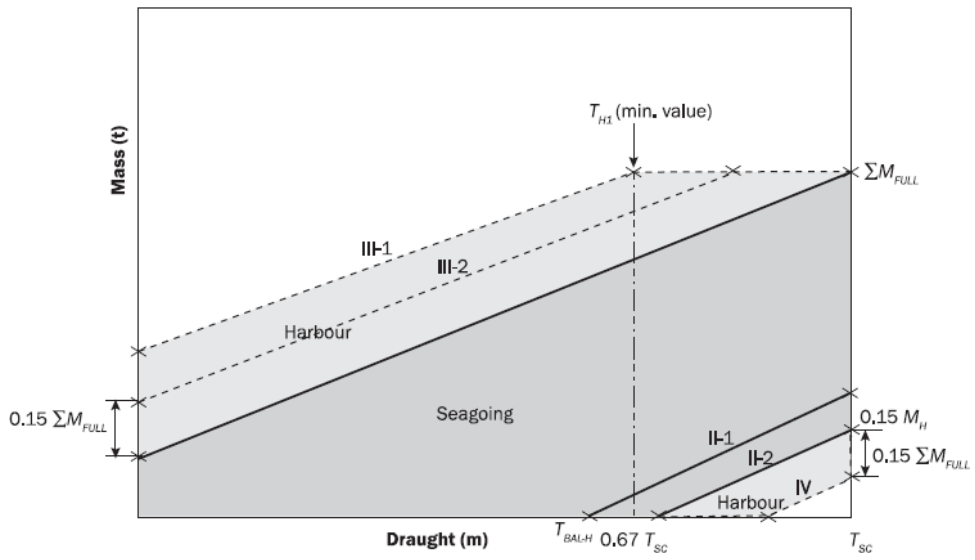


3.1.4 BC-B, BC-C ships, having {No MP} notation assigned

BC-B and BC-C ships having {No MP} notation assigned **Table 8**

Loading conditions	Max / Min curves	Curve	Ref
Seagoing	Maximum: $W_{maxS}(T_i) = \sum M_{Full} - 1.025 V_H \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_{SC} - T_i) \le M_{Full}$	I	Ch 4, Sec8, [4.2.1] a
	Minimum: $W_{minS}(T_i) = \max \begin{cases} 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_i - T_{BAL-H}) \ge 0 \\ 0.5 \sum M_H - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_{SC} - T_i) \ge 0 \end{cases}$	II-1 II-2	Ch 4, Sec 8, [4.2.1] c Ch 4, Sec 8, [4.2.1] b
Harbour	Maximum: $W_{maxH}(T_i) = \max \begin{cases} \sum M_{Full} - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (0.67 T_{SC} - T_i) \le \sum M_{Full} \\ W_{maxS}(T_i) + 0.15 \sum M_{Full} \le M_{Full} \end{cases}$	III-1 III-2	Ch 4, Sec 8, [4.2.6] a Ch 4, Sec 8, [4.2.5]
	Minimum: $W_{minH}(T_i) = W_{minS}(T_i) - 0.15 \sum M_{Full} \ge 0$	IV	Ch 4, Sec 8, [4.2.5]

Example BC-B and BC-C ships having {No MP} for two adjacent holds



Chapter 5 HULL GIRDER STRENGTH

Section 1 HULL GIRDER YIELDING STRENGTH

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

M_{sw} : Permissible hogging and sagging vertical still water bending moment in intact seagoing condition, in kNm, at the hull transverse section considered, defined in Ch 4, Sec 4, [2.2.2].

$M_{sw\text{-}p}$: Permissible hogging and sagging vertical still water bending moment for harbour/sheltered water operation, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.3].

$M_{sw\text{-}f}$: Permissible hogging and sagging vertical still water bending moment in flooded condition at sea, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.4].

M_{wv} : Vertical wave bending moment in seagoing condition, in kNm, in intact or flooded conditions at the hull transverse section considered, defined in Ch 4, Sec 4, [3.1.1].

M_{wh} : Horizontal wave bending moment, in kNm, at the hull transverse section considered, defined in Ch 4, Sec 4, [3.3.1].

Q_{sw} : Permissible positive or negative still water shear force for seagoing operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.3].

$Q_{sw\text{-}p}$: Permissible positive or negative still water shear force for harbour/sheltered operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.4].

$Q_{sw\text{-}f}$: Permissible positive or negative still water shear force for in flooded condition at sea, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.5].

Q_{wv} : Vertical wave shear force in seagoing condition, in kN, in intact or flooded conditions at the hull transverse section considered, defined in Ch 4, Sec 4, [3.2.1].

$Q_{sw\text{-}Lcd}$: Vertical still water shear force for the considered loading condition in seagoing operation, in kN, at the hull transverse section considered.

$Q_{sw\text{-}Lcd\text{-}p}$: Vertical still water shear force for the considered loading condition in harbour/sheltered operation, in kN, at the hull transverse section considered.

$Q_{sw\text{-}Lcd\text{-}f}$: Vertical still water shear force for the considered flooded condition in seagoing operation, in kN, at the hull transverse section considered.

x : X coordinate, in m, of the calculation point with respect to the reference coordinate system defined in Ch1, Sec 4, [3.6].

V_D : Vertical distance to the equivalent deck line, in m, as defined in [1.4.3].

z : Z coordinate, in m, of the calculation point with respect to the reference coordinate system defined in Ch1, Sec 4, [3.6].

z_n : Z coordinate, in m, of horizontal neutral axis of the hull transverse section with net scantling defined in [1.2], with respect to the reference coordinate system defined in Ch 1, Sec 4, [3.6].

$I_{y\text{-}n50}$: Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to [1.5].

$I_{z\text{-}n50}$: Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to [1.5].

$Z_{A\text{-}n50}$: Net section modulus, in m^3, at any point of the hull transverse section, to be calculated according [1.4.1].

$Z_{B\text{-}n50}$, $Z_{D\text{-}n50}$: Net section moduli, in m3, at bottom and deck, respectively, to be calculated according to [1.4.2] and [1.4.3].

z_{VD} : Z coordinate, in m, taken equal to $V_D + z_n$.

C_w : Wave parameter defined in Ch 4, Sec 4.

ρ : Seawater density, taken equal to 1.025 t/m^3.

f_β : Heading correction factor, to be taken as:

f_β = 1.05 for seagoing conditions.

f_β =1.0 for ballast water exchange at sea, harbour/sheltered water and accidental flooded design load scenarios.

1 STRENGTH CHARACTERISTICS OF HULL GIRDER TRANSVERSE SECTIONS

1.1 General

1.1.1

This section specifies the criteria for calculating the hull girder strength characteristics to be used for the checks in [2] to [3], in association with the hull girder loads specified in Ch 4, Sec 4.

1.2 Hull girder transverse sections

1.2.1 General

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below and including the strength deck defined in [1.3], taking into account the requirements in [1.2.2] to [1.2.13].

1.2.2 Net scantling

The members contributing to the hull girder longitudinal strength are to be considered using the net offered scantlings based on gross offered thickness reduced by $0.5t_c$, as defined in Ch3, Sec3, when the hull girder strength characteristics are used for the hull girder yielding check according to [2] to [3].

1.2.3 Structural members not contributing to hull girder sectional area

The following members are not to be considered in the calculation as they are considered not contributing to the hull girder sectional area:

- Superstructures which do not form a strength deck.
- Deckhouses.
- Vertically corrugated bulkheads, according to [1.2.7].
- Bulwarks and gutter plates.
- Bilge keels.
- Sniped or non-continuous longitudinal stiffeners.
- Non-continuous hatch coaming.

1.2.4 Continuous trunks and longitudinal continuous hatch coamings

Continuous trunks and longitudinal continuous hatch coamings may be included in the hull girder transverse sections, provided that they are effectively supported by longitudinal bulkheads or primary supporting members.

1.2.5 Longitudinal stiffeners or girders welded above the strength deck

Longitudinal stiffeners or girders welded above the strength deck, including the deck of any trunk fitted as specified in [1.2.4], are to be included in the hull girder transverse sections.

1.2.6 Longitudinal girders between hatchways, supported by longitudinal bulkheads

Where longitudinal girders, effectively supported by longitudinal bulkheads, are fitted between hatchways, the sectional area of these longitudinal girders are to be included in the hull girder transverse section.

1.2.7 Longitudinal bulkheads with vertical corrugations

For longitudinal bulkheads with vertical corrugations, the vertical corrugations are not to be included in the hull girder transverse section. Longitudinal bulkheads with vertical corrugations are not effective for hull girder bending, but they are effective for hull girder shear force.

1.2.8 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a Young's modulus, E equal to 2.06×10^5 N/mm^2, the steel equivalent sectional area that may be included in hull girder transverse section is obtained, in m^2, from the following formula:

$$A_{SE-n50} = \frac{E}{2.06\times10^5} A_{M-n50}$$

where:

$A_{M\text{-}n50}$: Sectional area, in m^2, of the member under consideration.

1.2.9 Definitions of openings

The following definitions of opening are to be applied:

a) Large openings are:
- Elliptical openings exceeding 2.5 m in length or 1.2 m in breadth.
- Circular openings exceeding 0.9 m in diameter.

b) Small openings (i.e. drain holes, etc) are openings that are not large ones.

c) Manholes

d) solated openings are openings spaced not less than 1 m apart in the ship's transverse/vertical direction.

1.2.10 Large openings, manholes and nearby small openings

Large openings and manholes are to be deducted from the sectional area used in hull girder moment of inertia and section modulus. When small openings are spaced less than 1 m apart in the ship's transverse/vertical direction to large openings or manholes, the total breadth of them is to be deducted from the sectional area.

Additionally, isolated small openings which do not comply with the arrangement requirements given in Ch 3, Sec 6, [6.3.2] are to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.11 Isolated small openings

Isolated small openings in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$$\sum b_s \le 0.06(B - \sum b)$$

Σb_S :Total breadth of isolated small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Figure 1, not deducted from the section area as per [1.2.10].

Σb :Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Figure 1, deducted from the section area as defined in [1.2.10].

Where the total breadth of isolated small openings Σb_s does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

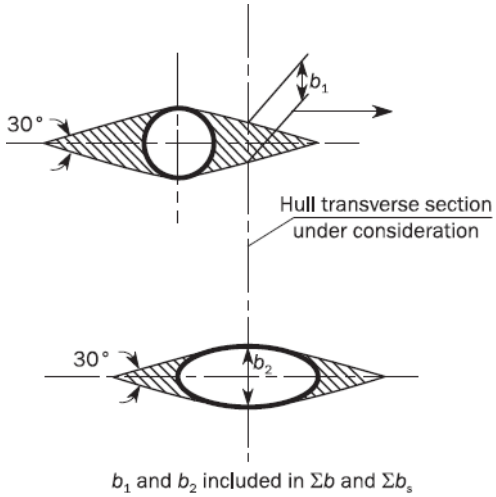


Figure 1 Calculation of Σb and Σb_s

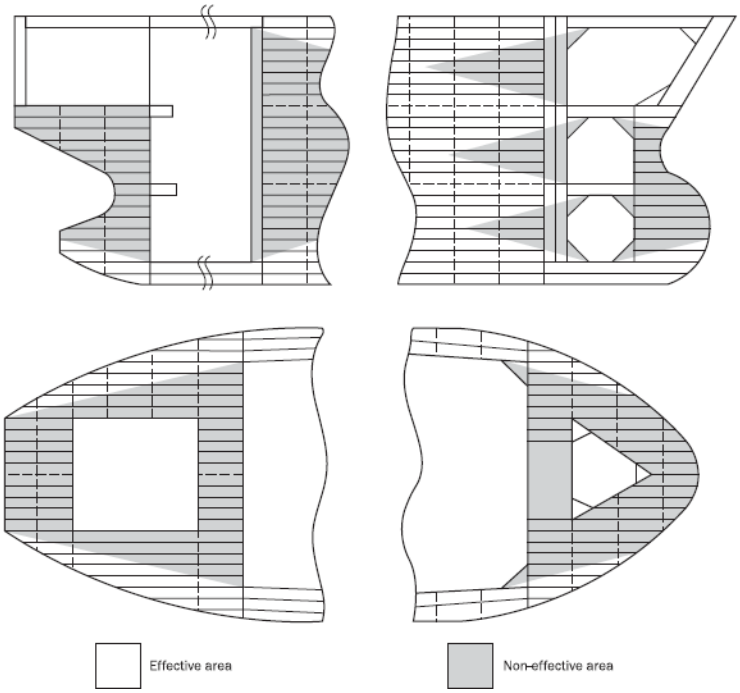


Figure 2 Effective area in way of non-continuous decks and bulkheads

1.2.12 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than $0.25h_w$, where h_w is the web height of the longitudinals, in mm. Otherwise, the excess is to be deducted from the sectional area or compensated.

1.2.13 Non-continuous decks and longitudinal bulkheads

When calculating the effective area in way of non-continuous decks and longitudinal bulkheads, the effective area is to be taken as shown in Figure 2. The shadow area, which indicates the ineffective area, is obtained by drawing two tangent lines with an angle of 15 deg to the longitudinal axis of the ship.

1.3 Strength deck

1.3.1

The strength deck is, in general, the uppermost continuous deck. In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

1.4 Section modulus

1.4.1 Section modulus at any point

The section modulus at any point of a hull transverse section is obtained, in m^3, from the following formula:

$$Z_{A-n50} = \frac{I_{y-n50}}{|Z - Z_n|}$$

1.4.2 Section modulus at bottom

The section modulus at bottom is obtained, in m^3, from the following formula:

$$Z_{B-n50} = \frac{I_{y-n50}}{Z_n}$$

1.4.3 Section modulus at deck

The section modulus at equivalent deck line is obtained, in m^3, from the following formula:

$$Z_{D-n50} = \frac{I_{y-n50}}{V_D}$$

where:

V_D : Vertical distance of the equivalent deck line, in m, taken equal to:

When no effective longitudinal members specified in [1.2.4] and [1.2.5] are positioned above a line extending from strength deck at side to a position $(z_D - z_n)/0.9$ from the neutral axis at the centreline

$V_D = z_D - z_n$

When effective longitudinal members as specified in [1.2.4] and [1.2.5] are positioned above a line extending from strength deck at side to a position $(z_D - z_n)/0.9$ from the neutral axis at the centreline

$$V_D = (z_T - z_n)\left(0.9 + 0.2\frac{y_T}{B}\right) \geq z_D - z_n$$

z_D : Z coordinate, in m, of strength deck at side, defined in [1.3].

y_T, z_T : Y and Z coordinates, in m, of the top of continuous trunk, hatch coaming, longitudinal stiffeners or girders, to be measured for the point which maximises the value of V_D.

1.5 Moments of inertia

1.5.1

The net moment of inertia, I_{y-n50} and I_{z-n50} in m^4, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in [1.2].

2 HULL GIRDER BENDING ASSESSMENT

2.1 General

2.1.1

Scantlings of all continuous longitudinal members of the hull girder based on moment of inertia and section modulus requirement in [2.3] are to be maintained within 0.4L amidships.

2.1.2

The k material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to [1]. When material factors for higher strength steels are used, the requirements in [2.4] apply.

2.2 Normal stresses

2.2.1

The normal stress, σ_L induced by vertical bending moments, is to be assessed for both hogging and sagging conditions, along the full length of the hull girder, from AE to FE.

The normal stress, σ_L at any point of the hull transverse section located below z_{VD} is to comply with the following formula:

$$\sigma_L \leq \sigma_{perm}$$

where:

σ_L : Normal stress, in N/mm^2, as defined in [2.2.2].

σ_{perm} : Permissible hull girder bending stress, in N/mm^2, as given in Table 1.

2.2.2

The normal stresses, σ_L in N/mm^2, induced by vertical bending moments are given in Table 2.

2.2.3

The normal stresses in a member made in material other than steel with a Young's modulus, E equal to 2.06×10^5 N/mm^2, included in the hull girder transverse sections as specified in [1.2.8], are obtained from the following formula:

$$\sigma_L = \frac{E}{2.06\times10^5}\sigma_{Ls}$$

where:

σ_{LS} : Normal stress, in N/mm^2, in the member under consideration, calculated according to [2.2.2] considering this member as having the steel equivalent sectional area A_{SE} defined in [1.2.8].

Permissible hull girder bending stress **Table 1**

Operation	Design load	Permissible hull girder bending stress, σ_{perm}				
		$\frac{x}{L} \le 0.1$	$0.1 < \frac{x}{L} < 0.3$	$0.3 < \frac{x}{L} < 0.7$	$0.7 < \frac{x}{L} < 0.9$	$\frac{x}{L} \ge 0.9$
Seagoing	(S+D)	140/k	Linear interpolation	190/k	Linear interpolation	140/k
Harbour/ sheltered water	(S)	105/k	Linear interpolation	143/k	Linear interpolation	105/k
Flooded condition at sea for bulk carriers having a freeboard length L_{LL} of 150 m or above	(A:S+D)	140/k	Linear interpolation	190/k	Linear interpolation	140/k

Normal stress, σ_L **Table 2**

Operation	Normal stress, σ_L		
	At any point located below Z_{VD}	At bottom (1)	At deck (1)
Seagoing	$\sigma_L = \frac{M_{sw} + f_\beta M_{wv}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw} + f_\beta M_{wv}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw} + f_\beta M_{wv}}{Z_{D-n50}} 10^{-3}$
Harbour/sheltered water	$\sigma_L = \frac{M_{sw-p}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-p}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-p}}{Z_{D-n50}} 10^{-3}$
Flooded condition at sea for bulk carriers having a freeboard length L_{LL} of 150 m or above	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{D-n50}} 10^{-3}$
(1) The σ_L values at bottom and deck, correspond to the application of formula given for any point, calculated at equivalent deck line and at baseline.			

2.3 Minimum net moment of inertia and net section modulus at midship section

2.3.1

At the transverse section in the midship part, the net moment of inertia about the horizontal axis, $I_{y\text{-}n50}$ is to be not less than the value obtained, in m^4, from the following formula:

$$I_{yR} = 2.7 C_w L^3 B (C_b + 0.7) 10^{-8}$$

2.3.2

At the transverse section in the midship part, the vertical hull girder net section modulus at the deck and the bottom, $Z_{D\text{-}n50}$ and $Z_{B\text{-}n50}$, are not to be less than the value obtained, in m3, from the following formula:

$$Z_R = 0.9 k C_w L^2 B (C_b + 0.7) 10^{-6}$$

2.4 Extent of high tensile steel

2.4.1 Vertical extent

The vertical extent of higher strength steel, $z_{hts,i}$ in m, used in the deck zone or bottom zone and

measured respectively from the moulded deck line at side or baseline is not to be taken less the value obtained from the following formula, see Figure 3:

$$z_{hts,i} = z_1\left(1 - \frac{\sigma_{perm,i}}{\sigma_L}\right)$$

where:

z_1 : Distance from horizontal neutral axis to moulded deck line or baseline respectively, in m.

$\sigma_{perm,i}$: Permissible hull girder bending stress of the considered steel, in N/mm^2, as given in Table 1 and Figure 3.

σ_L : Hull girder bending stress, σ_{dk} at moulded deck line or σ_{bl} at baseline respectively, in N/mm^2 given in Table 3.

Hull girder stresses at baseline and moulded deck line **Table 3**

Operation	At baseline	At moulded deck line
Seagoing	$\sigma_{bl} = \frac{\lvert M_{sw} + f_\beta M_{wv}\rvert}{I_{y-n50}} z_n 10^{-3}$	$\sigma_{dk} = \frac{\lvert M_{sw} + f_\beta M_{wv}\rvert}{I_{y-n50}} (z_{dk-s} - z_n) 10^{-3}$
Harbour/sheltered water	$\sigma_{bl} = \frac{\lvert M_{sw-p}\rvert}{I_{y-n50}} z_n 10^{-3}$	$\sigma_{dk} = \frac{\lvert M_{sw-p}\rvert}{I_{y-n50}} (z_{dk-s} - z_n) 10^{-3}$
Flooded condition at sea for bulk carriers having a freeboard length L_{LL} of 150 m or above	$\sigma_{bl} = \frac{\lvert M_{sw-f} + M_{wv}\rvert}{I_{y-n50}} z_n 10^{-3}$	$\sigma_{dk} = \frac{\lvert M_{sw-f} + M_{wv}\rvert}{I_{y-n50}} (z_{dk-s} - z_n) 10^{-3}$
z_{dk-s}: Distance from baseline to moulded deck line at side, in m.		

2.4.2 Longitudinal extent

Where used, the application of higher strength steel is to be continuous over the length of the ship to the location where the longitudinal stress levels are within the allowable range for mild steel structure, as shown in Figure 4.

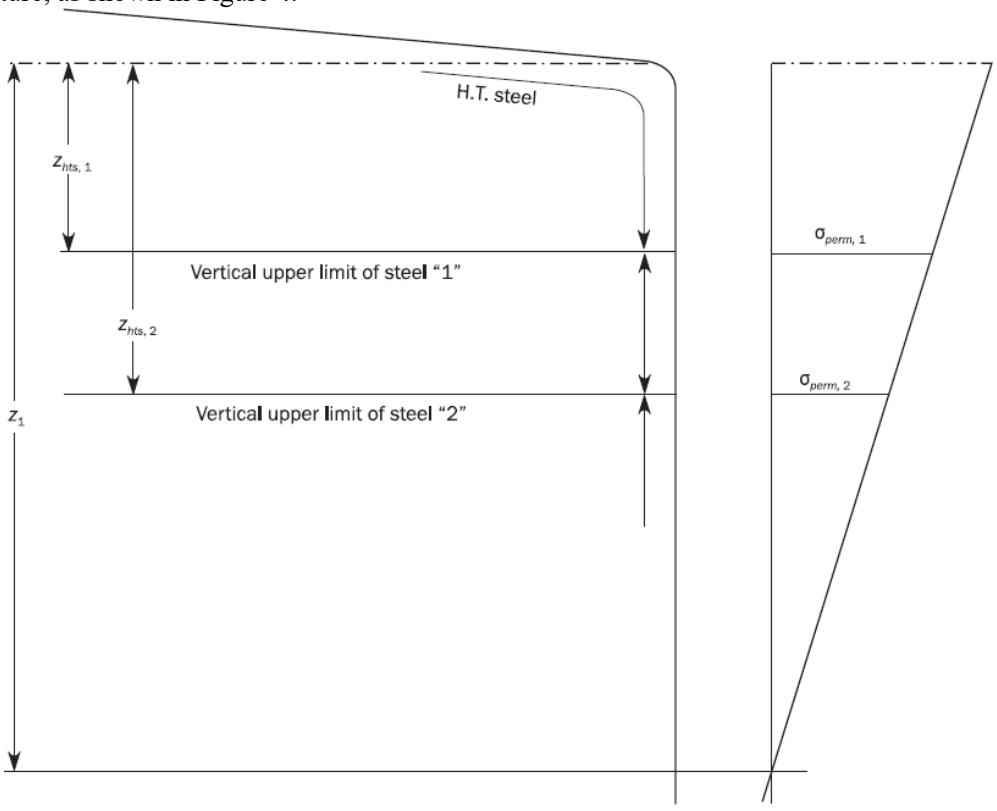


Figure 3 Vertical extent of higher strength steel

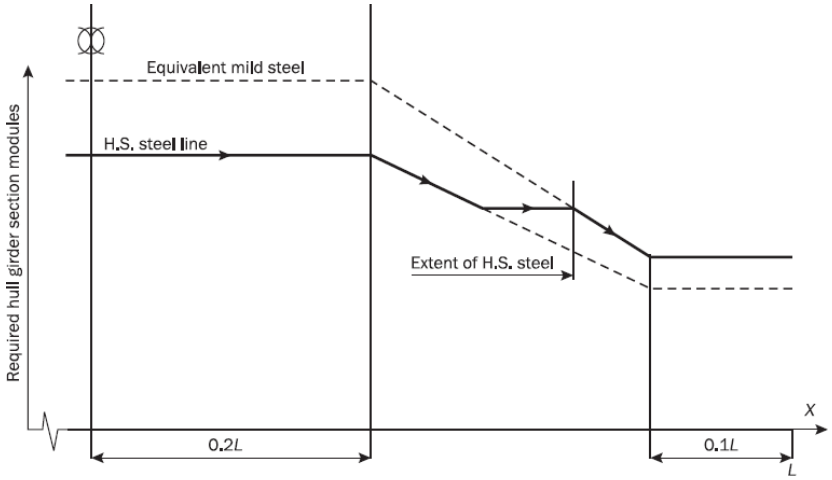


Figure 4 Longitudinal extent of higher strength steel

3 HULL GIRDER SHEAR STRENGTH ASSESSMENT

3.1 General

3.1.1

The hull girder shear strength requirements apply along the full length of the hull girder, from AE to FE.

3.2 Hull girder shear capacity

3.2.1

The total vertical hull girder shear capacity, Q_R in kN, is the minimum of the calculated values for all plates i contributing to the hull girder shear of the considered transverse section and is to be taken as:

$$Q_R = \min_i \left(\frac{\tau_{i-perm} \cdot t_{i-n50}}{q_{vi}} \cdot 10^{-3} \right)$$

where:

$t_{i\text{-}n50}$: Net thickness of plate i, in mm. For longitudinal bulkheads between cargo tanks of oil tankers, $t_{i\text{-}n50}$ is to be taken as $t_{sfi\text{-}n50}$ (see [3.4.1]) and $t_{sti\text{-}k\text{-}n50}$ (see [3.5.1]) as appropriate.

q_{vi} : Contribution ratio for hull girder shear force per mm, in mm^{-1}, for the plate i based on net scantlings with deduction of $0.5t_c$, which is equal to the unit shear flow per mm, in N/mm, obtained from a numerical calculation based on thin-walled beam theory according to Ch 5, App 1.

$\tau_{i\text{-}perm}$: Permissible shear stress, in N/mm^2, as given in Table 4, for plate i.

Permissible hull girder shear stress **Table 4**

Operation	Design load	Permissible hull girder shear, $\tau_{i\text{-}perm}$
Seagoing	(S+D)	120/k
Harbour/sheltered water	(S)	105/k
Flooded condition at sea of bulk carriers having a freeboard length L_{LL} of 150 m or above	(A:S+D)	120/k

3.3 Acceptance criteria

3.3.1 Permissible vertical shear force

The positive and negative permissible vertical shear forces are to comply with the following criteria:

- For seagoing operation:

$$|Q_{sw}| \le Q_R - |f_\beta Q_{wv}|$$

- For harbour/sheltered water operation:

$$|Q_{sw-p}| \le Q_R$$

- For flooded condition at sea of bulk carriers having a freeboard length L_{LL} of 150 m or above:

$$\left|Q_{sw-f}\right| \le Q_R - \left|Q_{wv}\right|$$

where:
Q_R : Total vertical hull girder shear capacity, in kN, as defined in [3.2.1].
The shear force Q_{wv}, used in 2 above criteria is to be taken with the same sign as the considered shear forces Q_{sw}, and $Q_{sw\text{-}f}$ respectively.

3.3.2 Vertical still water shear force

The vertical still water shear forces, in kN, for all loading conditions are to comply with the following criteria:

- For seagoing operation:

$$\left|Q_{sw-Lcd} - \Delta Q_{mdf}\right| \le \left|Q_{sw}\right|$$

- For harbour/sheltered water operation:

$$\left|Q_{sw-Lcd-p} - \Delta Q_{mdf}\right| \le \left|Q_{sw-p}\right|$$

- For flooded condition at sea of bulk carriers having a freeboard length L_{LL} of 150 m or above:

$$\left|Q_{sw-Lcd-f} - \Delta Q_{mdf}\right| \le \left|Q_{sw-f}\right|$$

where:
ΔQ_{mdf} : Shear force correction at the transverse section considered, in kN, taken as:

- For bulk carriers, the value defined in [3.6.1].
- For oil tankers, $\Delta Q_{mdf} = 0$.

The permissible shear forces Q_{sw}, $Q_{sw\text{-}p}$ and $Q_{sw\text{-}f}$ are to be taken with the same sign as the considered shear forces $Q_{sw\text{-}Lcd}$, $Q_{sw\text{-}Lcd\text{-}p}$ and $Q_{sw\text{-}Lcd\text{-}f}$ respectively.

3.4 Effective net thickness for longitudinal bulkheads between cargo tanks of oil tankers

3.4.1

For longitudinal bulkheads between cargo tanks, the effective net thickness of the plating above the inner bottom, $t_{sfi\text{-}n50}$ for plate i, in mm, is given by:

$$t_{sfi-n50} = t_{i-n50} - t_{\Delta i}$$

where:
$t_{\Delta i}$: Thickness deduction for plate i, in mm, as defined in [3.4.2].

3.4.2

The vertical distribution of thickness reduction for shear force correction is to be triangular as indicated in Figure 5. The thickness deduction, $t_{\Delta i}$ in mm, to account for shear force correction on the plate i, is to be taken as:

$$t_{\Delta i} = \frac{\delta Q_3}{h_{blk}\tau_{i-perm}}\left(1 - \frac{x_{blk}}{0.5 l_{tk}}\right)\left(2 - \frac{2\left(z_p - h_{db}\right)}{h_{blk}}\right)$$

where:
δQ_3 : Shear force correction for longitudinal bulkhead as defined in [3.4.3] and [3.4.4] for ships with one or two longitudinal bulkheads respectively, in kN.
l_{tk} : Length of cargo tank, in m.
h_{blk} : Height of longitudinal bulkhead, in m, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in Figure 5.
x_{blk} : Minimum longitudinal distance from section considered to the nearest cargo tank transverse bulkhead, in m. To be taken positive and not greater than $0.5 l_{tk}$.
z_p : Vertical distance from the lower edge of plate i to the base line, in m, but not taken less than h_{db}.
h_{db} : Height of double bottom, in m, as shown in Figure 5.
$\tau_{i\text{-}perm}$: Permissible hull girder shear stress, in N/mm^2, for plate i:
$\tau_{i\text{-}perm} = 120/k$.

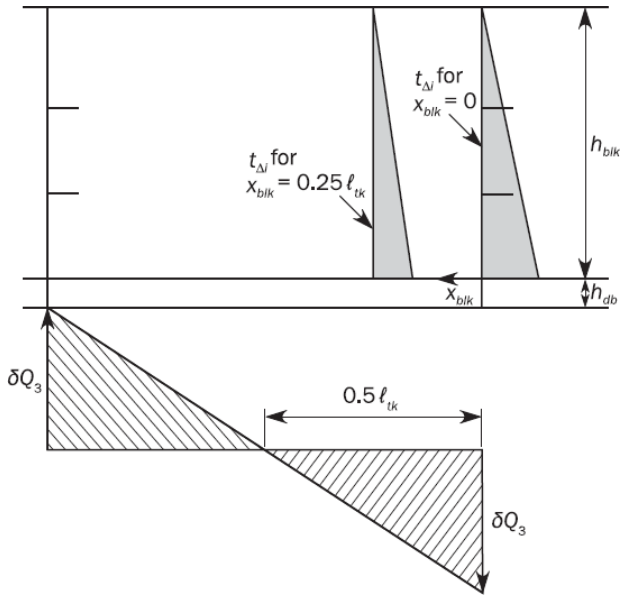


Figure 5 Shear force correction for longitudinal bulkheads

3.4.3 Shear force correction for a ship with a centreline longitudinal bulkhead

For ships with a centreline longitudinal bulkhead, the shear force correction in way of transverse bulkhead, δQ_3, in kN, is to be obtained from the following formula:

$$\delta Q_3 = 0.5 K_3 F_{db}$$

where:

F_{db} : Maximum resulting force on the double bottom in a tank, in kN, as defined in [3.4.5].

K_3 : Correction factor, to be taken equal to:

$$K_3 = 0.4 \cdot \left(1 - \frac{1}{1+n}\right) - f_3$$

n : Number of floors between transverse bulkheads.

f_3 : Shear force distribution factor, as defined in Table 7.

3.4.4 Shear force correction for a ship with two longitudinal bulkheads between the cargo tanks

For ships with two longitudinal bulkheads between the cargo tanks, the shear force correction, δQ_3 in kN, is to be obtained from the following formula:

$$\delta Q_3 = 0.5 K_3 F_{db}$$

where:

F_{db} : Maximum resulting force on the double bottom in a tank, in kN, as defined in [3.4.5].

K_3 : Correction factor, to be taken equal to:

$$K_3 = 0.5 \cdot \left(1 - \frac{1}{1+n}\right)\left(\frac{1}{r+1}\right) - f_3$$

where:

n : Number of floors between transverse bulkheads.

r : Ratio of the part load carried by the wash bulkheads and floors from longitudinal bulkhead to the double side taken as:

$$r = \frac{1}{\left[\dfrac{A_{3-n50}}{A_{1-n50} + A_{2-n50}} + \dfrac{2 \times 10^4 b_{80}\left(n_s + 1\right) A_{3-n50}}{l_{lk}\left(n_s A_{T-n50} + R\right)}\right]}$$

l_{tk} : Length of cargo tank, between transverse bulkheads in the side cargo tank, in m.

b_{80} : 80% of the distance from longitudinal bulkhead to the inner hull longitudinal bulkhead, in m, at tank mid length.

$A_{T\text{-}n50}$: Net shear area of the transverse wash bulkhead, including the double bottom floor directly below, in the side cargo tank, in cm^2, taken as the smallest area in a vertical section.

$A_{1\text{-}n50}$, $A_{2\text{-}n50}$, $A_{3\text{-}n50}$:Net areas, as defined in Table 7, in m^2.
f_3 : Shear force distribution factor, as defined in Table 7.
n_S : Number of wash bulkheads in the side cargo tank.
R : Total efficiency of the transverse primary supporting members in the side tank in cm^2.

$$R = \left(\frac{n - n_s}{2} - 1 \right) \frac{A_{Q-n50}}{\gamma}$$

$$\gamma = 1 + \frac{300 b_{80}{}^2 A_{Q-n50}}{I_{psm-n50}}$$

$A_{Q\text{-}n50}$: Net shear area, in cm^2, of a transverse primary supporting member in the wing cargo tank, taken as the sum of the net shear areas of floor, cross ties and deck transverse webs. The net shear area is to be calculated at the mid span of the members.

$I_{psm\text{-}n50}$: Net moment of inertia for transverse primary supporting members, in cm^4, in the wing cargo tank, taken as the sum of the moments of inertia of transverses and cross ties. The net moment of inertia is to be calculated at the mid span of the member including an attached plate width equal to the primary supporting member spacing.

3.4.5 Vertical force on double bottom

The maximum vertical resulting force on the double bottom in a tank, F_{db} is in no case to be less than that given by the minimum conditions given in Table 5.
The maximum resulting force on the double bottom in a tank, F_{db} in kN, is to be taken as:

$$F_{db} = g \left| W_{CT} + W_{CWBT} - \rho b_2 l_{lk} T_{mean} \right|$$

where:
W_{CT} : Weight of cargo, in tonnes, as defined in Table 6.
W_{CWBT} : Weight of ballast, in tonnes, as defined in Table 6.
b_2 : Breadth, in m, as defined in Table 6.
l_{tk} : Length of cargo tank, in m.
T_{mean} : Draught at the mid length of the tank for the loading condition considered, in m.

Minimum conditions for double bottom **Table 5**

Structural configuration	Positive/negative force, F_{db}	Minimum condition
Ships with centreline bulkhead	Max positive net vertical force, F_{db+}	0.9 *Tsc* and empty cargo tanks and ballast tanks
	Max negative net vertical force, F_{db-}	0.6 *Tsc* and full cargo tanks and empty ballast tanks
Ships with two longitudinal bulkheads	Max positive net vertical force, F_{db+}	0.9 *Tsc* and empty cargo tanks and ballast tanks
	Max negative net vertical force, F_{db-}	0.6 *Tsc* and full centre cargo tank and empty ballast tanks

Design conditions for double bottom **Table 6**

Structural configuration	W_{CT}	W_{CWBT}	b_2
Ships with centreline bulkhead	Weight of cargo in cargo tanks, in tonnes, using a minimum density of 1.025 t/m^3.	Weight of ballast between port and starboard inner sides, in t.	Maximum breadth between port and starboard inner sides at mid length of tank, in m, as shown in Figure 6.
Ships with two longitudinal bulkheads	Weight of cargo in the centre tank, in tonnes, using a minimum density of 1.025 t/m^3.	Weight of ballast below the centre cargo tank, in t.	Maximum breadth of the centre cargo tank at mid length of tank, in m, as shown in Figure 6.

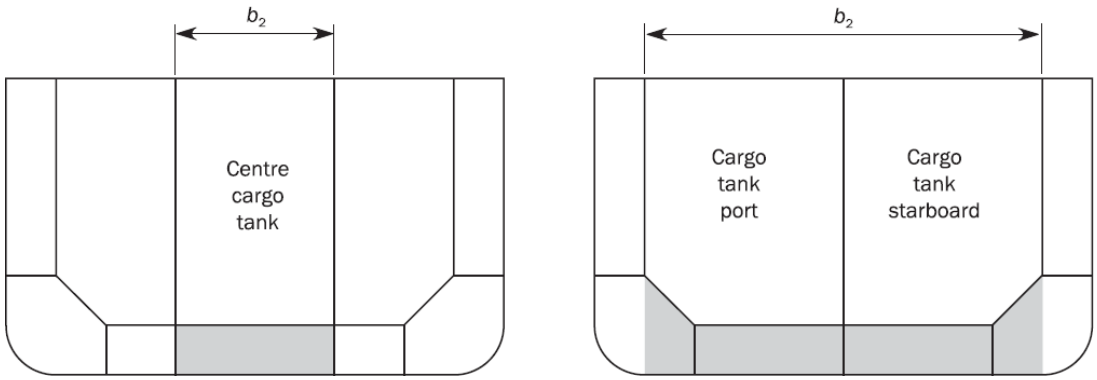
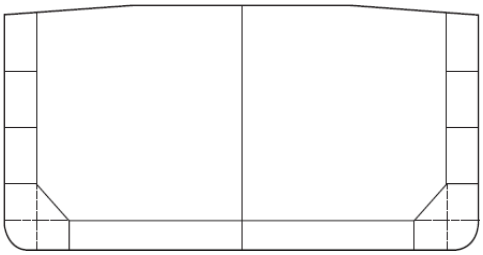
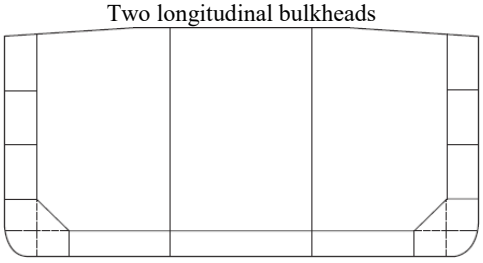


Figure 6 Tank breadth b_2

Shear force distribution factor for oil tanker **Table 7**

Hull configuration	f_3 factor
One centreline bulkhead 	$f_3 = 0.504 - 0.076\frac{A_{1-n50}}{A_{2-n50}} - 0.156\frac{A_{2-n50}}{A_{3-n50}}$
Two longitudinal bulkheads 	$f_3 = 0.353 - 0.049\frac{A_{1-n50}}{A_{2-n50}} - 0.095\frac{A_{2-n50}}{A_{3-n50}}$

where:

$A_{1\text{-}n50}$, $A_{2\text{-}n50}$, $A_{3\text{-}n50}$: Net projected area onto the vertical plane based on net thickness, t_{n50}, of the side shell, inner hull or the longitudinal bulkhead respectively, at one side of the section under consideration.

The area $A_{1\text{-}n50}$ includes the net plating area of the side shell, including the bilge.

The area $A_{2\text{-}n50}$ includes the net plating area of the inner hull, including the hopper side and the outboard girder under.

The Area $A_{3\text{-}n50}$ includes the net plating area of the longitudinal bulkheads, including the double bottom girders in line. The area $A_{3\text{-}n50}$ for the centreline bulkhead is not to be reduced for symmetry around the centreline. When the longitudinal bulkhead is made with corrugation, $A_{3\text{-}n50}$ is to consider the equivalent net thickness of the corrugation as defined in [3.4.6].

3.4.6 Equivalent net thickness of corrugation

The equivalent net thickness, in mm, of the corrugation of vertical and horizontal corrugated bulkheads, $t_{cor\text{-}n50}$, to be used for the calculation of the effective net shear area of $A_{3\text{-}n50}$ in Table 7 and for the unit shear flow, is given as follows:

$$t_{cor-n50} = \frac{t_{w-gr} + t_{f-gr}}{2} \cdot \frac{s_c}{c+a} - 0.5t_c$$

where:

$t_{w\text{-}gr}$: Gross corrugation web thickness, in mm.

$t_{f\text{-}gr}$: Gross corrugation flange thickness, in mm.

s_c : Projected length of one corrugation, in mm, as defined in Ch 3, Sec 6, Figure 21.

c : Breadth of corrugation web, in mm, as defined in Ch 3, Sec 6, Figure 21.
a : Breadth of corrugation flange, in mm, as defined in Ch 3, Sec 6, Figure 21.

3.5 Effective net thickness for longitudinal bulkheads between cargo tanks of oil tankers-Correction due to loads from transverse bulkhead stringers

3.5.1

In way of transverse bulkhead stringer connections, within areas as specified in Figure 8, the equivalent net thickness of plate, $t_{sti\text{-}k\text{-}n50}$ in mm, where the index k refers to the identification number of the stringer, is not to be taken greater than:

$$t_{sti-k-n50} = t_{sfi-n50}\left(1 - \frac{\tau_{sti-k}}{\tau_{i-perm}}\right)$$

where:

$\tau_{sti\text{-}k}$: Shear stress in plate i, in N/mm^2, in the longitudinal bulkhead due to the stringer force in way of stringer k, taken as:

$$\tau_{sti-k} = \frac{Q_{st-k}}{l_{st-k} t_{sfi-k-n50}}$$

$t_{sfi\text{-}k\text{-}n50}$: Effective net plating thickness as defined in [3.4.1], in mm, calculated at the transverse bulkhead for the height corresponding to the level of the stringer.

$t_{sfi\text{-}n50}$: Effective net plating thickness as defined in [3.4.1], calculated at the lower edge of plate i connecting to the stringer.

$\tau_{i\text{-}perm}$: permissible hull girder shear stress, in N/mm^2, for the plate i.

$\tau_{i\text{-}perm} = 120/k$

$l_{st\text{-}k}$: Connection length of stringer k, in m, as defined in Figure 7.

$Q_{st\text{-}k}$: Shear force on the longitudinal bulkhead from the stringer in loaded condition with tanks abreast full in kN, taken as:

$$Q_{st-k} = 0.8F_{st-k}\left(1 - \frac{Z_{st-k} - h_{db}}{h_{blk}}\right)$$

$F_{st\text{-}k}$: Total stringer supporting force in way of a longitudinal bulkhead, in kN, taken as:

h_{db} : Double bottom height, in m.

h_{blk} : Height of bulkhead, in m, defined as the distance from inner bottom to the deck at the top of the bulkhead.

$z_{st\text{-}k}$: Z coordinate of the stringer k, in m.

$P_{st\text{-}k}$: Pressure on stringer k, in kN/m^2, taken as:

$$P_{st-k} = g\rho_L \cdot h_{tt-k}$$

ρ_L : Density of the liquid in cargo tank, in t/m^3, ad defined in Ch 4, Sec 6.

$h_{tt\text{-}k}$: Height from the top of the tank to the midpoint of the load area between $h_k/2$ below and $h_{k\text{-}1}/2$ above the stringer k, in m.

h_k : Vertical distance from the considered stringer k to the stringer k+1 below. For the lowermost stringer, it is to be taken as 80% of the average vertical distance to the inner bottom, in m.

$h_{k\text{-}1}$: Vertical distance from the considered stringer k to the stringer k-1 above. For the uppermost stringer, it is to be taken as 80% of the average vertical distance to the upper deck, in m.

$b_{st\text{-}k}$: Load breadth acting on stringer k, in m, as defined in Figure 9 and Figure 10.

3.5.2

Where reinforcement is provided to meet the above requirement, the reinforced area based on the maximum value of $t_{sti\text{-}k\text{-}n50}$ is to extend longitudinally for the full length of the stringer connection and a minimum of one frame spacing forward and aft of the bulkhead. The reinforced area is to extend vertically from above the stringer level and down to 0.5 h_k below the stringer, where h_k, the vertical distance from the considered stringer to the stringer below is as defined in [3.5.1]. For the lowermost stringer the maximum plate thickness requirement, $t_{sti\text{-}k\text{-}n50}$ is to extend down to the inner bottom, see Figure 8.

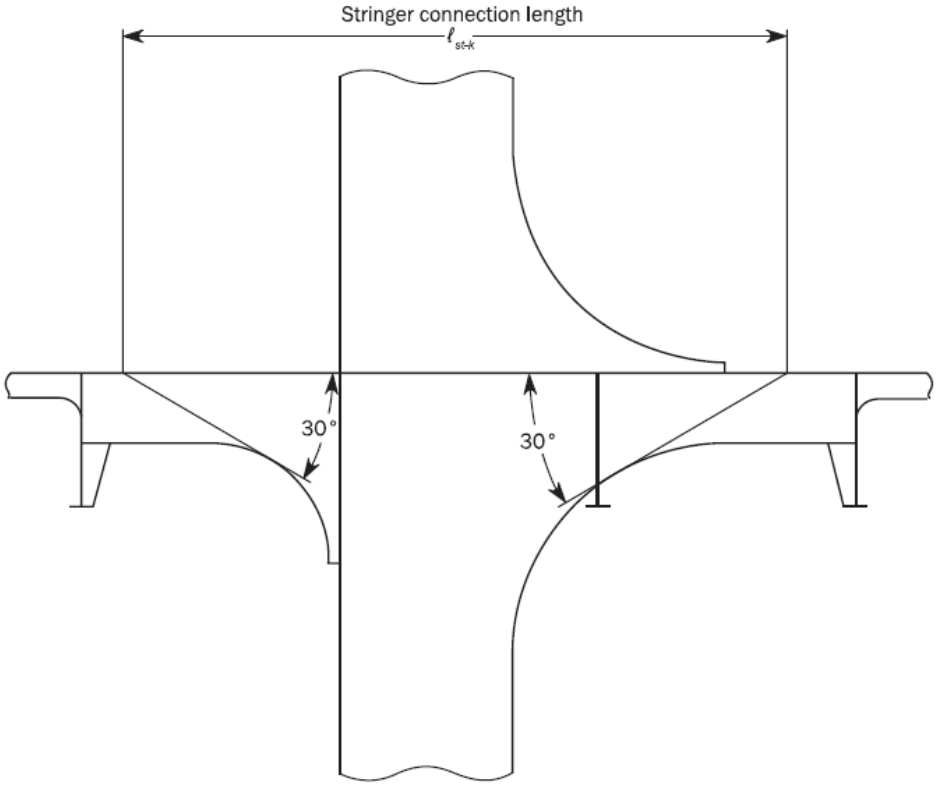


Figure 7 Effective connection length of stringer

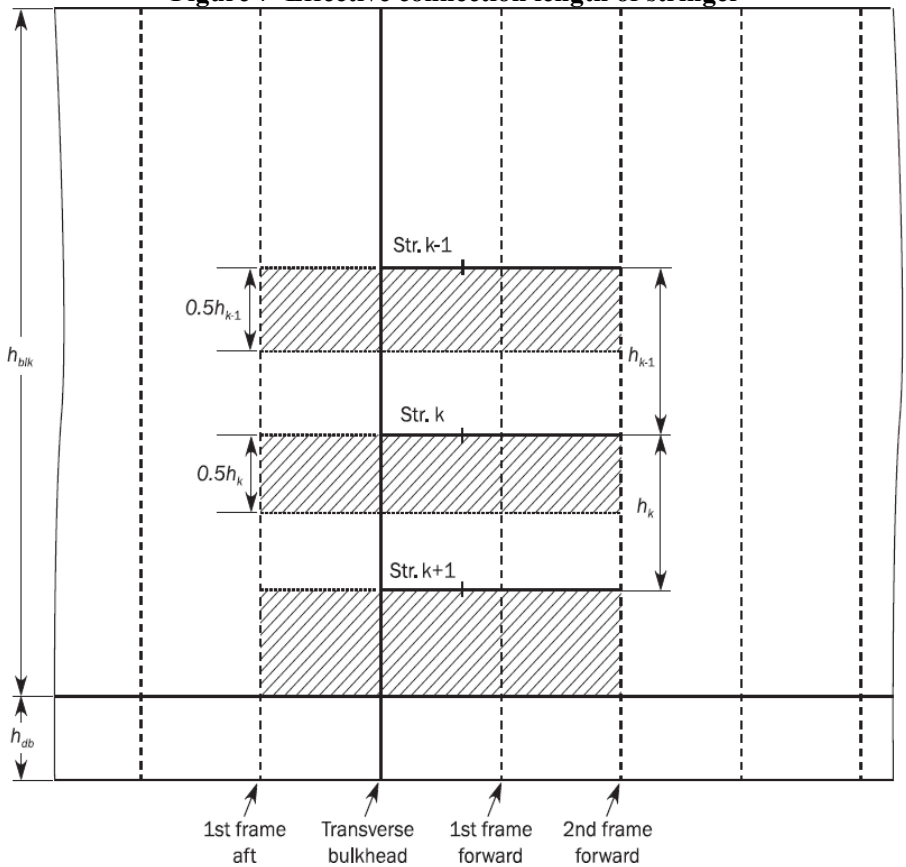


Figure 8 Region for stringer correction, t_i, for ships with 3 stringers

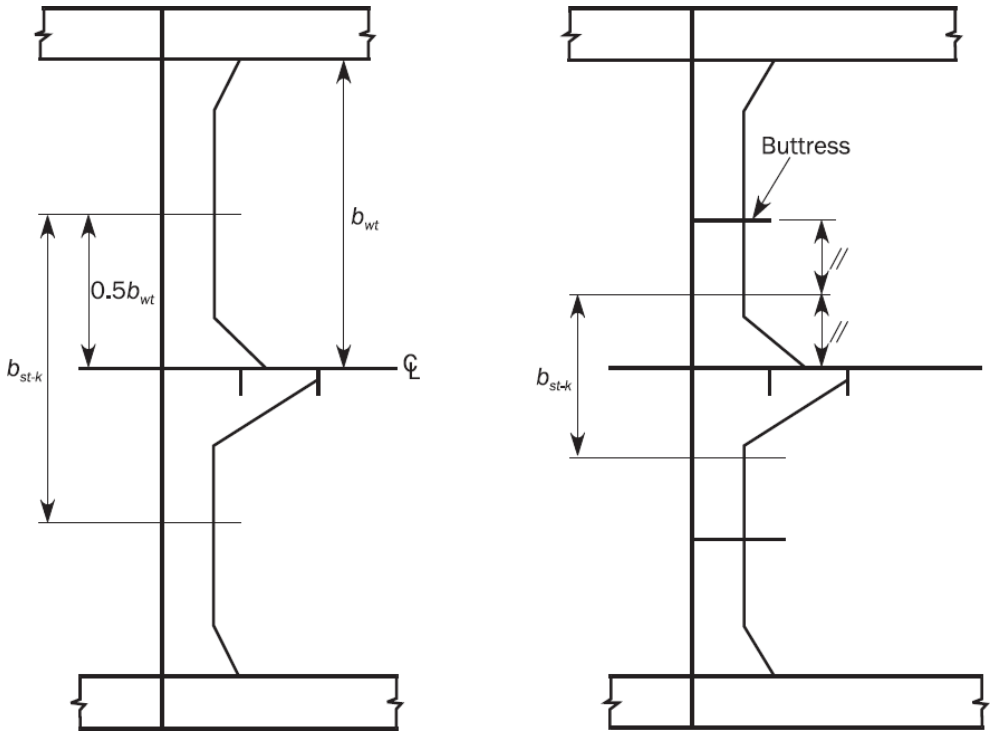


Figure 9 Load breadth of stringers for ships with a centreline bulkhead

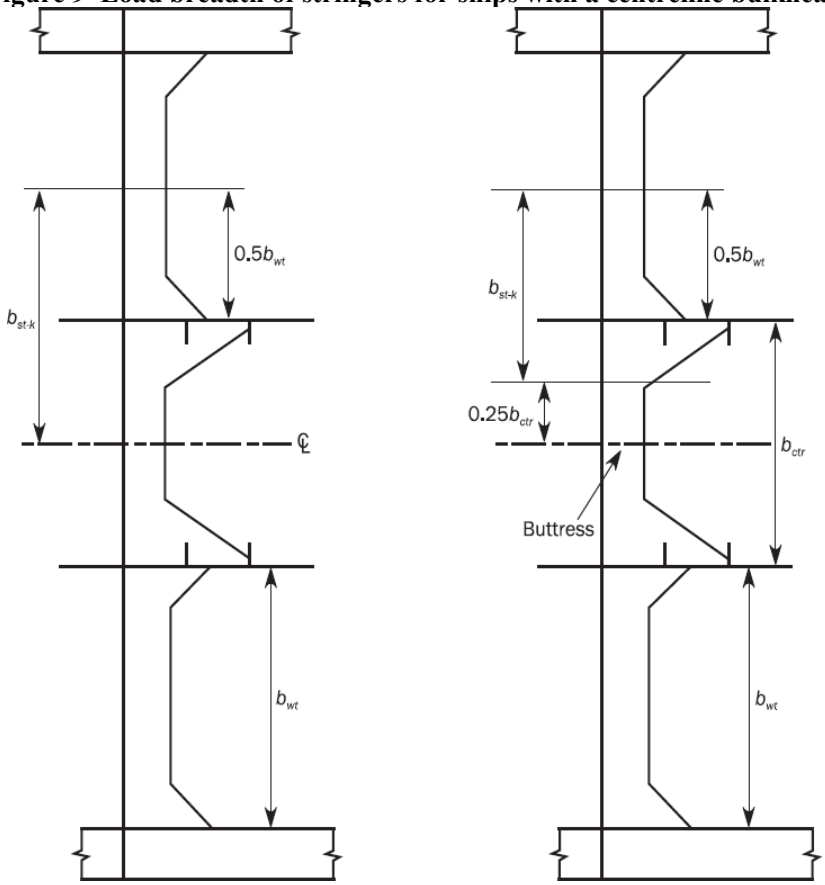


Figure 10 Load breadth of stringers for ships with 2 inner longitudinal bulkheads

In this figure:
b_{wt} is the breadth of wing cargo tank, in m.
b_{ctr} is the breadth of centre cargo tank, in m.

3.6 Shear force correction for bulk carriers

3.6.1

When hull girder shear strength assessment is performed in accordance with [3], shear force correction, which takes into account the portion of loads transmitted by the double bottom longitudinal girders to the transverse bulkheads, is to be considered.

For the considered cargo hold, the shear force correction at the considered transverse section is to be obtained, in kN, from the following formula:

$$\Delta Q_{mdf} = C_d \alpha \left(\frac{M}{B_H l_H} - \rho T_{LC,mh} \right)$$

where:

C_d : Distribution coefficient taken as:

- C_d = -1 at the aft end of the considered cargo hold except for aftmost cargo hold.
- C_d = 1 at the fore end of the considered cargo hold except for foremost cargo hold.
- C_d = 0 at mid-length of the cargo hold.
- C_d = 0 at the aft bulkhead of the aftmost cargo hold.
- C_d = 0 at the fore bulkhead of the foremost cargo hold.
- C_d: Linearly distributed at other locations.

α : Coefficient taken as:

$$\alpha = g \frac{l_0 b_0}{2 + \varphi \frac{l_0}{b_0}}$$

M : Mass, in t, in the hold in way of the considered transverse section for the considered loading condition. M is to include the mass of ballast water and fuel oil located directly below the flat portion of the inner bottom, if any, excluding the portion under the bulkhead stool.

B_H : Breadth of the cargo hold, in m, as defined in Ch 4, Sec 6.

l_H : Length of the cargo hold, in m, as defined in Ch 4, Sec 6.

l_0, b_0 : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the hold considered; b_0 is to be measured on the hull transverse section at the middle of the hold.

$$\varphi = 1.38 + 1.55 g \frac{l_0}{b_0}, \text{ but not greater than } 3.7$$

$T_{LC,mh}$: Draught, in m, measured vertically on the hull transverse section at the middle of the hold considered, from the moulded baseline to the waterline in the loading condition considered.

ΔQ_{CF} : Shear force correction for the full hold.

ΔQ_{CE} : Shear force correction for the empty hold.

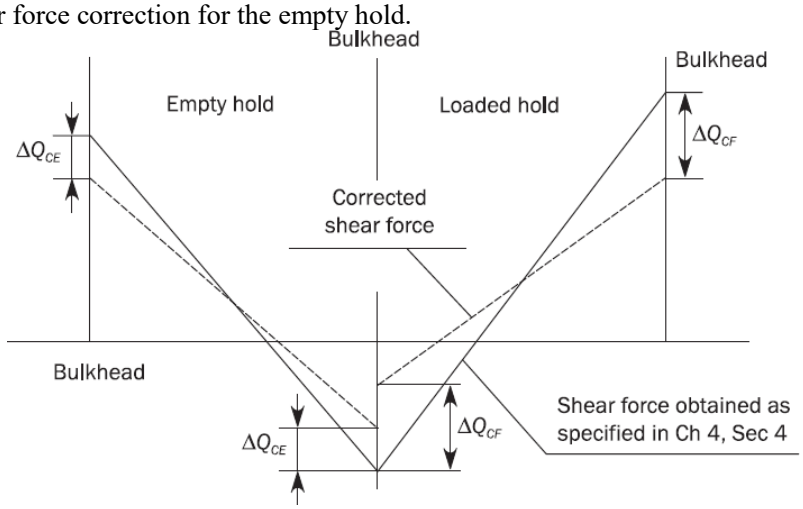


Figure 11 Shear force correction, ΔQ_C

Section 2 HULL GIRDER ULTIMATE STRENGTH

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4

$M_{sw\text{-}h}$, $M_{sw\text{-}s}$: Permissible hogging and sagging vertical still water bending moment in intact seagoing condition, in kNm, at the hull transverse section considered, defined in Ch 4, Sec 4, [2.2.2].

$M_{sw\text{-}p\text{-}h}$, $M_{sw\text{-}p\text{-}s}$: Permissible hogging and sagging vertical still water bending moment for harbour/sheltered water operation, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.3].

$M_{sw\text{-}f}$: Permissible hogging and sagging vertical still water bending moment in flooded condition at sea, in kNm, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.2.4].

1 APPLICATION

1.1 General

1.1.1

The requirements of this section apply to ships with freeboard length L_{LL} equal to or greater than 150 m.

1.1.2

The hull girder ultimate strength is to be assessed through the cargo hold region and machinery space.

1.1.3

The hull girder ultimate bending capacity is to be checked to ensure that it satisfies the checking criteria given in [2]. Such checking criteria are applicable to intact ship structures in the following conditions:

- For bulk carriers: seagoing, harbour/sheltered water and flooded conditions.
- For oil tankers: seagoing and harbour/sheltered water conditions.

2 CHECKING CRITERIA

2.1 General

2.1.1

The vertical hull girder ultimate bending capacity is to be checked for hogging and sagging conditions, for the following design load scenarios, as defined in Table 1:

- For bulk carriers: design load scenario A, for seagoing, harbour/sheltered water and flooded conditions.
- For oil tankers: design load scenario A, for seagoing and harbour/sheltered water conditions; and design load scenario B, for the operational seagoing homogeneous full load condition.

Design load scenarios **Table 1**

Design load scenarios		Permissible still water bending moment, $M_{sw\text{-}U}$
A	S+D	$M_{sw\text{-}h}$ or $M_{sw\text{-}s}$
	S	$M_{sw\text{-}p\text{-}h}$ or $M_{sw\text{-}p\text{-}s}$
	A: S+D	$M_{sw\text{-}f}$
B	S+D	Maximum sagging still water bending moment for operational seagoing homogeneous full load condition (1)

(1) The maximum still water bending moment is to be taken from the departure condition with the ship homogeneously loaded at maximum draught and corresponding arrival and any mid-voyage conditions.

2.1.2

The vertical hull girder ultimate bending capacity at any hull transverse section is to satisfy the following criteria:

$$M \le \frac{M_U}{\gamma_R}$$

where:

M : Vertical bending moment, in kNm, to be obtained as specified in [2.2.1].

M_U : Vertical hull girder ultimate bending capacity, in kNm, to be obtained as specified in [2.3].

γ_R : Partial safety factor for the vertical hull girder ultimate bending capacity to be taken equal to:

$$\gamma_R = \gamma_M \gamma_{DB}$$

γ_M : Partial safety factor for the vertical hull girder ultimate bending capacity, covering material, geometric and strength prediction uncertainties; in general, to be taken equal to:

$\gamma_M = 1.1$

γ_{DB} : Partial safety factor for the vertical hull girder ultimate bending capacity, covering the effect of double bottom bending, to be taken equal to:

- For hogging condition, except flooded conditions:
  - $\gamma_{DB} = 1.25$ for empty cargo holds in alternate condition of BC-A bulk carriers,
  - $\gamma_{DB} = 1.10$ for oil tankers, for BC-B and BC-C bulk carriers and loaded cargo holds in alternate condition of BC-A bulk carriers,
- For sagging condition, except flooded condition: $\gamma_{DB} = 1.0$
- For hogging and sagging condition, for flooded condition: $\gamma_{DB} = 1.0$

2.2 Hull girder ultimate bending loads

2.2.1

The vertical hull girder bending moment, M in hogging and sagging conditions, to be considered in the ultimate strength check is to be taken as:

$$M = \gamma_S M_{sw-U} + \gamma_W f_\beta M_{wv}$$

where:

M_{sw-U}: Permissible still water bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered as defined in Table 1.

M_{wv} : Vertical wave bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered as defined in Ch 4, Sec 4, [3.1].

γ_S : Partial safety factor for the still water bending moment, as defined in Table 2.

γ_W : Partial safety factor for the vertical wave bending moment, as defined in Table 2.

f_β : Heading correction factor, as defined in Sec 1.

Partial safety factors **Table 2**

Design load scenarios	γ_S	γ_W
A	1.0	1.2
B	1.0	1.3

2.3 Hull girder ultimate bending capacity

2.3.1

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity versus the curvature χ of the transverse section considered (see Figure 1). The curvature χ is positive for hogging condition and negative for sagging condition.

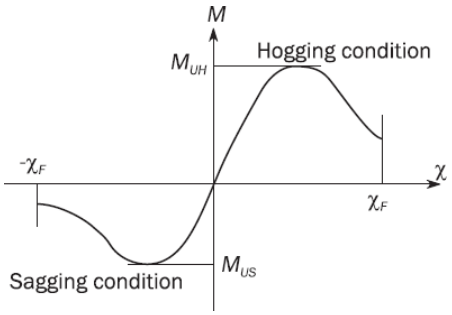


Figure 1 Bending moment capacity versus curvature χ

The hull girder ultimate bending capacity, M_U, is to be calculated according to Ch 5, App 2.

2.3.2
The effective area for the hull girder ultimate strength capacity assessment is specified in Ch 5, App 2.

Section 3 HULL GIRDER RESIDUAL STRENGTH

1 APPLICATION

1.1 General

1.1.1

The requirements of this section apply to ships with freeboard length L_{LL} equal to or greater than 150 m.

1.1.2

The hull girder ultimate bending capacity in the damaged condition is to be checked for the seagoing condition to ensure that it satisfies the residual strength checking criteria given in [2].

1.1.3

The hull girder residual strength is to be assessed through the cargo hold region and the machinery space.

2 CHECKING CRITERIA

2.1 General

2.1.1

The vertical hull girder ultimate bending capacity in the damaged condition is to be checked for the damage conditions specified in [2.2] in hogging and sagging conditions. For the damage conditions specified in [2.2], for the design load scenario A, as defined in Table 1:

Design load scenarios **Table 1**

	Design load scenario	Permissible still water bending moment in damage, $M_{sw\text{-}D}$
Collision	A: S+D	$M_{sw\text{-}h}$ or $M_{sw\text{-}s}$
Grounding	A: S+D	$M_{sw\text{-}h}$ or $M_{sw\text{-}s}$

2.1.2

The vertical hull girder ultimate bending capacity in the damaged condition at any hull transverse section is to satisfy the following criteria:

$$M_D \le \frac{M_{UD}}{\gamma_{RD} \cdot C_{NA}}$$

where:

M_D : Vertical bending moment in the damaged condition, in kNm, to be obtained as specified in [2.3].

M_{UD} : Vertical hull girder ultimate bending capacity in the damaged condition, in kNm, to be obtained as specified in [2.4].

γ_{RD} : Partial safety factor for the vertical hull girder ultimate bending capacity in the damaged condition, to be taken equal to:

$\gamma_{RD} = 1.0$

C_{NA} : Neutral axis coefficient taken as:

- $C_{NA} = 1.0$ for grounding,
- $C_{NA} = 1.1$ for collision.

2.2 Damage conditions

2.2.1 General

The damage conditions specified for collision in [2.2.2] and for grounding in [2.2.3] are to be considered. The damage extents specified in [2.2.2] and [2.2.3] are to be measured from the moulded lines of the ship.

Stiffener element is to be considered intact unless the connection of stiffener with attached plate is included in the damaged extent.

Plates and stiffeners of inner bottom and inner hull longitudinal bulkhead are to be considered intact unless the damage extent exceeds the moulded distance from inner bottom and inner hull longitudinal bulkhead plate respectively, to the hull envelope plate.

2.2.2 Collision

For the collision assessment of the considered transverse damage cross section, the damage is to be considered on one side and inclusive of the freeboard deck.

The damage for collision extends from the point of intersection of the moulded lines of deck and side:

- vertically downward for a distance *h* and upward without limit,
- transversally inboard for a distance *d* and outward without limit,

where *h* and *d* are given in Table 2 according to the side shell arrangement in the considered damage transverse section.

On ships with a rounded gunwale, the point of intersection is to be taken from the continuation of the moulded lines of deck and side.

Damage extent for collision **Table 2**

Damage penetration, in m	Side shell arrangement	
	Single side	Double side
Height, *h*	0.75 *D*	0.6*D*
Depth, *d*	*B*/16	*B*/16

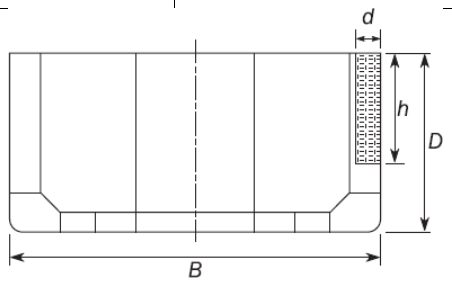


Figure 1 Damage extent for collision

The capacity of the damaged transverse cross section is calculated with the damage extent on one side, the ship kept in upright position.

2.2.3 Grounding

For the grounding assessment of the considered transverse damage cross section, the damage is to be considered on the bottom in the most unfavourable transversal position as regard to the structure considered by the damage.

The damage extent for grounding is given in Table 3.

Damage extent for grounding **Table 3**

Damage penetration, in m	Bulk carriers	Oil tankers
Height, *h*	Min (*B* /20, 2)	Min (*B* /15, 2)
Breadth, *b*	0.60 *B*	0.60 *B*

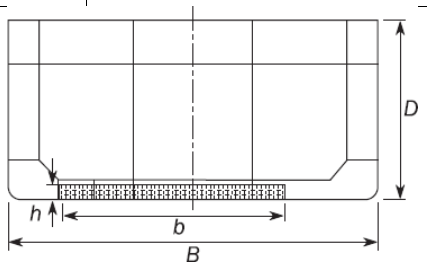


Figure 2 Damage extent for grounding

2.3 Hull girder ultimate bending loads in the damaged condition

2.3.1

The vertical bending moment, M_D in hogging and sagging conditions, to be considered in the ultimate strength check of the hull girder in the damaged condition, is to be obtained from the following formula:

$$M_D = \gamma_{SD} M_{sw-D} + \gamma_{WD} M_{wv}$$

where:

$Ms_{w\text{-}D}$: Permissible still water bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered, as defined in Table 1.

M_{wv} : Vertical wave bending moment, in kNm, in hogging and sagging conditions at the hull transverse section considered, as defined in Ch 4, Sec 4, [3.1].

γ_{SD} : Partial safety factor for the still water bending moment in the damaged condition, to be taken equal to:

$\gamma_{SD} = 1.1$

γ_{WD} : Partial safety factor for the vertical wave bending moment in the damaged condition, to be taken equal to:

$\gamma_{WD} = 0.67$

2.4 Hull girder ultimate bending capacity in the damaged condition

2.4.1

The hull girder ultimate bending capacity in the damaged condition is to be calculated according to Ch 5, App 2, with the damaged parts assumed not to contribute to the hull girder strength. When assessing the ultimate bending capacity, M_{UD} of the damaged hull sections, damaged area as defined in [2.2] carries no loads and is to be removed in the capacity model.

2.4.2

The effective area of the intact partsfor the hull girder ultimate strength capacity assessment is specified in Ch 5 App 2.

Appendix 1 DIRECT CALCULATION OF SHEAR FLOW

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.

1 CALCULATION FORMULA

1.1 General

1.1.1
This appendix describes the procedures of direct calculation of shear flow which is working along a ship cross section due to hull girder vertical shear force. Shear flow q_v, at each location in the cross section, is calculated where considering the cross section is subjected to a unit vertical shear force, 1 N, in the direction of z coordinate.
The unit shear flow per mm, q_v in N/mm, can be considered equal to:
$q_v = q_D + q_l$
where:
q_D : Determinate shear flow, as defined in [1.2].
q_l : Indeterminate shear flow which circulates around the closed cells, as defined in [1.3].
In the calculation of the unit shear flow, q_v, the longitudinal stiffeners are to be taken into account.

1.2 Determinate shear flow

1.2.1
The determinate shear flow, q_D in N/mm, at each location in the cross section can be obtained from the following line integration:

$$q_D(s) = -\frac{1}{10^6 I_{y-n50}} \int_0^s (z - z_n) t_{n50} ds$$

where:
s : Coordinate value of running coordinate along the cross section, in m.
$I_{y\text{-}n50}$: Moment inertia of the cross section, in m^4.
t_{n50} : Net thickness of plating, in mm, or equivalent net thickness of corrugated plate as defined in Ch 5, Sec 1, [3.4.6].

1.2.2
Assuming the cross section is composed of line segments as shown in Figure 1, the determinate shear flow can be calculated by the following equation.

$$q_{Dk} = q_D(l) = -\frac{t_{n50} l}{2 \times 10^6 I_{y-n50}} (z_k + z_i - 2z_n) + q_{Di}$$

where:
q_{Dk}, q_{Di} : Determinate shear flow at node k and node i respectively, in N/mm.
l : Length of line segments, in m.
z_k, z_i : Z coordinate of the end point of line segment, in m, as defined in Figure 1.

1.2.3
Where the cross section includes closed cells, the closed cell are to be cut with virtual slits, as shown in Figure 2 in order to obtain the determinate shear flow.
However, the virtual slits must not be located at the walls by which the other closed cell is also bounded.

1.2.4
Calculations of the determinate shear flow at bifurcation points can be calculated such as water flow calculations as shown in Figure 2.

1.3 Indeterminate shear flow

1.3.1
The indeterminate shear flow is working around the closed cells and can be considered as a

constant value within the same closed cell. The following system of equation for determination of indeterminate shear flows can be developed. In the equations, contour integrations of several parameters around all closed cells are performed.

$$q_{Ik}\oint_k \frac{1}{t_{n50}}ds - \sum_i q_{Ii}\oint_{k,i}\frac{1}{t_{n50}}ds = -\oint_k \frac{q_D}{t_{n50}}ds$$

q_{Ik}, q_{Ii} *:* Indeterminate shear flow around the closed cell *k* and *i* respectively, in N/mm.

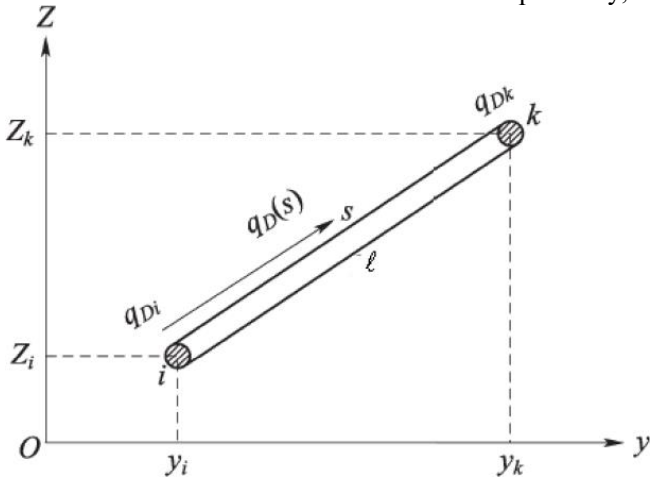


Figure 1 Definition of line segment

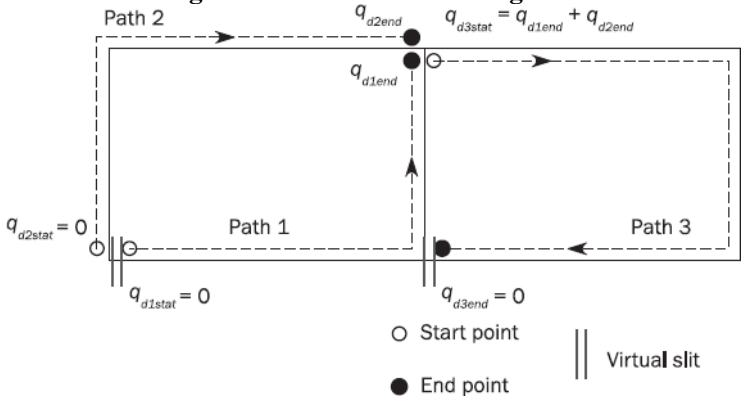


Figure 2 Calculation of determinate shear flow at bifurcation

1.3.2

With assuming assembly of line segments shown in Figure 1, the equations in [1.3.1] can be expressed as follows:

$$q_{Ik}\sum_{cell\ k}\frac{l}{t_{n50}} - \sum_i q_{Ii}\left(\frac{l}{t_{n50}}\right)\Bigg|_{common\ wall\ with\ cell\ k} = -\sum_{cell\ k}\phi$$

$$\phi = \int_0^l \frac{q_D(s)}{t_{n50}}ds = -\frac{l^2}{6\times10^3 I_{y-n50}}\left(z_k + 2z_i - 3z_G\right) + \frac{l}{t_{n50}}q_{Di}$$

q_{Di} *:* Determinate shear flow, in N/mm, calculated according to [1.2.2].

The difference in the directions of running coordinates specified in [1.2] and this sub-article is to be considered.

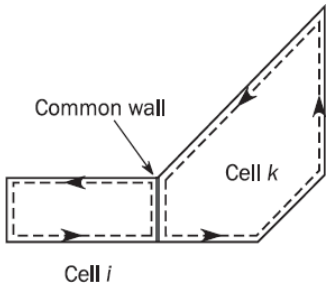


Figure 3 Closed cells and common wall

1.4 Computation of several properties of the cross section

1.4.1

Properties of the cross section can be obtained by the following formulae where the cross section is assumed as the assembly of line segments:

$$l = \sqrt{(y_k - y_i)^2 + (z_k - z_i)^2}$$

$$a_{n50} = 10^{-3} l t_{n50} \qquad A_{n50} = \sum a_{n50}$$

$$s_{y-n50} = \frac{a_{n50}}{2}(z_k + z_i) \qquad S_{y-n50} = \sum s_{y-n50}$$

$$i_{y0-n50} = \frac{a_{n50}}{3}(z_k^2 + z_k z_i + z_i^2) \quad I_{y0-n50} = \sum i_{y0-n50}$$

where:

a_{n50}, A_{n50} : Area of the line segment and the cross section respectively, in m^2.

s_{y-n50}, S_{y-n50} : First moment of the line segment and the cross section about the baseline, in m^3.

i_{y0-n50}, I_{y0-n50} :Moment inertia of the line segment and the cross section about the baseline, in m^4.

1.4.2

The height of horizontal neutral axis, z_n in m, can be obtained as follows:

$$z_n = \frac{S_{y-n50}}{A_{n50}}$$

1.4.3

Inertia moment about the horizontal neutral axis, in m^4, can be calculated as follows:

$$I_{y-n50} = I_{y0-n50} - z_n^2 A_{n50}$$

2 EXAMPLE OF CALCULATIONS FOR A SINGLE SIDE HULL CROSS SECTION

2.1 Cross section data

2.1.1

The cross section is shown in Figure 4. The coordinates of the node points marked by filled black circles in Figure 4 are given in Table 1, where the plate thickness and the line segments (marked by circles in Figure 4) of the cross section are given in Table 2.

The sample calculations are performed taking advantage of symmetry of the cross section.

Node coordinates of cross section **Table 1**

Node number	*Y* coordinate (m)	*Z* coordinate (m)
0	0.00	0.00
1	5.80	0.00
2	11.70	0.00
3	14.42	0.00
4	16.13	1.72
5	16.13	6.11

Node number	*Y* coordinate (m)	*Z* coordinate (m)
6	11.70	1.68
7	5.80	1.68
8	0.00	1.68
9	16.13	14.15
10	16.13	19.60
11	7.50	20.25
12	7.50	19.63

Calculation of cross sectional properties **Table 2**

Line no.	Node *i*	Node *k*	Thickness (mm)	Length (m)	a_{n50} (m^2)	$s_{y\text{-}n50}$ (m^3)	$I_{y0\text{-}n50}$ (m^4)
1	0	1	17.0	5.80	0.099	0.000	0.00
2	1	2	17.0	5.90	0.100	0.000	0.00
3	2	3	17.0	2.72	0.046	0.000	0.00
4	3	4	17.0	2.43	0.041	0.035	0.04
5	4	5	18.0	4.39	0.079	0.309	1.34
6	5	6	19.0	6.26	0.119	0.464	2.00
7	6	7	21.0	5.90	0.124	0.208	0.35
8	7	8	21.0	5.80	0.122	0.205	0.34
9	5	9	18.0	8.04	0.145	1.466	15.63
10	9	10	21.0	5.45	0.114	1.931	32.87
11	10	11	24.0	8.65	0.208	4.139	82.47
12	11	12	24.0	0.62	0.015	0.297	5.92
13	12	9	15.0	10.22	0.153	2.590	44.13
14	2	6	15.0	1.68	0.025	0.021	0.02
15	1	7	15.0	1.68	0.025	0.021	0.02
				Total	1.416	11.686	185.138

2.1.2

The *Z* coordinate of horizontal neutral axis and the inertia moment about the neutral axis are calculated as follow:

$$z_n = \frac{\sum s_{y-n50}}{\sum a_{n50}} = \frac{11.686}{1.416} = 8.255$$

$$I_{y-n50} = 2\left(\sum i_{y0-n50} - z_n^2 \sum a_{n50}\right) = 2\left(185.138 - 8.255^2 \times 1.416\right) = 177.34$$

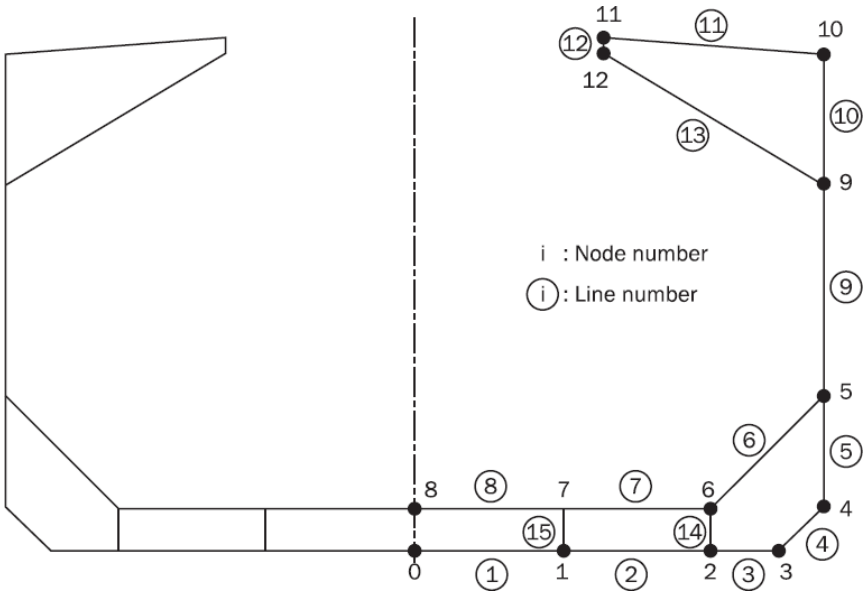


Figure 4 Numbering of nodes and lines

2.2 Calculations of the determinate shear flow

2.2.1

The virtual slits are added to cut the walls of the closed cells as shown in Figure 5. And then, the line integrations specified in [1.2.2] are performed to obtain determinate shear flow, q_D. The calculation results are shown in Table 3. The locations of the virtual slits and the paths of line integrations shown in Figure 5 are one such example. These definitions can be arbitrarily determined so as to calculate them easily.

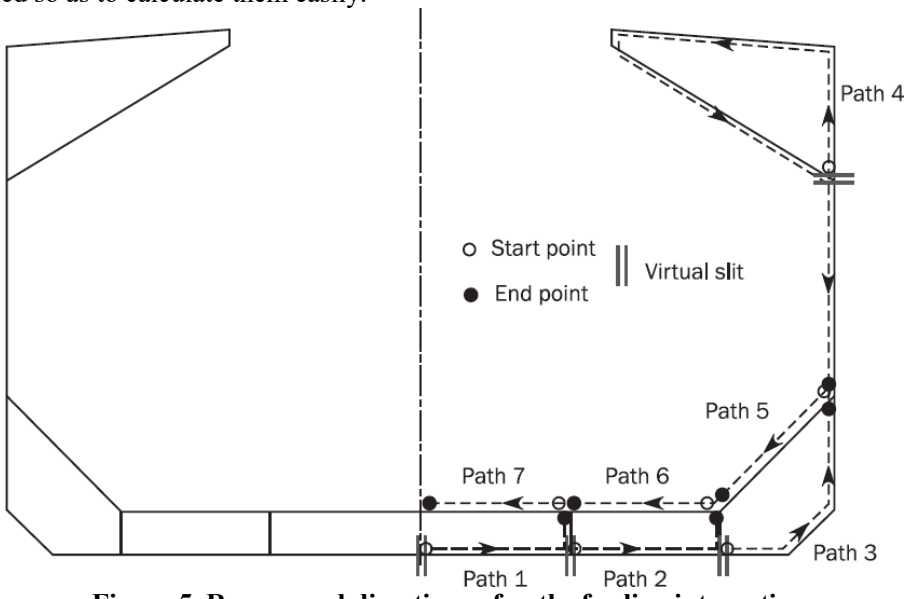


Figure 5 Ranges and directions of paths for line integrations

Calculation of determinate shear flow **Table 3**

	Line no.	Node *i*	Node *k*	$q_{Di}\times10^{-6}$ (N/mm)	$q_{Dk}\times10^{-6}$ (N/mm)	Note
1	1	0	1	0	4.6	Start from the virtual slit
	15	1	7	4.6	5.6	-
2	2	1	2	0	4.7	Start from the virtual slit
	14	2	6	4.7	5.7	-
3	3	2	3	0	2.2	Start from the virtual slit
	4	3	4	2.2	3.9	-

	Line no.	Node *i*	Node *k*	$q_{Di}\times10^{-6}$ (N/mm)	$q_{Dk}\times10^{-6}$ (N/mm)	Note
	5	4	5	3.9	5.8	-
4	10	9	10	0	-5.6	Start from the virtual slit
	11	10	11	-5.6	-19.2	-
	12	11	12	-19.2	-20.2	-
	13	12	9	-20.2	-27.7	-
	9	9	5	-27.7	-29.2	-
5	6	5	6	-23.4	-20.5	Start with the sum of q_{DK} at the ends of path 3 & 4
6	7	6	7	-14.8	-10.2	Start with the sum of q_{DK} at the ends of path 2 & 5
7	8	7	8	-4.5	0	Start with the sum of q_{DK} at the ends of path 1 & 6

2.3 Calculations of the indeterminate shear flow

2.3.1

To obtain the system of equations for indeterminate shear flows, the contour integrations around 3 closed cells as defined in Figure 6 are performed. The closed cell at the centre of double bottom is considered as an open shape since the symmetrical condition of the cross section is considered. The calculation results of contour integrations around the closed cells are shown in Table 4 to Table 6.

Contour integration of l/t_{n50} and ϕ around cell 1 **Table 4**

Line no.	Node *i*	Node *k*	$q_{Di}\times10^{-6}$ (N/mm)	l/t_{n50}	$\phi\times10^{-3}$ (N/mm)	Note
2	1	2	0	347.1	0.81	-
14	2	6	4.7	112	0.58	Common wall with cell 2
7	6	7	-14.8	281	-3.5	-
15	7	1	-5.6	112	-0.58	-
			Total	852	-2.68	-

Contour integration of l/t_{n50} and ϕ around cell 2 **Table 5**

Line no.	Node *i*	Node *k*	$q_{Di}\times10^{-6}$ (N/mm)	l/t_{n50}	$\phi\times10^{-3}$ (N/mm)	Note
3	2	3	0	160	0.17	-
4	3	4	2.2	142.7	0.43	-
5	4	5	3.9	243.9	1.22	-
6	5	6	-23.4	329.7	-7.32	-
14	6	2	-5.7	112	-0.58	Common wall with cell 1
			Total	988.3	-6.07	-

Contour integration of l/t_{n50} and ϕ around cell 3 **Table 6**

Line no.	Node *i*	Node *k*	$q_{Di}\times10^{-6}$ (N/mm)	l/t_{n50}	$\phi\times10^{-3}$ (N/mm)	Note
10	9	10	0	259.5	-0.65	-
11	10	11	-5.6	360.6	-4.45	-
12	11	12	-19.2	25.8	-0.51	-
13	12	9	-20.2	681.5	-16.59	-
			Total	1327.5	-22.19	-

2.3.2

The following system of equations can be developed by using the results of the contour integration around each closed cell:

- Cell 1: 852.0 q_{I1} – 112.0 q_{I2} = 2.68 × 10^{-3}
- Cell 2: -112.0 q_{I1} + 988.3 q_{I2} = 6.07 × 10^{-3}
- Cell 3: 1327.5 q_{I3} = 2.219×10^{-2}

The solution of this system gives indeterminate shear flows of the closed cell 1 to 3:
q_{I1} = 4.01 × 10^{-6}, q_{I2} = 6.60 × 10^{-6}, q_{I3} = 1.67 × 10^{-5}

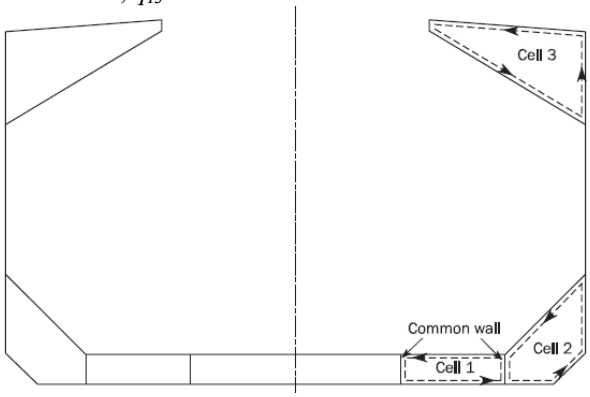


Figure 6 Numbering of closed cells

2.4 Summation

2.4.1

The shear flow q_v at all locations of the cross section can be obtained by the summation of determinate shear flow, q_D and indeterminate shear flow, q_I as shown in Figure 7.

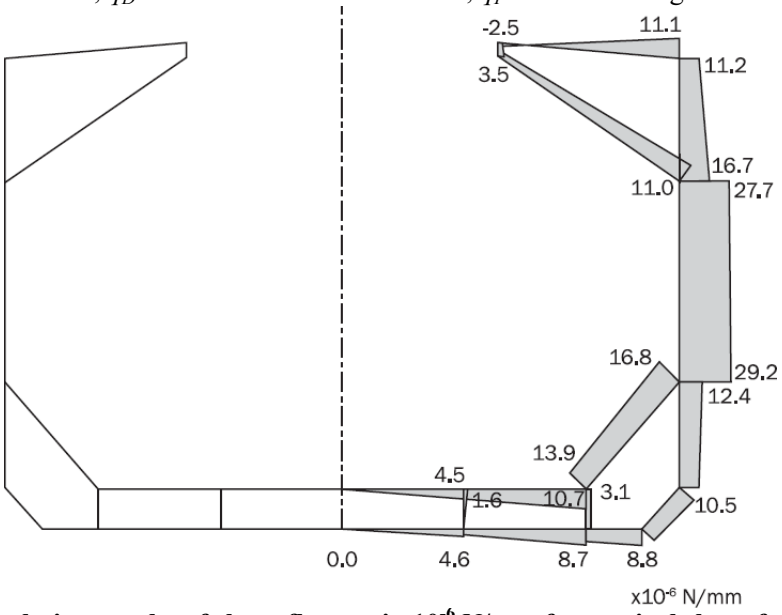


Figure 7 Calculation results of shear flow q_v, in 10^{-6} N/mm for vertical shear force with 1 N

Appendix 2 HULL GIRDER ULTIMATE CAPACITY

SYMBOLS

For symbols not defined in this article, refer to Ch 1, Sec 4.

$I_{y\text{-}n50}$: Moment of inertia, in m4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 5, Sec 1.

$Z_{B\text{-}n50}$, $Z_{D\text{-}n50}$: Section moduli, in m^3, at bottom and deck, respectively, defined in Ch 5, Sec 1.

R_{eHs} : Minimum yield stress, in N/mm^2, of the material of the considered stiffener.

R_{eHp} : Minimum yield stress, in N/mm^2, of the material of the considered plate.

$A_{s\text{-}n50}$: Net sectional area, in cm^2, of stiffener, without attached plating.

$A_{p\text{-}n50}$: Net sectional area, in cm^2, of attached plating.

z_i : z coordinate, in m, of centre of gravity of the i-th element.

1 GENERAL

1.1 Application

1.1.1

This appendix provides the criteria for obtaining the following ultimate longitudinal bending moment capacities:

- M_U to be used in the hull girder ultimate capacity check according to Ch 5, Sec 2,
- M_{UD} to be used in *the* hull girder residual strength capacity check according to Ch 5, Sec 3

1.1.2

The hull girder ultimate longitudinal bending moment capacity, M_U or M_{UD}, is defined as the maximum bending capacity of the hull girder beyond which the hull structure collapses. Hull girder failure is controlled by buckling, ultimate strength and yielding of longitudinal structural elements.

1.2 Methods

1.2.1 Incremental-iterative method

The hull girder ultimate bending capacity is to be assessed by the incremental-iterative method defined in [2].

1.2.2 Alternative methods

Principles for alternative methods for the calculation of the hull girder ultimate bending capacity; e.g. non- linear finite element analysis, are given in [3].

Application of alternative methods is to be agreed by the Society prior to commencement. Documentation of the analysis methodology and detailed comparison of its results are to be submitted for review and acceptance. The use of such methods may require the partial safety factors to be recalibrated.

1.3 Assumptions

1.3.1

The method for calculating the ultimate hull girder capacity is to identify the critical failure modes of all main longitudinal structural elements.

1.3.2

Structures compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements, such as plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling; and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

1.3.3

Only vertical bending is considered. The effects of shear force, torsional loading, horizontal bending moment and lateral pressure are neglected.

1.3.4

For the calculation of the ultimate longitudinal bending moment capacity, M_{UD}, used in the hull girder residual strength check according to Ch 5, Sec 3, the structural members in way of the damage part are to be excluded from the members participating to the considered cross section strength.

2 INCREMENTAL-ITERATIVE METHOD

2.1 Assumptions

2.1.1

In applying the procedure described in [2.2], the following assumptions are generally to be made:

- The ultimate strength is calculated at hull transverse sections between two adjacent transverse webs.
- The hull girder transverse section remains plane during each curvature increment.
- The hull material has an elasto-plastic behaviour.
- The hull girder transverse section is divided into a set of elements, which are considered to act independently.

These elements are:

- Transversely framed plating panels and/or stiffeners with attached plating, whose structural behaviour is described in [2.3.1].
- Hard corners, constituted by plating crossing, whose structural behaviour is described in [2.3.2].
- According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ corresponding to the element strain, ε is to be obtained for each curvature increment from the non-linear load-end shortening curves σ-ε of the element.

These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [2.2]. The stress, σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ-ε.

The procedure is to be repeated until the value of the imposed curvature reaches the value χ_F in m^{-1}, in hogging and sagging condition, obtained from the following formula:

$$\chi_F = \pm 0.003 \frac{M_Y}{EI_{y\text{-}n50}}$$

where:

M_Y : Lesser of the values M_{Y1} and M_{Y2}, in kNm.

$M_{Y1} = 10^3 R_{eH} Z_{B\text{-}n50}$

$M_{Y2} = 10^3 R_{eH} Z_{D\text{-}n50}$

If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

2.2 Procedure

2.2.1 General

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart in Figure 1.

In this procedure, the ultimate hull girder bending moment capacity, M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature χ of the ship cross section as shown in Figure 1. The curve is to be obtained through an incremental-iterative approach.

Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.

For each step, the value χ_i is to be obtained by summing an increment of curvature, $\Delta\chi$ to the value relevant to the previous step χ_{i-1}. This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

This rotation increment induces axial strains, ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened, and vice-

versa in sagging condition.
The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ-ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.
The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, since the relationship σ-ε is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements.
Once the position of the neutral axis is known and the relevant stress distribution in the section structural elements is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.
The main steps of the incremental-iterative approach described above are summarised as follows (see also Figure1):

a) Step 1 : Divide the transverse section of hull into stiffened plate elements.
b) Step 2 : Define stress-strain relationships for all elements as shown in Table 1.
c) Step 3: Initialise curvature χ_1 and neutral axis for the first incremental step with the value of incremental curvature (i.e. curvature that induces a stress equal to 1% of yield strength in strength deck) as:

$$\chi_1 = \Delta\chi = 0.01 \frac{R_{eH}}{E} \frac{1}{z_D - z_n}$$

where:
z_D : Z coordinate, in m, of strength deck at side, with respect to reference coordinate defined in Ch 1, Sec 4, [3.6]

d) Step 4: Calculate for each element the corresponding strain, $\varepsilon_i = \chi(z_i - z_n)$ and the corresponding stress σ_i .
e) Step 5: Determine the neutral axis z_{NA_cur} at each incremental step by establishing force equilibrium over the whole transverse section as:
$\sum A_{i\text{-}n50}\sigma_i = \sum A_{j\text{-}n50}\sigma_j$ (i-th element is under compression, j-th element under tension).
f) Step 6: Calculate the corresponding moment by summing the contributions of all elements as:

$$M_U = \sum \sigma_{Ui} A_{i-n50} \left| \left(z_i - z_{NA_cur} \right) \right|$$

g) Step7: Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in M-χ relationship is less than a negative fixed value, terminate the process and define the peak value of M_U Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to Step 4.

2.2.2 Modelling of the hull girder cross section

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.

Sniped stiffeners are also to be modelled, taking account that they do not contribute to the hull girder strength. The structural members are categorised into a stiffener element, a stiffened plate element or a hard corner element.
The plate panel including web plate of girder or side stringer is idealised into either a stiffened plate element, an attached plate of a stiffener element or a hard corner element.

The plate panel is categorised into the following two kinds:

- Longitudinally stiffened panel of which the longer side is in the longitudinal direction, and
- Transversely stiffened panel of which the longer side is in the perpendicular direction to the longitudinal direction.

a) Hard corner element:
Hard corner elements are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding);

they are generally constituted by two plates not lying in the same plane.
The extent of a hard corner element from the point of intersection of the plates is taken equal to $20t_{n50}$ on transversely stiffened panel and to 0.5 s on a longitudinally stiffened panel, see Figure 2.
where:
t_{n50} : Net offered thickness of the plate, in mm.
s : Spacing of the adjacent longitudinal stiffener, in m.

Bilge, sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners. Enlarged stiffeners, with or without web stiffening, used for Permanent Means of Access (PMA) are not to be considered as a large girder so the attached plate/web connection is only considered as a hard corner, see Figure 3.

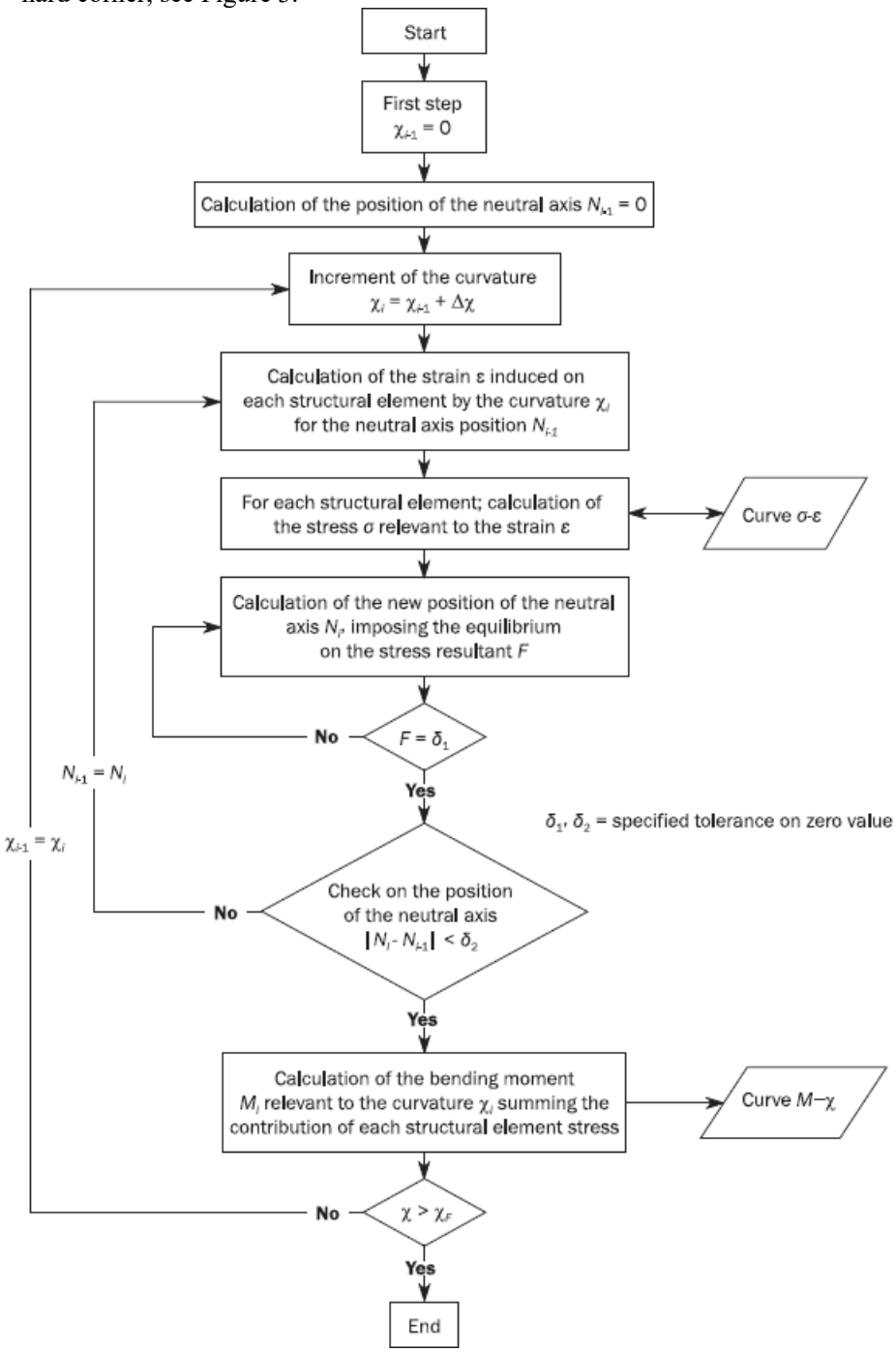


Figure 1 Flow chart of the procedure for the evaluation of the curve M-χ

b) Stiffener element:
The stiffener constitutes a stiffener element together with the attached plate. The attached plate width is in principle:
- Equal to the mean spacing of the stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or
- Equal to the width of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened, see Figure 2.

c) Stiffened plate element:
The plate between stiffener elements, between a stiffener element and a hard corner element or between hard corner elements is to be treated as a stiffened plate element, see Figure 2.

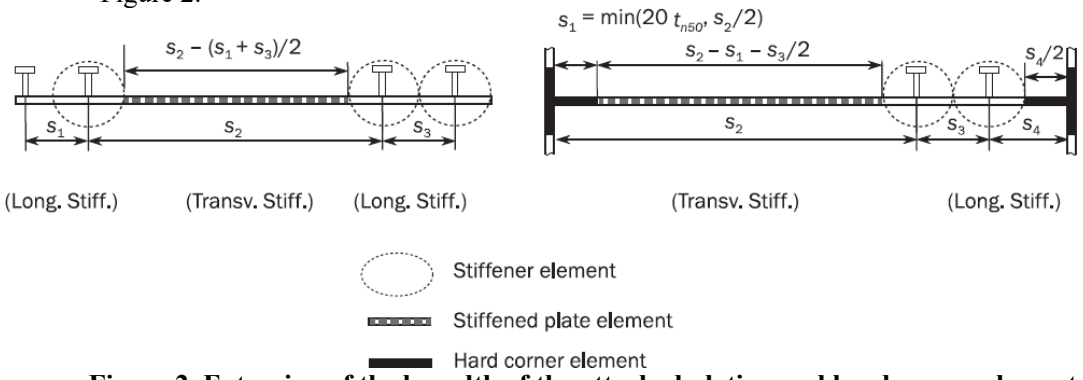


Figure 2 Extension of the breadth of the attached plating and hard corner element

The typical examples of modelling of hull girder section are illustrated in Figure 3 and Figure 4. Notwithstanding the foregoing principle, these figures are to be applied to the modelling in the vicinity of upper deck, sheer strake and hatch side girder.

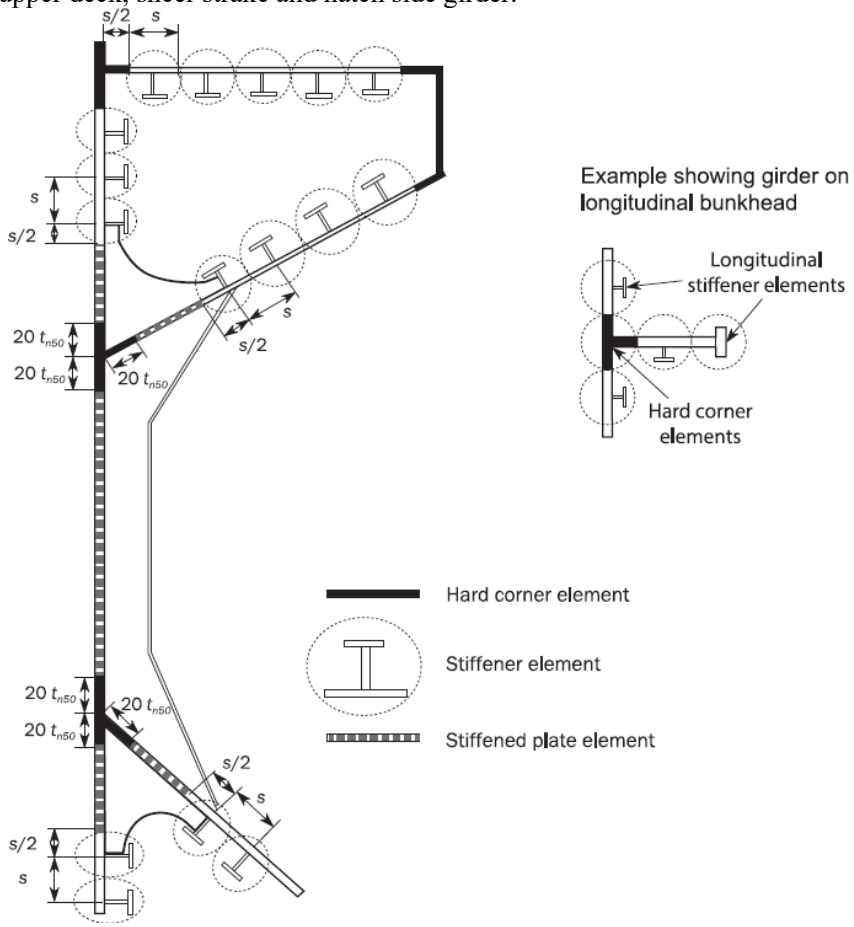


Figure 3 Examples of the configuration of stiffened plate elements, stiffener elements and hard corner elements on a hull section

- In case of the knuckle point as shown in Figure 5, the plating area adjacent to knuckles in the plating with an angle greater than30 deg is defined as a hard corner. The extent of one side of the corner is taken equal to $20t_{n50}$ on transversely framed panels and to 0.5 s on longitudinally framed panels from the knuckle point.
- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels.
- Where the opening is provided in the stiffened plate element, the openings are to be considered in accordance with Ch 5, Sec 1, [1.2.9].
- Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress obtained from the following formula are to be used for the calculation.

$$t_{n50} = \frac{t_{1-n50}s_1 + t_{2-n50}s_2}{s} \quad R_{eHp} = \frac{R_{eHp1}t_{1-n50}s_1 + R_{eHp2}t_{2-n50}s_2}{t_{n50}s}$$

where R_{eHp1}, R_{eHp2}, $t_{1\text{-}n50}$, $t_{2\text{-}n50}$, s_1, s_2 and s are shown in Figure 6.

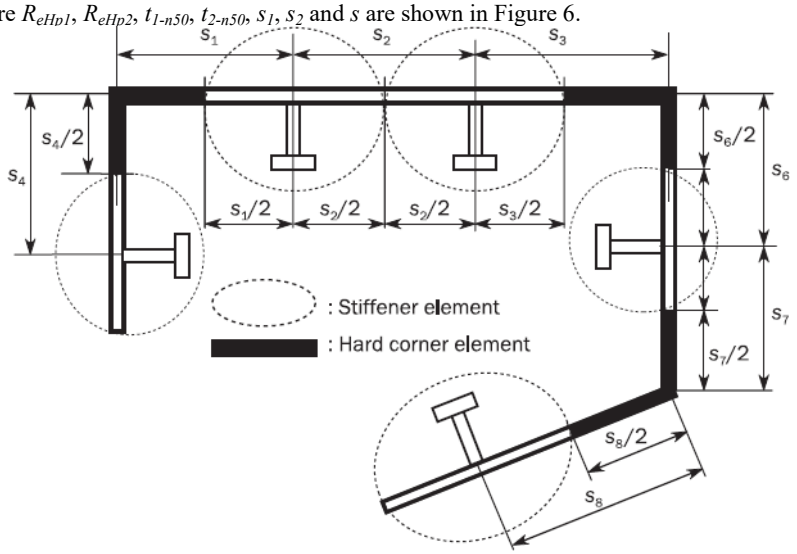


Figure 4 Extension of the breadth of the attached plating and hard corner element

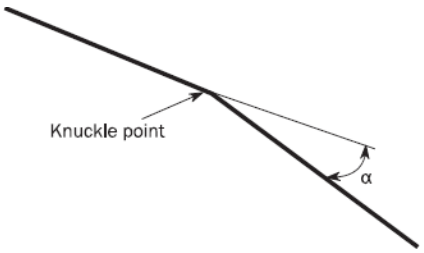


Figure 5 Plating with knuckle point

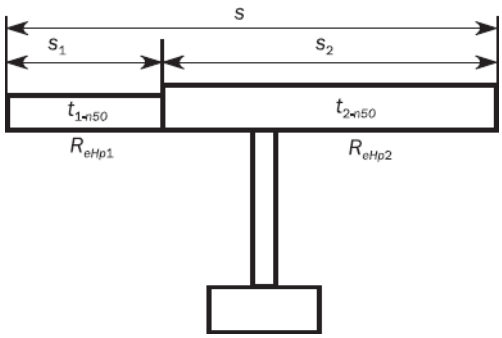


Figure 6 Element with different thickness and yield strength

2.3 Load-end shortening curves

2.3.1 Stiffened plate element and stiffener element

Stiffened plate element and stiffener element composing the hull girder transverse sections may

collapse following one of the modes of failure specified in Table 1.

- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with [2.3.3] to [2.3.8], taking into account the non-continuous longitudinal stiffener. In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as zero.
- Where the opening is provided in the stiffened plate element, the considered area of the stiffened plate element is to be obtained by deducting the opening area from the plating in calculating the total forces for checking the hull girder ultimate strength. The consideration of the opening is in accordance with the requirement in Ch 5, Sec 1, [1.2.9] to Ch 5, Sec 1, [1.2.13].
- For stiffened plate element, the effective width of plate for the load shortening portion of the stress- strain curve is to be taken as full plate width, i.e. to the intersection of other plate or longitudinal stiffener – neither from the end of the hard corner element nor from the attached plating of stiffener element, if any. In calculating the total forces for checking the hull girder ultimate strength, the area of the stiffened plate element is to be taken between the hard corner element and the stiffener element or between the hard corner elements, as applicable.

Modes of failure of stiffened plate element and stiffener element Table 1

Element	Mode of failure	Curve σ-ε defined in
Lengthened stiffened plate element or stiffener element	Elasto-plastic collapse	[2.3.3]
Shortened stiffener element	Beam column buckling Torsional buckling Web local buckling of flanged profiles Web local buckling of flat bars	[2.3.4] [2.3.5] [2.3.6] [2.3.7]
Shortened stiffened plate element	Plate buckling	[2.3.8]

2.3.2 Hard corner element

The relevant load-end shortening curve σ-ε is to be obtained for lengthened and shortened hard corners according to [2.3.3].

2.3.3 Elasto-plastic collapse of structural elements

The equation describing the load-end shortening curve σ-ε for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains, see Figure 7:

$$\sigma = \Phi R_{eHA}$$

where:

R_{eHA}: Equivalent minimum yield stress, in N/mm^2, of the considered element, obtained by the following formula:

$$R_{eHA} = \frac{R_{eHp} A_{p-50} + R_{eHs} A_{s-n50}}{A_{p-n50} + A_{s-n50}}$$

Φ : Edge function, equal to:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 \leqslant \varepsilon \leqslant 1$

$\Phi = 1$ for $\varepsilon > 1$

ε : Relative strain, equal to:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain.

ε_Y : Strain at yield stress in the element, equal to:

$$\varepsilon_Y = \frac{R_{eHA}}{E}$$

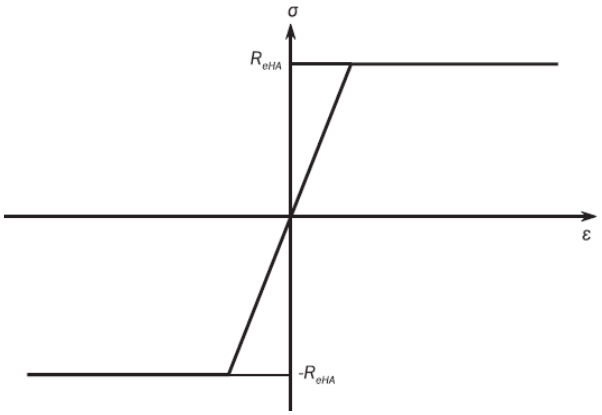


Figure 7 Load-end curve σ-ε for elasto plastic collapse

2.3.4 Beam column buckling

The equation describing the load-end shortening curve σ_{CR10}-ε for the beam column buckling of stiffeners composing the hull girder transverse section is to be obtained from the following formula, see Figure 8:

$$\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_{s-n50} + A_{pE-n50}}{A_{s-n50} + A_{p-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].

σ_{C1} : Critical stress, in N/mm^2, equal to:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \qquad \text{for } \sigma_{E1} \le \frac{R_{eHB}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eHB}\left(1 - \frac{R_{eHB}\varepsilon}{4\sigma_{E1}}\right) \quad \text{for } \sigma_{E1} > \frac{R_{eHB}}{2}\varepsilon$$

R_{eHB}: Equivalent minimum yield stress, in N/mm^2, of the considered element, obtained by the following formula:

$$R_{eHB} = \frac{R_{eHp}A_{pEI-n50}l_{pE} + R_{eHs}A_{s-n50}l_{sE}}{A_{pEI-n50}l_{pE} + A_{s-n50}l_{sE}}$$

$A_{pEl\text{-}n50}$: Effective area, in cm^2, equal to:

$$A_{pEl\text{-}n50} = 10 b_{E1} t_{n50}$$

l_{pE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the bottom of the attached plate.

l_{sE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plating of width b_{E1} to the top of the stiffener.

ε : Relative strain, as defined in [2.3.3].

σ_{E1} : Euler column buckling stress, in N/mm^2, equal to:

$$\sigma_{E1} = \pi^2 E \frac{I_{E-n50}}{A_{E-n50}l^2}10^{-4}$$

$I_{E\text{-}n50}$: Net moment of inertia of stiffeners, in cm^4, with attached plating of width b_{E1}.

$A_{E\text{-}n50}$: Net area, in cm^2, of stiffeners with attached plating of width b_E.

b_{E1} : Effective width corrected for relative strain, in m, of the attached plating, equal to:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for } \beta_E > 1.0$$

$$b_{E1} = s \quad \text{for } \beta_E \le 1.0$$

β_E : $\beta_E = 10^3 \dfrac{s}{t_{n50}} \sqrt{\dfrac{\varepsilon R_{eHp}}{E}}$

$A_{pE\text{-}n50}$: Net sectional area, in cm^2, of attached plating of width b_E, equal to:

$$A_{pE-n50} = 10 b_E t_{n50}$$

b_E : Effective width, in m, of the attached plating, equal to:

$$b_E = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) s \quad \text{for } \beta_E > 1.25$$

$$b_E = s \quad \text{for } \beta_E \le 1.25$$

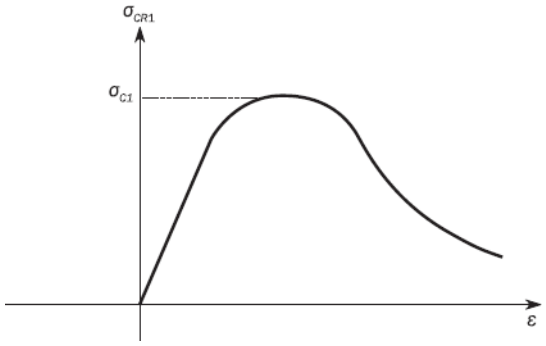


Figure 8 Load-end shortening curve σ_{CR1}-ε for beam column buckling

2.3.5 Torsional buckling

The equation describing the load-end shortening curve σ_{CR2}-ε for the flexural-torsional buckling of stiffeners composing the hull girder transverse section is to be obtained according to the following formula, see Figure 9.

$$\sigma_{CR2} = \Phi \frac{A_{s-n50}\sigma_{C2} + A_{p-n50}\sigma_{CP}}{A_{s-n50} + A_{p-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].

σ_{C2} : Critical stress, in N/mm^2, equal to:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for } \sigma_{E2} \le \frac{R_{eHs}}{2}\varepsilon$$

$$\sigma_{C2} = R_{eHs}\left(1 - \frac{R_{eHs}\varepsilon}{4\sigma_{E2}}\right) \quad \text{for } \sigma_{E2} > \frac{R_{eHs}}{2}\varepsilon$$

σ_{E2} : Euler torsional buckling stress, in N/mm^2, taken as σ_{ET} in Ch 8, Sec 5, [2.3.4].

ε : Relative strain, as defined in [2.3.3].

σ_{CP} : Buckling stress of the attached plating, in N/mm^2, equal to:

$$\sigma_{CP} = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) R_{eHp} \quad \text{for} \quad \beta_E > 1.25$$

$$\sigma_{CP} = R_{eHp} \quad \text{for} \quad \beta_E \le 1.25$$

β_E : Coefficient, as defined in [2.3.4].

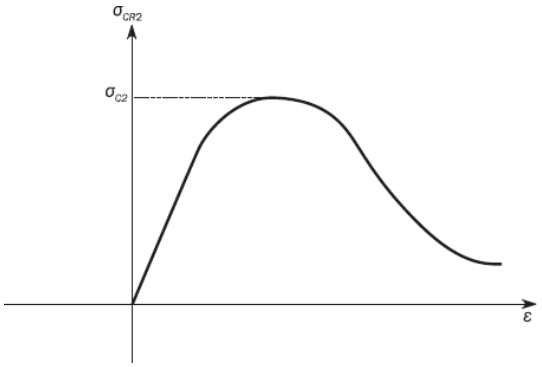


Figure 9 Load-end shortening curve σ_{CR2}-ε for flexural-torsional buckling

2.3.6 Web local buckling of stiffeners made of flanged profiles

The equation describing the load-end shortening curve σ_{CR3}-ε for the web local buckling of flanged stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{10^3 b_E t_{n50} R_{eHp} + \left(h_{we} t_{w-n50} + b_f t_{f-n50}\right) R_{eHs}}{10^3 s t_{n50} + h_w t_{w-n50} + b_f t_{f-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].

b_E : Effective width, in m, of the attached shell plating, as defined in [2.3.4].

h_{we} : Effective height, in mm, of the web, equal to:

$$h_{we} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right) h_w \quad \text{for} \quad \beta_w \geq 1.25$$

$$h_{we} = h_w \quad \text{for} \quad \beta_w < 1.25$$

ε : Relative strain, as defined in [2.3.3].

2.3.7 Web local buckling of stiffeners made of flat bars

The equation describing the load-end shortening curve σ_{CR4}-ε for the web local buckling of flat bar stiffeners composing the hull girder transverse section is to be obtained from the following formula, see Figure 10:

$$\sigma_{CR4} = \Phi \frac{A_{P-n50}\sigma_{CP} + A_{s-n50}\sigma_{C4}}{A_{p-n50} + A_{s-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3].

σ_{CP} : Buckling stress of the attached plating, in N/mm^2, as defined in [2.3.5].

σ_{C4} : Critical stress, in N/mm^2, equal to:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \quad \text{for} \quad \sigma_{E4} \leq \frac{R_{eHs}}{2}\varepsilon$$

$$\sigma_{C4} = R_{eHs}\left(1 - \frac{R_{eHs}\varepsilon}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{R_{eHs}}{2}\varepsilon$$

σ_{E4} : Local Euler buckling stress, in N/mm^2, equal to:

$$\sigma_{E4} = 160000\left(\frac{t_{w-n50}}{h_w}\right)^2$$

ε : Relative strain, as defined in [2.3.3].

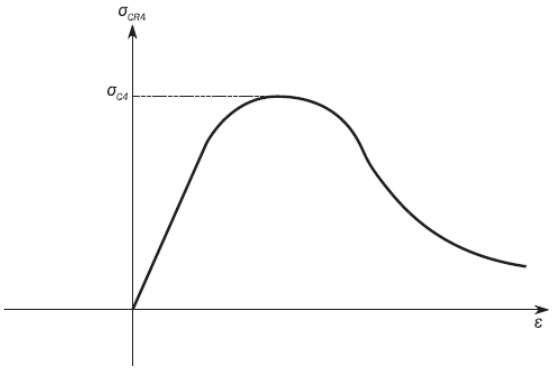


Figure 10 Load-end shortening curve σ_{CR4}-ε for web local buckling

2.3.8 Plate buckling

The equation describing the load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

where:

$$\sigma_{CR5} = \min\left\{ \begin{array}{c} R_{eHp}\Phi \\ \Phi R_{eHp}\left[\frac{s}{l}\left(\frac{2.25}{\beta_E}-\frac{1.25}{\beta_E^2}\right)+0.1\left(1-\frac{s}{l}\right)\left(1+\frac{1}{\beta_E^2}\right)^2\right] \end{array} \right.$$

Φ : Edge function, as defined in [2.3.3].

$$\beta_E : \beta_E = 10^3 \frac{s}{t_{n50}}\sqrt{\frac{\varepsilon R_{eHp}}{E}}$$

s : Plate breadth, in m, taken as the spacing between the stiffeners.

l : Longer side of the plate, in m.

3 ALTERNATIVE METHODS

3.1 General

3.1.1

The bending moment-curvature relationship, M-χ, may be established by alternative methods. Such models are to consider all the relevant effects important to the non-linear response with due considerations of:

a) Non-linear geometrical behaviour.
b) Inelastic material behaviour.
c) Geometrical imperfections and residual stresses (geometrical out-of-flatness of plate and stiffeners).
d) Simultaneously acting loads:
   - Bi-axial compression.
   - Bi-axial tension.
   - Shear and lateral pressure.
e) Boundary conditions.
f) Interactions between buckling modes.
g) Interactions between structural elements such as plates, stiffeners, girders, etc.
h) Post-buckling capacity.
i) Overstressed elements on the compression side of hull girder cross section possibly leading to local permanent sets/buckle damages in plating, stiffeners etc (double bottom effects or similar).

3.2 Non-linear finite element analysis

3.2.1

Advanced non-linear finite element analyses models may be used for the assessment of the hull girder ultimate capacity. Such models are to consider the relevant effects important to the non-linear responses with due consideration of the items listed in [3.1.1].

CCS 3.2.1a The non-linear finite element analysis method used for the assessment of the ultimate strength of hull girders are given in CCS Appendix C of this PART.

3.2.2

Particular attention is to be given to modelling the shape and size of geometrical imperfections. It is to be ensured that the shape and size of geometrical imperfections trigger the most critical failure modes.

Chapter 6 HULL LOCAL SCANTLING

Section 1 GENERAL

1 APPLICATION

1.1 Application

1.1.1

This chapter applies to hull structure over the full length of the ship including fore end, cargo hold region, machinery space and aft end, the side shell above the freeboard deck, engine casing, exposed decks of superstructure and internal decks except those inside superstructure and deckhouse.

1.1.2

This chapter provides requirements for evaluation of plating, stiffeners and Primary Supporting Members (PSM) subject to lateral pressure, local loads and to hull girder loads, as applicable. Requirements are specified for:

- Load application in Ch 6, Sec 2.
- Minimum thickness of plates, stiffeners and PSM in Ch 6, Sec 3.
- Plating in Ch 6, Sec 4.
- Stiffeners in Ch 6, Sec 5.
- PSM and pillars in Ch 6, Sec 6.

In addition, other requirements not related to defined design load sets, are provided.

1.1.3 Required scantlings

The offered net scantling is to be greater than or equal to the required scantlings based on requirements provided in this chapter.

1.1.4 Additional local strength requirements

Additional local strength requirements are provided in Ch 10 considering bow impact loads, bottom slamming loads and sloshing loads, and for fore end, machinery space and aft end.

1.2 Acceptance criteria

1.2.1

Acceptance criteria set to be selected based on design load as follows:

- AC-S for design load S; static loads.
- AC-SD for design load S+D; combination of static and dynamic loads.

Section 2 LOAD APPLICATION

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.

1 LOAD COMBINATION

1.1 Hull girder bending

1.1.1 Normal stresses

The normal stress σ_{hg}, in N/mm^2, induced by acting vertical and horizontal bending moments at the position being considered is given as follow. This stress is to be calculated for each design load set, as defined in [2] covering all dynamic load cases defined in Ch 4 in combination with M_{sw} both in hogging and in sagging.

$$\sigma_{hg} = \left(\frac{M_{sw} + M_{wv-LC}}{I_{y-n50}} (z - z_n) - \frac{M_{wh-LC}}{I_{z-n50}} y \right) 10^{-3}$$

where:

M_{sw} : Still water bending moment, in kNm, as defined in Ch 4, Sec 4, [2.2] in accordance with the considered design load scenario in Ch 4, Sec 7, Table 1.

$M_{wv\text{-}LC}$: Vertical wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, [3.5.2] in accordance with the considered design load scenario in Ch 4, Sec 7, Table 1, at the considered longitudinal position.

$M_{wh\text{-}LC}$: Horizontal wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, [3.5.4] in accordance with the considered design load scenario in Ch 4, Sec 7, Table 1, at the considered longitudinal position.

$I_{y\text{-}n50}$: Net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4.

$I_{z\text{-}n50}$: Net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m^4.

y : Transverse coordinate of load calculation point, in m.

z : Vertical coordinate of the load calculation point under consideration, in m.

z_n : Distance from the baseline to the horizontal neutral axis, in m.

1.2 Lateral pressures

1.2.1 Static and dynamic pressures in intact conditions

The static and dynamic lateral pressures in intact condition induced by the sea and the various types of cargoes, ballast and other liquids are to be considered. Applied loads will depend on the location of the elements under consideration, and the adjacent type of compartments.

1.2.2 Lateral pressure in flooded conditions

Watertight boundaries of compartments not intended to carry liquids, excluding shell envelope, are to be subjected to lateral pressure in flooded conditions.

1.3 Pressure combination

1.3.1 Elements of the outer shell

If the compartment adjacent to the outer shell is intended to carry liquids, the static and dynamic lateral pressures to be considered are the differences between the internal pressures and the external sea pressures at the corresponding draught.

If the compartment adjacent to the outer shell is not intended to carry liquids, the internal pressures and external sea pressures are to be considered independently.

1.3.2 Elements other than those of the outer shell

Except as specified in [1.3.1], the static and dynamic lateral pressures on an element separating two adjacent compartments are those obtained considering the two compartments individually loaded.

2 DESIGN LOAD SETS

2.1 Application of load components

2.1.1 Application

These requirements apply to:

- Plating and stiffeners along the full length of the ship.
- PSM outside the cargo hold region.

2.1.2 Load components

The static and dynamic load components are to be determined in accordance with Ch 4, Sec 7, Table 1.

Radius of gyration, k_r, and metacentric height, GM, are to be in accordance with Ch 4, Sec 3, Table 1 and Ch 4, Sec 3, Table 2 for the considered loading conditions specified in the design load sets given in Table 1.

2.1.3 Design load sets for plating, stiffeners and PSM

Design load sets for plating, stiffeners and primary supporting members are given in Table 1.

In addition, the design load sets for primary supporting members of bulk carriers with freeboard length L_{LL} less than 150 m and of oil tankers within the cargo hold region are given respectively in Pt 2, Ch 1, Sec 4, [4.2] and in Pt 2, Ch 2, Sec 3, [1.2].

Design load sets **Table 1**

Item	Design load set	Load component	Draught	Design load	Loading condition
External shell and exposed deck	SEA-1	P_{ex}, P_D	T_{SC}	S+D	Full Load condition (1)
	SEA-2	P	T	S	Harbour condition (2)
Water ballast tank (oil tanker and bulk carrier)	WB-1	$P_{in} - P_{ex}$ (3)	T_{BAL}	S+D	Normal ballast condition
	WB-2	$P_{in} - P_{ex}$ (3)	T_{BAL}	S+D	Normal ballast condition Water ballast exchange
	WB-3	$P_{in} - P_{ex}$ (3)	$0.25T_{SC}$	S	Harbour/test condition
Water ballast tank (bulk carrier) and bulk cargo hold assigned as ballast hold	WB-4	$P_{in} - P_{ex}$ (3)	T_{BAL-H} (7)	S+D	Heavy ballast condition
	WB-5 (4)	$P_{in} - P_{ex}$ (3)	T_{BAL-H} (7)	S+D	Heavy ballast condition Water ballast exchange
	WB-6 (5)	P_{in}	-	S	Harbour/test condition
Cargo oil tank	OT-1	P_{in}	T_{SC}	S+D	Full Load condition
	OT-2	P_{in}	$0.6T_{SC}$	S+D	Partial load condition
	OT-3	P_{in}	-	S	Harbour/Test condition
Bulk cargo hold	BC-1	P_{in}	T_{SC}	S+D	Homogeneous loading, fully filled
	BC-2	P_{in}	-	S	
	BC-3	P_{in}	T_{SC}	S+D	Homogeneous heavy cargo, partially filled (BC-A, B ships)
	BC-4	P_{in}	-	S	
	BC-5	P_{in}	T_{SC}	S+D	Alternate light cargo, fully filled (BC-A ships)
	BC-6	P_{in}	-	S	
	BC-7	P_{in}	T_{SC}	S+D	Alternate heavy cargo, partially filled (BC-A ships.)
	BC-8	P_{in}	-	S	
Other tanks (fuel oil tank, fresh water tank)	TK-1	$P_{in} - P_{ex}$ (3)	T_{BAL}	S+D	Normal ballast condition
	TK-2	$P_{in} - P_{ex}$ (3)	$0.25T_{SC}$	S	Harbour/test condition
Compartments not carrying liquids	FD-1 (6)	P_{in}	T_{SC}	S+D	Flooded condition
	FD-2 (6)	P_{in}	-	S	Flooded condition
Exposed deck, internal decks or platforms	DL-1 (8)	P_{dl}, F_U	T_{SC}	S+D	Full Load condition
	DL-2 (8)	P_{dl}, F_U	-	S	Harbour condition

(1) For bulk carrier BC-A and BC-B, full load condition means ‘homogeneous heavy cargo’.
(2) For external shell only.
(3) P_{ex} is to be considered for external shell only.
(4) Not to be applied to bulk cargo hold assigned as ballast hold.
(5) Bulk cargo hold only.
(6) FD-1 and FD-2 are not applicable to external shell and corrugations of transverse vertically corrugated bulkhead separating cargo holds. Requirement in flooded conditions of transverse corrugated bulkhead are given in Pt 2, Ch 1, Sec 3, [3]. FD-1 and FD-2 are to be considered for strength deck whenever applicable.
(7) Minimum draught among heavy ballast conditions is to be used.
(8) Distributed or concentrated loads only. Need not be combined with simultaneously occurring green sea pressure.

Section 3 MINIMUM THICKNESSES

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.

1 PLATING
1.1 Minimum thickness requirements
1.1.1
The net thickness of plating in mm, is to comply with the appropriate minimum thickness requirements given in Table 1.

Minimum net thickness for plating **Table 1**

Element	Location	Area	Net thickness
Shell	Keel	-	7.5 + 0.03 L_2
	Bottom Side shell Bilge	Fore Part	6.5 + 0.03 L_2
		Machinery space Aft part	7.0 + 0.03 L_2
		Elsewhere	5.5 + 0.03 L_2
Breasthook	Fore part	Breasthook	6.5
Deck	Weather deck, strength deck, internal tank boundary	-	4.5 + 0.02 L_2
	Platform deck	Machinery space	2.8 + 0.0067s
		Elsewhere	6.5
Inner bottom (1)	-	Machinery space	6.6 + 0.024 L_2
		Elsewhere	5.5 + 0.03 L_2
Longitudinal bulkheads of bulk carriers	Inner side, hopper tank top, top wing tank longitudinal bulkhead	Cargo hold region	0.7 L_2
Bulkheads	Internal tank boundary, Transverse/longitudinal watertight bulkhead	-	4.5 + 0.02 L_2
	Non-tight bulkhead, Wash bulkhead, Bulkheads between dry spaces.	-	4.5 + 0.01 L_2
	Pillar bulkheads in fore and aft peaks	-	7.5
Other members	Diaphragms in lower/upper stool	-	5.0 + 0.015 L_2
	Engine casing (in the cargo hold region)	Cargo hold region	5.5
	Engine casing (in way of accommodation)	Accommodation	4.0
	Other plates in general	-	4.5 + 0.01L_2
(1) Applicable for both tight and non tight members			

2 STIFFENERS AND TRIPPING BRACKETS
2.1 Minimum thickness requirements
2.1.1
The net thickness of the web and face plate, if any, of stiffeners and tripping brackets in mm, is to comply with the minimum net thickness given in Table 2.

In addition, the net thickness of the web of stiffeners and tripping brackets, in mm, is to be:

- Not less than 40% of the net required thickness of the attached plating, to be determined

according to Ch 6, Sec 4.

- Less than twice the net offered thickness of the attached plating.

Minimum net thickness for stiffeners and tripping brackets **Table 2**

Element	Location	Net thickness
Stiffeners and attached end brackets	Watertight boundary	$3.5 + 0.015\ L_2$
	Other structure	$3.0 + 0.015\ L_2$
Cargo hold side frames webs of single side bulk carriers	Foremost hold (1)	$6.0 + 0.026\ L$
	Other holds (1)	$5.2 + 0.023\ L$
Tripping brackets		$5.0 + 0.015\ L_2$
(1) L needs not to be taken greater than 200 m		

3 PRIMARY SUPPORTING MEMBERS

3.1 Minimum thickness requirements

3.1.1

The net thickness of web plating and flange of primary supporting members in mm, is to comply with the minimum net thickness given in Table 3.

Minimum net thickness for primary supporting members **Table 3**

Element	Location		Net thickness
Double bottom centreline girder	Machinery space		$1.55\ L_2^{1/3}+3.5$
	Elsewhere		$5.5 + 0.025\ L_2$
Other bottom girder	Machinery space		$1.7\ L_2^{1/3}+1.0$
	Fore part of ships with $L \geqslant 150$ m		$0.7\ L_2^{1/2}$
	Elsewhere and fore part of ships with $L < 150$ m		$5.5 + 0.02\ L_2$
Girders bounding a duct keel	Machinery space		$0.8\ L_2^{1/2} + 2.5$
Bottom floor	Machinery space		$1.7\ L_2^{1/3} + 1.0$
	Fore part		$0.7\ L_2^{1/2}$
	Elsewhere		$0.6\ L_2^{1/2}$
Aft peak floor	-		$0.7\ L_2^{1/2}$
Other primary supporting member	Aft part / fore part		$0.7\ L_2^{1/2}$
	Elsewhere	In oil cargo tanks	$5.5+0.015L_2$
		For other cases	$0.6\ L_2^{1/2}$

Section 4 PLATING

SYMBOLS

For symbols not defined in this section, refer to Ch1, Sec 4.

α_p : Correction factor for the panel aspect ratio to be taken as follow but not to be taken greater than 1.0.

$$\alpha_p = 1.2 - \frac{b}{2.1a}$$

a : Length of plate panel, in mm, as defined in Ch 3, Sec 7, [2.2.2].

b : Breadth of plate panel, in mm, as defined in Ch 3, Sec 7, [2.2.2].

P : Design pressure for the considered design load set, see Ch 6, Sec 2, [2], calculated at the load calculation point defined in Ch 3, Sec 7, [2.2], in kN/m^2.

σ_{hg} : Hull girder bending stress, in N/mm^2, as defined in Ch 6, Sec 2, [1.1], calculated at the load calculation point as defined in Ch 3, Sec 7, [2.2].

χ : Coefficient taken equal to:

- In intact condition:
  - χ= 0.70 for inner bottom and bilge hopper tank plating in cargo holds of bulk carriers,
  - χ= 1.00 for other cases.
- In flooded condition:
  - χ= 1.00 for collision bulkheads for acceptance criteria set AC-S,
  - χ= 0.95 for collision bulkheads for acceptance criteria set AC-SD,
  - χ= 1.15 for other watertight boundaries of compartments.

1 PLATING SUBJECTED TO LATERAL PRESSURE

1.1 Yielding check

1.1.1 Plating

The net thickness, t in mm, is not to be taken less than the greatest value for all applicable design load sets, as defined in Ch 6, Sec 2, [2.1.3], given by:

$$t = 0.0158\alpha_p b\sqrt{\frac{|P|}{\chi C_a R_{eH}}}$$

C_a : Permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta - \alpha\frac{|\sigma_{hg}|}{R_{eH}} \text{ not to be taken greater than } C_{a\text{-}max}.$$

β : Coefficient as defined in Table 1.

α : Coefficient as defined in Table 1.

$C_{a\text{-}max}$: Maximum permissible bending stress coefficient as defined in Table 1.

Definition β, α and $C_{a\text{-}max}$ **Table 1**

Acceptance criteria set	Structural member		β	α	$C_{a\text{-}max}$
AC-S	Longitudinal strength members	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely stiffened plating	0.9	1.0	0.8
	Other members		0.8	0.8	0
AC-SD	Longitudinal strength members	Longitudinally stiffened plating	1.05	0.5	0.95
		Transversely stiffened plating	1.05	1.0	0.95
	Other members		1.0	1.0	0

1.2 Plating of corrugated bulkheads

1.2.1 Cold hot formed and built up corrugations

The net thicknesses, t in mm, of the web and flange plates of corrugated bulkheads are not to be

taken less than the greatest value calculated for all applicable design load sets, as defined in Ch 6, Sec 2, [2.1.3], given by:

$$t = 0.0158 b_p \sqrt{\frac{|P|}{C_{CB} R_{eH}}}$$

where:

b_p : Breadth of plane corrugation plating:

$b_p = b_{f\text{-}cg}$ for flange plating, in mm, as defined in Ch 3, Sec 6, Figure 21.

$b_p = b_{w\text{-}cg}$ for web plating, in mm, as defined in Ch 3, Sec 6, Figure 21.

C_{CB} : Permissible bending stress coefficient for corrugated bulkhead plating taken equal to:

- For acceptance criteria set AC-S for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads.
  $C_{CB} = 0.75$
- For acceptance criteria set AC-SD for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads.
  $C_{CB} = 0.90$
- For horizontally corrugated longitudinal bulkheads, without being greater than $C_{CB\text{-}max}$.

$$C_{CB} = \beta_{CB} - \alpha_{CB} \frac{|\sigma_{hg}|}{R_{eH}}$$

β_{CB} : Coefficient as defined in Table 2.

α_{CB} : Coefficient as defined in Table 2.

$C_{CB\text{-}max}$: Maximum permissible bending stress coefficient as defined in Table 2.

Definition β_{CB}, α_{CB} and $C_{CB\text{-}max}$ **Table 2**

Acceptance criteria set	Structural member	β_{CB}	α_{CB}	$C_{CB\text{-}max}$
AC-S	Horizontally corrugated longitudinal bulkheads	0.90	0.50	0.75
AC-SD	Horizontally corrugated longitudinal bulkheads	1.05	0.50	0.90

1.2.2 Built-up corrugations

For built-up corrugations, with flange and web plate of different thickness, the net thickness, t_1 in mm, is to be taken as the greatest value calculated for all applicable design load sets, as defined in Ch 6, Sec 2, [2.1.3], given by:

$$t_1 = \sqrt{\frac{0.0005 b_p^2 |P|}{C_{CB} R_{eH}} - t_2^2}$$

where:

t_1 : Net thickness of the thicker plating, either flange or web, in mm.

t_2 : Net thickness of the thinner plating, either flange or web, in mm.

b_P : Breadth of thicker plate, either flange or web, in mm.

C_{CB} : Permissible bending stress coefficient as defined in [1.2.1].

2 SPECIAL REQUIREMENTS

2.1 Minimum thickness of keel plating

2.1.1

The net thickness of the keel plating is not to be taken less than the offered net thickness of the adjacent 2m width bottom plating, measured from the edge of the keel strake.

The width of the keel is defined in Ch 3, Sec 6, [7.2.1].

2.2 Bilge plating

2.2.1 Definition of bilge plating

The definition of bilge plating is given in Ch 1, Sec 4, [3.8.1].

2.2.2 Bilge plating thickness

a) The net thickness of transversely stiffened bilge plating is not to be taken less than the net required thickness for the adjacent bottom shell plating and adjacent side shell plating, by Ch 6 and Ch 8, Sec 2 and Sec 3, whichever is greater. When bilge plating is divided into two or more strakes, in accordance with this requirement, the net thicknesses of lower and upper strakes are to be determined in comparison with the net required thicknesses of adjacent bottom shell plating and side shell plating respectively.

b) The net thickness of rounded bilge plating, t, in mm, is not to be taken less than:

$$t_{net} = 6.45\times10^{-4}(P_{ex}s_b)^{0.4}R^{0.6}$$

where:

P_{ex} : Design sea pressure for the design load set SEA-1 as defined in Ch 6, Sec 2, [2.1.3] calculated at the lower turn of the bilge, in kN/m^2.

R : Effective bilge radius in mm.

$$R = R_0 + 0.5(\Delta s_1 + \Delta s_2)$$

R_0 : Radius of curvature, in mm. See Figure 1.

Δs_1 : Distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, see Figure 1. Where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero.

Δs_2 : Distance between the upper turn of bilge and the lowest side longitudinal, in mm, see Figure 1. Where the lowest side longitudinal is within the curvature, this distance is to be taken as zero.

s_b : Distance between transverse stiffeners, webs or bilge brackets, in mm.

c) Longitudinally stiffened bilge plating is to be assessed as regular stiffened plating. The bilge thickness is not to be less than the lesser of the value obtained by [1.1.1] and [2.2.2] b). A bilge keel is not considered as an effective 'longitudinal stiffening' member.

2.2.3 Transverse extension of bilge minimum plate thickness

Where a plate seam is located in the straight plate just below the lowest stiffener on the side shell, any increased thickness required for the bilge plating does not have to be extended to the adjacent plate above the bilge provided the plate seam is not more than $s_2/4$ below the lowest side longitudinal. Similarly, for the flat part of adjacent bottom plating, any increased thickness for the bilge plating does not have to be extended to the adjacent plate provided that the plate seam is not more than $s_1/4$ beyond the outboard bottom longitudinal. For definition of s_1 and s_2, see Figure 1.

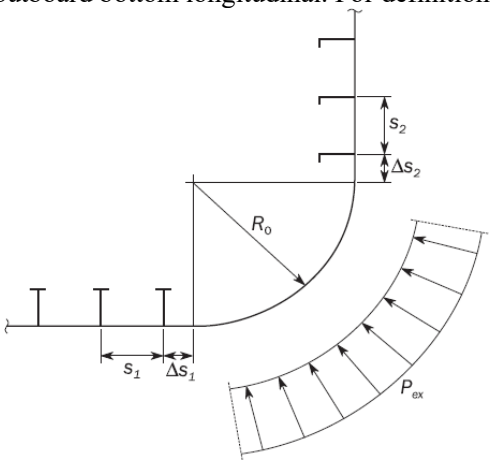


Figure 1 Transverse stiffened bilge plating

2.2.4 Hull envelope framing in bilge area

For transversely stiffened bilge plating, a longitudinal is to be fitted at the bottom and at the side close to the position where the curvature of the bilge plate starts. The scantling of those longitudinals are to be not less than the one of the closer adjacent stiffener. The distance between the lower turn of bilge and the outermost bottom longitudinal, Δs_1, is generally not to be greater than one-third of the spacing between the two outermost bottom longitudinals, s_1. Similarly, the distance between the upper turn of the bilge and the lowest side longitudinal, Δs_2, is generally not

to be greater than one-third of the spacing between the two lowest side longitudinals, s_2. See Figure 1.

2.3 Side shell plating

2.3.1 Fender contact zone

The net thickness, t in mm, of the side shell plating within the fender contact zone as specified in [2.3.2] is not to be taken less than:

$$t = 26\left(\frac{b}{1000} + 0.7\right)\left(\frac{BT_{SC}}{R_{eH}{}^2}\right)^{0.25}$$

2.3.2 Application of fender contact zone requirement

The application extends within the cargo hold region as defined in Ch 1, Sec 1, [2.4.3], from the ballast draught T_{BAL} to $0.25T_{SC}$ (minimum 2.2 m) above T_{SC}.

2.4 Sheer strake

2.4.1 General

The minimum width of the sheer strake is defined in Ch 3, Sec 6, [8.2.4].

2.4.2 Welded sheer strake

The net thickness of a welded sheer strake is not to be less than the offered net thickness of the adjacent side plating, provided this adjacent side plating is located entirely within the top wing tank or double side tank as the case may be.

2.4.3 Rounded sheer strake

The net thickness of a rounded sheer strake is not to be less than:

- The offered net thickness of the adjacent 2 m width deck plating, or
- The offered net thickness of the adjacent 2 m width side plating, whichever is greater.

2.5 Deck stringer plating

2.5.1

The minimum width of deck stringer plating is defined in Ch 3, Sec 6, [9.1.2].

2.5.2

Within $0.6L$ of amidships, the net thickness of the deck stringer plate is not to be less than the offered net thickness of the adjacent deck plating.

2.6 Supporting structure in way of corrugated bulkheads

2.6.1 General

Requirements for the arrangement of bulkhead as given in Ch 3, Sec 6, [10.4] are to be considered together with [2.6.2] to [2.6.4].

2.6.2 Lower stool

a) The net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation. The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

b) The net thickness of the stool side plate, within the region of the corrugation depth from the stool top plate, is not to be less than the corrugated bulkhead flange net required thickness at the lower end and is to be of at least the same material yield strength. The net thickness may be reduced to 90% of corrugation flange thickness if continuity is provided between the corrugation web and supporting brackets inside the stool as defined in (c).

c) For oil tankers, continuity between corrugation web and lower stool supporting brackets is to be maintained inside the stool. Alternatively, lower stool supporting brackets inside the stool are to be aligned with every knuckle point of corrugation web.

d) The net thickness of supporting bracket is not to be less than 80% of the required net thickness of the corrugation webs and is to be of at least the same material yield strength.

e) The net thickness of supporting floors is not to be less than the net required thickness of the stool side plating (excluding the application of GRAB requirements as defined in Pt 2, Ch 1, Sec 6) connected to the inner bottom and is to be of at least the same material yield strength. If material of different yield strength is used, the required thickness is to be adjusted by the ratio of the two material factors k, as defined in Ch 3, Sec 1, [2.2.1].

f) Where a lower stool is fitted, particular attention is to be given to the through-thickness properties, and arrangements for continuity of strength, at the connection of the bulkhead stool to the inner bottom. For requirements for plates with specified through-thickness properties, see Ch 3, Sec 1, [2.5].

2.6.3 Upper stool

a) The net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation. The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

b) The net thickness of the lower portion of stool side plating is not to be less than the greater of the following,
- The net thickness obtained from [1.1],
- 80% of the net thickness of the upper part of the bulkhead plating as required by
  - [1.2],
  - Pt 2, Ch 1, Sec 3, [3.1], or Pt 2, Ch 2, Sec 3, [2.2.1] as applicable,

  where the same material is used.

If materials of different yield strength are used, the required thickness is to be adjusted by the ratio of the two material factors k as defined in Ch 3, Sec 1, [2.2.1].

2.6.4 Local supporting structure in way of corrugated bulkheads without a lower stool

a) The net thickness of the supporting floors and pipe tunnel beams in way of a corrugated bulkhead are not to be less than the required net thickness of the corrugation flanges and are to be of at least the same material yield strength. The inner bottom and hopper tank in way of the corrugation is to be of at least the same material yield strength as the attached corrugation, and Z grade steel as defined in Ch 3, Sec 1, [2.5.1] is to be used unless through thickness properties are documented for approval.

b) Brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0.5 times the corrugation depth and a net thickness not less than 80% of the net thickness of the corrugation webs and are to be of at least the same material yield strength. Where support is provided by gussets with shedder plates instead of brackets/carlings, the height of the gusset plate, see h_G in Pt 2, Ch 1, Sec 3, Figure 5, is to be at least equal to the corrugation depth. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thickness of the gusset and shedder plates is not to be less than 100% and 80%, respectively, of the net thickness of the corrugation flange and is to be of at least the same material yield strength.

2.7 Aft peak bulkhead

2.7.1

The net thickness of the aft peak bulkhead plating in way of the stern tube penetration is to be at least 1.6 times the required thickness for the bulkhead plating.

Section 5 STIFFENERS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

d_{shr} : Effective shear depth, in mm, as defined in Ch 3, Sec 7, [1.4.3].

l_{bdg} : Effective bending span, in m, as defined in Ch 3, Sec 7, [1.1.2].

l_{shr} : Effective shear span, in m, as defined in Ch 3, Sec 7, [1.1.3].

P : Design pressure for the design load set being defined in Ch 6, Sec 2 and calculated at the load calculation point defined in Ch 3, Sec 7, [3.2], in kN/m^2.

χ : Coefficient taken equal to:

- In intact condition:
  - χ= 0.90 for stiffeners attached to inner bottom or bilge hopper tank plating in cargo holds of bulk carriers,
  - χ= 1.00 for other cases.
- In flooded condition: χ as defined in Ch 6, Sec 4 for flooded condition.

1 STIFFENERS SUBJECT TO LATERAL PRESSURE

1.1 Yielding check

1.1.1 Web plating

The minimum net web thickness, tw in mm, is not to be taken less than the greatest value calculated for all applicable design load sets as defined in Ch 6, Sec 2, [2], given by:

$$t_w = \frac{f_{shr}\left|P\right| s l_{shr}}{d_{shr}\chi C_t \tau_{eH}}$$ with C_t not to be taken greater than 1.0.

where:

f_{shr} : Shear force distribution factor taken as:

- For continuous stiffeners with fixed ends, f_{shr} is not to be taken less than:
  - f_{shr} = 0.5 for horizontal stiffeners and upper end of vertical stiffeners.
  - f_{shr} = 0.7 for lower end of vertical stiffeners.
- For stiffeners with reduced end fixity, variable load or being part of grillage, the requirement in [1.2] applies.

C_t : Permissible shear stress coefficient for the design load set being considered, taken as:

- C_t = 0.75 for acceptance criteria set AC-S.
- C_t = 0.90 for *acceptance* criteria set AC-SD.

1.1.2 Section modulus

The minimum net section modulus, Z in cm3, is not to be taken less than the greatest value calculated for all applicable design load sets as defined in Ch 6, Sec 2, [2.1.3], given by:

$$Z = \frac{\left|P\right| s l_{bdg}^2}{f_{bdg}\chi C_s R_{eH}}$$ with χ C_s not to be taken greater than 1.0.

where:

f_{bdg} : Bending moment factor taken as:

- For continuous stiffeners with fixed ends, f_{bdg} is not to be taken higher than:
  - f_{bdg} = 12 for horizontal stiffeners and upper end of vertical stiffeners.
  - f_{bdg} = 10 for lower end of vertical stiffeners.
- For stiffeners with reduced end fixity, variable load or being part of grillage, the requirement in [1.2] applies.

C_s : Permissible bending stress coefficient as defined in Table 1 for the design load set being considered.

σ_{hg} : Hull girder bending stress, in N/mm^2, as defined in Ch 6, Sec 2, [1.1], calculated at the load calculation point as defined in Ch 3, Sec 7, [3.2].

β_s : Coefficient as defined in Table 2.

α_s : Coefficient as defined in Table 2.

$C_{s\text{-}max}$: Coefficient as defined in Table 2.

Definition of C_s **Table 1**

Sign of hull girder bending stress, σ_{hg}	Lateral pressure acting on	Coefficient C_s
Tension (positive)	Stiffener side	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression	Compression	
Tension (positive)	Plate side	
Compression (negative)	Stiffener side	$C_s = C_{s\text{-}max}$

Definition of β_s, α_s and $C_{s\text{-}max}$ **Table 2**

Acceptance criteria set	Structural member	β_s	α_s	$C_{s\text{-}max}$
AC-S	Longitudinal strength member	0.85	1.0	0.75
	Transverse or vertical member	0.75	0	0.75
AC-SD	Longitudinal strength member	1.0	1.0	0.9
	Transverse or vertical member	0.9	0	0.9

1.1.3 Group of stiffeners

Scantlings of stiffeners based on requirements in [1.1.1] and [1.1.2] may be decided based on the concept of grouping designated sequentially placed stiffeners of equal scantlings on a single stiffened panel between primary supporting members. The scantling of the group is to be taken as the greater of the following:

- The average of the required scantling of all stiffeners within a group.
- 90% of the maximum scantling required for any one stiffener within the group.

1.1.4 Plate and stiffener of different materials

When the minimum specified yield stress of a stiffener exceeds the minimum specified yield stress of the attached plate by more than 35%, the following criterion is to be satisfied:

$$R_{eH-S} \le \left(R_{eH-P} - \frac{\alpha_S \lvert\sigma_{hg}\rvert}{\beta_S} \right) \frac{Z_P}{Z} + \frac{\alpha_S \lvert\sigma_{hg}\rvert}{\beta_S}$$

where:

$R_{eH\text{-}S}$: Minimum specified yield stress of the material of the stiffener, in N/mm^2.

$R_{eH\text{-}P}$: Minimum specified yield stress of the material of the attached plate, in N/mm^2.

σ_{hg} : Hull girder bending stress, in N/mm^2, as defined in Ch 6, Sec 2, [1.1] with $\lvert\sigma_{hg}\rvert$ not to be taken less than 0.4 $R_{eH\text{-}P}$.

Z : Net section modulus, in way of face plate/free edge of the stiffener, in cm^3.

Z_P : Net section modulus, in way of the attached plate of stiffener, in cm^3.

α_s, β_s : Coefficients defined in Table 2.

1.2 Beam analysis

1.2.1 Direct analysis

The maximum normal bending stress, σ and shear stress, τ in a stiffener using net properties with reduced end fixity, variable load or being part of grillage are to be determined by direct calculations taking into account:

- The distribution of static and dynamic pressures and forces, if any.
- The number and position of intermediate supports (e.g. decks, girders, etc).
- The condition of fixity at the ends of the stiffener and at intermediate supports.
- The geometrical characteristics of the stiffener on the intermediate spans.

1.2.2 Stress criteria

The stress is to comply with the following criteria where the coefficients C_t and C_s, are defined in [1.1.1] and [1.1.2].

$$\tau \le \chi C_t \tau_{eH}$$

$$\sigma \le \chi C_s R_{eH}$$

Section 6 PRIMARY SUPPORTING MEMBERS AND PILLARS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

P : Design pressure for the design load set being considered as defined in Ch 6, Sec 2 and calculated at the load calculation point as defined in Ch 3, Sec 7, [4.1.1], in kN/m^2.

l_{bdg} : Effective bending span, as defined in Ch 3, Sec 7, [1.1.6], in m.

l_{shr} : Effective shear span, as defined in Ch 3, Sec 7, [1.1.7], in m.

χ : Coefficient taken equal to:

- In intact condition:
  - χ= 0.90 for primary supporting members attached to inner bottom or bilge hopper tank plating in cargo holds of bulk carriers,
  - χ= 1.00 for other cases.
- In flooded condition: χ as defined in Ch 6, Sec 4 for flooded condition.

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to primary supporting members subjected to lateral pressure and concentrated loads and pillars subjected to compressive axial loads. The yielding check is to be carried out for such members subjected to specific loads.

2 PRIMARY SUPPORTING MEMBERS WITHIN CARGO HOLD REGION

2.1 Flooded condition

2.1.1

The requirements in this sub-article apply to the primary supporting members of watertight boundaries other than outer shell or tank boundaries, subject to lateral pressure in flooded condition.

2.1.2

The verification against flooded condition is to be made by using the pressure and hull girder loads for the appropriate design load set as defined in Ch 6, Sec 2 and the scantling requirements given in [3.2].

2.2 Bulk carriers

2.2.1 Bulk carriers having a freeboard length L_{LL} of 150m and above

The scantlings of primary supporting members within the cargo hold region are to be verified by FE structural analysis as defined in Ch 7.

2.2.2 Bulk carriers having a freeboard length L_{LL} less than 150m

The scantlings of primary supporting members within the cargo hold region are to comply with the requirements given in Pt 2, Ch 1, Sec 4, [4]. Alternatively, the scantlings of such members may be verified by direct strength assessment as deemed appropriate by the Society.

CCS 2.2.2a Alternatively, the scantlings of primary supporting members within the cargo area may be verified by direct strength assessment in accordance with the requirements of CCS 4.1.2a, Section 4, Chapter 1 of PART 9-2.

2.3 Oil tankers

2.3.1

Scantlings of primary supporting members within the cargo hold region are to comply with the requirements given in Pt 2, Ch 2, Sec 3, [1] and are to be verified by FE structural analysis, as defined in Ch 7.

3 PRIMARY SUPPORTING MEMBERS OUTSIDE CARGO HOLD REGION

3.1 Application

3.1.1
The requirements of this article apply to primary supporting members, subjected to lateral pressure within the fore part, aft part and machinery space.

3.2 Scantling requirements

3.2.1 Net section modulus

The net section modulus, Z_{n50} in cm^3, of primary supporting members subjected to lateral pressure is not to be taken less than the greatest value for all applicable design load sets defined in Ch 6, Sec 2, [2], given by:

$$Z_{n50} = 1000 \frac{|P| Sl_{bdg}{}^2}{\chi f_{bdg} C_s R_{eH}}$$

f_{bdg} : Bending moment distribution factor, as given in Table 2.
C_s : Permissible bending stress coefficient for the acceptance criteria set, as given in Table 1.

3.2.2 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of primary supporting members subjected to lateral pressure is not to be taken less than the greatest value for all applicable design load sets defined in Ch 6, Sec 2, [2], given by:

$$A_{shr-n50} = 10 \frac{f_{shr} |P| Sl_{shr}}{\chi C_t \tau_{eH}}$$

where:
f_{shr} : Shear force distribution factor, as given in Table
C_t : Permissible shear stress coefficient for the acceptance criteria set being considered, as given in Table 1.

Permissible bending and shear stress coefficients for primary supporting members Table 1

Acceptance criteria set	Structure attached to primary supporting member	C_s and C_t
AC-S	All boundaries, including decks and flats	0.70
AC-SD	All boundaries, including decks and flats	0.85

3.3 Advanced calculation methods

3.3.1 Direct analysis

Where complex grillage structures are employed or cross ties are fitted in side shell primary supporting members, the scantlings are to be determined by direct calculation taking into account:

- The distribution of still water and wave pressure and forces, if any.
- The number and position of intermediate supports (e.g. decks, girders, etc).
- The condition of fixity at the ends of the primary supporting members and at intermediate supports.
- The geometrical characteristics of the primary supporting members on the intermediate spans.

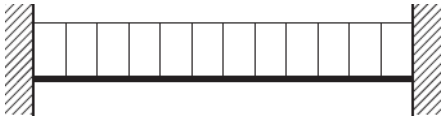
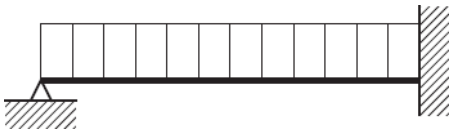
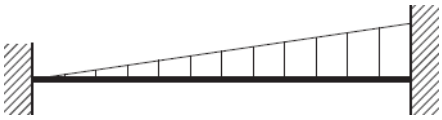
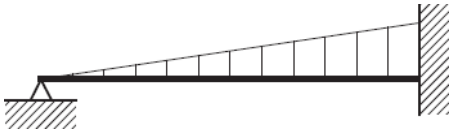
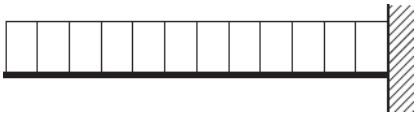
3.3.2 Analysis criteria

The calculated stresses are to comply with the following criteria where the coefficients C_t and C_s, are defined in [3.2]:

- $\sigma \leqslant \chi C_s R_{eH}$
- $\tau \leqslant \chi C_t \tau_{eH}$

where:
σ : Shear stress in member, in N/mm^2, based on t_{n50}.
τ : Normal stress in member, in N/mm^2, based on t_{n50}.

Bending moment and shear force factors, f_{bdg} and f_{shr} **Table 2**

Load and boundary condition				Bending moment and shear force distribution factors (based on load at mid span, where load varies)		
Position				1 f_{bdg1} f_{shr1}	2 f_{bdg2} -	3 f_{bdg3} f_{shr3}
Load model	1 Support	2 Field	3 Support			
A				12.0 0.50	24.0 -	12.0 0.50
B				- 0.38	14.2 -	8.0 0.63
C				- 0.50	8.0 -	- 0.50
D				15.0 0.30	23.3 -	10.0 0.70
E				- 0.20	16.8 -	7.5 0.80
F				- -	- -	2.0 1.0

Note1: The bending moment distribution factor, f_{bdg} for the support positions is applicable for a distance of $0.2l_{bdg}$ from the end of the effective bending span of the primary supporting member.

Note2: The shear force distribution factor, $_{f}f_{shr}$ for the support positions is applicable for a distance of 0.2 l_{shr} from the end of the effective shear span of the primary supporting member.

Note3: Application of f_{bdg} and f_{shr}:
The section modulus requirement within $0.2l_{bdg}$ from the end of the effective span is to be determined using the applicable f_{bdg1} and f_{bdg3}, however f_{bdg} is not to be taken greater than 12.
The section modulus of mid-span area is to be determined using f_{bdg} = 24, or f_{bdg2} from the table if lesser.
The shear area requirement of end connections within $0.2l_{shr}$ from the end of the effective span is to be determined using f_{shr} = 0.5 or the applicable f_{shr1} or f_{shr3}, whichever is greater.
For models A through F, the value of f_{shr} may be gradually reduced outside of $0.2l_{shr}$ towards $0.5f_{shr}$ at mid-span, where f_{shr} is the greater value of f_{shr1} and f_{shr3}.

4 PILLARS

4.1 Pillars subjected to compressive axial load

4.1.1 Criteria

The maximum applied compressive axial load on a pillar, F_{pill}, in kN, is to be taken as the greatest value calculated for all applicable design load sets defined in Ch 6, Sec 2, [2], and is given by the following formula:

$F_{pill}=Pb_{a\text{-}sup}I_{a\text{-}sup}+F_{pill\text{-}upr}$

where:
$b_{a\text{-}sup}$: Mean breadth of area supported, in m.
$l_{a\text{-}sup}$: Mean length of area supported, in m.
$F_{pill\text{-}upr}$: Axial load from pillar including axial load from pillars above, in kN, if any.
$A_{pill\text{-}n50}$: Net cross section area of the pillar, in cm^2.
The buckling check of the pillar is to be performed according to Ch 8, Sec 4, [5.1], with σ_{av} in N/mm^2, as defined in Ch 8, Sec 5, [3.1] given by:

$$\sigma_{av} = 10\frac{F_{pill}}{A_{pill-n50}}$$

4.2 Pillars subject to tensile axial load

4.2.1 Criteria

Pillars and PSM members subjected to tensile axial load are to satisfy the criteria given in [3.3.2].

Chapter 7 DIRECT STRENGTH ANALYSIS

Section 1 STRENGTH ASSESSMENT

1 GENERAL

1.1 Application

1.1.1

This chapter provides requirements applicable to ships having rule a freeboard length L_{LL} of 150 m or above to assess the scantlings of the hull structure using finite element analysis.

1.1.2

The finite element analysis consists of three parts:

a) Cargo hold analysis to assess the strength of longitudinal hull girder structural members, primary supporting structural members and bulkheads.
b) Fine mesh analysis to assess detailed stress levels in local structural details.
c) Very fine mesh analysis to assess the fatigue capacity of the structural details according to Ch 9.

1.1.3

The strength assessment performed with finite element analysis is to verify that the scantlings comply with the acceptance criteria specified in this chapter for:

- Cargo hold structural analysis 6v-vvperformed in accordance with Ch 7, Sec 2.
- Local structural analysis performed in accordance with Ch 7, Sec 3.

1.1.4

Strength assessment based on finite element analysis is applicable for the entire cargo hold region.

1.1.5

The analysis is to verify the following:

a) Stress levels are within the acceptance criteria for yielding.
b) Buckling capability of plates and stiffened panels are within the acceptance criteria for bucking defined in Ch 8.
c) Fatigue capacity of structural details is within the acceptance criteria defined in Ch 9.

1.1.6

A flow diagram showing the minimum requirement of finite element analysis is shown in Figure 1.

2 NET SCANTLING

2.1 Net scantling application

2.1.1

FE models for cargo hold FE analyses, local fine mesh FE analysis and very fine mesh FE analyses, are to be based on the net scantling approach, applying a corrosion addition as defined in Ch 3, Sec 2, Table 1.

All buckling capacity assessment are to be based on corrosion addition, as defined in Ch 3, Sec 2, Table 1.

3 FINITE ELEMENT TYPES

3.1 Used finite element types

3.1.1

The structural assessment is to be based on linear finite element analysis of three dimensional structural models. The general types of finite elements to be used in the finite element analysis are given in Table 1.

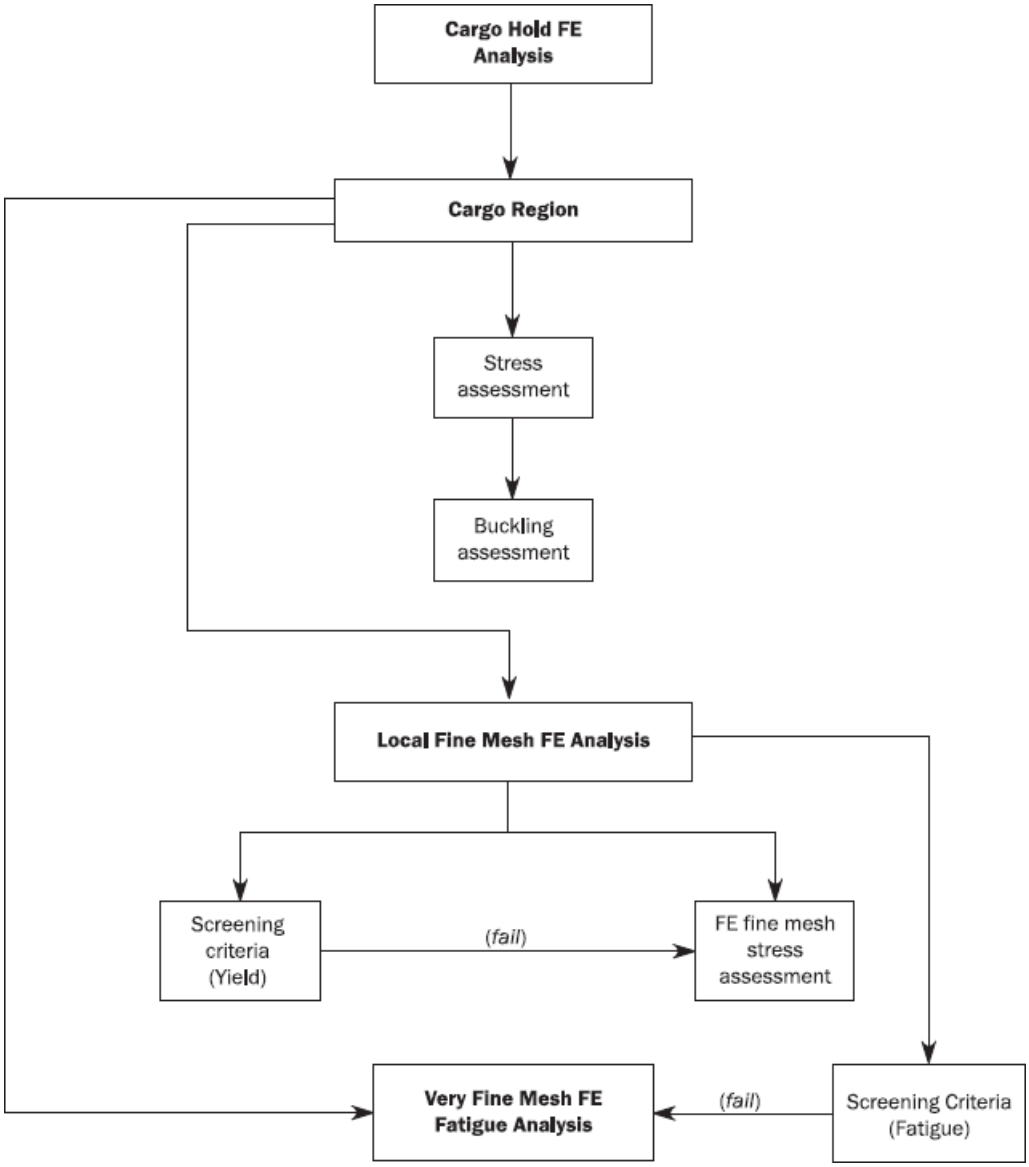


Figure 1 Flow diagram of finite element analysis

Types of finite element **Table 1**

Type of finite element	Description
Rod (or truss) element	Line element with axial stiffness only and constant cross sectional area along the length of the element.
Beam element	Line element with axial, torsional and bi-directional shear and bending stiffness and with constant properties along the length of the element.
Shell (or plate) element	Shell element with in-plane stiffness and out-of-plane bending stiffness with constant thickness.

3.1.2

Two node line elements and four node shell elements are, in general, considered sufficient for the representation of the hull structure. The mesh requirements given in this chapter are based on the assumption that these elements are used in the finite element models. However, higher order elements may also be used.

4 SUBMISSION OF RESULTS

4.1 Detailed report

4.1.1

A detailed report of the structural analysis is to be submitted by the designer/builder to demonstrate compliance with the specified structural design criteria. This report is to include the following information:

a) List of plans used including dates and versions.
b) Detailed description of structural modelling including all modelling assumptions and any deviations in geometry and arrangement of structure compared with plans.
c) Plots to demonstrate correct structural modelling and assigned properties.
d) Details of material properties, plate thickness, beam properties used in the model. e) Details of boundary conditions.
e) Details of all loading conditions reviewed with calculated hull girder shear force, bending moment and torsional moment distributions.
f) Details of applied loads and confirmation that individual and total applied loads are correct.
g) Plots and results that demonstrate the correct behaviour of the structural model under the applied loads.
h) Summaries and plots of global and local deflections.
i) Summaries and sufficient plots of stresses to demonstrate that the design criteria are not exceeded in any member.
j) Plate and stiffened panel buckling analysis and results.
k) Tabulated results showing compliance, or otherwise, with the design criteria.
l) Proposed amendments to structure where necessary, including revised assessment of stresses, buckling and fatigue properties showing compliance with design criteria.
m) Reference of the finite element computer program, including its version and date.

5 COMPUTER PROGRAMS

5.1 Use of computer programs

5.1.1

Any finite element computation program complying with Ch 1, Sec 3 may be employed to determine the stress and deflection of the hull structure, provided that the combined effects of bending, shear, axial and torsional deformations are considered.

Section 2 CARGO HOLD STRUCTURAL STRENGTH ANALYSIS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

M_{sw} : Permissible vertical still water bending moment, in kNm, as defined in Ch 4, Sec 4.

M_{wv} : Vertical wave bending moment, in kNm, in hogging or sagging condition, as defined in Ch 4, Sec 4.

M_{wh} : Horizontal wave bending moment, in kNm, as defined in Ch 4, Sec 4.

M_{wt} : Wave torsional moment in seagoing condition, in kNm, as defined in Ch 4, Sec 4.

Q_{sw} : Permissible still water shear force, in kN, at the considered bulkhead position, as provided in Ch 4, Sec 4.

Q_{wv} : Vertical wave shear force, in kN, as defined in Ch 4, Sec 4.

$x_{b\text{-}aft}$, $x_{b\text{-}fwd}$: X-coordinate, in m, of respectively the aft and forward bulkhead of the mid-hold.

x_{aft} : X-coordinate, in m, of the aft end support of the FE model.

x_{fore} : X-coordinate, in m, of the fore end support of the FE model.

x_i : X-coordinate, in m, of web frame station i.

Q_{aft} : Vertical shear force, in kN, at aft bulkhead of mid-hold as defined in [4.4.6].

Q_{fwd} : Vertical shear force, in kN, at fore bulkhead of mid-hold as defined in [4.4.6].

$Q_{targ\text{-}aft}$: Target shear force, in kN, at the aft bulkhead of mid-hold as defined in [4.3.3].

$Q_{targ\text{-}fwd}$: Target shear force, in kN, at the forward bulkhead of mid-hold as defined in [4.3.3].

1 OBJECTIVE AND SCOPE

1.1 General

1.1.1

The cargo hold structural strength analysis is used for the assessment of scantlings of longitudinal hull girder structural members, primary supporting members and bulkheads within the cargo hold region. This section gives the requirements for cargo hold structural strength analysis.

1.1.2

Cargo hold structural strength analysis is mandatory within the cargo hold region including the aft bulkhead of the aftmost cargo hold and the collision bulkhead. The evaluation areas are defined in [5.1].

1.1.3

For the purpose of FE structural assessment and load application, the cargo hold region contains the following cargo hold regions, which may vary depending on the ship length and cargo hold arrangement, as defined in Figure 1:

- Midship cargo hold region,
- Forward cargo hold region,
- After cargo hold region,
- Foremost cargo hold(s),
- Aftmost cargo hold(s).

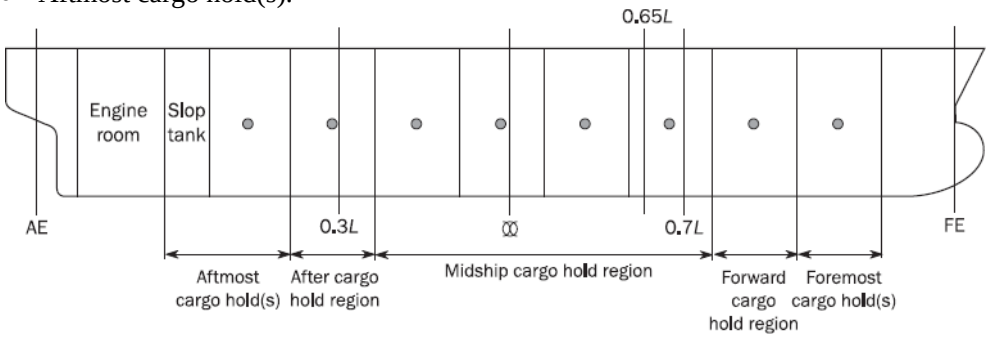


Figure 1 Definition of cargo hold regions for FE structural assessment

Holds in the forward cargo hold region are defined as holds with their longitudinal centre of gravity position forward of 0.7L from AE, except foremost cargo hold.

Holds in the midship cargo hold region are defined as holds with their longitudinal centre of

gravity position at or forward of 0.3*L* from AE and at or aft of 0.7*L* from AE.
Holds in the after cargo hold region are defined as holds with their longitudinal centre of gravity position aft of 0.3 *L* from AE, except aftmost cargo hold.
Foremost cargo hold(s) is (are) defined as hold(s) in the foremost location of the cargo hold region.
Aftmost cargo hold(s) is (are) defined as hold(s) in the aftmost location of the cargo hold region.

1.2 Cargo hold structural strength analysis procedure

1.2.1 Procedure description

The structural FE analysis is to be performed in accordance with the following:

- Model: Three cargo hold model with:
  - Extent as given in [2.2]
  - Finite element types as given in [2.3]
  - Structural modelling as defined in [2.4]
- Boundary conditions as defined in [2.5]
- FE load combinations as defined in [3]
- Load application as defined in [4]
- Evaluation area as defined in [5.1]
- Strength assessment as defined in [5.2] and [5.3]

1.2.2 Mid-hold definition

For the purpose of the FE analysis, the mid-hold is defined as the middle hold(s) of the three cargo hold length FE model.
In case of foremost and aftmost cargo hold assessment, the mid-hold represents the foremost and aftmost cargo hold including the slop tank if any, respectively.

1.2.3 Scantling assessment

The scantling assessment is carried out according to Ch 7, Sec 1 for each individual cargo hold using the FE load combinations defined in Ch 4, Sec 8 applicable to the considered cargo hold. The FE analysis results are applicable to the evaluation area as defined in [5.1.1], of the considered cargo hold.
The individual transverse bulkhead structural elements, inclusive plating, stiffeners and horizontal stringers, are to be assessed considering two cargo hold finite element analyses, i.e. the analysis for the hold forward and the one for the hold aft of the considered transverse bulkhead.

2 STRUCTURAL MODEL

2.1 Members to be modelled

2.1.1

All main longitudinal and transverse structural elements are to be modelled. These include:

- Inner and outer shell,
- Deck,
- Double bottom floors and girders,
- Transverse and vertical web frames,
- Hatch coamings,
- Stringers,
- Transverse and longitudinal bulkhead structures,
- Other primary supporting members,
- Other structural members which contribute to hull girder strength.

All plates and stiffeners on the structure, including web stiffeners, are to be modelled. Brackets which contribute to primary supporting member strength and the size of which is not less than the typical mesh size (*s*-by-*s*) described in [2.4.2], are to be modelled.

2.2 Extent of model

2.2.1 Longitudinal extent

Except the foremost and aftermost cargo hold models, the longitudinal extent of the cargo hold FE model is to cover three cargo hold lengths. The transverse bulkheads at the ends of the model are to be modelled. Where corrugated transverse bulkheads are fitted, the model is to include the extent of the bulkhead stool structure forward and aft of the tanks/holds at the model ends. The

web frames at the ends of the model are to be modelled. Typical finite element models representing the midship cargo hold region of different ship type configurations are shown in Figure 3 and Figure 4.

The foremost and the aftmost cargo holds are located at the middle of the FE models as follows:

- Foremost cargo hold: from the after bulkhead of the cargo hold no. 2 to the ship's foremost cross section where the reinforced ring or web frame remains continuous from the base line to the strength deck.
- Aftermost cargo hold: from the after bulkhead of the engine room to the forward bulkhead of no. N-1 cargo hold, where N is the number of holds or sets of holds numbered from forward to aft.

Examples of finite element models representing the foremost and aftermost cargo holds of different ship type configurations are shown in Figure 5 and Figure 6.

2.2.2 Hull form modelling

In general, the finite element model is to represent the geometry of the hull form. In the midship cargo hold region, the finite element model may be prismatic provided the mid-hold has a prismatic shape.

In the foremost cargo hold model, the hull form forward of the transverse section at the middle of the fore part up to the model end as defined in [2.2.1] may be modelled with a simplified geometry. The transverse section at the middle of the fore part up to the model end may be extruded out to the fore model end, as shown in Figure 2.

In the aftmost cargo hold model, the hull form aft of the middle of the machinery space may be modelled with a simplified geometry. The section at the middle of the machinery space may be extruded out to its aft bulkhead, as shown in Figure 2.

When the hull form is modelled by extrusion, the geometrical properties of the transverse section located at the middle of the considered space (fore or machinery space) are copied along the simplified model. The transverse web frames are to be considered along this extruded part with the same properties as the ones in the fore part or in the machinery space.

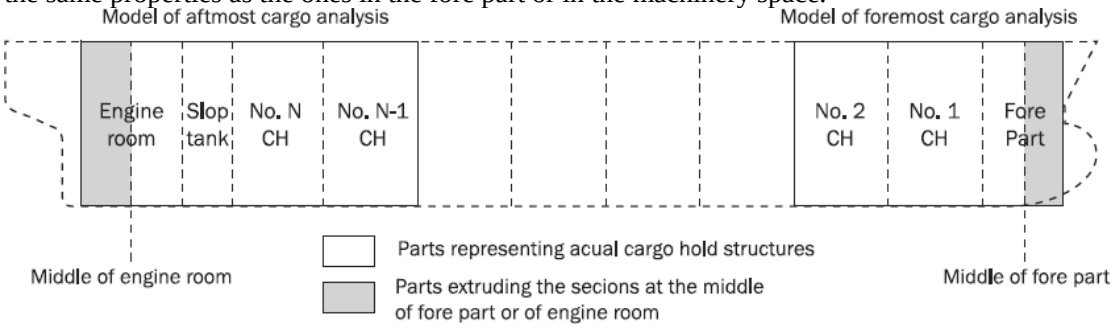


Figure 2 Hull form simplification for foremost and aftmost cargo hold model

2.2.3 Transverse extent

Both port and starboard sides of the ship are to be modelled.

2.2.4 Vertical extent

The full depth of the ship is to be modelled including primary supporting members above the upper deck, trunks, forecastle and/or cargo hatch coaming, if any.

The superstructure or deck house in way of the machinery space and the bulwark are not required to be included in the model.

2.3 Finite element types

2.3.1

Shell elements are to be used to represent plates.

2.3.2

All stiffeners are to be modelled with beam elements having axial, torsional, bi-directional shear and bending stiffness. The eccentricity of the neutral axis is to be modelled.

2.3.3

Face plates of primary supporting members and brackets are to be modelled using rod or beam elements.

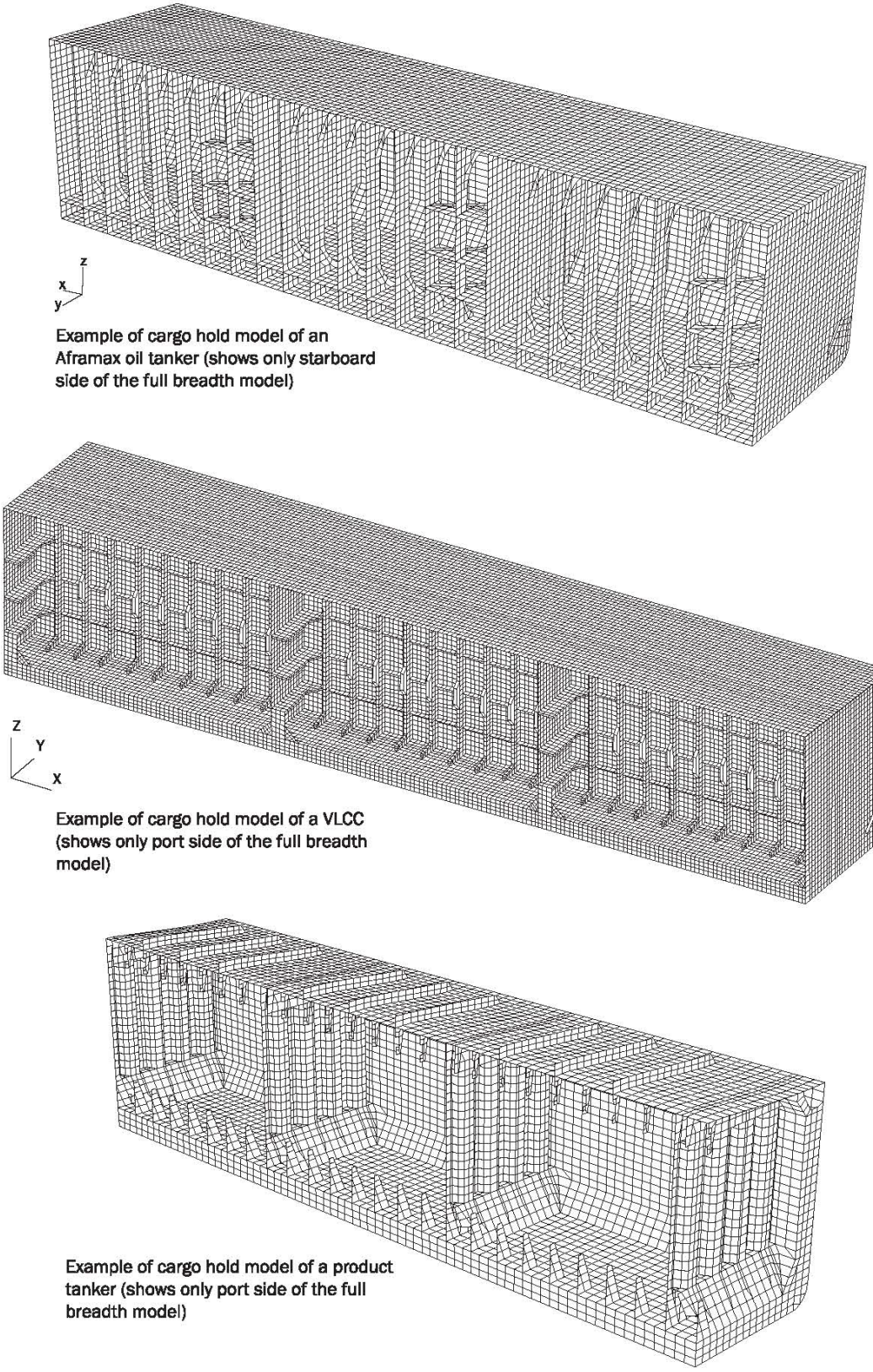


Figure 3 Example of 3 cargo hold model within midship region of oil tankers

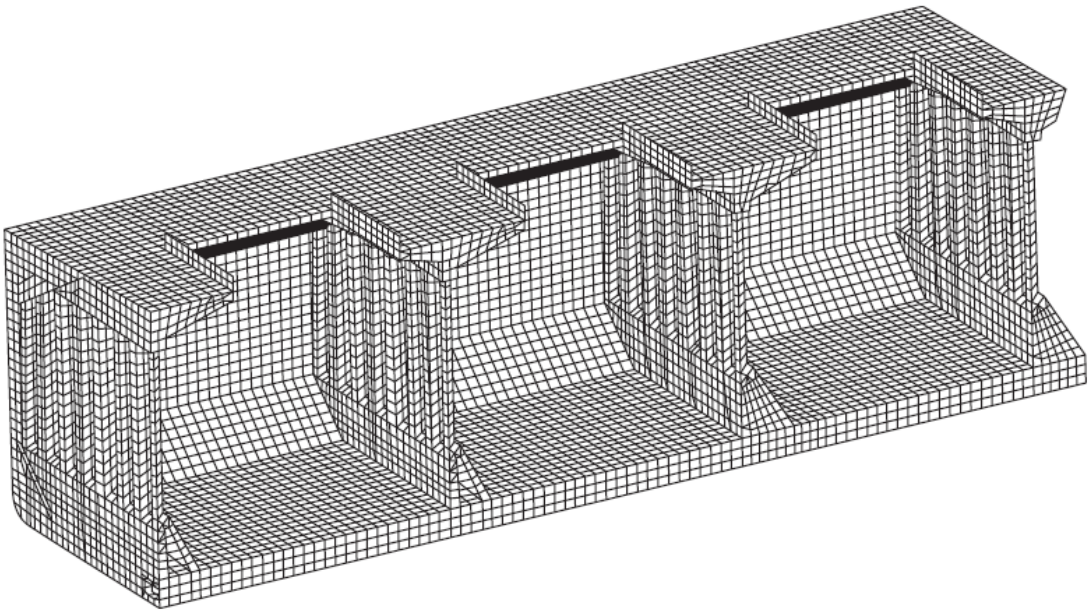


Figure 4 Example of 3 cargo hold model within midship region of a bulk carrier
Example of cargo hold model of a bulk carrier (shows only port side of the full breadth model)

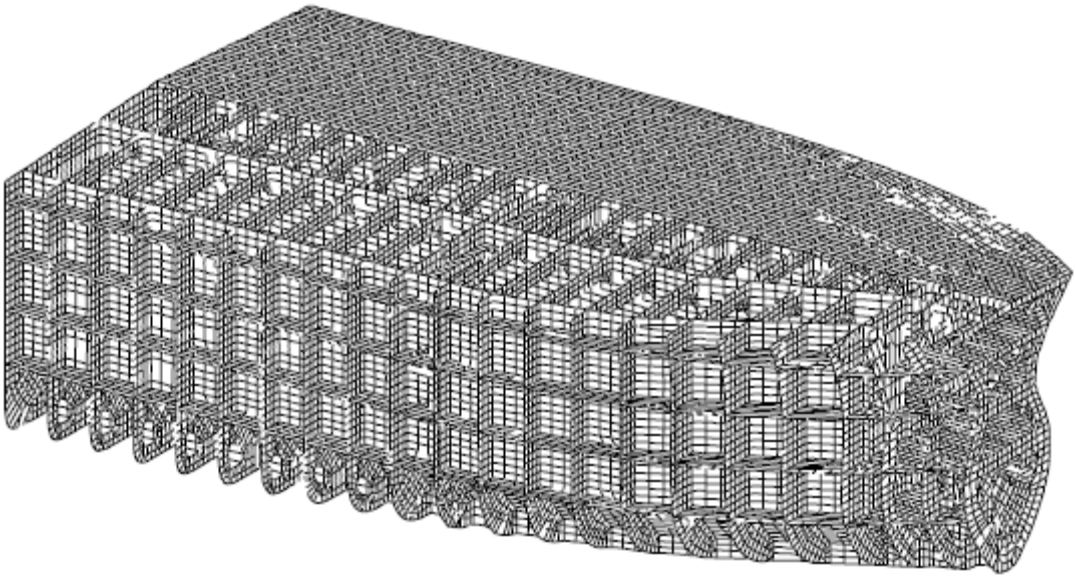


Figure 5 Example of FE model for the foremost cargo hold structure of an oil tanker

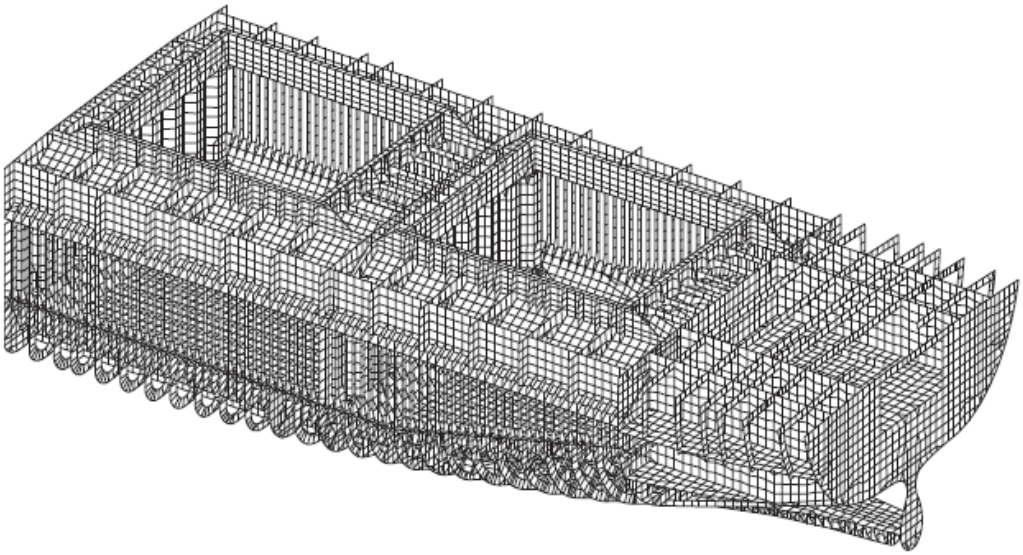


Figure 6 Example of FE model for the aftermost cargo hold structure of a bulk carrier

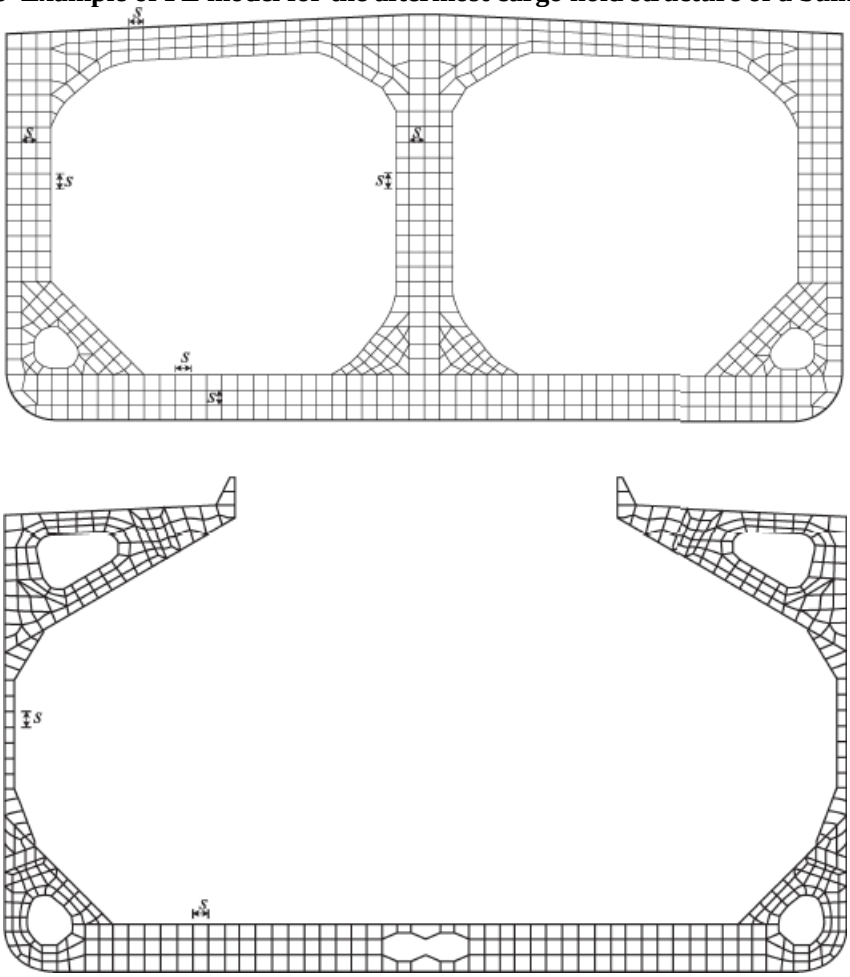


Figure 7 Typical finite element mesh on web frame

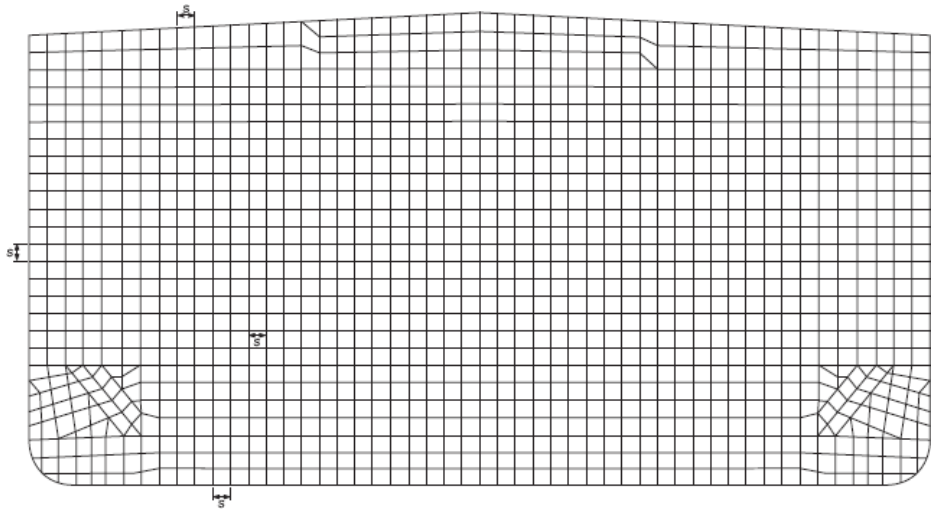


Figure 8 Typical finite element mesh on transverse bulkhead

s = Stiffener spacing

2.4 Structural modelling

2.4.1 Aspect ratio

The aspect ratio of the shell elements is in general not to exceed 3. The use of triangular shell elements is to be kept to a minimum. Where possible, the aspect ratio of shell elements in areas where there are likely to be high stresses or a high stress gradient is to be kept close to 1 and the use of triangular elements is to be avoided.

2.4.2 Mesh

The shell element mesh is to follow the stiffening system as far as practicable, hence representing the actual plate panels between stiffeners. In general, the shell element mesh is to satisfy the following requirements:

a) One element between every longitudinal stiffener, see Figure 7. Longitudinally, the element length is not to be greater than 2 longitudinal spaces with a minimum of three elements between primary supporting members.

b) One element between every stiffener on transverse bulkheads, see Figure 8.

c) One element between every web stiffener on transverse and vertical web frames, cross ties and stringers, see Figure 7 and Figure 9.

d) At least 3 elements over the depth of double bottom girders, floors, transverse web frames, vertical web frames and horizontal stringers on transverse bulkheads. For cross ties, deck transverse and horizontal stringers on transverse wash bulkheads and longitudinal bulkheads with a smaller web depth, modelling using 2 elements over the depth is acceptable provided that there is at least 1 element between every web stiffener. For a single side bulk carrier, 1 element over the depth of side frames is acceptable. The mesh size of adjacent structure is to be adjusted accordingly.

e) The mesh on the hopper tank web frame and the topside web frame is to be fine enough to represent the shape of the web ring opening, as shown in Figure 7.

f) The curvature of the free edge on large brackets of primary supporting members is to be modelled to avoid unrealistic high stress due to geometry discontinuities. In general, a mesh size equal to the stiffener spacing is acceptable. The bracket toe may be terminated at the nearest nodal point provided that the modelled length of the bracket arm does not exceed the actual bracket arm length. The bracket flange is not to be connected to the plating, as shown in Figure 10. The modelling of the tapering part of the flange is to be in accordance with [2.4.8]. An example of acceptable mesh is shown in Figure 10. A finer mesh is to be used for the determination of detailed stress at the bracket toe, as given in Ch 7, Sec 3.

2.4.3 Finer mesh

Where the geometry cannot be adequately represented in the cargo hold model and the stress exceeds the cargo hold mesh acceptance criteria, a finer mesh may be used for such geometry to

demonstrate satisfactory scantlings. The mesh size required for such analysis can be governed by the geometry. In such cases, the average stress within an area equivalent to that specified in [2.4] is to comply with the requirements given in [5.2].

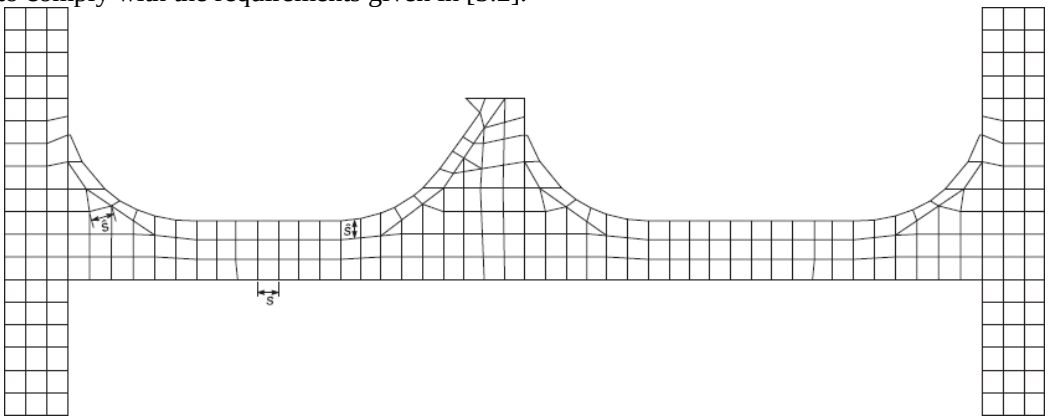


Figure 9 Typical finite element mesh on horizontal transverse stringer on transverse bulkhead

s = Stiffener spacing

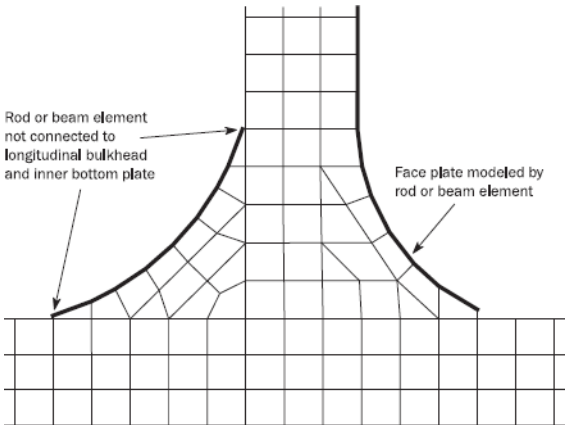


Figure 10 Typical finite element mesh on transverse web frame main bracket

2.4.4 Corrugated bulkhead

Diaphragms in the stools, supporting structure of corrugated bulkheads and internal longitudinal and vertical stiffeners on the stool plating are to be included in the model. Modelling is to be carried out as follows:

a) The corrugation is to be modelled with its geometric shape.
b) The mesh on the flange and web of the corrugation is in general to follow the stiffener spacing inside the bulkhead stool.
c) The mesh on the longitudinal corrugated bulkhead is to follow longitudinal positions of transverse web frames, where the corrections to hull girder vertical shear forces are applied in accordance with [4.4.7].
d) The aspect ratio of the mesh in the corrugation is not to exceed 2 with a minimum of 2 elements for the flange breadth and the web height.
e) Where difficulty occurs in matching the mesh on the corrugations directly with the mesh on the stool, it is acceptable to adjust the mesh on the stool in way of the corrugations.
f) For a corrugated bulkhead without an upper stool and/or lower stool, it may be necessary to adjust the geometry in the model. The adjustment is to be made such that the shape and position of the corrugations and primary supporting members are retained. Hence, the adjustment is to be made on stiffeners and plate seams if necessary.
g) When corrugated bulkhead is subjected to liquid cargo or ballast, dummy rod elements with a cross sectional area of 1 mm2 are to be modelled at the corrugation knuckle between the flange and the web. Dummy rod elements are to be used as minimum at the two corrugation knuckles closest to the intersection between:
   - Transverse and longitudinal bulkheads,
   - Transverse bulkhead and inner hull,

- Transverse bulkhead and side shell.

h) Manholes in diaphragms are to be modelled according to [2.4.9].

2.4.5

Example of mesh arrangements of the cargo hold structure are shown in Figure 11 to Figure 14.

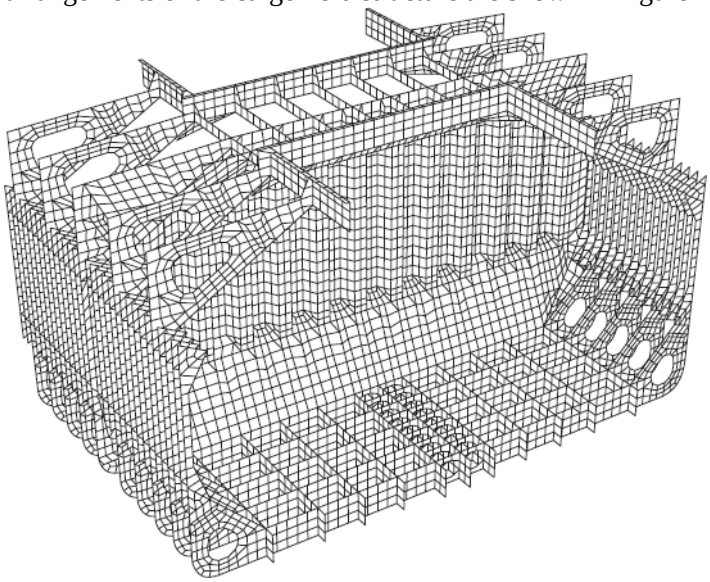


Figure 11 Example of FE mesh arrangements of cargo hold structure for a bulk carrier

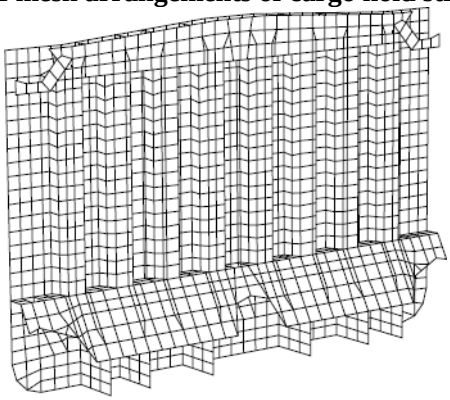


Figure 12 Example of FE mesh on transverse corrugated bulkhead structure for a product tanker

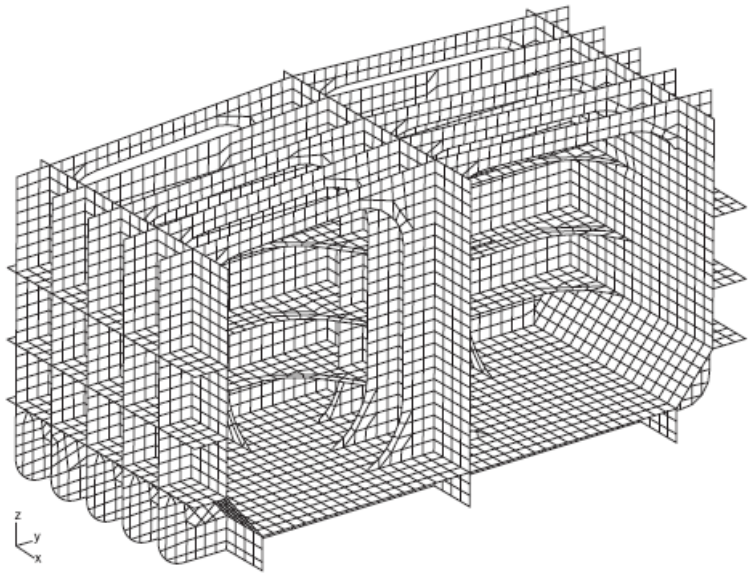


Figure 13 Example of FE mesh arrangements of cargo tank structure for an aframax tanker

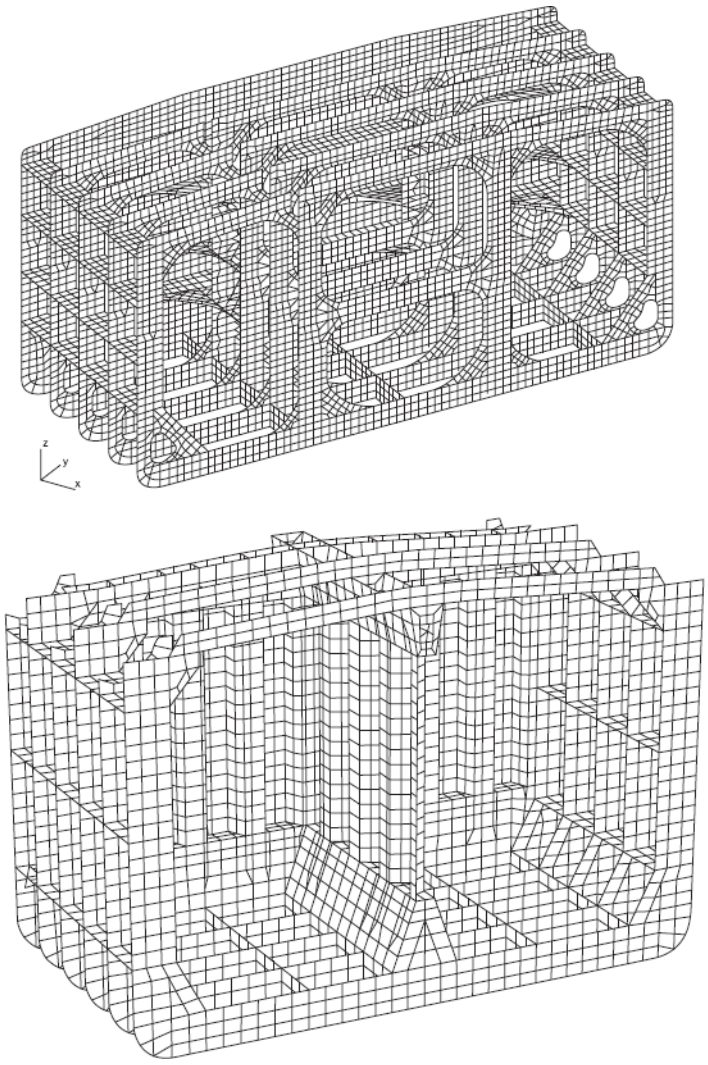


Figure 14 Examples of FE mesh arrangements of cargo tank structure for VLCC and product tanker

2.4.6 Sniped stiffener

Non continuous stiffeners are to be modelled as continuous stiffeners, i.e. the height web reduction in way of the snip ends are not to be modelled.

2.4.7 Web stiffeners of primary supporting members

Web stiffeners of primary supporting members are to be modelled. Where these stiffeners are not in line with the primary FE mesh, it is sufficient to place the line element along the nearby nodal points provided that the adjusted distance does not exceed 0.2 times the stiffener spacing under consideration. The stresses and buckling utilisation factors obtained need not be corrected for the adjustment. Buckling stiffeners on large brackets, deck transverses and stringers parallel to the flange are to be modelled. These stiffeners may be modelled using rod elements.

2.4.8 Face plate of primary supporting member

The effective cross sectional area at the curved part of the face plate of primary supporting members and brackets is to be calculated in accordance with Ch 3, Sec 7. The cross sectional area of a rod or beam element representing the tapering part of the face plate is to be based on the average cross sectional area of the face plate in way of the element length.

2.4.9 Openings

Methods of representing openings and manholes in webs of primary supporting members are to be in accordance with Table1. Regardless of size, manholes are to be modelled by removing the appropriate elements.

Representation of openings in primary supporting member webs Table 1

Criteria	Modelling decision	Analysis
$h_o / h < 0.5$ and $g_o < 2.0$	Openings do not need to be modelled	To be evaluated by the screening procedure as given in Ch 7, Sec 3, 3.1.1
manholes	The geometry of the opening is to be modelled by removing the adequate elements	To be evaluated by the screening procedure as given in Ch 7, Sec 3, 3.1.1
$h_o / h \geqslant 0.5$ or $g_o \geqslant 2.0$	The geometry of the opening is to be modelled	To be evaluated by fine mesh as given in Ch 7, Sec 3, 2.1.1

where:

$$g_0 = \left(1 + \frac{l_0^2}{2.6(h - h_0)^2}\right)$$

l_0 : Length of opening parallel to primary supporting member web direction, in m, see Figure 15.
For sequential openings where the distance, d_o between openings is less than 0.25 h, the length l_0 is to be taken as the length across openings as shown in Figure 16.

h_o : Height of opening parallel to depth of web, in m, see Figure 15 and Figure 16.

h : Height of web of primary supporting member in way of opening, in m, see Figure 15 and Figure 16.

2.5 Boundary conditions

2.5.1 General

All boundary conditions described in this section are in accordance with the global coordinate system defined in Ch 4, Sec 1.

2.5.2 Application

The boundary conditions given [2.5.3] are applicable to cargo hold finite element model analyses in cargo hold region.

2.5.3 Boundary conditions

The boundary conditions consist of the rigid links at model ends, point constraints and end-beams. The rigid links connect the nodes on the longitudinal members at the model ends to an independent point at neutral axis in centreline. The boundary conditions to be applied at the ends of the cargo hold FE model, except for the foremost cargo hold, are given in Table 2. For the foremost cargo hold analysis, the boundary conditions to be applied at the ends of the cargo hold FE model are given in Table 3.

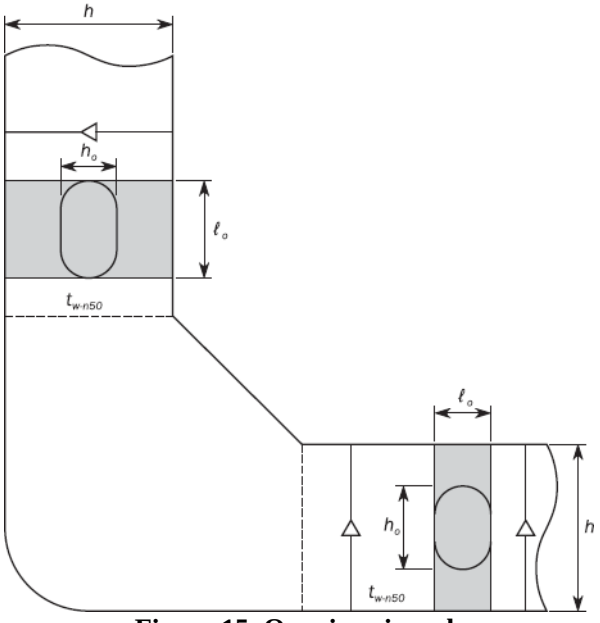


Figure 15 Openings in web

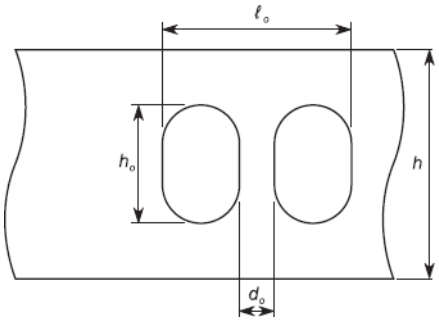


Figure 16 Length l_o for sequential openings with $d_o < h/4$

Boundary constraints at model ends except the foremost cargo hold models Table 2

Location	Translation			Rotation		
	θ_x	θ_y	θ_z	θ_x	θ_y	θ_z
Aft End						
Independent point	-	Fix	Fix	$M_{T\text{-}end}$	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-
	End beam, see [2.5.4]					
Fore End						
Independent point	-	Fix	Fix	Fix	-	-
Intersection of centreline and inner bottom	Fix	-	-	-	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-
	End beam, see [2.5.4]					

Note 1: [-] means no constraint applied (free).
Note 2: See Figure 17.

Boundary constraints at model ends of the foremost cargo hold model Table 3

Location	Translation			Rotation		
	θ_x	θ_y	θ_z	θ_x	θ_y	θ_z
Aft End						
Independent point	-	Fix	Fix	Fix	-	-
Intersection of centreline and inner bottom	Fix	-	-	-	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-
	End beam, see [2.5.4]					
Fore End						
Independent point	-	Fix	Fix	$M_{T\text{-}end}$	-	-
Cross section	-	Rigid link	Rigid link	Rigid link	-	-

Note 1: [-] means no constraint applied (free).
Note 2: See Figure 17.
Note 3: Boundary constraints in fore end are to be located at the most forward reinforced ring or web frame which remains continuous from the base line to the strength deck.

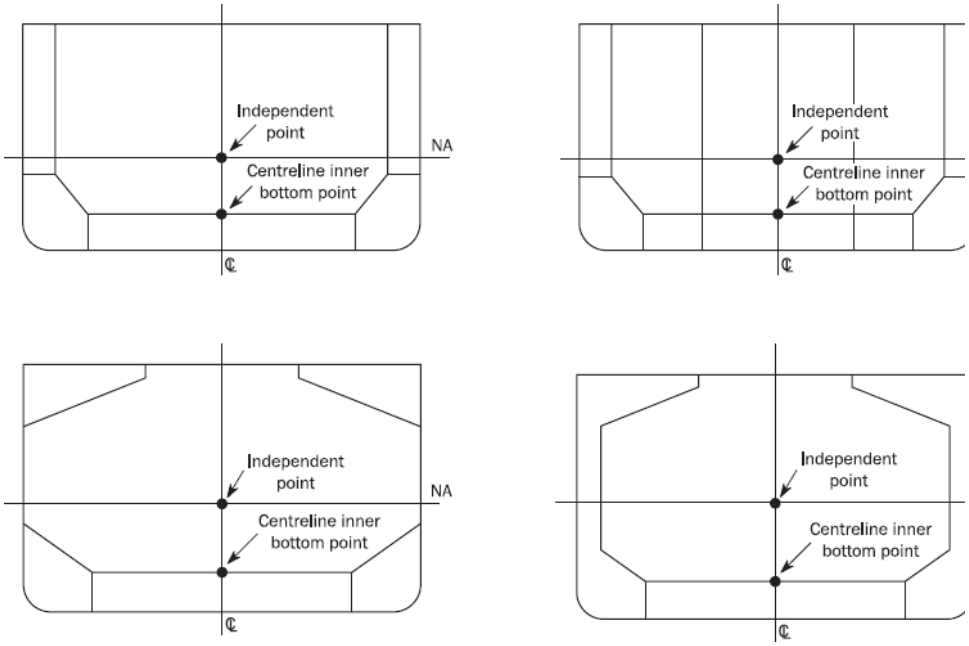


Figure 17 Boundary conditions applied at the model end sections

2.5.4 End constraint beams

End constraint beams are to be modelled at the both end sections of the model along all longitudinally continuous structural members and along the cross deck plating of bulk carriers. An example of end beams at one end for a double hull bulk carrier is shown in Figure 18.

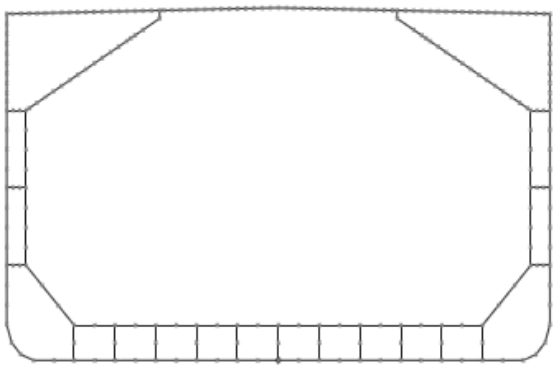


Figure 18 End constraint beams for a bulk carrier

The properties of beams are calculated at fore and after sections separately and all beams at each end section have identical properties as follows:

- Net moment of inertia: $I_{yy\text{-}n50}$ =$I_{zz\text{-}n50}$ =$I_{xx\text{-}n50}$(J)=1/25 of the vertical hull girder moment of inertia of fore/aft end cross sections based on the net FE model.
- Net cross sectional area: $A_{y\text{-}n50}$ and $A_{z\text{-}n50}$ =1/80 of the fore/aft end cross sectional areas based on the net FE model.

where:

$I_{yy\text{-}n50}$: Moment of inertia about local beam Y axial, in m^4.
$I_{zz\text{-}n50}$: Moment of inertia about local beam Z axial, in m^4.
$I_{xx\text{-}n50}$(J) : Torsional inertia, in m^4.
$A_{y\text{-}n50}$: Shear area in local beam Y direction, in m^2.
$A_{z\text{-}n50}$: Shear area in local beam Z direction, in m^2.

3 FE LOAD COMBINATIONS

3.1 Design Load combinations

3.1.1 FE load combination definition

A FE load combination is defined as a loading pattern, a draught, a value of still water bending and shear force, associated with a given dynamic load case.

3.1.2 Mandatory load combinations

For cargo hold structural strength analysis, the design load combinations specified in Ch4, Sec 8 are to be used for considered ship type and considered cargo hold regions.

Each design load combination given in Ch 4, Sec 8 consists of a loading pattern and dynamic load cases as given in Ch4, Sec 2. Each load combination requires the application of the structural weight, internal and external pressures and hull girder loads. For seagoing condition, both static and dynamic load components (S+D) are applied. For harbour and tank testing condition, only static load components (S) are applied.

3.1.3 Additional loading conditions

Where the loading conditions specified by the designer are not covered by the load combinations given in Ch4, Sec 8, these additional loading conditions are to be examined according to the procedure in [4].

4 LOAD APPLICATION

4.1 General

4.1.1 Structural weight

Effect of the weight of hull structure is to be included in static loads, but is not to be included in dynamic loads. Density of steel is to be taken as given in Ch 4, Sec 6.

4.1.2 Sign convention

Unless otherwise mentioned in this Section, the sign of moments and shear force is to be in accordance with the sign convention defined in Ch 4, Sec 1.

4.2 External and internal loads

4.2.1 External pressure

External pressure is to be calculated for each load case in accordance with Ch 4, Sec 5. External pressures include static sea pressure, wave pressure and green sea pressure.

The forces applied on the hatch cover by the green sea pressure are to be distributed along the top of the corresponding hatch coamings. The total force acting on the hatch cover is determined by integrating the hatch cover green sea pressure as defined in Ch 4, Sec 5, [5]. Then the total force is to be distributed to the total length of the hatch coamings using the average line load. The effect of the hatch cover self weight is to be ignored in the loads applied to the ship structure.

4.2.2 Internal pressure

Internal pressure is to be calculated for each load case in accordance with Ch 4, Sec 6 for design load scenarios given in Ch 4, Sec 7, Table 1. Internal pressures include static dry and liquid cargo, ballast and other liquid pressure, setting pressure on relief valve and dynamic pressure of dry and liquid cargo, ballast and other liquid pressure due to acceleration.

4.2.3 Pressure application on FE element

Constant pressure, calculated at the element's centroid, is applied to the shell element of the loaded surfaces, e.g. outer shell and deck for external pressure and tank/hold boundaries for internal pressure. Alternately, pressure can be calculated at element nodes applying linear pressure distribution within elements.

4.3 Hull girder loads

4.3.1 General

Each loading condition is to be associated with its corresponding hull girder loads which is to be applied to the model according to the procedure described in [4.4] for shear force and bending moment and in [4.5] for torsional moment. The hull girder loads are the combinations of still water hull girder loads and wave induced hull girder loads as specified in Ch 4, Sec 8. For each required FE load combination, the wave induced hull girder loads are to be calculated with the Load Combination Factors (LCFs), specified in Ch 4, Sec 2.

4.3.2 Target hull girder vertical bending moment

The target hull girder vertical bending moment, $M_{v\text{-}targ}$, in kNm, at a longitudinal position for a

given FE load combination is taken as:

$M_{v\text{-}targ}=C_{BM\text{-}LC}M_{sw}+M_{wv\text{-}LC}$

where:

C_{BM-LC} : Percentage of permissible still water bending moment applied for the load combination under consideration as given in Ch 4, Sec 8,

M_{sw} : Permissible still water bending moments in kNm, at the considered longitudinal position for seagoing and harbour conditions as defined in Ch 4, Sec 4, [2.2.2] and Ch 4, Sec 4, [2.2.3] respectively.

M_{wv-LC}: Vertical wave bending moment in kNm, for the dynamic load case under consideration, calculated in accordance with Ch 4, Sec 4, [3.5.2].

The values of $M_{v\text{-}targ}$ are taken as:

Midship cargo hold region: the maximum hull girder bending moment within the mid-hold(s) for each individual cargo hold for each given FE load combination as defined in Ch 4, Sec 8.

Outside midship cargo hold region: the values at all web frame and transverse bulkhead positions of the FE model under consideration.

Both $C_{BM\text{-}LC}M_{sw}$ *and* $M_{wv\text{-}LC}$ are either in sagging or in hogging condition according to the FE load combinations given in the tables of Ch 4, Sec 8.

4.3.3 Target hull girder shear force

The target hull girder vertical shear force at the aft and forward transverse bulkheads of the mid-hold, $Q_{targ\text{-}aft}$ and $Q_{targ\text{-}fwd}$, in kN, for a given FE load combination is taken as:

- $Q_{fwd} \geqslant Q_{aft}$:

$$Q_{targ\text{-}aft} = C_{SF-LC} \cdot Q_{sw-neg} - \Delta Q_{swa} + f_\beta \left| C_{QW} \right| Q_{wv-neg}$$

$$Q_{targ\text{-}fwd} = C_{SF-LC} \cdot Q_{sw-pos} + \Delta Q_{swf} + f_\beta \left| C_{QW} \right| Q_{wv-pos}$$

- $Q_{fwd} < Q_{aft}$:

$$Q_{targ\text{-}aft} = C_{SF-LC} \cdot Q_{sw-pos} - \Delta Q_{swa} + f_\beta \left| C_{QW} \right| Q_{wv-pos}$$

$$Q_{targ\text{-}fwd} = C_{SF-LC} \cdot Q_{sw-neg} + \Delta Q_{swf} + f_\beta \left| C_{QW} \right| Q_{wv-neg}$$

where:

Q_{fwd}, Q_{aft} :Vertical shear forces, in kN, due to the local loads respectively at the forward and aft bulkhead position of the mid-hold, as defined in [4.4.6].

$C_{SF\text{-}LC}$: Percentage of permissible still water shear force as given in Ch 4, Sec 8, for the FE load combination under consideration.

$Q_{sw\text{-}pos}$, $Q_{sw\text{-}neg}$: Positive and negative permissible still water shear forces, in kN, at any longitudinal position for seagoing and harbour conditions as defined in Ch 4, Sec 4, [2.3.3] and Ch 4, Sec 4, [2.3.4] respectively.

ΔQ_{swf} : Shear force correction, in kN, for the considered FE loading pattern at the forward bulkhead taken as:

- For bulk carriers:

Minimum of the absolute values of ΔQ_{mdf} as defined in Ch 5, Sec 1, [3.6.1] calculated at forward bulkhead for the mid-hold and the value calculated at aft bulkhead of the forward cargo hold taken as:

$$\Delta Q_{swf} = \text{Min}(\left|\Delta Q_{mdf}\right|_{Mid}, \left|\Delta Q_{mdf}\right|_{Fwd})$$

- For oil tankers:

$\Delta Q_{swf} = 0$

ΔQ_{swa} : Shear force correction, in kN, for the considered FE loading pattern at the aft bulkhead taken as:

- For bulk carriers:

Minimum of the absolute values of ΔQ_{mdf} as defined in Ch 5, Sec 1, [3.6.1] calculated at aft bulkhead for the mid-hold and the value calculated at forward bulkhead of the aft cargo hold taken as:

$$\Delta Q_{swa} = \text{Min}(\left|\Delta Q_{mdf}\right|_{Mid}, \left|\Delta Q_{mdf}\right|_{Aft})$$

- For oil tankers:

$\Delta Q_{swa}=0$

f_β : Wave heading factor, as given in Ch 4, Sec 4.

C_{QW} : Load combination factor for vertical wave shear force, as given in Ch 4, Sec 2.

$Q_{wv\text{-}pos}$, Q_{wv_neg} : Positive and negative vertical wave shear force, in kN, as defined in Ch 4, Sec 4, [3.2.1].

The values of $Q_{targ\text{-}aft}$ and $Q_{targ\text{-}fwd}$ are to be taken at after and forward transverse bulkheads of the mid-hold under consideration.

4.3.4 Target hull girder horizontal bending moment

The target hull girder horizontal bending moment, $M_{h\text{-}targ}$, in kNm, for a given FE load combination is taken as:

$M_{h-targ} = M_{wh-LC}$

where:

M_{wh-LC}: Horizontal wave bending moment, in kNm, for the dynamic load case under consideration, calculated in accordance with Ch 4, Sec 4, [3.5.4].

The values of $M_{wh\text{-}LC}$ are taken as:

- Midship cargo hold region: the value calculated for the middle of the individual cargo hold under consideration.
- Outside midship cargo hold region: the values calculated at all web frame and transverse bulkhead positions of the FE model under consideration.

4.3.5 Target hull girder torsional moment

For bulk carriers only, the target hull girder torsional moment, $M_{wt\text{-}targ}$, in kNm, for the dynamic load cases OST and OSA is the value at the target location taken as:

$M_{wt-targ} = M_{wt-LC}\ (x_{targ})$

where:

$M_{wt\text{-}LC\ (x)}$: Wave torsional moment, in kNm, for the dynamic load case OST and OSA, defined in Ch 4, Sec 4, [3.5.5], calculated at x position.

x_{targ} : Target location for hull girder torsional moment taken as:

- For midship cargo hold region:
  - If $x_{mid} \leqslant 0.531\ L$: after bulkhead of the mid-hold.
  - If $x_{mid} > 0.531\ L$: forward bulkhead of the mid-hold.
- Outside midship cargo hold region:
  The transverse bulkhead of mid-hold where the following formula is minimum:

$$\frac{M_{wt-LC}(x_{bhd})}{\left|M_{wt-LC}(x_{bhd})\right|} \cdot [M_{wt-LC}(x_{bhd}) - M_{T-FEM}(x_{bhd})]$$

x_{mid} : X-coordinate, in m, of the mid-hold centre.

x_{bhd} : X-coordinate, in m, of the after or forward transverse bulkhead of mid-hold.

For dynamic load cases of bulk carriers other than OST and OSA and for all dynamic load cases of oil tankers, hull girder torsional moment $M_{wt\text{-}targ}$, at middle of mid-hold is to be adjusted to zero.

4.4 Procedure to adjust hull girder shear forces and bending moments

4.4.1 General

The procedure given in this sub-article [4.4] describes how to adjust the hull girder horizontal bending moment, vertical force and vertical bending moment distribution on the three cargo hold FE model to achieve the required target values at required locations. The hull girder load target values are specified in [4.3].

The target locations for hull girder shear force are at the transverse bulkheads of the mid-hold. The final adjusted hull girder shear force at the target location should not exceed the target hull girder shear force.

The target location for hull girder bending moment is, in general, located at the centre of the mid-hold. If the maximum value of bending moment is not located at the centre of the mid-hold, the final adjusted maximum bending moment within the mid-hold is not to exceed the target hull girder bending moment.

4.4.2 Local load distribution

The following local loads are to be applied for the calculation of hull girder shear and bending

moments:

a) Ship structural steel weight distribution over the length of the cargo hold model (static loads). The structural steel weight is to be calculated based on the FE model with a net thickness of 0.5 *tc* deduction, as used in the cargo hold FE model.
b) Weight of cargo and ballast (static loads).
c) Static sea pressure, dynamic wave pressure and, where applicable, green sea load. For the harbour/tank testing load cases, only static sea pressure needs to be applied.
d) Dynamic cargo and ballast loads for seagoing load cases.

With the above local loads applied to the FE model, the FE nodal forces are obtained through FE loading procedure. The 3D nodal forces will then be lumped to each longitudinal station to generate the one dimension local load distribution. The longitudinal stations are located at transverse bulkheads/frames and typical longitudinal FE model nodal locations in between the frames according to the cargo hold model mesh size requirement. Any intermediate nodes created for modelling structural details are not treated as the longitudinal stations for the purpose of local load distribution. The nodal forces within half of forward and half of afterward of longitudinal station spacing are lumped to that station. The lumping process will be done for vertical and horizontal nodal forces separately to obtain the lumped vertical and horizontal local loads, f_{vi} and f_{hi}, at the longitudinal station *i*.

4.4.3 Hull girder forces and bending moment due to local loads

With the local load distribution, the hull girder load longitudinal distributions are obtained by assuming the model is simply supported at model ends. The reaction forces at both ends of the model and longitudinal distributions of hull girder shear forces and bending moments induced by local loads at any longitudinal station are determined by the following formulae:

$$R_{V_fore} = -\frac{\sum_j (x_i - x_{aft}) f_{vi}}{x_{fore} - x_{aft}} \qquad R_{V_aft} = \sum_i f_{vi} + R_{V_fore}$$

$$R_{H_fore} = -\frac{\sum_j (x_i - x_{aft}) f_{hi}}{x_{fore} - x_{aft}} \qquad R_{V_aft} = \sum_i f_{vi} + R_{H_fore}$$

$$F_l = \sum_i f_{li}$$

$$Q_{V_FEM}(x_j) = R_{V_aft} - \sum_i f_{hi} \qquad \text{when} x_i < x_j$$

$$Q_{H_FEM}(x_j) = R_{H_aft} + \sum_i f_{hi} \qquad \text{when} x_i < x_j$$

$$M_{V_FEM}(x_j) = R_{V_aft} - \sum_i (x_j - x_i) f_{vi} \quad \text{when} \quad x_i < x_j$$

$$M_{H_FEM}(x_j) = R_{H_aft} + \sum_i (x_j - x_i) f_{hi} \quad \text{when} \quad x_i < x_j$$

Where:

R_{V_aft}, R_{V_fore}, R_{H_aft}, R_{H_fore} : Vertical and horizontal reaction forces at the aft and fore ends, in kN.

x_{aft} : *X*-coordinate of the aft end support, in m.

x_{fore} : *X*-coordinate of the fore end support, in m.

f_{vi} :Lumped vertical local load at longitudinal station *i* as defined in [4.4.2], in kN.

f_{hi} :Lumped horizontal local load at longitudinal station *i* as defined in [4.4.2], in kN.

F_l : Total net longitudinal force of the model, in kN.

f_{li} : Lumped longitudinal local load at longitudinal station *i* as defined in [4.4.2], in kN.

x_j : *X*-coordinate, in m, of considered longitudinal station *j*.

x_i : *X*-coordinate, in m, of longitudinal station *i*.

$Q_{V_FEM}(x_j)$, $Q_{H_FEM}(x_j)$, $M_{V_FEM}(x_j)$, $M_{H_FEM}(x_j)$: Vertical and horizontal shear forces, in kN, and bending moments, in kNm, at longitudinal station x_j created by the local loads applied on the FE model. The sign convention for reaction forces is that a positive creates a positive shear force.

4.4.4 Longitudinal unbalanced force

In case total net longitudinal force of the model, F_l, is not equal to zero, the counter longitudinal force, $(F_x)_j$, is to be applied at one end of the model, where the translation on X-direction, δ_x, is fixed, by distributing longitudinal axial nodal forces to all hull girder bending effective longitudinal elements, as follows:

$$(F_x)_j = \frac{F_l}{A_{x-n50}} \frac{A_{j-n50}}{n_j}$$

where:

$(F_x)_j$: Axial force applied to a node of the j-th element, in kN.

F_l : Total net longitudinal force of the model, as defined in [4.4.3], in kN.

$A_{j\text{-}n50}$: Net cross sectional area of the j-th element, in m^2.

$A_{x\text{-}n50}$: Net cross sectional area of fore end section, in m^2,

$$A_{x-n50} = \sum_j A_{j-n50}$$

n_j : Number of nodal points of j-th element on the cross section, $n_j = 1$ for beam element, $n_j = 2$ for 4- node shell element.

4.4.5 Hull girder shear force adjustment procedure

The hull girder shear force adjustment procedure defined in this requirement applies to all FE load combinations given in Ch 4, Sec 8. The FE load combinations not directly covered by the load combination tables of Ch 4, Sec 8 are to be considered on a case by case basis.

The two following methods are to be used for the shear force adjustment:

- Method 1 (M1): for shear force adjustment at one bulkhead of the mid-hold as given in [4.4.6],
- Method 2 (M2): for shear force adjustment at both bulkheads of the mid-hold as given in [4.4.7].

For the considered FE load combination, the method to be applied is to be selected as follows:

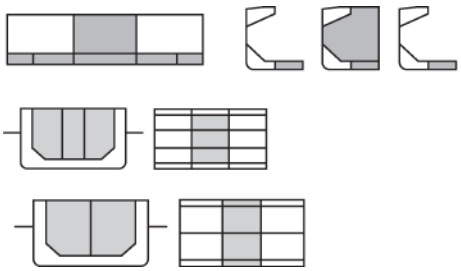
- For maximum shear force load combination (Max SFLC), the method 1 applies at the bulkhead mentioned in Table 4 if the shear force after the adjustment with method 1 at the other bulkhead does not exceed the target value. Otherwise, the method 2 applies.
- For other shear force load combination:
  - The shear force adjustment is not requested when the shear forces at both bulkheads are lower or equal to the target values. This applies to cargo hold analysis in whole cargo area except for aft most and foremost cargo hold.
    For aft most and foremost cargo hold analyses, the shear force adjustment is to be applied with method 1. The target hull girder vertical shear force at the aft and forward transverse bulkheads, $Q_{targ\text{-}aft}$ and $Q_{targ\text{-}fwd}$, are to be set to values of vertical shear force due to local loads Q_{aft} and Q_{fwd} accordingly:
    $$Q_{targ-fwd} = Q_{fwd}$$
    $$Q_{targ-aft} = Q_{aft}$$
  - The method 1 applies when the shear force exceeds the target at one bulkhead and the shear force at the other bulkhead after the adjustment with method 1 does not exceed the target value. Otherwise the method 2 applies,
  - The method 2 applies when the shear forces at both bulkheads exceed the target values,

CCS 4.4.5a For the considered conditions not included in the tables of loading conditions in Section 8, Chapter 4, the hull girder shear force is to be adjusted as follows:

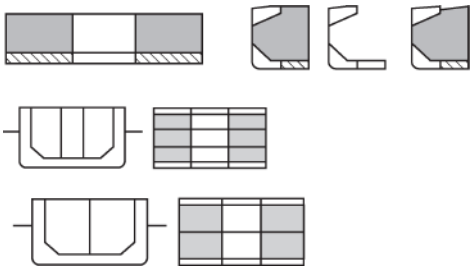
(1) The shear force of hull girders is to be adjusted for the following load combinations:

① Loading pattern: alternate loading of holds in longitudinal direction.

(a) All middle holds are loaded while end holds are empty, as shown in the figure below.



(b) All middle holds are empty while end holds are loaded, as shown in the figure below.

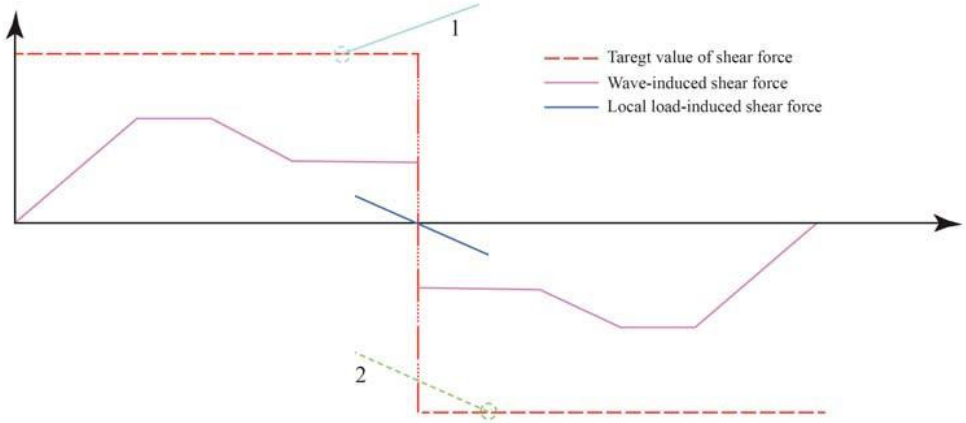


② Dynamic load cases: head sea model (HSM) or following sea model (FSM) or harbor condition.

③ Target bulkheads:

(a)For the model of a mid-hold of which both fore and aft bulkheads are located fore or aft of 0.5L amidships, the shear force adjustment is to be made at the bulkhead location defined in Table 4, Section 2, Chapter 7.

(b)For the model of a mid-hold situated amidships, of which the fore bulkhead is located fore of 0.5L amidships and the aft bulkhead aft of 0.5L amidships, the shear force adjustment is to be made at the bulkhead location where the absolute target value is greater. E.g.: where the absolute target value at the aft bulkhead is greater than that at the fore bulkhead, the shear force adjustment is to be made at the aft bulkhead location according to 1 as shown in the figure below, otherwise according to 2.



④ Method of hull girder shear force adjustment:

The method of hull girder shear force adjustment is to be in accordance with 4.4.5 Section 2 Chapter 7.

(2) For other load combinations:

The hull girder shear force adjustment is to be in accordance with 4 .4.5 Section 2 Chapter 7.

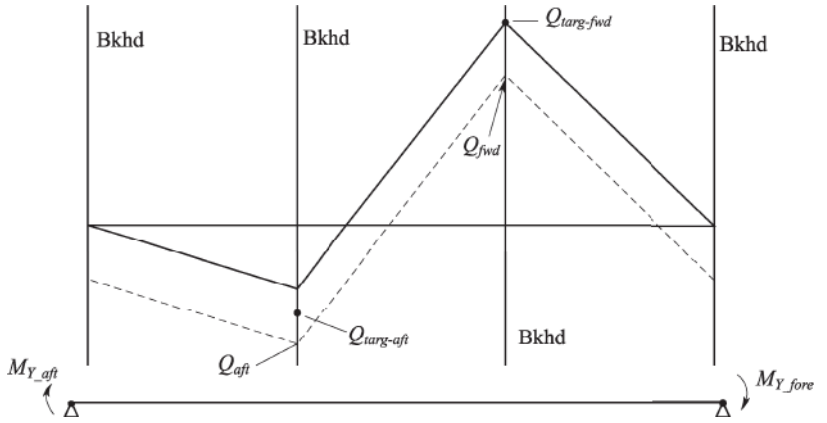
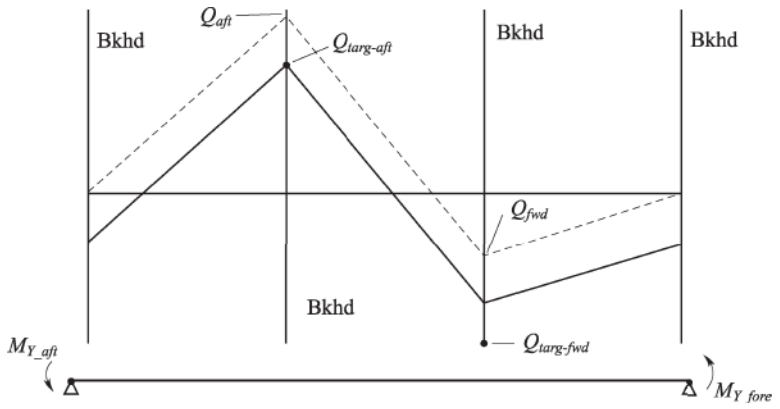
(3) The tart hull g ŕder shear force are to be taken ń accordance w ťh 4.3 Sect ón 2 Chapter 7 and the shear force adjustment procedure ś to be ń accordance w ťh the relevant requ ŕements of 4.4Sect ón2Chapter 7.

Mid-hold bulkhead location for shear force adjustment **Table 4**

Design loading conditions	Bulkhead location	$M_{wv\text{-}LC}$	Condition on Q_{fwd}	Mid-hold bulkhead for SF adjustment
Seagoing conditions	$X_{b\text{-}aft} > 0.5L$	< 0 (sagging)	$Q_{fwd} > Q_{aft}$	Fwd
			$Q_{fwd} \leqslant Q_{aft}$	Aft
		0 (hogging)	$Q_{fwd} > Q_{aft}$	Aft
			$Q_{fwd} \leqslant Q_{aft}$	Fwd
	$X_{b\text{-}fwd} < 0.5L$	< 0 (sagging)	$Q_{fwd} > Q_{aft}$	Aft
			$Q_{fwd} \leqslant Q_{aft}$	Fwd
		0 (hogging)	$Q_{fwd} > Q_{aft}$	Fwd
			$Q_{fwd} \leqslant Q_{aft}$	Aft
	$X_{b\text{-}aft} \leqslant 0.5L$ and $X_{b\text{-}fwd} \geqslant 0.5L$	-	-	(1)
Harbour and testing conditions	whatever the location	-	-	(1)

(1) For the FE load combinations covered by the load combination tables of Ch 4, Sec 8, the bulkhead where the shear force adjustment is to be done is indicated in those tables.

Vertical shear force adjustment by application of vertical bending moments M_{Y_aft} and M_{Y_fore} for method 1 **Table 5**

Vertical shear force diagram	Target position in mid-hold
	Forward bulkhead
	Aft bulkhead
Vertical shear force after adjustment Vertical shear due to local adjustment	

4.4.6 Method 1 for vertical shear force adjustment at one bulkhead

The required adjustments in shear force at aft or forward transverse bulkhead of the mid-hold are

to be made by applying vertical bending moments, M_{Y_aft}, M_{Y_fore} at model ends. For aft most cargo and foremost cargo hold models, the following additional vertical loads are to be applied at the transverse frame positions as shown in Table 7:

- $\delta w'_1$ - for aft most cargo hold model
- $\delta w'_3$ - for foremost cargo hold model

The required adjustments in shear force at following transverse bulkheads of the mid-hold are given by:

- Aft bulkhead:

$$M_{Y_aft} = M_{Y_fore} = \frac{(X_{fore} - X_{aft})}{2}(Q_{targ-aft} - Q_{aft}) - M'_{1-aft}$$

$$\Delta Q_{aft} = \Delta Q_{fwd} = 0$$

$$\delta w'_1 = \frac{Q_{targ-aft} - Q_{aft} + R_{v_aft}}{(n_1 - 1)} \quad \text{for aftmost cargo hold model only}$$

$$\delta w'_3 = \frac{Q_{targ-aft} - Q_{aft} + R_{v_fore}}{(n_3 - 1)} \quad \text{for foremost cargo hold model only}$$

- Forward bulkhead:

$$M_{Y_aft} = M_{Y_fore} = \frac{(X_{fore} - X_{aft})}{2}(Q_{targ-fwd} - Q_{fwd}) - M'_{1-fwd}$$

$$\Delta Q_{aft} = \Delta Q_{fwd} = 0$$

$$\delta w'_1 = \frac{Q_{targ-fwd} - Q_{fwd} + R_{v_aft}}{(n_1 - 1)} \quad \text{for aftmost cargo hold model only}$$

$$\delta w'_3 = \frac{Q_{targ-fwd} - Q_{fwd} + R_{v_fore}}{(n_3 - 1)} \quad \text{for foremost cargo hold model only}$$

where:

M_{Y_aft}, M_{Y_fore}: Vertical bending moment, in kNm, to be applied at the aft and fore ends in accordance with [4.4.10], to enforce the hull girder vertical shear force adjustment as shown in Table 5. The sign convention is that of the FE model axis.

Q_{aft} : Vertical shear force, in kN, due to local loads at aft bulkhead location of mid-hold, x_{b_aft}, resulting from the local loads calculated according to [4.4.3].Since the vertical shear force is discontinued at the transverse bulkhead location, Q_{aft} is the maximum absolute shear force between the stations located right after and right forward of the aft bulkhead of mid-hold.

Q_{fwd} : Vertical shear force, in kN, due to local loads at the forward bulkhead location of mid-hold, x_{b_fwd}, resulting from the local loads calculated according to [4.4.3].Since the vertical shear force is discontinued at the transverse bulkhead location, Q_{fwd} is the maximum absolute shear force between the stations located right after and right forward of the forward bulkhead of mid-hold.

$M'_{1\text{-}aft}$,$M'_{1\text{-}fwd}$: Additional vertical bending moment, in kNm, applicable for aftmost and foremost cargo hold analysis only, taken as:

- Aft most cargo hold model

$$M'_{1-aft} = \frac{l_1}{4}(Q_{targ-aft} - Q_{aft} + R_{v-aft})$$

$$M'_{1-fwd} = \frac{l_1}{4}(Q_{targ-fwd} - Q_{fwd} + R_{v-aft})$$

- Foremost cargo hold model

$$M'_{1-aft} = \frac{l_3}{4}(Q_{targ-aft} - Q_{aft} + R_{v-fore})$$

$$M'_{1-fwd} = \frac{l_3}{4}(Q_{targ-fwd} - Q_{fwd} + R_{v-fore})$$

$\delta w'_1$: Distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model, see also Table 8.

$\delta w'_3$: Distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model, see also Table 8.

ΔQ_{aft} ,ΔQ_{fwd} : Shear force adjustments, as given in Table 8

R_{v_aft}, M_{v_fore} : Reaction forces at the aft and fore ends, in kN, as defined in [4.4.3].

l_1 : Length of the modelled engine room in aftmost cargo hold model, in m. See also Table 8.

l_3 : Length of the modelled forepeak in foremost cargo hold model, in m. See also Table 8.

n_1, n_3 :Number of frame spaces, see Table 8.

4.4.7 Method 2 for vertical shear force adjustment at both bulkheads

The required adjustments in shear force at both transverse bulkheads of the mid-hold are to be made by applying:

- Vertical bending moments, M_{Y_aft}, M_{Y_fore} at model ends and,
- Vertical loads at the transverse frame positions as shown in Table 7 in order to generate vertical shear forces, ΔQ_{aft} and ΔQ_{fwd}, at the transverse bulkhead positions.
- For aft most cargo and foremost cargo hold models, the following additional vertical loads are to be applied at the transverse frame positions as shown in Table 7:
  - $\delta w'_1$: for aft most cargo hold model
  - $\delta w'_3$: for foremost cargo hold model

Table 6 shows examples of the shear adjustment application due to the vertical bending moments and to vertical loads.

$$M_{Y_aft} = M_{Y_fore} = \frac{(X_{fore} - X_{aft})}{2}(Q_{targ-fwd} - Q_{fwd})$$

$$M_{Y_aft} = \frac{X_{fore} - X_{aft}}{2} \cdot \frac{Q_{targ-fwd} - Q_{fwd} + Q_{targ-aft} - Q_{aft}}{2}$$

$$M_{Y_fore} = M_{Y_aft}$$

$$\Delta Q_{fwd} = \frac{Q_{targ-fwd} - Q_{fwd} - (Q_{targ-aft} - Q_{aft})}{2}$$

$$\Delta Q_{aft} = -\Delta Q_{fwd}$$

- Aft most cargo hold model

$$\delta w'_1 = \left(\frac{(Q_{targ-aft} - Q_{aft})(l - l_2 - l_1) + (Q_{targ-fwd} - Q_{fwd})(l - l_2 - l_3)}{(2l - l_1 - 2l_2 - l_3)} + R_{v_aft} \right) \frac{1}{(n_1 - 1)}$$

- Foremost cargo hold model

$$\delta w'_3 = \left(\frac{(Q_{targ-fwd} - Q_{fwd})(l - l_2 - l_3) + (Q_{targ-aft} - Q_{aft})(l - l_2 - l_1)}{(2l - l_1 - 2l_2 - l_3)} + R_{v_fore} \right) \frac{1}{(n_3 - 1)}$$

where:

M_{Y_aft}, M_{Y_fore}: Vertical bending moment, in kNm, to be applied at the aft and fore ends in accordance with [4.4.10], to enforce the hull girder vertical shear force adjustment. The sign convention is that of the FE model axis.

ΔQ_{aft} : Adjustment of shear force, in kN, at aft bulkhead of mid-hold.

ΔQ_{fwd} : Adjustment of shear force, in kN, at fore bulkhead of mid-hold.

M'_2 : Additional vertical bending moment, in kNm, applicable for aftmost and foremost cargo hold analysis only, taken as:

- Aftmost cargo hold model $M'_2 = \frac{l_1(n_1 - 1)\delta w'_1}{4}$

- Foremost cargo hold model $M'_2 = \dfrac{l_3(n_3 - 1)\delta w'_3}{4}$

$\delta w'_1$: Distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model, see also Table 8.

$\delta w'_3$: Distributed load, in kN, at frame in the the modelled forepeak of foremost cargo hold model, see also Table 8.

R_{v_aft}, M_{v_fore}: Reaction forces at the aft and fore ends, in kN, as defined in [4.4.3].

l_1 : Length of the modelled engine room in aftmost cargo hold model, in m. See also Table 8.

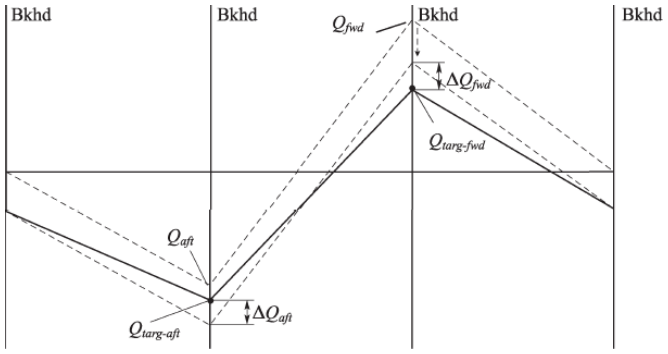
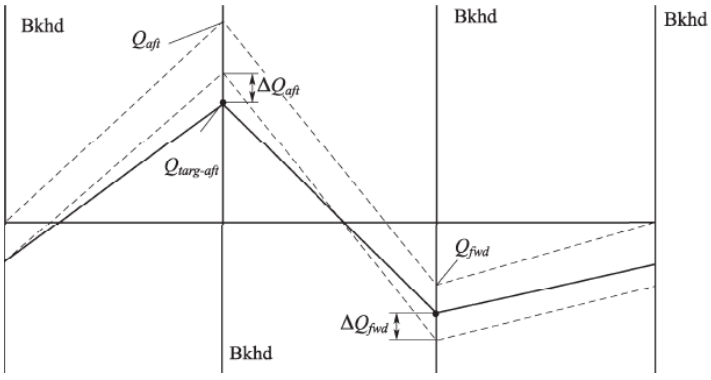
l_3 : Length of the modelled forepeak in foremost cargo hold model, in m. See also Table 8.

$n_{1,3}$: Number of frame spaces, see Table 8.

The above adjustments in shear forces, ΔQ_{aft} and ΔQ_{fwd}, at the transverse bulkhead positions are to be generated by applying vertical loads at the transverse frame positions as shown in Table 7. For bulk carriers, the transverse frame positions correspond to the floors. Vertical correction loads are not to be applied to any transverse tight bulkheads, any frames forward of the forward cargo hold and any frames aft of the aft cargo hold of the FE model.

The vertical loads to be applied to each transverse frame to generate the increase/decrease in shear force at the bulkheads may be calculated as shown in Table 7. In case of uniform frame spacing, the amount of vertical force to be distributed at each transverse frame may be calculated in accordance with Table 8.

Target and required shear force adjustment by applying vertical forces Table 6

Vertical shear force diagram	Aft Bhd	Fore Bhd
	SF target	SF target
	$Q_{targ\text{-}aft}$ *(-ve)*	$Q_{targ\text{-}fwd}$ *(+ve)*
	$Q_{targ\text{-}aft}$ *(+ve)*	$Q_{targ\text{-}fwd}$ *(-ve)*

Vertical shear force after both adjustment

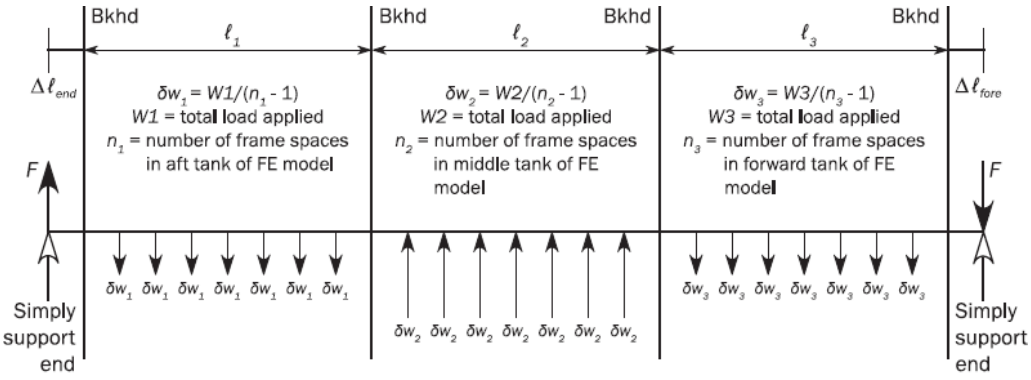
Vertical shear force after adjustment by use of M_{Y_aft} and M_{Y_fore}

Vertical shear due to local loads

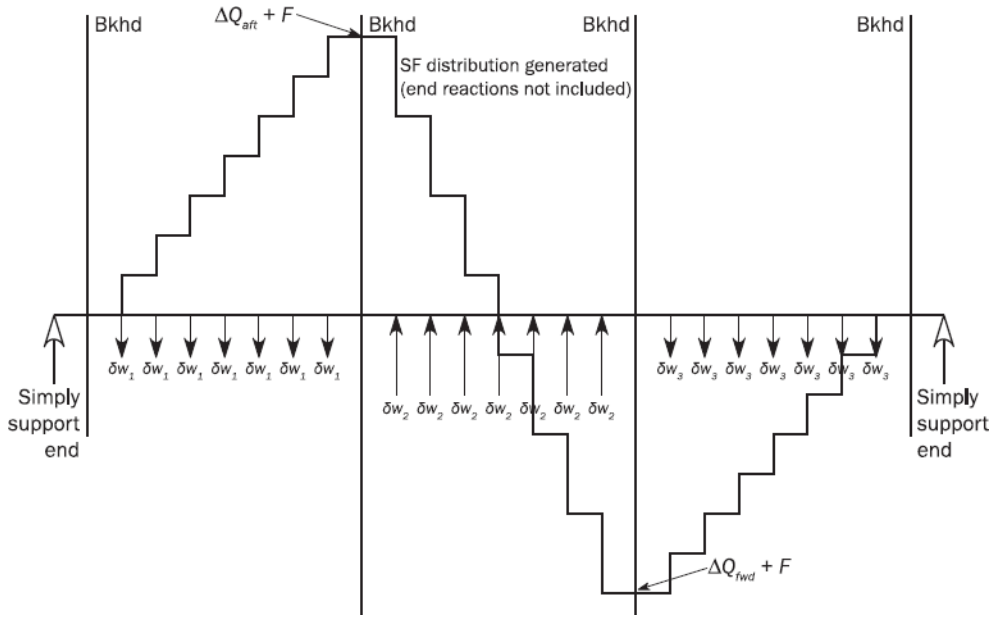
Vertical shear force diagram	Aft Bhd	Fore Bhd
	SF target	SF target
Note1: -ve means negative. Note2: +ve means positive.		

Distribution of adjusting vertical force at frames and resulting shear force distribution

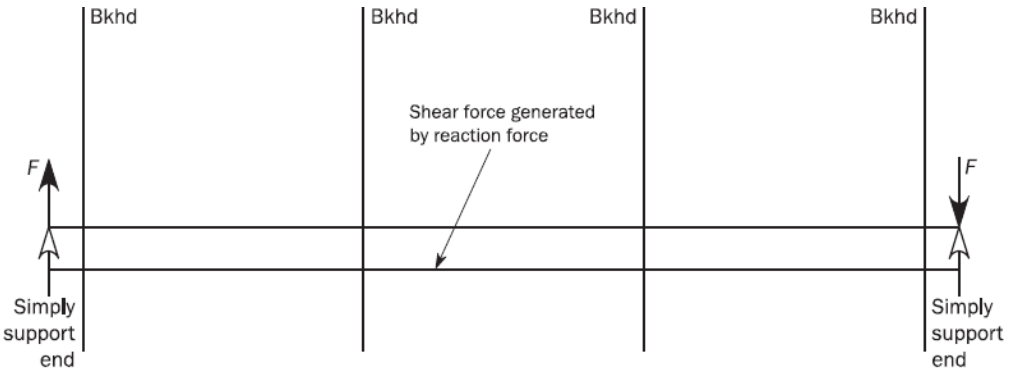
Table 7



Note: Transverse bulkhead frames not loaded
Frames beyond aft transverse bulkhead of aft most tank and forward bulkhead of forward most tank not loaded
F = Reaction load generated by supported ends



Shear Force distribution due to adjusting vertical force at frames



Note: F=0 if l_1=l_3 and l_{fore}=l_{end}, and loads are symmetrical about mid-length of model.

Note1: For definition of symbols, see Table 8.

Formulae for calculation of vertical loads for adjusting vertical shear forces Table 8

$$\delta w_1 = \frac{\Delta Q_{aft}(2l - l_2 - l_3) + \Delta Q_{fwd}(l_2 + l_3)}{(n_1 - 1)(2l - l_1 - 2l_2 - l_3)} + \delta w'_1$$

$$\delta w_2 = \frac{(W1 + W3)}{(n_2 - 1)} = \frac{(\Delta Q_{aft} - \Delta Q_{fwd})}{(n_2 - 1)}$$

$$\delta w_3 = \frac{-\Delta Q_{fwd}(2l - l_1 - l_2) - \Delta Q_{aft}(l_1 + l_2)}{(n_3 - 1)(2l - l_1 - 2l_2 - l_3)} - \delta w'_3$$

In general

$$F = F_{aft} = F_{fwd} = 0.5\left[\frac{W1(l_2 + l_1) - W3(l_2 + l_3)}{l}\right]$$

For aftmost and foremost cargo hold FE model

$$F = F_{aft} = \left(\frac{W1(\Delta l_{fore} + l_3 + l_2 + 0.5l_1) + W2(\Delta l_{fore} + l_3 + 0.5l_2) + W3(\Delta l_{fore} + 0.5l_3)}{l}\right)$$

where:

l_1 : Length of aft cargo hold of model, in m.

l_2 : Length of mid-hold of model, in m.

l_3 : Length of forward cargo hold of model, in m.

ΔQ_{aft} : Required adjustment in shear force, in kN, at aft bulkhead of middle hold, see [4.4.7].

ΔQ_{fwd} : Required adjustment in shear force, in kN, at fore bulkhead of middle hold, see [4.4.7].

F : End reactions, in kN, due to application of vertical loads to frames.

$W1$: Total evenly distributed vertical load, in kN, applied to aft hold of FE model, $(n_1 - 1)\ \delta w_1$.

$W2$: Total evenly distributed vertical load, in kN, applied to mid-hold of FE model, $(n_2 - 1)\ \delta w_2$.

$W3$: Total evenly distributed vertical load, in kN, applied to forward hold of FE model, $(n_3 - 1)\ \delta w_3$.

n_1 : Number of frame spaces in aft cargo hold of FE model.

n_2 : Number of frame spaces in mid-hold of FE model.

n_3 : Number of frame spaces in forward cargo hold of FE model.

δw_1 : Distributed load, in kN, at frame in aft cargo hold of FE model.

δw_2 : Distributed load, in kN, at frame in mid-hold of FE model.

δw_3 : Distributed load, in kN, at frame in forward cargo hold of FE model.

$\delta w'_1$: Additional distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model. Formulae of $\delta w'_1$ are given in [4.4.6] and [4.4.7] for shear force adjustment method 1 and method 2 accordingly.

$\delta w'_3$: Additional distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model. Formulae of $\delta w'_3$ are given in [4.4.6] and [4.4.7] for shear force adjustment method 1 and method 2 accordingly.

Δl_{end} : Distance, in m, between end bulkhead of aft cargo hold to aft end of FE model.
$\Delta l_{end} = 0$ in the aftmost cargo hold model

Δl_{fore} : Distance, in m, between fore bulkhead of forward cargo hold to forward end of FE model.
$\Delta l_{fore} = 0$ in the foremost cargo hold model

l : Total length, in m, of FE model including portions beyond end bulkheads:
$= l_1 + l_2 + l_3 + l_4 + \Delta l_{end} + \Delta l_{fore}$

Note1: Positive direction of loads, shear forces and adjusting vertical forces in the formulae is in accordance with Table 6 and Table 7.

Note2: $W1 + W3 = W2$. (not applicable for aftmost and foremost cargo FE model).

Note3: The above formulae are only applicable if uniform frame spacing is used within each hold. The length and frame spacing of individual cargo holds may be different.

If non-uniform frame spacing is used within each cargo hold, the average frame spacing $l_{av\text{-}i}$ is used to calculate the average distributed frame loads $wav\text{-}i$,, according to Table 8, where i = 1, 2, 3 for each hold.

Then $\delta w_{av\text{-}i}$ is redistributed to the non-uniform frame as follows:

$$\delta w_i^k = \delta w_{av-i} \frac{l_{av-i}^k}{l_{av-i}} \quad k=1, 2, \ldots, n_i - 1 \text{ for each frame in cargo hold i, i=1, 2, 3}$$

where:

$l_{av\text{-}i}$: Average frame spacing, in m, calculated as l_i / n_i, in cargo hold i with i = 1, 2, 3.

l_i : Length, in m, of the cargo hold i with i = 1, 2, 3 as defined in Table 8.

n_i : Number of frame spacing in cargo hold i with i = 1, 2, 3 as defined in Table 8.

$\delta w_{av\text{-}i}$: Average uniform frame spacing, in m, distributed force calculated according to Table 8 with the average frame spacing $l_{av\text{-}i}$ in cargo hold i with i = 1, 2, 3.

δw_i^k : Distributed load, in kN, for non-uniform frame k in cargo hold i.

$l^k_{av\text{-}i}$: Equivalent frame spacing, in m, for each frame k with k = 1, 2,..., ni - 1, in cargo hold i, taken as:

$$l_{av-i}^k = l_i^1 - \frac{l_{av-i} l_i^1}{l_i^1 + l_i^{n_i}} + \frac{l_i^2}{2} \quad \text{for } k = 1 \text{ (first frame), in cargo hold } i$$

$$l_{av-i}^k = \frac{l_i^k}{2} + \frac{l_i^{k+1}}{2} \quad \text{for } k = 2, 3, \ldots, n_1 - 2, \text{ in cargo } i$$

$$l_{av-i}^k = l_i^{n_i} - \frac{l_{av-i} l_i^{n_i}}{l_i^1 + l_i^{n_i}} + \frac{l_i^{n_i - 1}}{2} \quad \text{for } k = n_i - 1 \text{ (last frame), in cargo } i$$

l_i^k: Frame spacing, in m, between the frame k - 1 and k in the cargo hold i:

The required vertical load δw_i for a uniform frame spacing or $\delta_{wi}{}^k$ for non-uniform frame spacing, are to be applied by following the shear flow distribution at the considered cross section, as described in Ch 5, App 1. For a frame section under vertical load δw_i, the shear flow, q_f, at the middle point of the element is calculated as:

$$q_{f-k} = \frac{\delta w_i}{I_{y-n50}} Q_{k-n50}$$

where:

q_{f-k} : Shear flow calculated at the middle of the *k*-th element of the transverse frame, in N/mm.

δw_i : Distributed load at each transverse frame location for *i*-th cargo hold, *i* = 1, 2, 3, as defined in Table 8, in N.

I_{y-n50} : Moment of inertia of the hull girder cross section, in mm^4.

Q_{k-n50} : First moment about neutral axis of the accumulative section area starting from the open end (shear stress free end) of the cross section to the point s*k* for shear flow q_{f-k} in mm^3, taken as;

$$Q_{k-n50} = \int_0^{S_k} z_{neu} t_{n50} \mathrm{ds}$$

z_{neu} : Vertical distance from the integral point, *s*, to the vertical neutral axis.

t_{n50} : Net thickness, in mm, of the plate at the integral point of the cross section.

The distributed shear force at *j*-th FE grid of the transverse frame, F_{j-grid}, is obtained from the shear flow of the connected elements as following:

$$F_{j-grid} = \sum_{k=1}^{n} q_{f-k} \frac{l_k}{2}$$

where:

l_k : Length of the *k*-th element of the transverse frame connected to the grid *j*, in mm.

n : Total number of elements connect to the grid *j*.

The shear flow has direction along the cross section and therefore the distributed force, F_{j-grid}, is a vector force. For vertical hull girder shear correction, the vertical and horizontal force components calculated with above mentioned shear flow method need to be applied to the cross section.

4.4.8 Procedure to adjust vertical and horizontal bending moments for midship cargo hold region

In case the target vertical bending moment needs to be reached, an additional vertical bending moment is to be applied at both ends of the cargo hold FE model to generate this target value in the mid-hold of the model. This end vertical bending moment is given as follows:

$M_{v\text{-}end}=M_{v\text{-}targ}-M_{v\text{-}peak}$

where:

$M_{v\text{-}end}$: Additional vertical bending moment, in kNm, to be applied to both ends of FE model in accordance with [4.4.10].

$M_{v\text{-}targ}$: Hogging (positive) or sagging (negative) vertical bending moment, in kNm, as specified in [4.3.2].

$M_{v\text{-}peak}$:Maximum or minimum bending moment, in kNm, within the length of the mid-hold due to the local loads described in [4.4.3] and due to the shear force adjustment as defined in [4.4.5].

$M_{v\text{-}peak}$ is to be taken as the maximum bending moment if $M_{v\text{-}targ}$ is hogging (positive) and as the minimum bending moment if $M_{v\text{-}targ}$ is sagging (negative). $M_{v\text{-}peak}$ is to be calculated as follows based on a simply supported beam model:

$$M_{v-peak} = Extremum\left\{ M_{v_FEM}(x) + M_{lineload} + M_{Y_aft}\left(2\frac{x - x_{aft}}{x_{fore} - x_{aft}} - 1\right) \right\}$$

$M_{V_FEM(x)}$: Vertical bending moment, in kNm, at position *x*, due to the local loads as described in [4.4.3].

M_{Y_aft} : End bending moment, in kNm, to be taken as:

- When method 1 is applied: the value as defined in [4.4.6].
- When method 2 is applied: the value as defined in [4.4.7].
- Otherwise: M_{Y_af} = 0

$M_{lineload}$: Vertical bending moment, in kNm, at position x, due to application of vertical line loads at frames according to method 2, to be taken as:

$M_{lineload} = -(x - x_{aft})\,F - \sum_i (x - x_i)\,\delta w_i$ when $x_i < x$

F : Reaction force, in kN, at model ends due to application of vertical loads to frames as defined in Table 7.

x : X-coordinate, in m, of frame in way of the mid-hold.

δw_i : vertical load, in kN, at web frame station i applied to generate required shear force.

$\delta w_i = -\delta w_1$ when frame i is within after hold

$\delta w_i = \delta w_2$ when frame i is within mid-hold

$\delta w_i = -\delta w_3$ when frame i is within forward hold

In case the target horizontal bending moment needs to be reached, an additional horizontal bending moment is to be applied at the ends of the cargo tank FE model to generate this target value within the mid-hold. The additional horizontal bending moment is to be taken as:

$$M_{h-end} = M_{h\text{-}targ} - M_{h-peak}$$

where:

$M_{h\text{-}end}$: Additional horizontal bending moment, in kNm, to be applied to both ends of the FE model according to [4.4.10].

$M_{h\text{-}targ}$: Horizontal bending moment, as defined in [4.3.4].

$M_{h\text{-}peak}$: Maximum or minimum horizontal bending moment, in kNm, within the length of the mid-hold due to the local loads described in [4.4.3].

$M_{h\text{-}peak}$ is to be taken as the maximum horizontal bending moment if $M_{h\text{-}targ}$ is positive (starboard side in tension) and as the minimum horizontal bending moment if $M_{h\text{-}targ}$ is negative (port side in tension).

$M_{h\text{-}peak}$ is to be calculated as follows based on a simply supported beam model:

$$M_{h-peak} = Extremum\left\{M_{H_FEM}(x)\right\}$$

$M_{H_FEM\ (x)}$: Horizontal bending moment, in kNm, at position x, due to the local loads as described in [4.4.3].

The vertical and horizontal bending moments are to be calculated over the length of the mid-hold to identify the position and value of each maximum/minimum bending moment.

4.4.9 Procedure to adjust vertical and horizontal bending moments outside midship cargo hold region

To reach the vertical hull girder target values at each frame and transverse bulkhead position, as defined in [4.3.2], the vertical bending moment adjustments, *mvi*, are to be applied at web frames and transverse bulkhead positions of the finite element model, as shown in Figure 19. The vertical bending moment adjustment at each longitudinal location, i, is to be calculated as follows:

$$f(i) = M_{v\text{-}targ}(i) - M_{v\text{-}FEM}(i) - M_{lineload}(i) - M_{Y_aft}\left(2 \cdot \frac{x_i - x_{aft}}{x_{fore} - x_{aft}} - 1\right)$$

$$m_{vi} = \frac{f(i) + f(i+1)}{2} - \sum_{j=0}^{i-1} m_{vj}$$

$$m_{v-end} = -\sum_{j=0}^{n_t} m_{vj}$$

where:

i : Index corresponding to the i-th station, starting from i =1 at the aft end section up to n_t

n_t : Total number of longitudinal stations where the vertical bending moment adjustment, m_{vi}, is applied.

m_{vi} : Vertical bending moment adjustment, in kNm, to be applied at transverse frame or bulkhead at station i.

m_{v_end} : Vertical bending moment adjustment, in kNm, to be applied, at the fore end section (n_t+1 station).

m_{vj} : Argument of summation to be taken as:

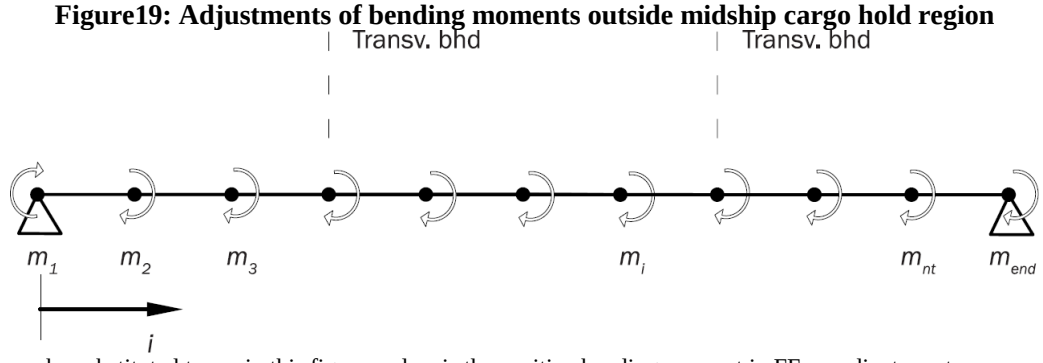
- m_{vo}= 0 when j=0
- $m_{vj} = m_{vi}$ when j=i

$M_{v\text{-}targ(i)}$: Required target vertical bending moment, in kNm, at station *i*, calculated in accordance with [4.3.2].

$M_{V\text{-}FEM(i)}$: Vertical bending moment distribution, in kNm, at station *i* due to local loads as given in [4.4.3].

$M_{lineload(i)}$:Vertical bending moment, in kNm, at station *i*, due to the line load for the vertical shear force correction as required in [4.4.8].

Figure19: Adjustments of bending moments outside midship cargo hold region



m_{hi} can be substituted to m_{vi} in this figure and m_i is the positive bending moment in FE coordinate system.

To reach the horizontal hull girder target values at each frame and transverse bulkhead position as defined in [4.3.4], the horizontal bending moment adjustments, *mhi*, are to be applied at web frames and transverse bulkhead positions of the finite element model, as shown in Figure 19. The horizontal bending moment adjustment at each longitudinal location, *i*, is to be calculated as follows:

$$f(i) = M_{h\text{-}targ}(i) - M_{H-FEM}(i)$$

$$m_{hi} = \frac{f(i) + f(i+1)}{2} - \sum_{j=0}^{i-1} m_{hj}$$

$$m_{h-end} = -\sum_{j=0}^{n_t} m_{hj}$$

where:

i : Longitudinal location for bending moment adjustments, m_{hi}.

n_t : Total number of longitudinal stations where the horizontal bending moment adjustment, m_{hi}, is applied.

m_{hi} : Horizontal bending moment adjustment, in kNm, to be applied at transverse frame or bulkhead at station *i*.

m_{h_end} :Horizontal bending moment adjustment, in kNm, to be applied at the fore end section (*nt*+1 station).

m_{hj} :Argument of summation to be taken as:

- $m_{ho} = 0$ when $j=0$
- $m_{hj} = m_{hi}$ when $j=i$

$M_{h\text{-}targ(i)}$: Required target horizontal bending moment, in kNm, at station *i*, calculated in accordance with [4.3.4].

$M_{H\text{-}FEM(i)}$: Horizontal bending moment distribution, in kNm, at station *i* due to local loads as given in [4.4.3].

The vertical and horizontal bending moment adjustments, m_{vi} and m_{hi}, are to be applied at all web frames and bulkhead positions of the FE model. The adjustments are to be applied in FE model by distributing longitudinal axial nodal forces to all hull girder bending effective longitudinal elements in accordance with [4.4.10].

4.4.10 Application of bending moment adjustments on the FE model

The required vertical and horizontal bending moment adjustments are to be applied to the considered cross section of the cargo hold model by distributing longitudinal axial nodal forces to all hull girder bending effective longitudinal elements of the considered cross section according to Ch 5, Sec 1, [1.2] as follows:

- For *vertical* bending moment:

$$(F_x)_i = \frac{M_v}{I_{y-n50}} \frac{M_{i-n50}}{n_i} z_i$$

- For *horizontal* bending moment:

$$(F_x)_i = \frac{M_h}{I_{z-n50}} \frac{A_{i-n50}}{n_i} y_i$$

where:

M_v : Vertical bending moment adjustment, in kNm, to be applied to the considered cross section of the model.

M_h : Horizontal bending moment adjustment, in kNm, to be applied to the considered cross section the ends of the model.

$(F_x)_i$: Axial force, in kN, applied to a node of the *i*-th element.

$I_{y\text{-}n50}$: Hull girder vertical moment of inertia, in m^4, of the considered cross section about its horizontal neutral axis.

$I_{z\text{-}n50}$: Hull girder horizontal moment of inertia, in m^4, of the considered cross section about its vertical neutral axis.

Z_i : Vertical distance, in m, from the neutral axis to the centre of the cross sectional area of the *i*-th element.

Y_i : Horizontal distance, in m, from the neutral axis to the centre of the cross sectional area of the *i*-th element.

$A_{i\text{-}n50}$: Cross sectional area, in m^2, of the *i*-th element.

n_i : Number of nodal points of *i*-th element on the cross section, $n_i = 1$ for beam element, $n_i = 2$ for 4- node shell element.

For cross sections other than cross sections at the model end, the average area of the corresponding *i*-th elements forward and aft of the considered cross section is to be used.

4.5 Procedure to adjust hull girder torsional moments

4.5.1 General

The procedure in this sub-article describes how to adjust the hull girder torsional moment distribution on the cargo hold FE model to achieve the target torsional moment at the target location. The hull girder torsional moment target values are given in [4.3.5].

4.5.2 Torsional moment due to local loads

Torsional moment, in kNm, at longitudinal station *i* due to local loads, $M_{T\text{-}FEMi}$ in kNm, is determined by the following formula (see Figure 20):

$$M_{T-FEM_i} = \sum_k [f_{hik}(z_{ik} - z_r)] - \sum_k (f_{vik} y_{ik})$$

where:

$M_{T\text{-}FEMi}$: Lumped torsional moment, in kNm, due to local load at longitudinal station *i*.

z_r : Vertical coordinate of torsional reference point, in m:

For bulk carrier, $z_r = 0$.

For oil tanker, $z_r = z_{sc}$, shear centre at the middle of the mid-hold.

f_{hik} : Horizontal nodal force, in kN, of node *k* at longitudinal station *i*.

f_{vik} : Vertical nodal force, in kN, of node *k* at longitudinal station *i*.

y_{ik} : *Y*-coordinate, in m, of node *k* at longitudinal station *i*.

z_{ik} : *Z*-coordinate, in m, of node *k* at longitudinal station *i*.

$M_{T\text{-}FEM0}$: Lumped torsional moment, in kNm, due to local load at aft end of the FE model (forward end for foremost cargo hold model), taken as:

$M_{T-FEM0} = -\sum_k [f_{h0k}(z_{0k} - z_r)] + \sum_k (f_{v0k} y_{0k}) + R_{H_fwd} \cdot (z_{ind} - z_r)$ for foremost cargo hold model

$M_{T-FEM0} = \sum_k [f_{h0k}(z_{0k} - z_r)] - \sum_k (f_{v0k} y_{0k}) + R_{H_aft} \cdot (z_{ind} - z_r)$ for the other cargo hold models

R_{H_fwd} : Horizontal reaction forces, in kN, at the forward end, as defined in [4.4.3].
R_{H_aft} : Horizontal reaction forces, in kN, at the aft end, as defined in [4.4.3].
z_{ind} : Vertical coordinate, in m, of independent point as defined in [2.5.3].

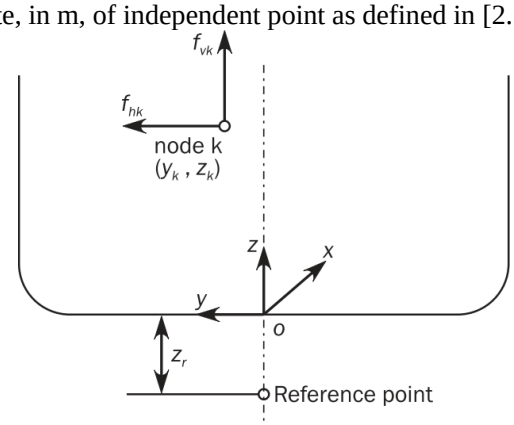


Figure20 Station forces and acting location of torsional moment at section

4.5.3 Hull girder torsional moment

The hull girder torsional moment, $M_{T\text{-}FEM}$ (x_j) in kNm, is obtained by accumulating the station torsional moment from the aft end section (forward end for foremost cargo hold model) as follows:

$$M_{T-FEM}(x_j) = \sum_i M_{T-FEMi}$$

- when $x_i \geqslant x_j$ for foremost cargo hold model,
- when $x_i < x_j$ otherwise.

where:

$M_{T\text{-}FEM}$ (x_j): Hull girder torsional moment, in kNm, at longitudinal station x_j.
x_j : X-coordinate, in m, of considered longitudinal station j.

The torsional moment distribution given in [4.5.2], has a step at each longitudinal station.

4.5.4 Procedure to adjust hull girder torsional moment to target value

The torsional moment is to be adjusted by applying a hull girder torsional moment $M_{T\text{-}end}$ in kNm, at the independent point of the aft end section of the model (forward end for foremost cargo hold model), given as follows:

$$M_{T-end} = M_{wt\text{-}targ} - M_{wt}(x_{targ})$$

where:

x_{targ} : X-coordinate, in m, of the target location for hull girder torsional moment, as defined in [4.3.5].
$M_{wt\text{-}targ}$: Target hull girder torsional moment, in kNm, specified in [4.3.5], to be achieved at the target location.
$M_{T\text{-}FEM}$ (x_{targ}) : Hull girder torsional moment, in kNm, at target location due to local loads.

Due to the step of hull girder torsional moment at each longitudinal station, the hull girder torsional moment is to be selected from the values aft and forward of the target location as follows: Maximum value for positive torsional moment and minimum value for negative torsional moment.

4.6 Summary of hull girder load adjustments

4.6.1

The required methods of hull girder load adjustments for different cargo hold regions are given in Table 9.

Overview of hull girder load adjustments in FE analyses **Table 9**

	Midship cargo hold region	After and Forward cargo hold region	Aft most cargo holds	Foremost cargo holds
Adjustment of Vertical Shear Forces	See [4.4.5]			
Adjustment of Bending Moments	See [4.4.8]	See [4.4.9]		

Adjustment of Torsional Moment	See [4.5.4]

5 ANALYSIS CRITERIA

5.1 General

5.1.1 Evaluation areas

Verification of results against the acceptance criteria is to be carried out within the longitudinal extent of the mid-hold, as shown in Figure 21 and Figure 22.

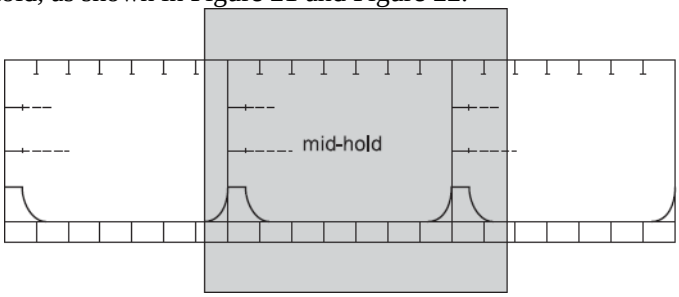


Figure21 Longitudinal extent of evaluation area for oil tanker

5.1.2 Structural members

The following structural elements within the evaluation area are to be verified with the criteria given in [5.2] and [5.3]:

- All hull girder longitudinal structural members,
- All primary supporting structural members and bulkheads within the mid-hold,
- All structural members being part of the transverse bulkheads, such as:
- For oil tanker: stringer, buttress structure, stool tanks, partial girders together with attached transverse structures,
- For bulk carrier: stool tanks together with connected longitudinal girders and double bottom floors,
- All structural members being part of the collision bulkhead, and extending to one web frame spacing forward of the collision bulkhead,
- All structural members being part of the forward transverse bulkhead of the machinery space and all hull girder longitudinal structural members aft of this transverse bulkhead within the extent of 15% of the aftmost cargo hold length excluding slop tanks.

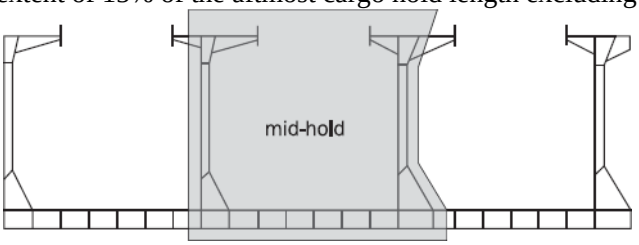


Figure 22 Longitudinal extent of evaluation area for bulk carrier

5.2 Yield strength assessment

5.2.1 Von Mises stress

For all plates of the structural members defined in [5.1.2], the von Mises stress, σ_{vm}, in N/mm^2, is to be calculated based on the membrane normal and shear stresses of the shell element. The stresses are to be evaluated at the element centroid of the mid-plane (layer), as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2}$$

where:

σ_x, σ_y : Element normal membrane stresses, in N/mm^2.

τ_{xy} : Element shear stress, in N/mm^2.

5.2.2 Axial stress in beams and rod elements

For beams and rod elements, the axial stress, σ_{axial}, in N/mm^2, is to be calculated based on axial force alone. The axial stress is to be evaluated at the middle of element length.

5.2.3 Coarse mesh permissible yield utilisation factors

The coarse mesh permissible yield utilisation factors, λ_{yperm}, given in Table 10, are based on the mesh sizes and element types described in [2.3] to [2.4].

The yield utilisation factor resulting from element stresses of each structural component are not to exceed the permissible values as given in Table 10.

Coarse mesh permissible yield utilisation factor **Table 10**

Structural component	Coarse mesh permissible yield utilisation factor, λ_{yperm}
Plating of all longitudinal hull girder structural members, primary supporting structural members and bulkheads. Face plate of primary supporting members modelled using shell or rod elements. Dummy rod of corrugated bulkhead	1.0 (load combination S+D) 0.8 (load combination S)
Corrugation of vertically corrugated bulkheads with lower stool and horizontally corrugated bulkhead, under lateral pressure from liquid loads, for shell elements only. Supporting structure in way of lower end of corrugated bulkheads without lower stool (1).	0.90 (load combination S+D) 0.72 (load combination S)
Corrugation of vertically corrugated bulkheads without lower stool under lateral pressure from liquid loads and without lower stool, for shell elements only.	0.81 (load combination S+D) 0.65 (load combination S)

1) Supporting structure for a transverse corrugated bulkhead refers to the structure in the longitudinal direction within half a web frame space forward and aft of the bulkhead, and within a vertical extent equal to the corrugation depth.
Supporting structure for a longitudinal corrugated bulkhead refers to the structure in transverse direction within 3 longitudinal stiffener spacings from each side of the bulkhead, and within a vertical extent equal to the corrugation depth.

5.2.4 Yield criteria

The structural elements given in [5.1.2] are to comply with the following criteria:

$\lambda_y \leqslant \lambda_{ype\ rm}$

where:

λ_y : yield utilisation factor.

$$\lambda_y = \frac{\sigma_{vm}}{R_y} \text{ for shell elements in general.}$$

$$\lambda_y = \frac{|\sigma_{axial}|}{R_y} \text{ for rod or beam elements in general.}$$

σ_{vm} : Von Mises stress, in N/mm^2.

σ_{axial} : Axial stress in rod or beam element, in N/mm^2.

λ_{yperm} : Coarse mesh permissible yield utilisation factors defined in Table 10.

The yield check criteria is to be based on axial stress for the following members:

- The flange of primary supporting members,
- The intersections between the flange and web of the corrugations, according to [5.2.5].

Where the von Mises stress of the elements in the cargo hold FE model in way of the area under investigation by fine mesh exceeds the yield criteria, average von Mises stress, obtained from the fine mesh analysis, calculated over an area equivalent to the mesh size of the cargo hold finite element model is to satisfy the yield criteria above.

In way of cut-outs, yield utilisation factor is to be obtained with shear stress correction, as given in [5.2.6].

5.2.5 Corrugation of corrugated bulkhead

The stress in corrugation of corrugated bulkheads is to be evaluated based on:

a) The von Mises stress, σ_{vm}, in shell elements on the flange and web of the corrugation.
b) The axial stress, σ_{axial}, in dummy rod elements, modelled with unit cross sectional properties at the intersection between the flange and web of the corrugation.

5.2.6 Shear stress correction for cut-outs

Except as indicated in [5.2.7], the element shear stress in way of cut-outs in webs is to be corrected for loss in shear area in accordance with the following formula. The corrected element shear stress is to be used to calculate the von Mises stress of the element for verification against the yield criteria.

$$\tau_{cor} = \frac{ht_{mod-n50}}{A_{shr-n50}} \tau_{elem}$$

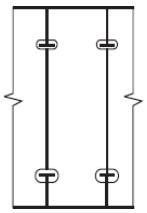
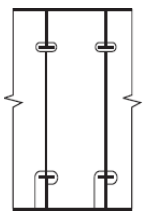
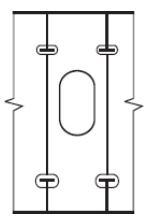
where:

τ_{cor} : Corrected element shear stress, in N/mm^2.
h : Height of web of girder, in mm, in way of opening, see Table 1. Where the geometry of the opening is modelled, h is to be taken as the height of web of the girder deducting the height of the modelled opening.
$t_{mod\text{-}n50}$: Modelled web thickness, in mm, in way of opening.
$A_{shr\text{-}n50}$: Effective net shear area of web, in mm^2, taken as the web area deducting the area lost of all openings, including slots for stiffeners, calculated in accordance with Ch 3, Sec 7, [1.4.8].
τ_{elem} : Element shear stress, in N/mm^2, before correction.

5.2.7 Exceptions for shear stress correction for openings

Correction of element shear stress due to presence of cut-outs is not required for cases given in Table 11 provided λ_y/C_r complies with the criteria given in [5.2.4].

Exceptions for shear stress correction **Table 11**

Identification	Figure	Difference between modelled shear area and the net effective shear area in % of the modelled shear area $\frac{A_{FEM-n50} - A_{shr-n50}}{A_{FEM-n50}} \cdot 100\%$	Reduction factor for yield criteria, C_r
Upper and lower slots for local support stiffeners fitted with lugs or collar plates		< 15%	0.85
Upper or lower slots for local support stiffeners fitted with lugs or collar plates		< 20%	0.80
In way of opening; upper and lower slots for local support stiffeners fitted with collar plates		< 40%	0.60

Identification	Figure	Difference between modelled shear area and the net effective shear area in % of the modelled shear area $\frac{A_{FEM-n50} - A_{shr-n50}}{A_{FEM-n50}} \cdot 100\%$	Reduction factor for yield criteria, C_r
$A_{shr\text{-}n50}$: Effective net shear area of the web, in mm^2, taken as the web area without the all opening areas and without the slots for stiffeners, in accordance with Ch 3, Sec 7, [1.4.8].			

5.3 Buckling strength assessment

5.3.1

All structural elements in FE analysis carried out in accordance with this Section are to be assessed individually against the buckling requirements as defined in Ch 8, Sec 4.

Section 3 LOCAL STRUCTURAL STRENGTH ANALYSIS

1 OBJECTIVE AND SCOPE

1.1 General

1.1.1

The local strength analysis of structural details is to be in accordance with the requirements given in this section.

1.1.2

The selection of critical locations on the structural members for fine mesh analysis is to be in accordance with this section.

1.1.3 Fine mesh analysis procedure

The details to be assessed by fine mesh analysis are to be modelled according to the requirements given in [4], under the FE load combinations defined in [5] and to comply with the criteria given in [6].

1.1.4 Scope of local structural strength verification

The fine mesh verification is to be performed as follows:

- Fine mesh analysis for the structural details given in [2],
- Screening procedure according to [3].

2 LOCAL AREAS TO BE ASSESSED BY FINE MESH ANALYSIS

2.1 List of mandatory structural details

2.1.1 List of structural details

In the midship cargo hold region, the following structural details are to be assessed according to the fine mesh analysis procedure defined in [1.1.3]:

a) Hopper knuckles for ship with double side as given in [2.1.2],
b) Side frame end brackets and lower hopper knuckle for single side bulk carrier as given in [2.1.3],
c) Large openings as given in [2.1.4],
d) Connections of deck and double bottom longitudinal stiffeners to transverse bulkhead as given in [2.1.5],
e) Connections of corrugated bulkhead to adjoining structure as given in [2.1.6].
f) Bracket at the heel of horizontal stringer as given in [2.1.7].

For each above mentioned structural detail, one fine mesh model is required within all the cargo hold models covering the midship cargo hold region. The selection of the location of this fine mesh model is to be based on requirements given from [2.1.2] to [2.1.7] from all cargo hold analyses in the midship cargo hold region.

2.1.2 Hopper knuckles for ship with double side

Fine mesh analysis is to be carried out for the lower and upper hopper knuckles of either welded or bent type, in way of a typical transverse web frame, as indicated in Figure 1.

For double side arrangements without the hopper plating, i.e. where the inner hull longitudinal bulkhead is fitted directly to the inner bottom, fine mesh analysis is to be carried out for the heel of the transverse web frame.

The transverse web frame which, in the cargo hold analysis, has the maximum yield utilisation factor, λ_y, in knuckle is to be selected for the fine mesh analysis.

2.1.3 Side frame end brackets and lower hopper knuckle for single side bulk carrier

Fine mesh analysis is to be carried out for the lower hopper knuckle of either welded or bent type, lower and upper end bracket of side frame, as indicated in Figure 2.

The side frame which in the cargo hold analysis has the maximum yield utilisation factor, λ_y , in end bracket joints is to be selected for the fine mesh analysis.

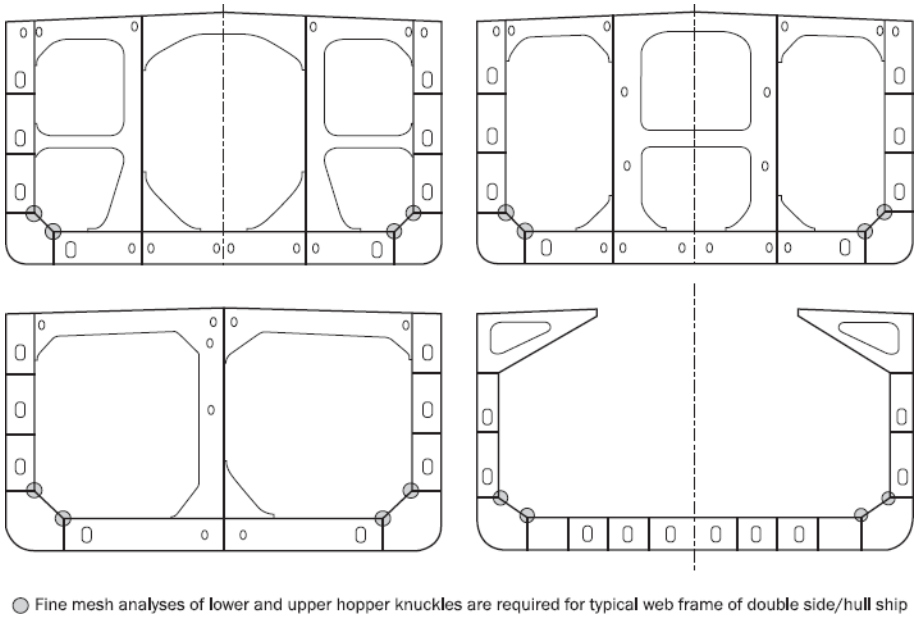


Figure 1 Mandatory areas at hopper knuckles for ships with double side

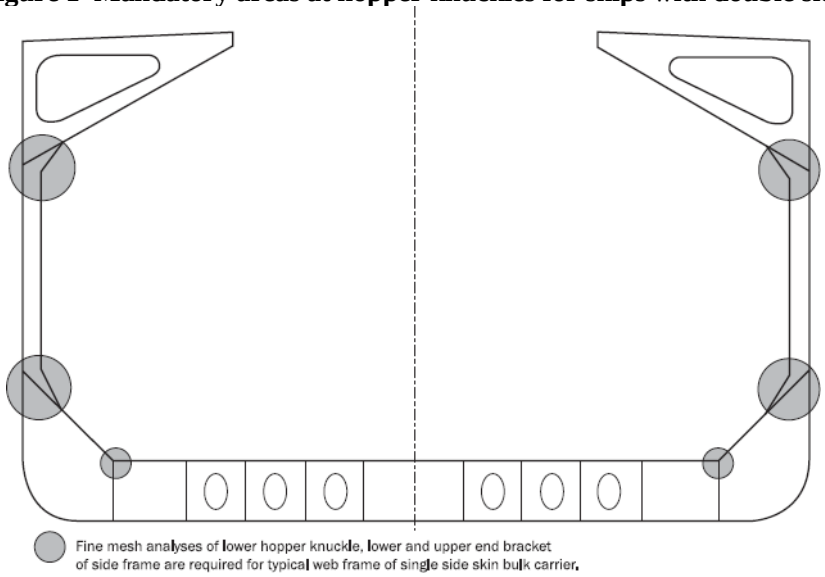


Figure 2 Mandatory areas at lower upper knuckle and side frame end brackets for single side bulk carrier

2.1.4 Large openings

Large openings in way of primary supporting members, for which their geometry is required to be represented in the cargo hold model in accordance with Ch 7, Sec 2, [2.4.9], are to be assessed by fine mesh analysis.

The structural member in way of the large openings having the maximum yield utilisation factor, λ_y , in the cargo hold analysis is to be selected for the fine mesh analysis.

2.1.5 Connections between deck and double bottom longitudinal stiffeners and adjoining structures of transverse bulkhead

Fine mesh analysis is to be carried out for the connections of deck and double bottom longitudinal stiffeners and adjoining structures of transverse bulkhead, either plane or corrugated bulkhead. The adjoining structures of transverse bulkhead include the structural members in way of the bulkhead, the partial deck girders and partial double bottom girders, if any.

For example, the following structural members are to be assessed, some of them being shown in Figure 3:

- At least one pair of connections between inner and outer bottom longitudinal stiffeners and adjoining structures of transverse bulkhead.

- At least one pair of connections between inner and outer bottom longitudinal stiffeners and adjoining structures of adjacent floor to the transverse bulkhead.
- At least one connection between deck longitudinal stiffener (fitted above or below deck) and adjoining vertical structure of transverse oil tight bulkhead.
- Connection between deck longitudinal partial girder on top of transverse oil tight bulkheads when fitted and adjoining vertical structure of transverse oil tight bulkhead.
- Connection between bottom longitudinal partial girder in way of transverse oil tight bulkheads when fitted and adjoining vertical structure of transverse oil tight bulkhead.

The selection of the connections between longitudinal and vertical stiffeners to be analysed is to be based on the maximum relative deflection between supports, i.e. between floor and transverse bulkhead or between deck transverse and transverse bulkhead. Where there is a significant variation in end connection arrangement between stiffeners or scantlings, analyses of additional connections may be required by the Society.

Outside the midship cargo hold region, the scantlings of the connections as given above are not to be less than the required scantlings obtained for the midship cargo hold region unless an equivalent strength is demonstrated by fine mesh analysis.

CCS 2.1.5a Additional fine mesh analysis is to be carried out in the following cases:
Where there is a significant variation in the end connection arrangement between stiffeners or scantlings, e.g. a variation of the shape or arm length of the stiffener end connection bracket, the connecting structure with the maximum relative deflection between supports is to be selected from attached end connections for analysis.

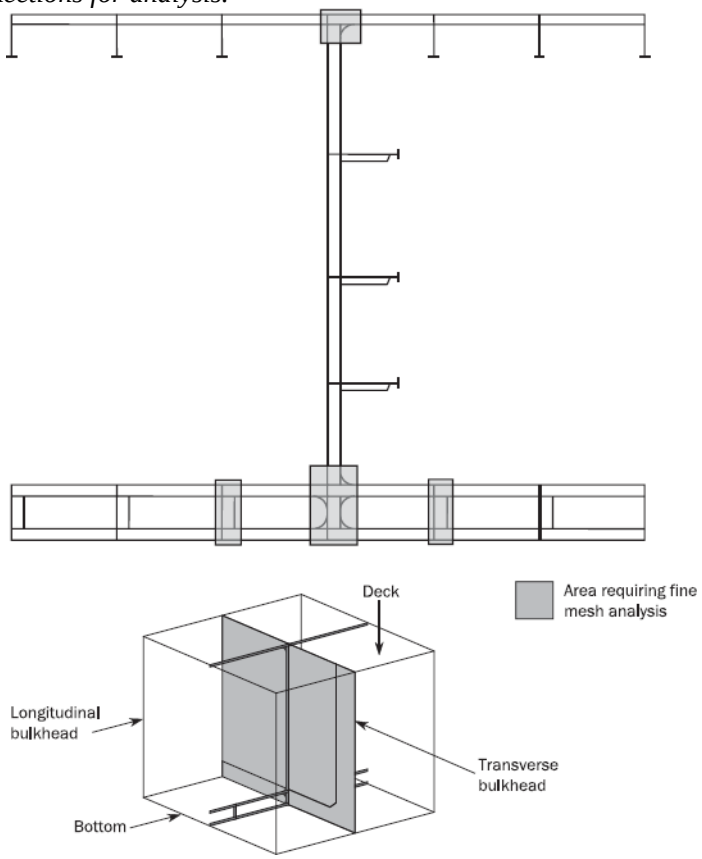


Figure 3 Examples of mandatory areas at connections between double bottom and deck longitudinals and adjoining structure of transverse bulkhead

2.1.6 Connections between corrugation and adjoining lower structure

Fine mesh analysis is to be carried out for connections between corrugation and adjoining lower supporting structures. For example, the following structural members, as shown in Figure 4, are to be assessed:

- Connection of the corrugation and supporting structure in way of lower stool shelf plate.
- Connection of the corrugation and lower supporting structure to inner bottom if no

lower stool is fitted.

- Connection of the corrugation and the upper corner of the gusset plate if shedder plate with a gusset plate is fitted at top of the lower stool.

The corrugation unit as defined in Ch 8, Sec 4, [3.3.2] which, in the cargo hold analysis, has the maximum yield utilisation factor, λ_y, in way of the corrugation connection, is to be selected for the fine mesh analysis.

Where there is a significant variation in the arrangement of supporting structure of the corrugation, analysis of additional locations may be required by the Society.

For ships with both longitudinal and transverse corrugated bulkheads, fine mesh analysis is required for the connection between corrugations and supporting structure in way of the lower stool shelf plate or inner bottom, if no lower stool is fitted, at the intersection between longitudinal and transverse corrugated bulkheads.

CCS 2.1.6a Additional fine mesh analysis is to be carried out in the following cases:

1) For corrugation structure fitted with lower stool, where the corrugation unit which has been selected for fine mesh analysis is not intersected by the diaphragm of lower stool, the fine mesh analysis is to be carried out to the corrugation unit with the maximum yield utilisation factor that is intersected by the diaphragm of lower stool.

2) For longitudinal corrugated bulkheads not fitted with lower stool, where the corrugation unit which has been selected for fine mesh analysis is not intersected by the double bottom floor, the fine mesh analysis is to be carried out to the corrugation unit with the maximum yield utilisation factor that is intersected by the double bottom floor.

3) For transverse corrugated bulkheads not fitted with lower stool, where the corrugation unit which has been selected for fine mesh analysis is not intersected by the double bottom girder, the fine mesh analysis is to be carried out to the corrugation unit with the maximum yield utilisation factor that is intersected by the double bottom girder.

4) When the shape of the corrugation unit as defined in 3.3.2, Section 4, Chapter 8 of this PART is different from the one which has been selected for fine mesh analysis, the fine mesh analysis is to be carried out to the location with the maximum yield utilisation factor for areas of the corrugation units having a different shape respectively.

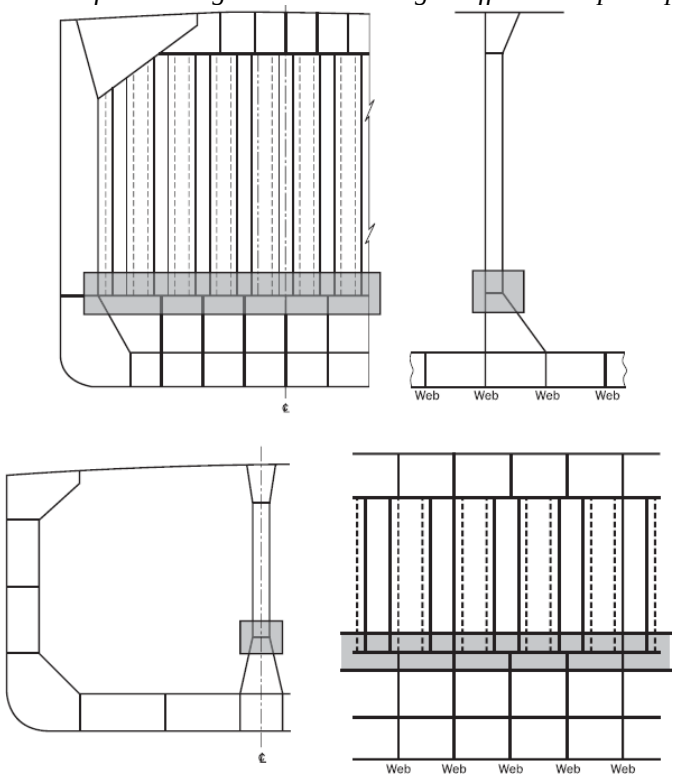


Figure 4 Mandatory areas at connections between corrugations and adjoining lower stool

2.1.7 Bracket at the heel of horizontal stringer

Fine mesh analysis is to be carried out for the bracket at the heel of horizontal stringers. All structural elements adjacent to the heel including the inner hull, longitudinal and transverse bulkhead are to satisfy the stress acceptance criteria. The heel of horizontal stringer which, in the cargo hold analysis, has the maximum yield utilization factor, λ_y, is to be selected for the fine mesh analysis. Where there is a significant variation in the arrangement of the bracket at the heel and the horizontal stringer, analysis of additional locations may be required by the Society.

3 SCREENING PROCEDURE

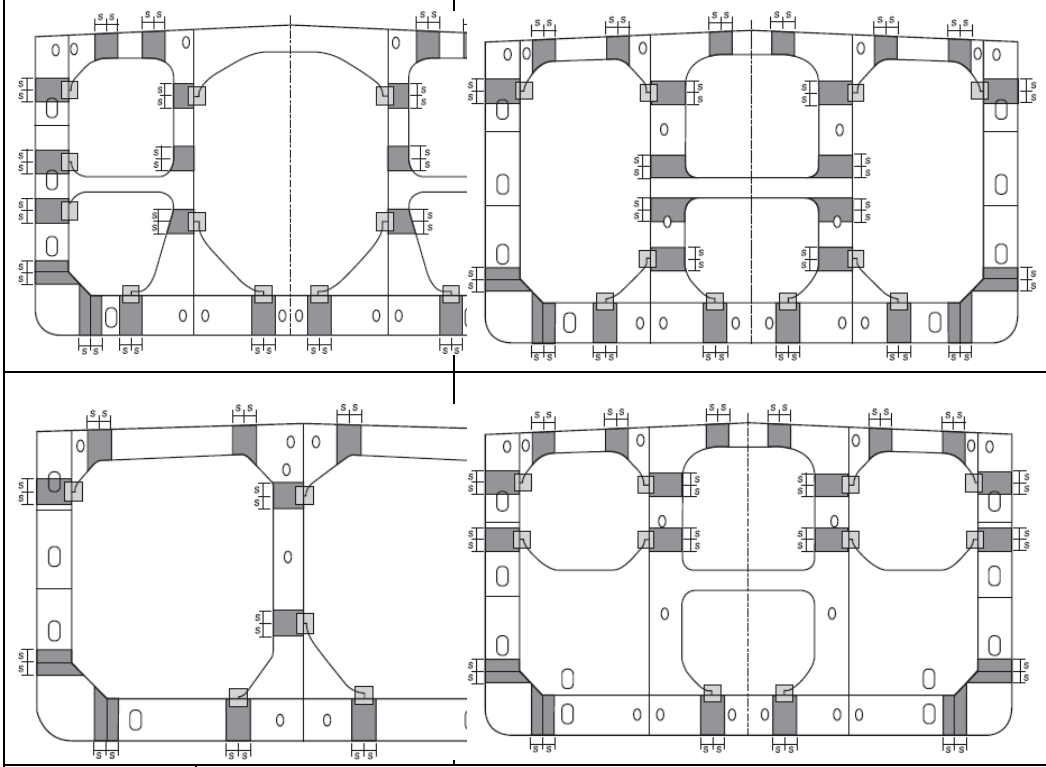
3.1 Screening areas

3.1.1

The structural details subject to this screening procedure are checked in the following ship areas:

- Within the full cargo hold region for the details given in [3.2.1],
- Outside midship cargo hold region for the details given in [3.2.2].

Screening areas of transverse web frame in oil tanker **Table 1**

<table>
<tr><td colspan="3">  </td></tr>
<tr><td></td><td colspan="2">Bracket toes</td></tr>
<tr><td></td><td colspan="2">Openings and manholes (shaded regions)</td></tr>
<tr><td></td><td>Openings and manholes (unshaded regions)</td><td>Screening check to be performed for openings except if:
$h_0/h < 0.35$ and $g_0 < 1.2$, and, each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$). This criterion does not apply to manholes which are to be evaluated by screening irrespective of size.
h_0, h and go is defined in Ch 7, Sec 2, [2.4.9], b is the smallest of the length and breadth of the opening.</td></tr>
</table>

3.2 List of structural details

3.2.1 Cargo hold region

The following structural details and areas in the cargo hold region are to be evaluated by screening:

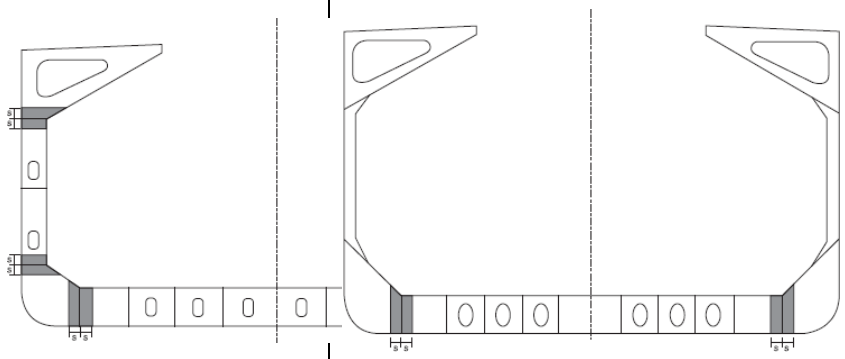
a) Openings which do not require modelling and manholes, see Ch 7, Sec 2, [2.4.9, in way of web of primary supporting members, such as transverse web frame as indicated in

Table 1 and Table 2, horizontal stringers as indicated in Table 3, floors and longitudinal girders in double bottom.

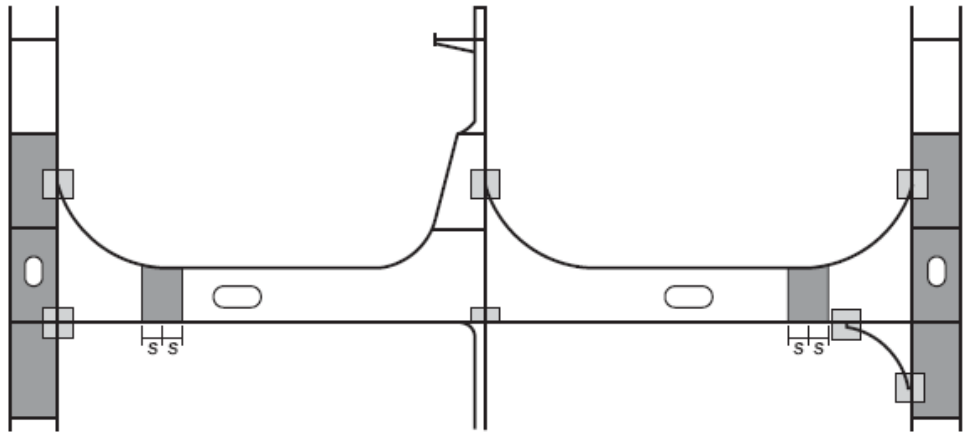
b) Bracket toes on transverse web frame as indicated in Table 1 and Table 2, horizontal stringer and transverse plane bulkhead connected to double bottom or buttress structure specified in Table 3.
c) Heels of transverse bulkhead horizontal stringers specified in Table 3.
d) Connections of transverse lower stool to double bottom girders and longitudinal lower stool to double bottom floors as indicated in Figure 5.
e) Connection of lower hopper to transverse lower stool structure as indicated in Figure 5.
f) Connection of topside tank to inner side as indicated in Figure 6.
g) Connection of corrugation and upper supporting structure to upper stool as indicated in Figure 7.
h) Hatch corner area, such as the hatch coaming end bracket, the hatch corner and the hatch end beam connection as indicated in Figure 8.

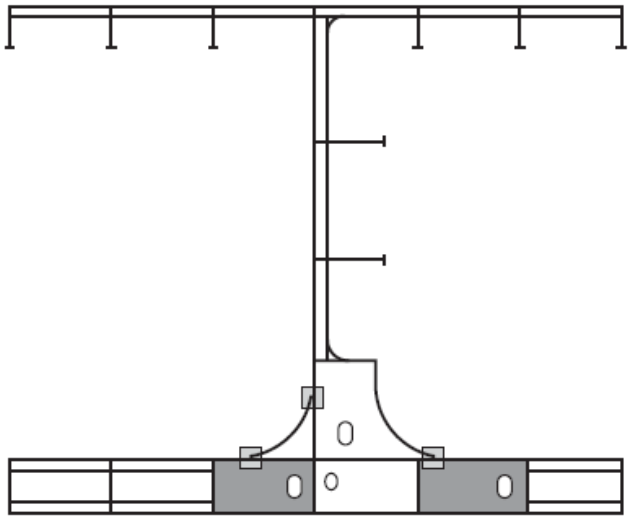
Within each group of the structural details having the same geometry and the same relative location inside the cargo region, the screening verification can be performed for the detail for which the yield utilisation factor, λ_y, is maximum.

Screening areas for transverse web frame in bulk carrier **Table 2**

<table>
<tr><td colspan="3">  </td></tr>
<tr><td></td><td colspan="2">Bracket toes</td></tr>
<tr><td></td><td colspan="2">Openings and manholes (shaded regions)</td></tr>
<tr><td></td><td>Openings and manholes (unshaded regions)</td><td>Screening check to be performed for openings except if:
$h_0/h < 0.35$ and $g_0 < 1.2$, and, each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$)， This criterion does not apply to manholes which are to be evaluated by screening irrespective of size.
h_0, h and g_0 is defined in Ch 7, Sec 2, [2.4.9], b is the smallest of the length and breadth of the opening.</td></tr>
</table>

Screening areas for horizontal stringer and transverse bulkhead to double bottom connections in oil tanker **Table 3**





	Bracket toes and heels	
	Openings and manholes (shaded regions)	
	Openings and manholes (unshaded regions)	Screening check to be performed for openings except if: $h_0/h < 0.35$ and $go < 1.2$, and, each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$). . This criterion does not apply to manholes which are to be evaluated by screening irrespective of size. h_0, h and g_0 is defined in Ch 7, Sec 2, [2.4.9], b is the smallest of the length and breadth of the opening.

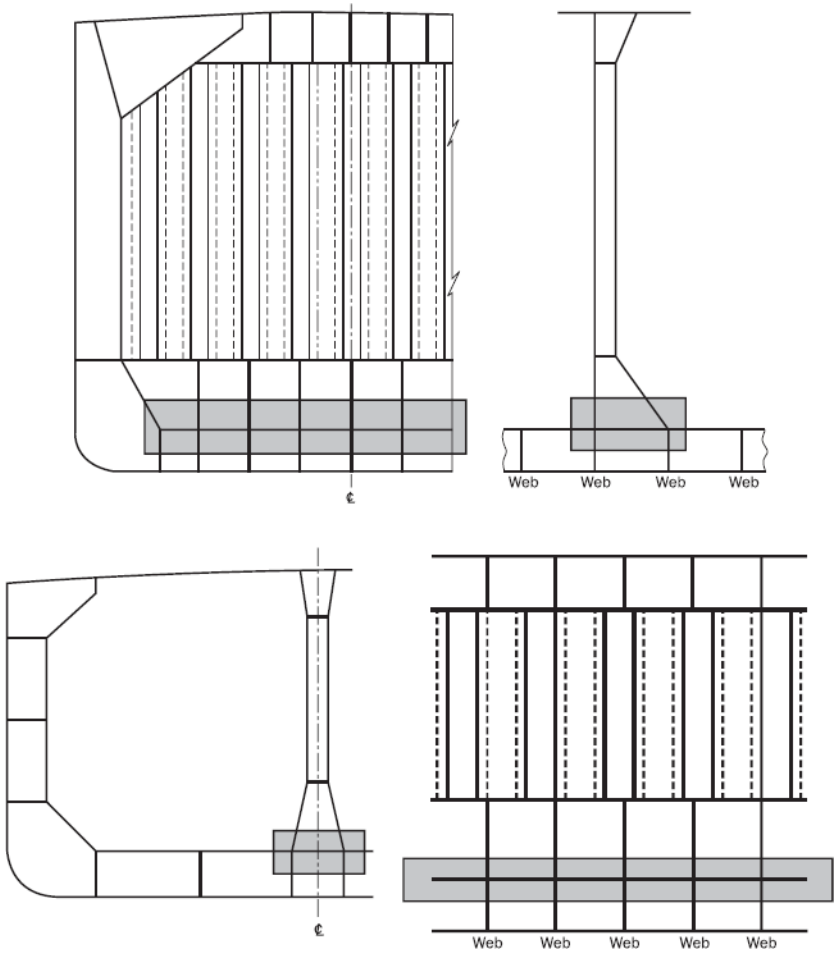


Figure 5 Screening areas at connections of lower stool to inner bottom and hopper tank

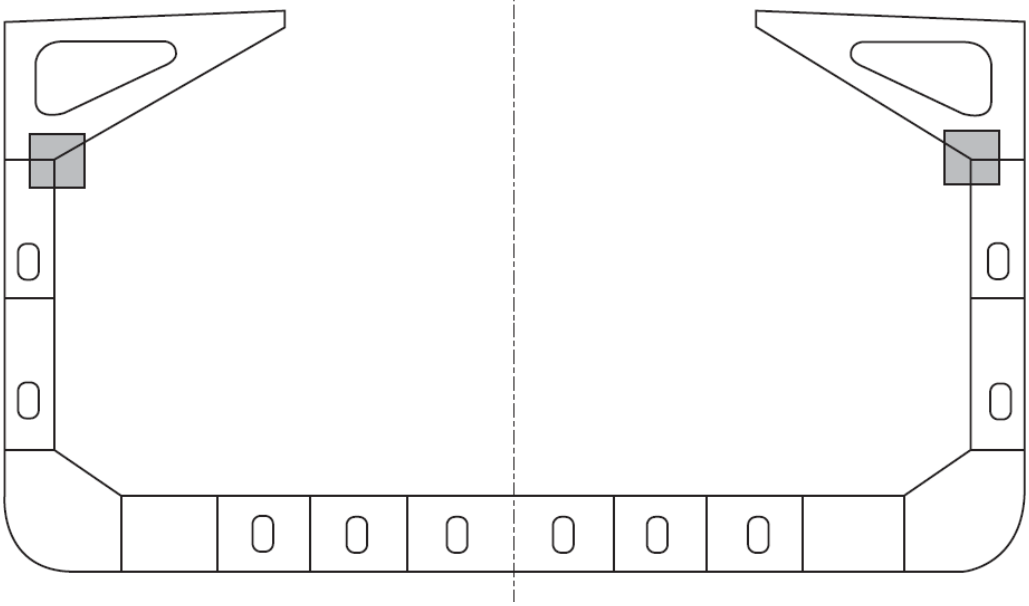


Figure 6 Screening areas at connections of topside tank to inner side

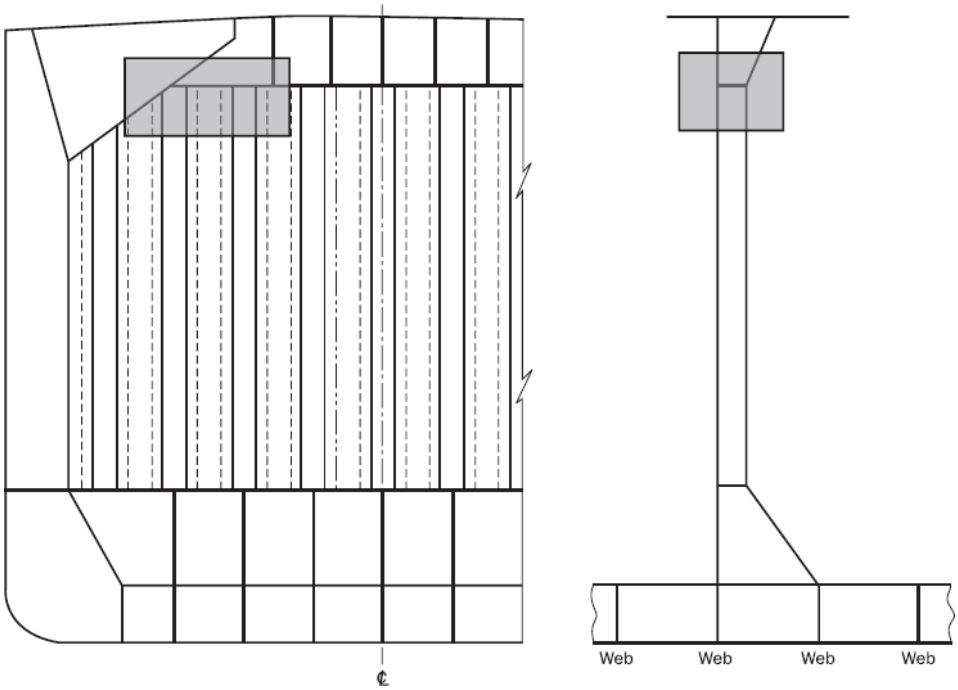


Figure 7 Screening areas at connection of corrugation and upper supporting structure to upper stool

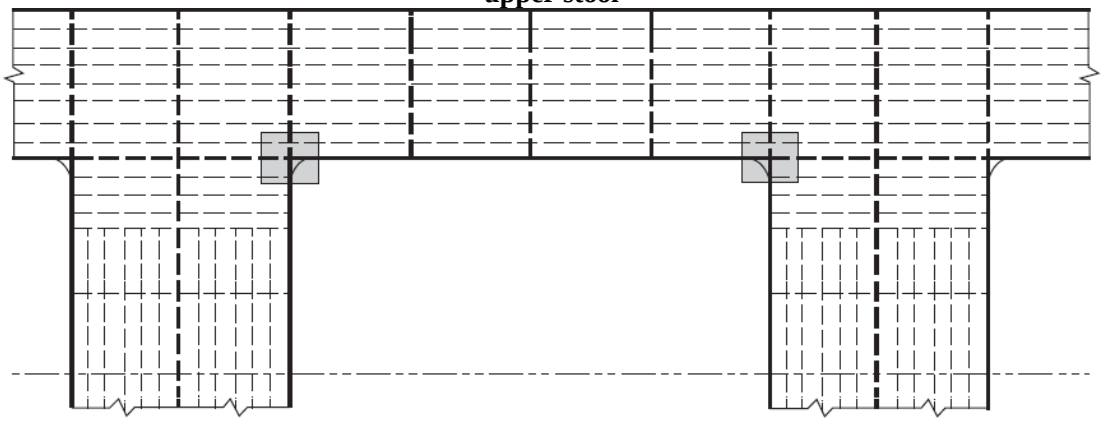


Figure 8 Screening areas at hatch corner in bulk carrier

3.2.2 Outside midship cargo hold region

The following structural details outside midship cargo hold region are to be evaluated by screening:

a) Hopper knuckle, as defined in [2.1.2] and [2.1.3],
b) Side frame end bracket, as defined in [2.1.3],
c) Large openings, as defined in [2.1.4],
d) Connections of corrugation to adjoining structure, as defined in [2.1.6],
e) Bracket at the heel of horizontal stringers in [2.1.7],
f) The connections of corrugation to adjoining structure and the bracket at the heel of horizontal stringers to be screened are to be similar in its geometry, its proportion and its relative location to the corresponding detail modelled in fine mesh in the midship cargo hold region.

When the connections of corrugation to adjoining structure and the bracket at the heel of horizontal stringers outside the midship cargo hold region are different from the corresponding detail modelled in fine mesh in the midship cargo hold region, a fine mesh analysis is to be performed for the detail located where the yield utilisation factor, λ_y, is maximum for structural details having the same geometry and the same relative location.

When it is deemed necessary, the Society may request a fine mesh analysis to be performed according to [1.1.3].

3.3 Screening criteria

3.3.1 Screening factors and permissible screening factors

The screening factors, λ_{sc}, and the permissible screening factors, λ_{scperm}, are given in Table 4 for the screening areas defined in [3.1].

Screening factors and permissible screening factors **Table 4**

Type of Details	Screening factors, λ_{sc}	Permissible screening factors, λ_{scperm}	
Within the whole cargo hold region		S+D	S
Openings for which their geometry is not required to be represented in the cargo hold model in accordance with Ch 7, Sec 2, [2.4.9] in way of webs of primary supporting members, such as transverse web frame as indicated in Table 1 and Table 2, horizontal stringers as indicated in Table 3, floors and longitudinal girders in double bottom.	Table 5	1.70	1.36
Manholes (2)	λ_y	$0.85\lambda_{yperm}$	
Bracket toes on transverse web frames as indicated in Table 1 and Table 2, horizontal stringers and transverse plane bulkhead to double bottom connection or buttress structure specified in Table 3.	Table 6	1.50	1.20
Heels of transverse bulkhead horizontal stringers specified in Table 3.	Table 7	1.50	1.20
Connections of transverse lower stool to double bottom girders and longitudinal lower stool to double bottom floors as indicated in Figure 5. The connection of lower hopper to transverse lower stool structure as indicated in Figure 5. The connection of topside tank to inner side as indicated in Figure 6. The connection of corrugation and upper supporting structure to upper stool as indicated in Figure 7.	λ_y	$0.75\lambda_{yperm}$	
Hatch corner area.	λ_y	$0.95\lambda_{yperm}$	
Outside midship cargo hold region			
Hopper knuckle	$\lambda_{sc} = \frac{K_{sc} \cdot \sigma_c}{R_y}$ (1)	$0.65\ \lambda_{yperm}$ $0.65\lambda_{yperm}$	
Side frame end bracket		$0.85\lambda_{yperm}$ $0.85\lambda_{yperm}$	
Large openings (2)		$0.85\lambda_{yperm}$	
Connections of corrugation to adjoining structure and bracket at the heel of horizontal stringer		1.50 f_f	$1.20f_f$

where:

λ_y : Coarse mesh yield utilisation factor, as defined in Ch 7, Sec 2, [5.2.4].

λ_{yperm} : Coarse mesh permissible yield utilisation factor, as defined in Ch 7, Sec 2, [5.2.4].

K_{sc} : Screening stress concentration factor, taken as:

$$K_{sc} = \frac{\sigma_{FM}}{\sigma_{CM}}$$

σ_{FM} : Von Mises fine mesh stress, in N/mm^2, for the considered detail calculated in the midship cargo hold region according to [2].

σ_{CM} : Von Mises coarse mesh stress, in N/mm^2, for the considered detail calculated in the midship cargo hold region according to Ch 7, Sec 2.

σ_c : Von Mises coarse mesh stress, in N/mm^2, for the area in way of considered detail.

f_f : Fatigue factor defined in [6.2.1].

(1) For each screened detail, σ_{FM} and σ_{CM} are to be taken from the corresponding elements in the same plane position.

(2) The representative element which has maximum yield utilisation factor around the manhole and the large opening is to be verified against criterion.

Screening factor for openings in primary supporting members **Table 5**

λ_{sc} : Screening factor taken as

$$\lambda_{sc} = 0.85C_h(|\sigma_x + \sigma_y| + (2 + (\frac{l_0}{2r})^{0.74})|\tau_{xy}|)\frac{k}{235}$$

C_h : Coefficient taken as (2):

- For opening in web of PSM.

$$C_h = 1.0 - 0.23(\frac{h_0}{h}) + 2.12(\frac{h_0}{h})^2$$

- For opening in web of main bracket and buttress (see figures below).

C_h = 1.0

r : Radius of opening, in mm.

h_0 : Height of opening parallel to depth of web, in mm.

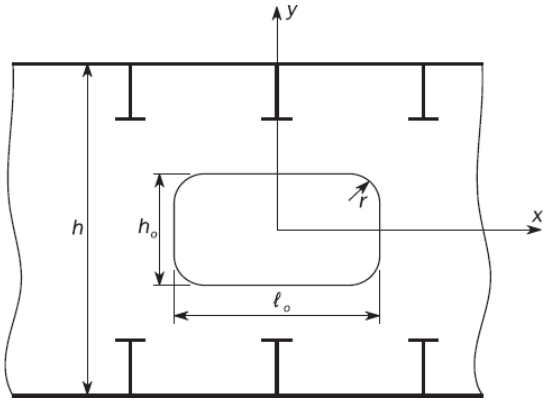
l_0 : Length of opening parallel to girder web direction, in mm.

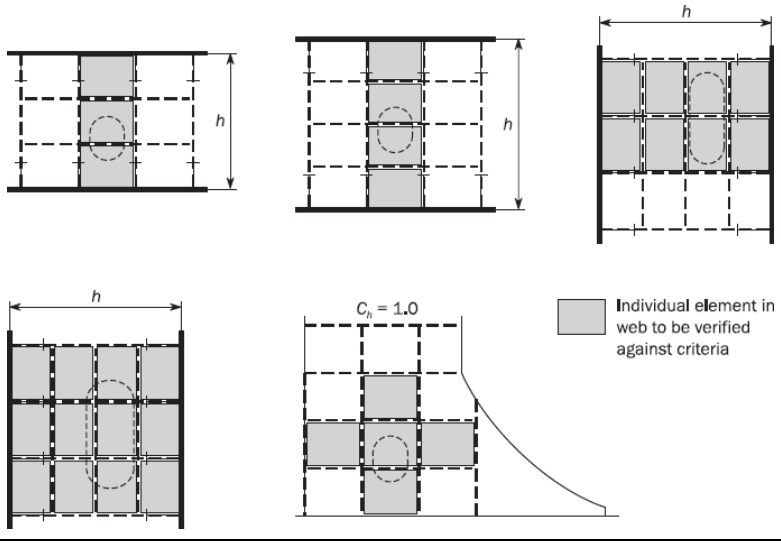
h : Height of web of girder in way of opening, in mm.

σ_x : Axial stress in element x-direction determined from cargo hold FE analysis according to the coordinate system shown, in N/mm^2.

σ_y : Axial stress in element y-direction determined from cargo hold FE analysis according to the coordinate system shown, in N/mm2.

σ_{xy} : Element shear stress determined from cargo hold FE analysis (1), in N/mm^2.





(1) The element shear stress is to be adjusted using the formula given in Ch 7, Sec 2, [5.2.6] prior to the evaluation of yield utilisation factor for verification against the screening criteria.

(2) Where the geometry of the opening is required to be modelled in accordance with Ch 7, Sec 2, [2.4.9], fine mesh FE analysis is to be carried out to determine the stress level and the screening criteria are not applicable.

Screening factor for bracket toes of primary supporting members Table 6

λ_{sc} : Screening factor taken as:

$$\lambda_{sc} = C_a \left(0.68(\frac{b_2}{b_1})^{0.5} \sigma_{vm} + 0.50(\frac{A_{beam-n50}}{b_1 t_{n50}})^{0.5} |\sigma_{beam}| \right) \frac{k}{235}$$

C_a : Coefficient taken as:

$$C_a = 1.0 - 0.2(\frac{R_a}{1400})^2$$

b_1, b_2 : Height of shell element in way of bracket toe in cargo hold FE model, in mm.

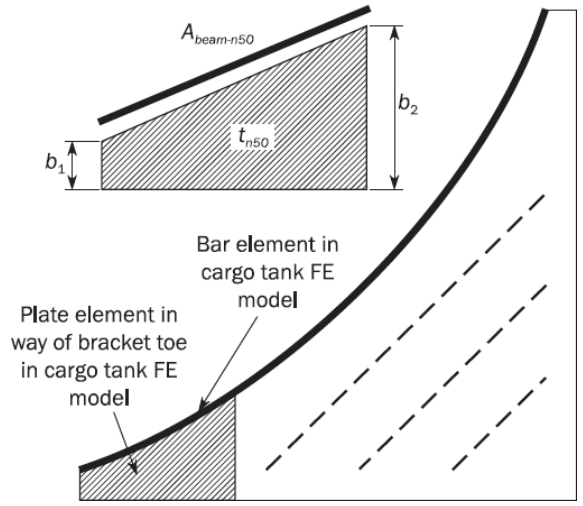
$A_{beam\text{-}n50}$: Sectional area of beam or rod element in cargo hold FE model representing the face plate of bracket, in mm^2.

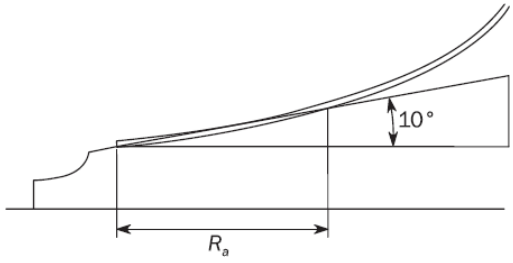
σ_{beam} : Beam or rod element axial stress determined from cargo hold FE analysis, in N/mm^2.

σ_{vm} : Von Mises stress of shell element in way of bracket toe determined from cargo hold FE analysis, in N/mm^2.

t_{n50} : Net thickness of shell element in way of bracket toe, in mm.

R_a : Leg length, in mm, not to be taken as greater than 1400 mm.





3.3.2 Screening criteria

Stresses in areas defined in [3.1], calculated for all applicable FE load combinations given in [5], are to be checked against the following screening criteria.

$\lambda_{sc} \leq \lambda_{scperm}$

where:

λ_{sc} : Screening factor defined in [3.3.1]

λ_{scperm} : Permissible screening factor defined in [3.3.1]

Where the screening criteria are not met, fine mesh analysis of the corresponding structural detail is required and to be performed according to [1.1.3].

Screening factor for heels of transverse bulkhead horizontal stringers Table 7

λ_{sc} : Screening factor taken as:

- For heels at side horizontal girder and transverse bulkhead horizontal stringer, at the locations 1, 2 and 3 in figure below.

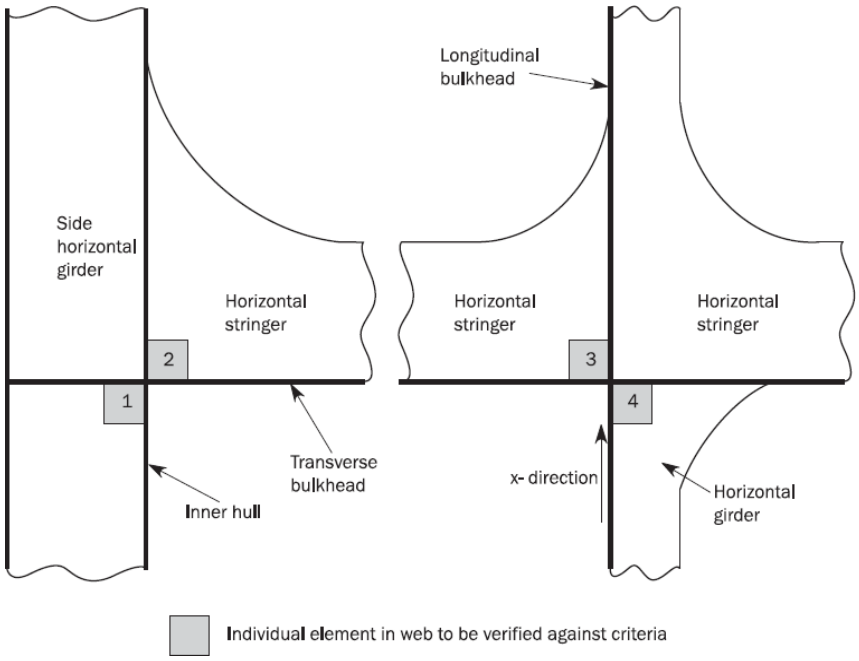
$$\lambda_{sc} = 1.67\sigma_{vm} \frac{k}{235}$$

- For heel at longitudinal bulkhead horizontal stringer, at the location 4 in figure below.

$$\lambda_{sc} = 3.2|\sigma_x| \frac{k}{235}$$

σ_x : Axial stress in element x direction determined from cargo hold FE analysis in accordance with the coordinate system shown, in N/mm^2.

σ_{vm} : Von Mises stress of shell element in way of heel determined from cargo hold FE analysis, in N/mm^2.



	Individual element in web to be verified against criteria.

4 STRUCTURAL MODELLING

4.1 General

4.1.1

Evaluation of detailed stresses requires the use of refined finite element mesh in way of areas of high stress. This fine mesh analysis can be carried out by fine mesh zones incorporated into the cargo hold model. Alternatively, separate local FE model with fine mesh zones in conjunction with the boundary conditions obtained from the cargo hold model may be used.

4.2 Extent of model

4.2.1

If a separate local fine mesh model is used, its extent is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions. The boundary of the fine mesh model is to coincide with primary supporting members in the cargo hold model, such as web frame, girders, stringers and floors.

4.3 Mesh size

4.3.1

The mesh size in the fine mesh zones is not to be greater than 50×50 mm.

4.3.2

The extent of the fine mesh zone is not to be less than 10 elements in all directions from the area under investigation. A smooth transition of mesh density from fine mesh zone to the boundary of the fine mesh model is to be maintained.

4.4 Elements

4.4.1

All plating within the fine mesh zone is to be represented by shell elements. The aspect ratio of elements within the fine mesh zone is to be kept as close to 1 as possible. Variation of mesh density within the fine mesh zone and the use of triangular elements are to be avoided. In all cases, the elements within the fine mesh model are to have an aspect ratio not exceeding 3. Distorted elements, with element corner angles of less than $45°$ or greater than $135°$, are to be avoided. Stiffeners inside the fine mesh zone are to be modelled using shell elements. Stiffeners outside the fine mesh zones may be modelled using beam elements.

4.4.2
Where fine mesh analysis is required for main bracket end connections, including the end connection of hold frames of single skin bulk carriers, the fine mesh zone is to be extended at least 10 elements in all directions from the area subject to assessment, see Figure 9.

4.4.3
Where fine mesh analysis is required for an opening, the first two layers of elements around the opening are to be modelled with mesh size not greater than 50 × 50 mm. A smooth transition from the fine mesh to the coarser mesh is to be maintained. Edge stiffeners which are welded directly to the edge of an opening are to be modelled with shell elements. Web stiffeners close to an opening may be modelled using rod or beam elements located at a distance of at least 50 mm from the edge of the opening. Example of fine mesh zone around an opening is shown in Figure 10.

4.4.4
Face plates of openings, primary supporting members and associated brackets are to be modelled with at least two elements across their width on either side.

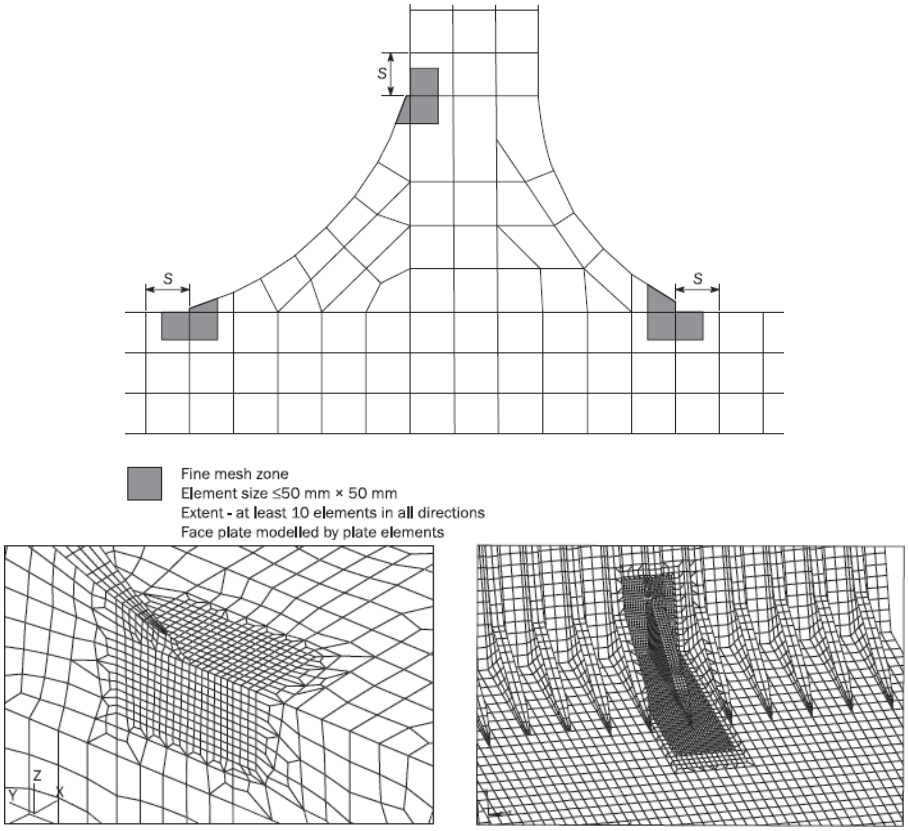


Figure 9 Fine mesh zone around bracket toes

4.5 Transverse web frames
4.5.1
In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-section are applicable to the analysis of a typical transverse web frame.

4.5.2
Where a FE sub model is used, the model is to have an extent of at least 1+1 web frame spaces, i.e. one web frame space extending either side of the transverse web frame under investigation. For bulk carriers, the web frame space is the longer space of web frames in the upper wing and the lower hopper tanks. The transverse web frames forward and aft of the web frame under investigation need not be included in the sub model.

4.5.3

The full depth and full breadth of the ship are to be modelled, see Figure 11.

Figure 12 shows a close up view of the finite element mesh at the lower part of the vertical web and backing brackets.

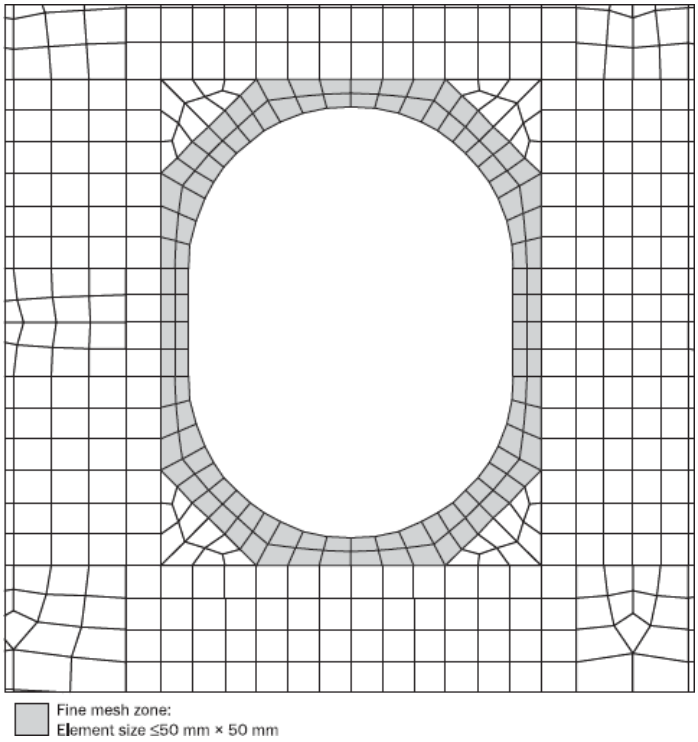


Figure 10 Fine mesh zone around an opening

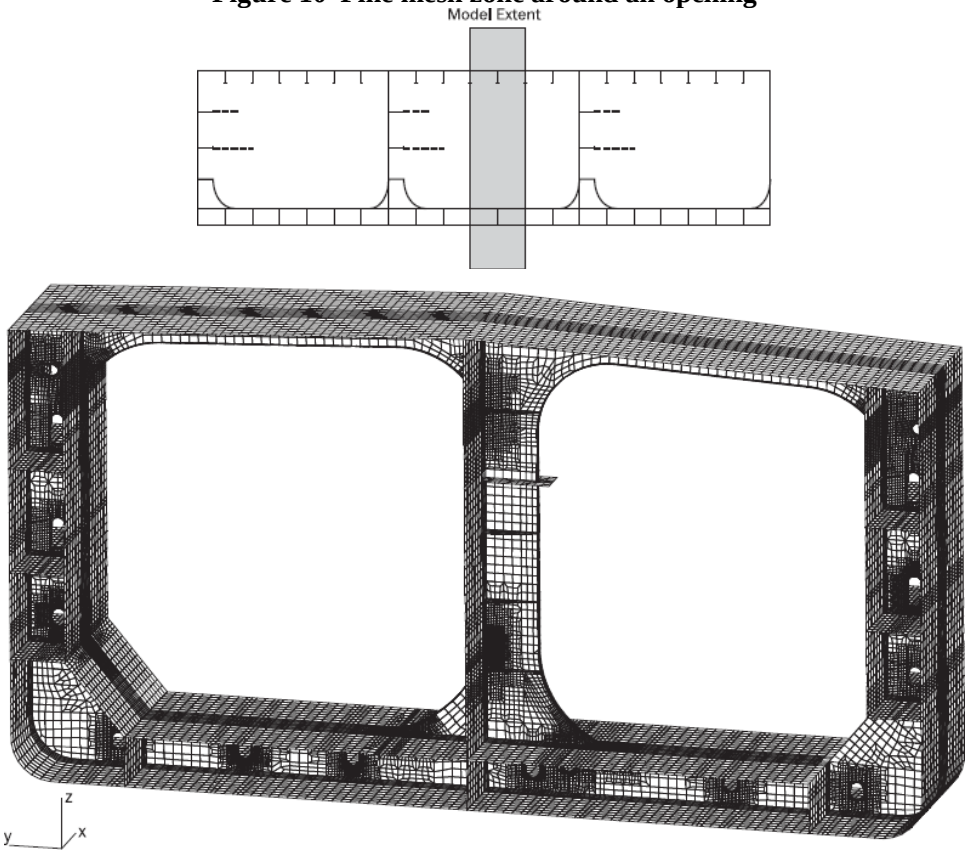


Figure 11 Example of extent of local model for fine mesh analysis of web frame bracket connections and openings

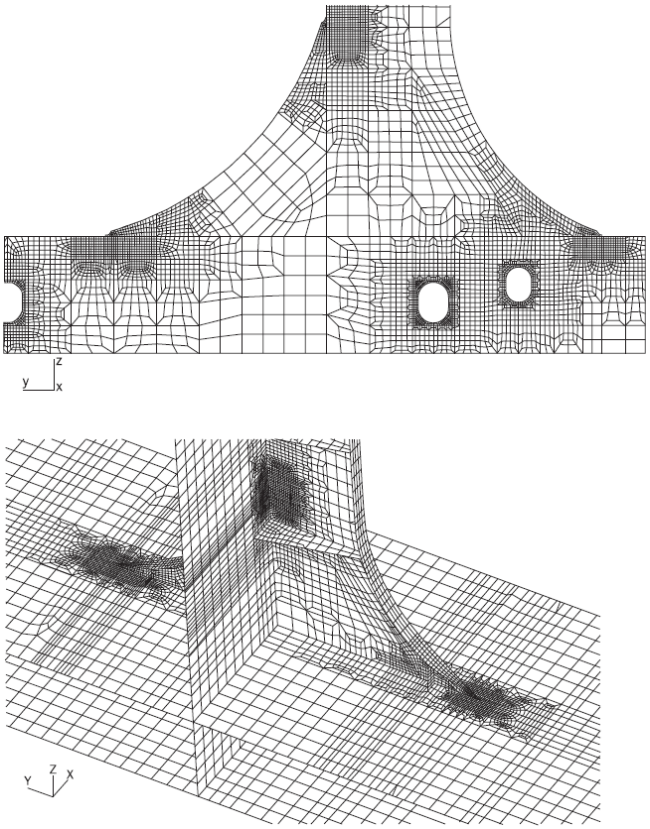


Figure 12 Close-up view of finite element mesh at the lower part of a transverse web frame

4.6 Transverse bulkhead stringers, buttress and adjacent web frame

4.6.1

In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-section are applicable to the analysis of transverse bulkhead structures and adjacent web frame.

4.6.2

Due to the structural interaction among the transverse bulkhead, horizontal stringers, web frames, deck and double bottom, it is recommended that the FE local model represents a full section of the hull. Longitudinally, the ends of the model should be extended at least one web frame space beyond the areas that require investigation, see Figure 13.

4.6.3

Alternatively, it is acceptable to use a number of local models, as shown in Figure 14, to analyse different parts of the structure. For the analysis of the transverse bulkhead horizontal stringers the full breadth of the ship are to be modelled. For the analysis of buttress structure, the local model width should be at least 4+4 longitudinal spaces, i.e. four longitudinal spaces at each side of the buttress.

4.6.4

Figure 15 shows the finite element mesh on a transverse bulkhead horizontal stringer. Figure 16 shows the local model for the analysis of buttress connections to transverse bulkhead and double bottom structure, and openings.

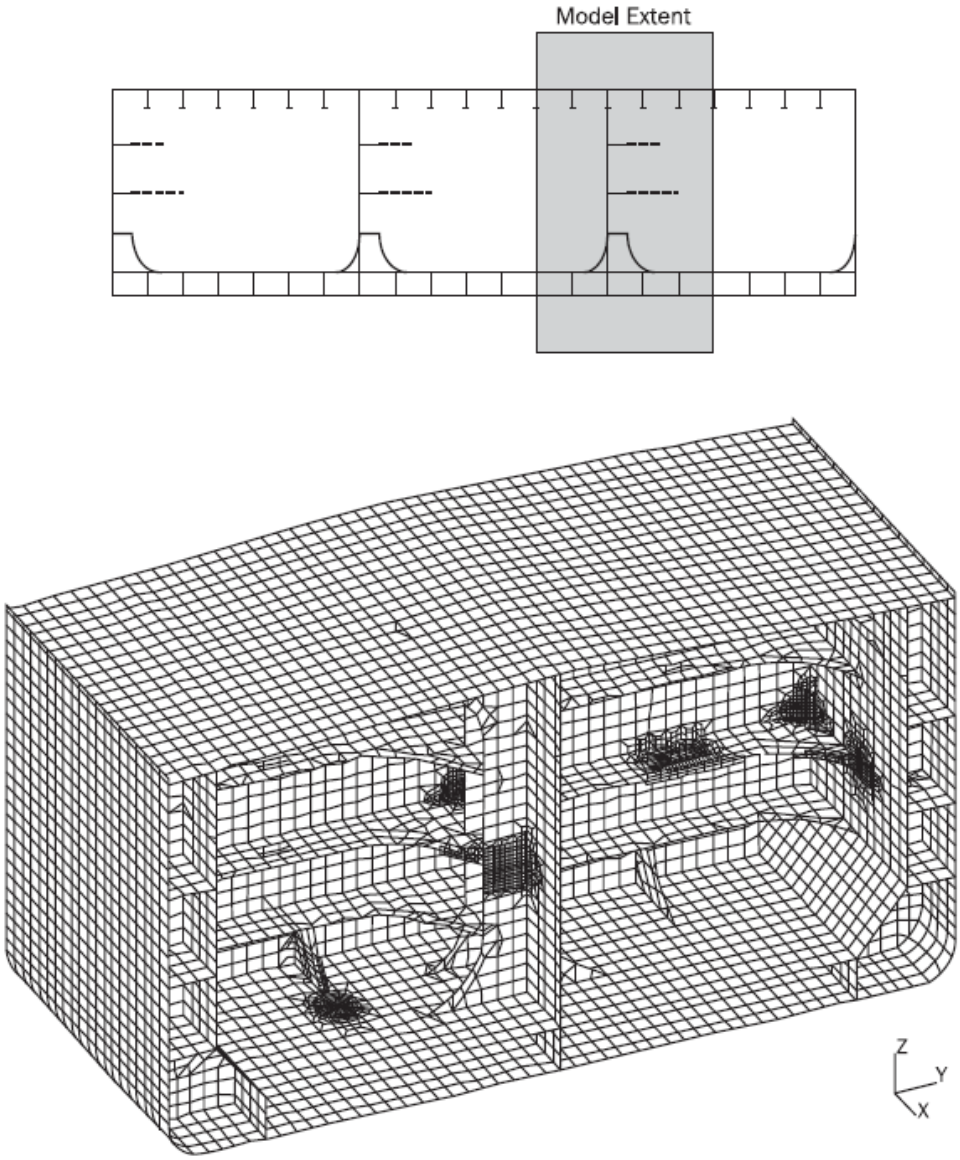


Figure 13 Example of local model for fine mesh analysis of transverse bulkhead and adjacent structure

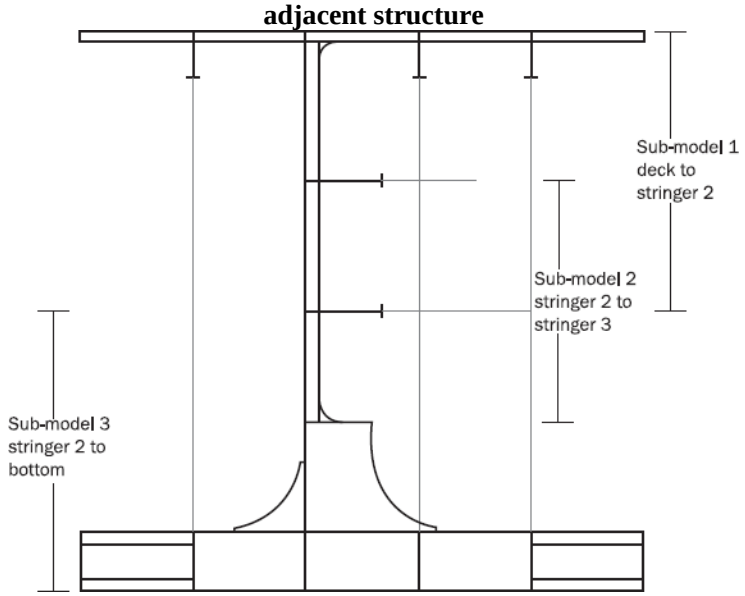


Figure 14 Example of local analysis of transverse bulkhead structure using local models

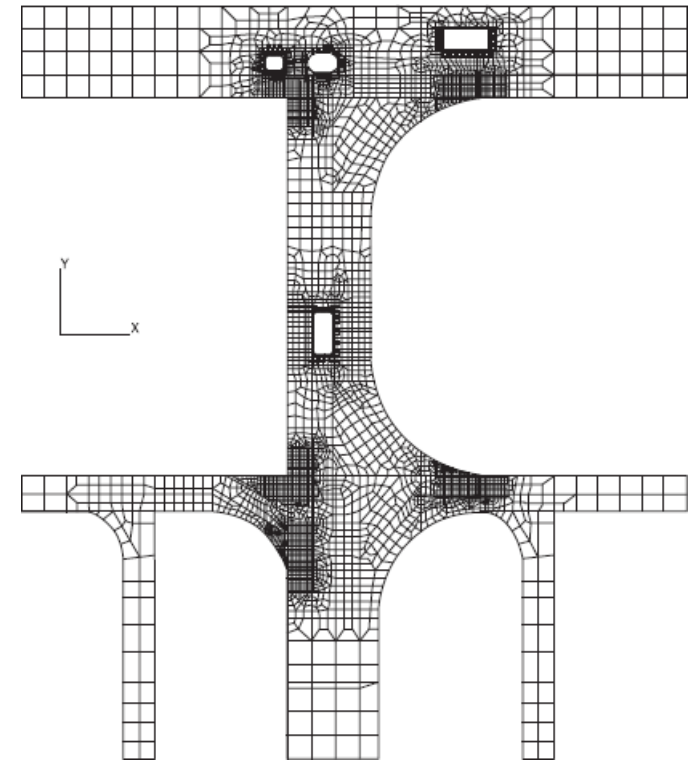


Figure 15 Example of finite element mesh on transverse bulkhead horizontal stringer

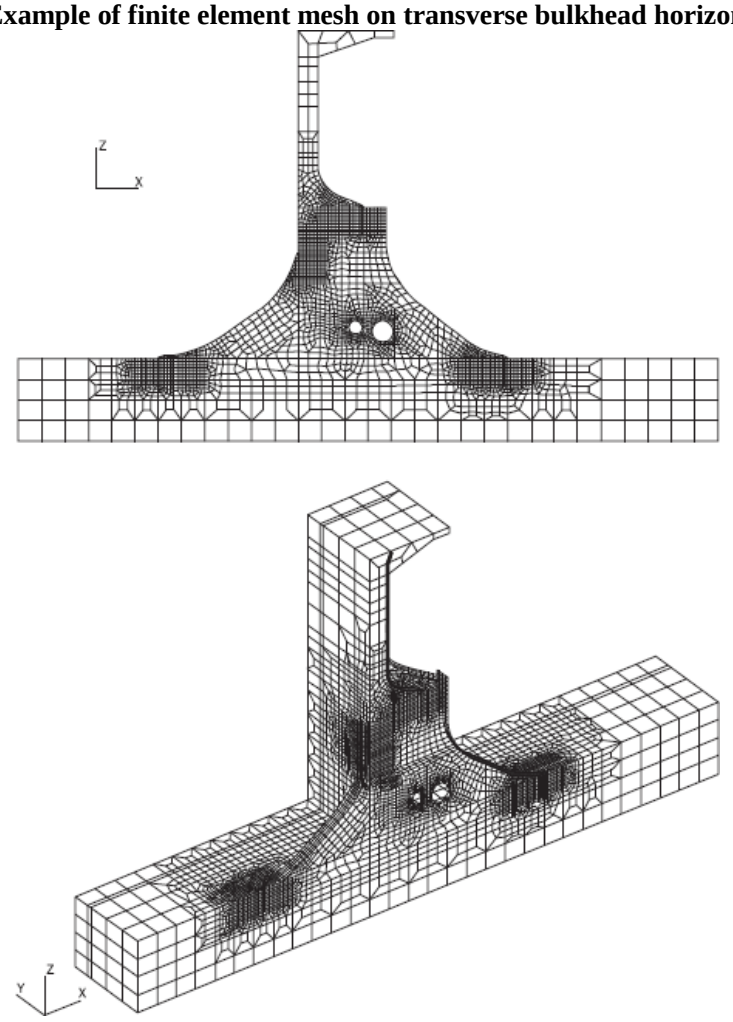


Figure 16 Example of local model for the analysis of buttress connections to bulkhead and double bottom structure, showing port half of model

4.7 Deck, double bottom longitudinal and adjoining transverse bulkhead vertical stiffeners

4.7.1

In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-section are applicable specifically to the analysis of longitudinal and vertical stiffener end connections and attached web stiffeners.

4.7.2

Where a local FE model is used, each end of the model is to be extended longitudinally at least two web frame spaces from the areas under investigation. The model width is to be at least 2+2 longitudinal spaces. Figure 17 shows the longitudinal extent of the local model for the analysis of deck and double bottom longitudinal stiffeners and adjoining transverse bulkhead vertical stiffener.

4.7.3

The web of the longitudinal stiffeners outside of the fine mesh zone should be represented by at least 3 shell elements across its depth. Similar size elements should be used to represent the plating of the bottom shell and inner bottom. The flange of the longitudinal stiffeners and face plate of brackets should be modelled with at least two shell elements across its width at one side.

4.7.4

The mesh size and extent of the fine mesh zone is to be in accordance with [4.3.1], see also Figure 17.

4.8 Corrugated bulkheads

4.8.1

In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-article are applicable to the analysis of connections of corrugated bulkheads to lower stool and the connection between lower stool and inner bottom.

4.8.2

The minimum extents of the local model are as follows, see also Figure 18:

a) Vertically, the model is to be extended from the bottom of the ship to a level at least 2 m above the corrugation and lower stool connection. The upper boundary of the local model is to coincide with the horizontal mesh line of the cargo hold FE model for the purpose of applying boundary displacements, see [4.2].

b) For transverse corrugated bulkheads, the local model is to be extended transversely to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. the local model covers two lower stool transverse web/diaphragm spaces). The end diaphragms need not be modelled.

c) For the longitudinal corrugated bulkheads, the local model is to be extended to the nearest web frame on each side of the fine mesh zone (i.e. the local model covers two frame spaces). The end web frames need not be modelled.

d) For the corrugation and lower stool connection located close to the intersection of transverse and longitudinal corrugated bulkheads, such as for product tanker, the local model is to cover the structure between the diaphragms (in transverse direction) and web frames (in longitudinal direction) closest to the detail, whichever is relevant. In addition the local model is to be extended at least one diaphragm/web frame outside the intersection between the transverse stool and the longitudinal stool.

e) For lower stool to inner bottom connection, the connection between inner bottom, lower stool plate, diaphragm and double bottom girder, where applicable, is the centre of the fine mesh zone.

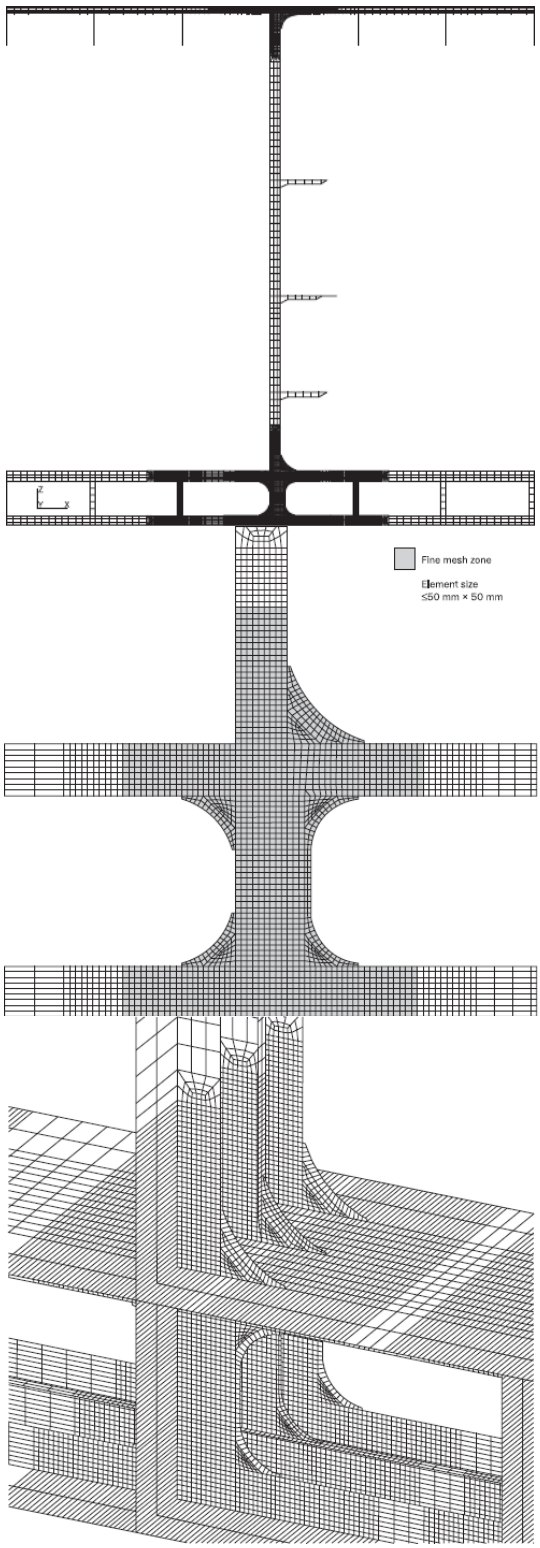


Figure 17 Example of local model for fine mesh analysis of end connections and web stiffeners of deck and double bottom longitudinals

4.8.3

For corrugation connection, the fine mesh zone is to cover at least the corrugation flange under investigation, the adjacent corrugation webs and a further extension of 500 mm from each end of the corrugation web, i.e. the fine mesh zone covers at least four corrugation knuckles, see Figure 18 and Figure 19. The mesh size within the fine mesh zone is not to be greater than 50 × 50 mm.

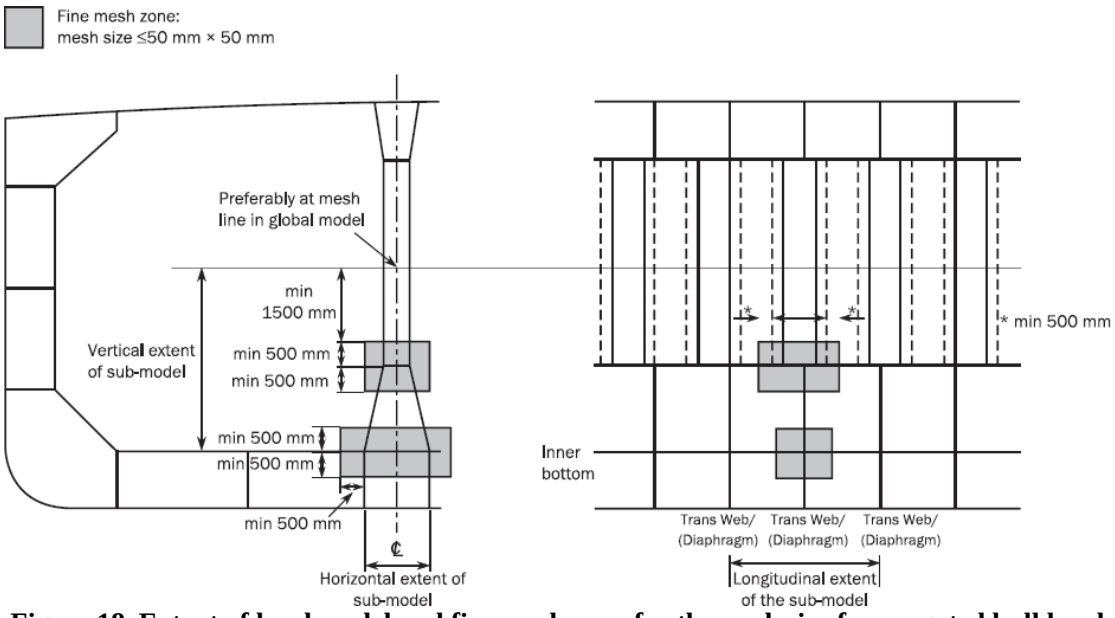


Figure 18 Extent of local model and fine mesh zone for the analysis of corrugated bulkhead connection to lower stool and inner bottom

Above figures show extent of local model and fine mesh zone on longitudinal corrugated bulkhead connection to lower stool. Similar extent applies to transverse corrugated bulkhead.
The model extents shown above are the minimum extents.

4.8.4

Diaphragm webs, brackets inside the lower stool and all stiffeners on the stool plate and diaphragm are to be modelled at their actual positions within the extent of the local model. Shell elements are to be used for modelling of diaphragm, web and flange of vertically orientated stiffeners, and brackets in the fine mesh zone.

4.8.5

Horizontally orientated stiffeners within the fine mesh zone are to be represented by either shell or beam elements.

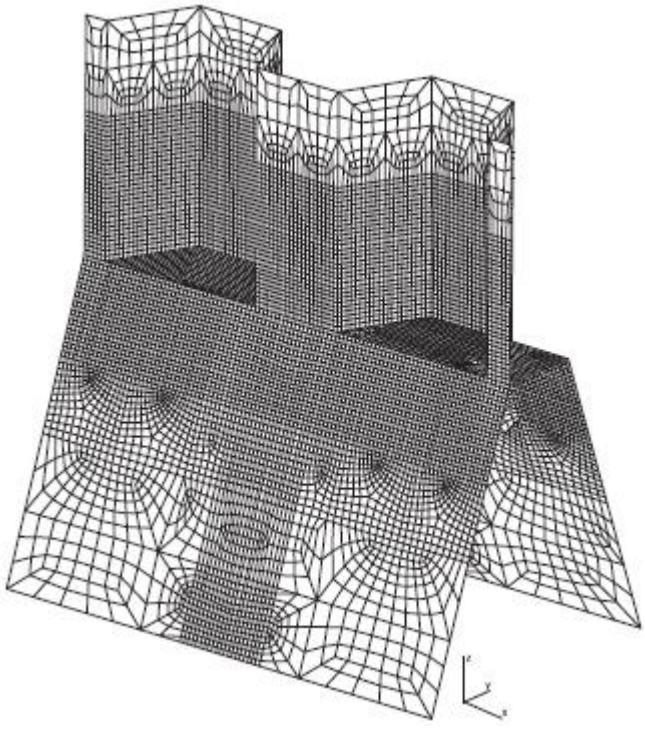


Figure 19 Example of partial local model for the analysis of connection of corrugated bulkhead to lower stool

4.8.6
Figure 19 shows the details of finite element local model for the fine mesh analysis of longitudinal bulkhead to lower stool connection.

4.8.7
Figure 20 shows the details finite element local model for the fine mesh analysis of lower stool to inner bottom connection.

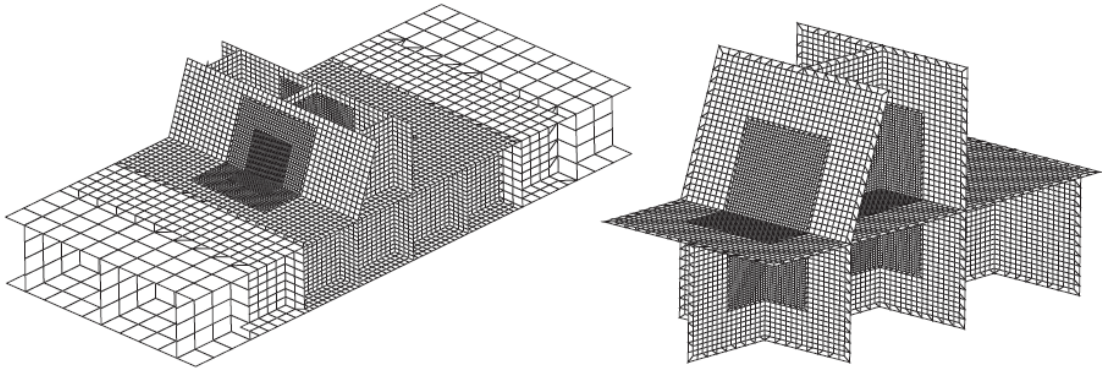


Figure 20 Example of partial local model for the analysis of connection of lower stool to inner bottom

4.9 Hatch corner structures
4.9.1
In addition to the requirements of [4.2] to [4.4], the modelling requirements in this sub-article are applicable to the analysis of hatch corner structures.

4.9.2
The high stress areas, such as the hatch coaming end bracket, the hatch corner and the hatch end beam connection, need to be analysed by fine mesh model. The fine mesh zones should cover these areas, see Figure 21.

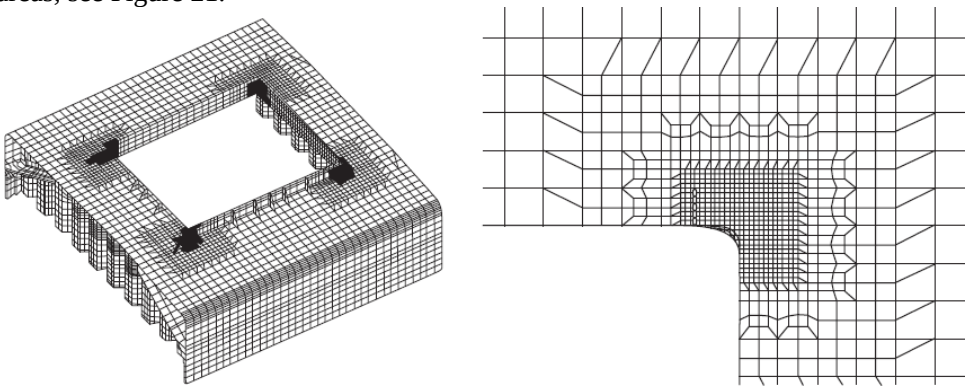


Figure 21 Example of local model for the analysis of hatch opening structures

5 FE LOAD COMBINATIONS
5.1 General
5.1.1
The fine mesh detailed stress analysis is to be carried out for all FE load combinations applied to the corresponding cargo hold analysis.
5.2 Application of loads and boundary conditions
5.2.1 General
Where a separate local model is used for the fine mesh detailed stress analysis, the nodal displacements from the cargo tank model are to be applied to the corresponding boundary nodes on the local model as prescribed displacements. Alternatively, equivalent nodal forces from the cargo tank model may be applied to the boundary nodes.
Where there are nodes on the local model boundaries which are not coincident with the nodal

points on the cargo tank model, it is acceptable to impose prescribed displacements on these nodes using multi-point constraints. The use of linear multi-point constraint equations connecting two neighbouring coincident nodes is considered sufficient.
All local loads, including any loads applied for hull girder bending moment and/or shear force adjustments, in way of the structure represented by the separate local finite element model are to be applied to the model.

6 ANALYSIS CRITERIA

6.1 Stress assessment

6.1.1 General

Stress assessment of the fine mesh analysis is to be carried out for the FE load combinations specified in Ch4, Sec 8.

6.1.2 Reference stress

Reference stress is von Mises stress, σ_{vm}, which is to be calculated based on the membrane normal and shear stresses of the shell element evaluated at the element centroid. The stresses are to be evaluated at the mid plane of the element.

6.1.3 Permissible stress

The maximum permissible stresses are based on the mesh size of 50 × 50 mm as specified in [4.1] to [4.4]. Where a smaller mesh size is used, an area weighted von Mises stress calculated over an area equal to the specified mesh size may be used to compare with the permissible stresses. The averaging is to be based only on elements with their entire boundary located within the desired area. The average stress is to be calculated based on stresses at element centroid; stress values obtained by interpolation and/or extrapolation are not to be used. Stress averaging is not to be carried across structural discontinuities and abutting structure.

6.2 Acceptance criteria

6.2.1

Verification of stress results against the acceptance criteria is to be carried out in accordance with [6.1]. The structural assessment is to demonstrate that the stress complies with the following criteria:

$\lambda_f \leqslant \lambda_{fperm}$

where:

λ_f : Fine mesh yield utilisation factor.

$$\lambda_f = \frac{\sigma_{vm}}{R_Y}$$ for shell elements in general

$$\lambda_f = \frac{|\sigma_{axial}|}{R_Y}$$ for rod or beam elements in general

σ_{vm} : Von Mises stress, in N/mm^2.

σ_{axial} : Axial stress in rod element, in N/mm^2.

λ_{fperm} : Permissible fine mesh utilisation factor, taken as:

- Element not adjacent to weld:
  - λ_{fperm} = 1.70 f_f for S+D
  - λ_{fperm} = 1.36 f_f for S
- Element adjacent to weld:
  - λ_{fperm} = 1.50 f_f for S+D
  - λ_{fperm} = 1.20 f_f for S

f_f : Fatigue factor, taken as:

- f_f = 1.0 in general, including the free edge of base material,
- f_f =1.2 for details assessed by very fine mesh analysis complying with the fatigue assessment criteria. given in Ch 9, Sec 2.

Note 1: The maximum permissible stresses are based on the mesh size of 50 × 50 mm. Where a smaller mesh size is used, an average von Mises stress calculated in accordance with [6.1] over an area equal to the specified mesh size may be used to compare with the permissible stresses.

Note 2: Average von Mises stress is to be calculated based on weighted average against element areas:

$$\sigma_{vm-av} = \frac{\sum_1^n A_i \sigma_{vm-i}}{\sum_1^n A_i}$$

where:

σ_{vm-av} is the average von Mises stress.

Note 3: Stress averaging is not to be carried across structural discontinuities and abutting structure.

6.2.2 Lower stool not fitted to a transverse or longitudinal corrugated bulkhead

Where a lower stool is not fitted to a transverse or longitudinal corrugated bulkhead, the permissible stresses given in [6.2.1] are to be reduced by 10% for the areas under investigation by fine mesh analysis.

Chapter 8 BUCKLING

Section 1 GENERAL

1 INTRODUCTION

1.1 Assumption

1.1.1

This chapter contains the strength criteria for buckling and ultimate strength of local supporting members, primary supporting members and other structures such as pillars, corrugated bulkheads and brackets. These criteria are to be applied as specified in Ch 6 for hull local scantlings and in Ch 7 for direct strength analysis.

1.1.2

For each structural member, the characteristic buckling strength is to be taken as the most unfavourable /critical buckling failure mode.

1.1.3

Unless otherwise specified, the scantling requirements of structural members in this chapter are based on net scantling obtained by removing *tc* from the gross offered thickness, where *tc* is defined in Ch 3, Sec 3.

1.1.4

In this chapter, compressive and shear stresses are to be taken as positive, tension stresses are to be taken as negative.

2 APPLICATION

2.1 Scope

2.1.1

The buckling checks are to be performed according to:

- Ch 8, Sec 2 for the slenderness requirements of plates, longitudinal and transverse stiffeners, primary supporting members and brackets.
- Ch 8, Sec 3 for the prescriptive buckling requirements of plates, longitudinal and transverse stiffeners, primary supporting members and other structures.
- Ch 8, Sec 4 for the buckling requirements of the FE analysis for the plates, stiffened panels and other structures.
- Ch 8, Sec 5 for the buckling capacity of prescriptive and FE buckling requirements.

2.1.2 Stiffener

The buckling check of the stiffeners referred to in this Chapter is applicable to the stiffener fitted along the long edge of the buckling panel.

2.1.3 Enlarged stiffener

Enlarged stiffeners, used for Permanent Means of Access (PMA), whose net web height are above 700 mm, and net offered section modulus are 3 times greater than the smaller one of adjacent surrounding stiffeners not used for PMA, are to comply with the following requirements:

a) Slenderness requirements for primary supporting members as follows:
   - For enlarged stiffener web, see item (a) of Ch 8, Sec 2, [4.1.1].
   - For enlarged stiffener flange, see item (b) of Ch 8, Sec 2, [4.1.1] and Ch 8, Sec 2, [5.1].
   - For stiffeners fitted on enlarged stiffener web, see Ch 8, Sec 2, [3.1.1] and Ch 8, Sec 2, [3.1.3].

b) Buckling strength of prescriptive requirements as follows:
   - For enlarged stiffener web, see Ch 8, Sec 3, [3.2].
   - For stiffeners fitted on enlarged stiffener web, see Ch 8, Sec 3, [3.1] and Ch 8, Sec 3, [3.3].

c) All structural elements used for PMA are to be complied with for the buckling requirements of the FE analysis in Ch 8, Sec 4 when applicable.

d) Buckling strength of longitudinal PMA platforms without stiffeners fitted on enlarged stiffener web is to be checked using the criteria for local supporting members in Ch 8, Sec 3, [3.1] and Ch 8, Sec 3, [3.3].

3 DEFINITIONS

3.1 General

3.1.1 Buckling definition

'Buckling' is used as a generic term to describe the strength of structures, generally under in-plane compressions and/or shear and lateral load. The buckling strength or capacity can take into account the internal redistribution of loads depending on the load situation, slenderness and type of structure.

3.1.2 Buckling capacity

Buckling capacity based on this principle gives a lower bound estimate of ultimate capacity, or the maximum load the panel can carry without suffering major permanent set.

Buckling capacity assessment utilises the positive elastic post-buckling effect for plates and accounts for load redistribution between the structural components, such as between plating and stiffeners. For slender structures, the capacity calculated using this method is typically higher than the ideal elastic buckling stress (minimum Eigen value). Accepting elastic buckling of structural components in slender stiffened panels implies that large elastic deflections and reduced in-plane stiffness will occur at higher buckling utilisation levels.

3.1.3 Assessment methods

The buckling assessment is carried out according to one of the two methods taking into account different boundary condition types:

- Method A: All the edges of the elementary plate panel are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates.
- Method B: The edges of the elementary plate panel are not forced to remain straight due to low in-plane stiffness at the edges and/or no surrounding structure/neighbouring plates.

3.2 Buckling utilisation factor

3.2.1

The utilisation factor, η, is defined as the ratio between the applied loads and the corresponding ultimate capacity or buckling strength.

3.2.2

For combined loads, the utilisation factor, η_{act}, is to be defined as the ratio of the equivalent applied stress and the corresponding buckling capacity, as shown in Figure 1, and is to be taken as:

$$\eta_{act} = \frac{W_{act}}{W_u} = \frac{1}{\gamma_c}$$

where:

W_{act} : Equivalent applied stress, in N/mm^2, the actual applied stress are given in Sec 3 and Sec 4 respectively for buckling assessment by prescriptive and direct strength analysis.

W_u : Equivalent buckling capacity, in N/mm^2, for plates and stiffeners, their respective buckling or ultimate capacities are given in Sec 5.

γ_c : Stress multiplier factor at failure.

For each typical failure mode, the corresponding capacity of the panel is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until collapse.

Figure 1 illustrates the buckling capacity and the buckling utilisation factor of a structural member subject to σ_x and σ_y stresses.

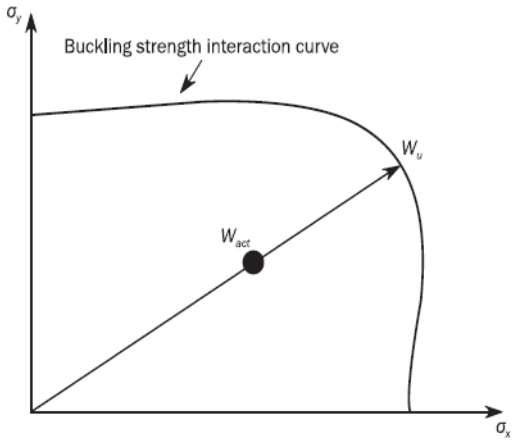


Figure 1 Example of buckling capacity and buckling utilisation factor

3.3 Allowable buckling utilisation factor

3.3.1 General structural elements

The allowable buckling utilisation factor is defined in Table 1.

Allowable buckling utilisation factor **Table 1**

Structural component	η_{all}, Allowable buckling utilisation factor
Plates and stiffeners Stiffened and unstiffened panels Vertically stiffened side shell plating of single side skin bulk carrier Web plate in ways of openings	1.00 for load combination: S+D 0.80 for load combination: S
Struts, pillars and cross ties	0.75 for load combination: S+D 0.65 for load combination: S
Corrugation of vertically corrugated bulkheads with lower stool and horizontally corrugated bulkhead, under lateral pressure from liquid loads, for shell elements only. Supporting structure in way of lower end of corrugated bulkheads without lower stool.	0.90 for load combination: S+D 0.72 for load combination: S
Corrugation of vertically corrugated bulkheads without lower stool under lateral pressure from liquid loads, for shell elements only.	0.81 for load combination: S+D 0.65 for load combination: S
Note1: Supporting structure for a transverse corrugated bulkhead refers to the structure in longitudinal direction within half a web frame space forward and aft of the bulkhead, and within a vertical extent equal to the corrugation depth. Note2: Supporting structure for a longitudinal corrugated bulkhead refers to the structure in transverse direction within three longitudinal stiffener spacings from each side of the bulkhead, and within a vertical extent equal to the corrugation depth.	

3.4 Buckling acceptance criteria

3.4.1

A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$\eta_{act} \leqslant \eta_{all}$

where:

η_{act} :Buckling utilisation factor based on the applied stress, defined in [3.2.2].

η_{all} :Allowable buckling utilisation factor as defined in [3.3].

Section 2 SLENDERNESS REQUIREMENTS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

$b_{f\text{-}out}$: Maximum distance, in mm, from mid thickness of the web to the flange edge, as shown in Figure 1.

h_w : Depth of stiffener web, in mm, as shown in Figure 1.

l_b : Effective length of edge of bracket, in mm, as defined in Table 3.

s_{eff} : Effective width of attached plate of stiffener, in mm, taken equal to:

$s_{eff} = 0.8\ s$

t_f : Net flange thickness, in mm.

t_p : Net thickness of plate, in mm.

t_w : Net web thickness, in mm.

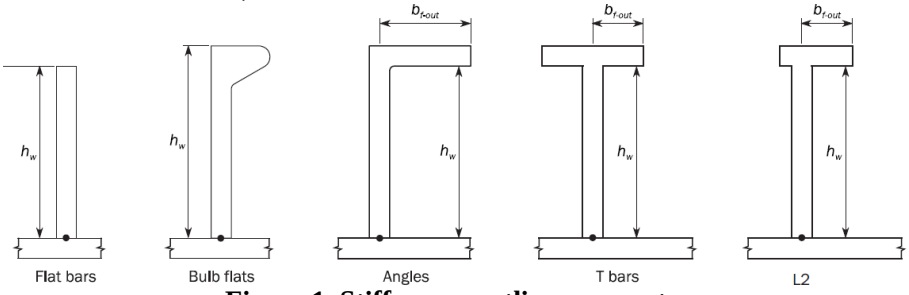


Figure 1 Stiffener scantling parameters

1 STRUCTURAL ELEMENTS

1.1 General

1.1.1

All structural elements are to comply with the applicable slenderness and proportion requirements given in [2] to [6], except for the ones listed below:

- Bilge plates within the cylindrical part of the ship and radius gunwale;
- Corrugation;
- Structure members in superstructures and deck houses, if the structural members do not contribute to the longitudinal strength.

Pillars in superstructures and deckhouses are to comply with the applicable slenderness and proportion requirements given in [6.1].

2 PLATES

2.1 Net thickness of plate panels

2.1.1

The net thickness of plate panels is to satisfy the following criteria:

$$t_p \geq \frac{b}{C}\sqrt{\frac{R_{eH}}{235}}$$

where:

C : Slenderness coefficient taken as:

$C = 100$ for hull envelope and cargo and tank boundaries.

$C = 125$ for other structures.

R_{eH} : Specified minimum yield stress of the plate material, in N/mm^2.

A lower specified minimum yield stress may be used in this slenderness criterion provided the requirements specified in Sec 3 and Sec 4 are satisfied for the strake assumed in the same lower specified minimum yield stress value

3 STIFFENERS

3.1 Proportions of stiffeners

3.1.1 Net thickness of all stiffener types

The net thickness of stiffeners is to satisfy the following criteria:

a) Stiffener web plate:

$$t_w \geq \frac{h_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

b) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where:
C_w, C_f : Slenderness coefficients given in Table 1.

If requirement b) is not fulfilled, the effective free flange outstand, in mm, used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-\max} = C_f t_f \sqrt{\frac{235}{R_{eH}}}$$

Slenderness coefficients **Table 1**

Type of Stiffener	C_w	C_f
Angle and L2 bars	75	12
T-bars	75	12
Bulb bars	45	-
Flat bars	22	-

For built-up profile where the relevant yielding strength defined in Ch 6 and Ch 7 for the web of built-up profile without the edge stiffener is acceptable, as an alternative the web can be assessed according to the web requirements of Angle and L2 in Ch 8, Sec 2, Table 1 and the edge stiffener can be assessed as a flat bar stiffener according to [3.1.1]. The requirement to flange in [3.1.2] shall still apply.

3.1.2 Net dimensions of angle , L2 and T-bars
The total flange breadth b_f in mm, for angle, L2 and T-bars is to satisfy the following criterion:
$b_f \geqslant 0.2h_w$

3.1.3 Bending stiffness of stiffeners
The net moment of inertia, in cm^4, of the stiffener with the effective width of attached plate, s_{eff} about the neutral axis parallel to the attached plating , is not to be less than the minimum value given by:

$$I_{st} \geq Cl^2 A_{eff}\frac{R_{eH}}{235}$$

where:
A_{eff} : Net sectional area of stiffener including effective attached plate, s_{eff}, in cm^2.
R_{eH} : Specified minimum yield stress of the material of the attached plate, in N/mm^2.
C : Slenderness coefficient taken as:
C = 1.43 for longitudinal stiffeners including sniped stiffeners.
C = 0.72 for other stiffeners.

4 PRIMARY SUPPORTING MEMBERS

4.1 Proportions and stiffness

4.1.1 Proportions of web plate and flange

The net thicknesses of the web plates and flanges of primary supporting members are to satisfy the following criteria:

a) Web plate:

$$t_w \geq \frac{s_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

b) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where:

s_w : Plate breadth, in mm, taken as the spacing of the web stiffeners.

C_w : Slenderness coefficient for the web plate taken as:
$C_w = 100$

C_f : Slenderness coefficient for the flange taken as:
$C_f = 12$

R_{eH} : Specified minimum yield stress of the plate material, in N/mm^2.
For the web plates, a lower R_{eH} may be used in this slenderness criterion provided the requirements specified in Sec 3 and Sec 4, if applicable, are satisfied for the structure assumed in the same lower R_{eH}.

If requirement b) is not fulfilled, the effective free flange outstand, in mm, used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-\max} = C_f t_f \sqrt{\frac{235}{R_{eH}}}$$

4.1.2 Deck transverse primary supporting members

The net moment of inertia for deck transverse primary supporting members, $I_{psm\text{-}n50}$, in cm^4, supporting deck longitudinals subject to axial compressive hull girder stress, is to comply, within its central half of the bending span, with the following criterion:

$$I_{psm-n50} \geq 300\frac{l_{bdg}^4}{S^4 s} I_{st}$$

where:

$I_{psm\text{-}n50}$: Net moment of inertia, in cm^4, of deck transverse primary supporting member, with effective width of attached plate equal to 0.8S.

l_{bdg} : Effective bending span of deck transverse primary supporting member, in m, as defined in Ch 3, Sec 7.

S : Spacing of deck transverse primary supporting members, in m, as defined in Ch 3, Sec 7.

I_{st} : Moment of inertia of deck stiffeners within the central half of the bending span, in cm4, as given in[3.1.3].

4.2 Web stiffeners of primary supporting members

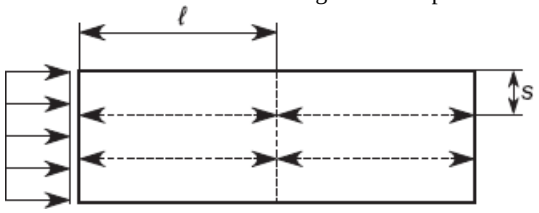
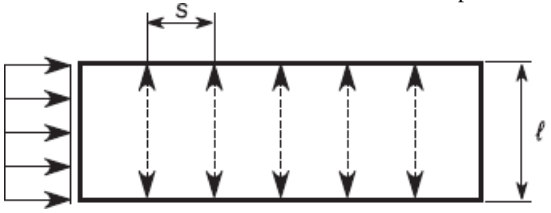
4.2.1 Proportions of web stiffeners

The net thickness of web and flange of web stiffeners fitted on primary supporting members is to satisfy the requirements specified in [3.1.1] and [3.1.2].

4.2.2 Bending stiffness of web stiffeners

The net moment of inertia, in cm^4, of web stiffener, I_{st}, fitted on primary supporting members, with effective attached plate, s_{eff}, is not to be less than the minimum moment of inertia defined in Table 2.

Stiffness criteria for web stiffeners **Table 2**

Stiffener arrangement		Minimum moment of inertia of web stiffeners, in cm^4
A	Web stiffeners fitted along the PSM span 	$I_{st} \geq Cl^2 A_{eff} \frac{R_{eH}}{235}$
B	Web stiffeners fitted normal to the PSM span 	$I_{st} \geq 1.14 ls^2 t_w \left(2.5 \frac{1000l}{s} - 2 \frac{s}{1000l} \right) \frac{R_{eH}}{235} \cdot 10^{-5}$

where:
C : Slenderness coefficient to be taken as:
C = 1.43 for longitudinal stiffeners including sniped stiffeners.
C = 0.72 for other stiffeners.
L : Length of web stiffener, in m.
For web stiffeners welded to local supporting members, the length is to be measured between the flanges of the local support members.
For sniped web stiffeners, the length is to be measured between the lateral supports, e.g. the total distance between the flanges of the primary supporting member as shown for stiffener arrangement B.
A_{eff} : Net section area of web stiffener including effective attached plate, s_{eff}, in cm^2.
t_w : Net web thickness of the primary supporting member, in mm.
R_{eH} : Specified minimum yield stress of the material of the web plate of the primary supporting member, in N/mm^2.

5 BRACKETS

5.1 Tripping brackets

5.1.1 Unsupported flange length

The unsupported length of the flange of the primary supporting member, in m, i.e. the distance between tripping brackets, is not to be greater than:

$$s_b = b_f C \sqrt{\frac{A_{f-n50}}{\left(A_{f-n50} + \frac{A_{w-n50}}{3} \right)} \left(\frac{235}{R_{eH}} \right)}$$, but need not be less than $S_{b\text{-}min}$

where:
b_f : Flange breadth of primary supporting members, in mm.
C : Slenderness coefficient taken as:
C = 0.022 for symmetrical flanges.
C = 0.033 for asymmetrical flanges.
$A_{f\text{-}n50}$: Net cross sectional area of flange, in cm^2.
$A_{w\text{-}n50}$: Net cross sectional area of the web plate, in cm^2.
R_{eH} : Specified minimum yield stress of the PSM material, in N/mm^2.
$S_{b\text{-}min}$: Minimum unsupported flange length taken as:
$S_{b\text{-}min}$= 3.0 m for tank/hold boundaries or hull envelope including external decks.
$S_{b\text{-}min}$= 4.0 m for other areas.

5.1.2 Edge stiffening

Tripping brackets on primary supporting members are to be stiffened by a flange or edge stiffener if the effective length of the edge, l_b as defined in Table 3, in mm, is greater than:

$l_b = 75t_b$

where:

t_b : Bracket net web thickness, in mm.

5.2 End brackets

5.2.1 Proportions

The net web thickness of end brackets, in mm, subject to compressive stresses is not to be less than:

$$t_b = \frac{d_b}{C}\sqrt{\frac{R_{eH}}{235}}$$

where:

d_b : Depth of brackets, in mm, as defined in Table 3.

C : Slenderness coefficient as defined in Table 3.

R_{eH} : Specified minimum yield stress of the end bracket material, in N/mm^2.

5.3 Edge reinforcement

5.3.1 Edge reinforcements of bracket edges

The depth of stiffener web, h_w in mm, of edge stiffeners in way of bracket edges is not to be less than:

$h_w = Cl_b / 1000\sqrt{\frac{R_{eH}}{235}}$ or 50 mm, whichever is greater.

where:

C : Slenderness coefficient taken as:

C = 75 for end brackets.

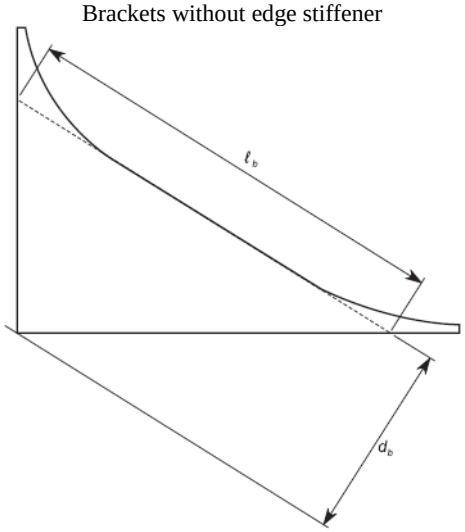
C = 50 for tripping brackets.

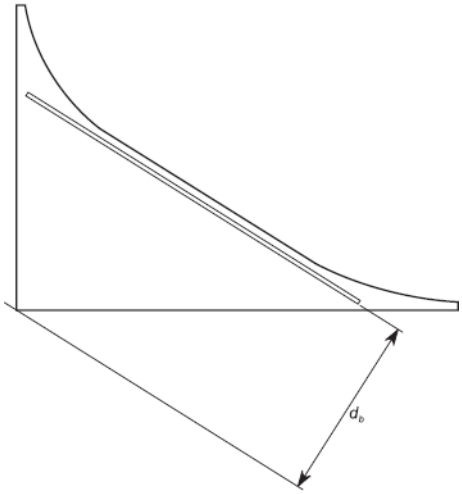
R_{eH} : Specified minimum yield stress of the stiffener material, in N/mm$_2$.

5.3.2 Proportions of edge stiffeners

The net thickness of the web plate and flange of the edge stiffener is to satisfy the requirements specified in[3.1.1] and [3.1.2].

Buckling coefficient, *C*, for proportions of brackets **Table 3**

Mode	*C*
Brackets without edge stiffener 	$C = 20\left(\frac{d_b}{l_b}\right) + 16$ where: $0.25 \le \frac{d_b}{l_b} \le 1.0$

Mode	*C*
Brackets with edge stiffener 	$C = 70$

6 OTHER STRUCTURES

6.1 Pillars

6.1.1 Proportions of I-section pillars

For I-sections, the thickness of the web plate and the flange thickness are to comply with requirements specified in [3.1.1] and [3.1.2].

6.1.2 Proportions of box section pillars

The thickness of thin walled box sections is to comply with the requirements specified in item (a) of [3.1.1].

6.1.3 Proportions of circular section pillars

The net thickness, *t*, of circular section pillars, in mm, is to comply with the following criterion:

$$t \geq \frac{r}{50}$$

where:

r : Mid thickness radius of the circular section, in mm.

6.2 Edge reinforcement in way of openings

6.2.1 Depth of edge stiffener

When fitted as shown in Figure 2, the depth of web, h_w in mm, of edge stiffeners in way of openings is not to be less than:

$h_w = Cl\sqrt{\frac{R_{eH}}{235}}$ or 50 mm, whichever is greater.

where:

C : Slenderness coefficient taken as:

$C = 50$

R_{eH} : Specified minimum yield stress of the edge stiffener material, in N/mm^2.

l : Length of edge stiffener in way of opening, in m, as defined in Figure 2.

6.2.2 Proportions of edge stiffeners

The net thickness of the web plate and flange of the edge stiffener is to satisfy the requirements specified in[3.1.1] and [3.1.2].

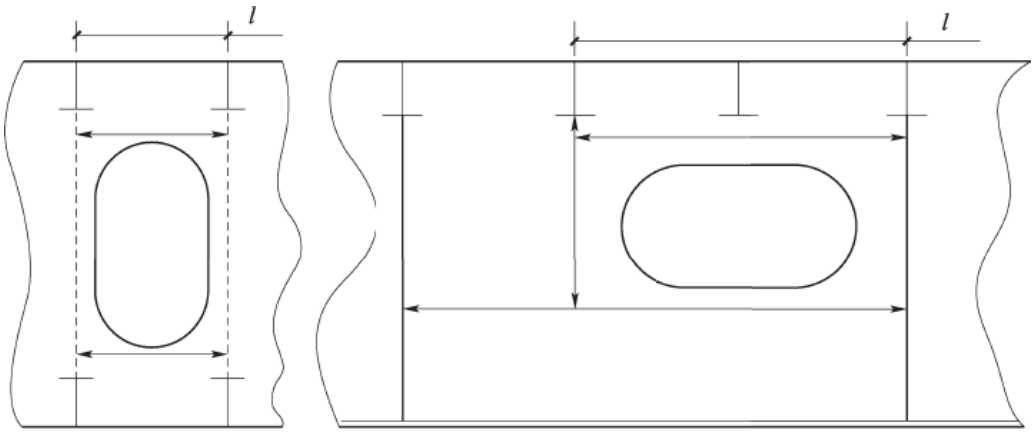


Figure 2 Typical edge reinforcements

Section 3 PRESCRIPTIVE BUCKLING REQUIREMENTS

SYMBOLS

η_{all} : Allowable buckling utilisation factor, as defined in Ch 8, Sec 1, [3.3].
EPP : Elementary Plate Panel as defined in Ch 3, Sec 7, [2.1].
LCP : Load calculation point as defined in Ch 3, Sec 7, [2.2.2] and Ch 3, Sec 7, [3.2].

1 GENERAL

1.1 Scope

1.1.1

This section applies to plate panels including curved plate panels and stiffeners subject to hull girder compression and shear stresses. In addition the following structural members subject to compressive stresses are to be checked:

- Corrugation of longitudinal corrugated bulkhead.
- Strut.
- Pillar.
- Cross tie.

1.1.2

The hull girder buckling strength requirements apply along the full length of the ship.

1.1.3 Design load sets

The buckling checks are to be performed for all design load sets defined in Ch 6, Sec 2, [2], both in intact and in flooded conditions with pressure combination defined in Ch 6, Sec 2, [1.3].
For each design load set, for all dynamic load cases, the lateral pressure is to be determined according to Ch 4 at the load calculation point defined in Ch 3, Sec 7, and is to be applied together with the hull girder stress combinations given in [2.2].

1.2 Equivalent plate panel

1.2.1

In longitudinal stiffening arrangement, when the plate thickness varies over the width *b*, of a plate panel, the buckling check is to be performed for an equivalent plate panel width, combined with the smaller plate thickness, t_1. The width of this equivalent plate panel, b_{eq}, in mm, is defined by the following formula:

$$b_{eq} = l_1 + l_2 \left(\frac{t_1}{t_2} \right)^{1.5}$$

where:

l_1: Width of the part of the net plate panel with the smaller net plate thickness, t_1, in mm, as defined in Figure 1.

l_2: Width of the part of the net plate panel with the greater net plate thickness, t_2, in mm, as defined in Figure 1.

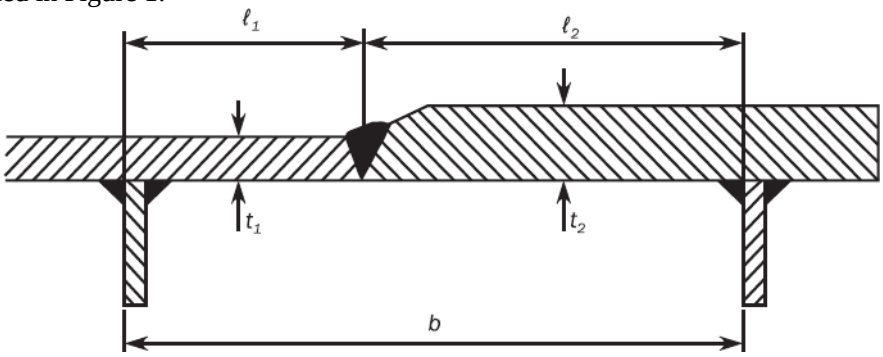


Figure 1 Plate thickness change over the width

1.2.2

In transverse stiffening arrangement, when an EPP is made with different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the EPP, the stresses and pressures being estimated for the EPP at the LCP.

1.2.3 Materials

When the plate panel is made of different materials, the minimum yield strength is to be used for the buckling assessment.

2 HULL GIRDER STRESS

2.1 General

2.1.1

The hull girder bending stresses, σ_{hg}, in N/mm^2, are determined according to Ch 6, Sec 2.

2.1.2

The hull girder shear stresses, τ_{hg}, in N/mm^2, in the plate *i* are determined as follows:

$$\tau_{hg} = \frac{Q_{Tot}(x) q_{vi}}{t_{i-n50}} 10^3$$

where:

$Q_{Tot}(x)$: Total vertical shear force, in kN, at the ship longitudinal location *x*, taken as follows:

- For the design load combination S+D
  - For seagoing operations:
    $$Q_{Tot}(x) = \left| Q_{sw} + Q_{wv-LC} \right|$$
  - For flooded conditions at sea for bulk carriers having a freeboard length L_{LL} of 150 m or above:
    $$Q_{Tot}(x) = \left| Q_{sw-f} + Q_{wv-LC} \right|$$
- For the design load combination S
  - For harbour/sheltered water operations:
    $$Q_{Tot}(x) = \left| Q_{sw-p} \right|$$

q_{vi} : Contribution ratio in way of the plate *i*, as defined in Ch 5, Sec 1, [3.2.1].

$t_{i\text{-}n50}$: Net thickness of the plate *i*, in mm as defined in Ch 5, Sec 1, [3.2.1], used for shear stress calculation.

Q_{sw} : Permissible positive or negative still water shear force for seagoing operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.3].

$Q_{sw\text{-}p}$: Permissible positive or negative still water shear force for harbour/sheltered operation, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.4].

$Q_{sw\text{-}f}$: Permissible positive or negative still water shear force in flooded condition at sea, in kN, at the hull transverse section considered, as defined in Ch 4, Sec 4, [2.3.5].

$Q_{wv\text{-}LC}$: Vertical wave shear force in seagoing condition, in kN, in intact or flooded conditions at the hull transverse section considered for the considered dynamic load case, defined in Ch 4, Sec 4, [3.5.3].

2.2 Stress combinations

2.2.1

Each elementary plate panel and stiffeners are to satisfy the criteria defined in [3] with the following stress combinations:

a) Longitudinal stiffening arrangement:
   - Stress combination 1 with:
     $\sigma_x = \sigma_{hg}$
     $\sigma_y = 0$
     $\tau = 0.7\tau_{hg}$
   - Stress combination 2 with:
     $\sigma_x = 0.7\sigma_{hg}$
     $\sigma_y = 0$

$\tau = \tau_{hg}$

b) Transverse stiffening arrangement:

- Stress combination 1 with:
  $\sigma_x = 0$
  $\sigma_y = \sigma_{hg}$
  $\tau = 0.7\tau_{hg}$
- Stress combination 2 with:
  $\sigma_x = 0$
  $\sigma_y = 0.7\sigma_{hg}$
  $\tau = \tau_{hg}$

where:

σ_{hg} : Hull girder bending stress in the elementary plate panel or stiffener, as defined in [2.1.1], in N/mm^2.

τ_{hg} : Hull girder shear stress, in N/mm^2, in the elementary plate panel or stiffener attached plate as defined in [2.1.2].

3 BUCKLING CRITERIA

3.1 Overall stiffened panel

3.1.1

The buckling strength of overall stiffened panels is to satisfy the following criterion:

$\eta_{Overall} \leqslant \eta_{all}$

where:

$\eta_{Overall}$: Maximum utilisation factor as defined in Ch 8, Sec 5, [2.1].

3.2 Plates

3.2.1

The buckling strength of elementary plate panels is to satisfy the following criterion:

$\eta_{Plate} \leqslant \eta_{all}$

where:

η_{Plate} : Maximum plate utilisation factor calculated according to SP-A, as defined in Ch 8, Sec 5, [2.2].

For the determination of η_{Plate} of the vertically stiffened side shell plating of single side skin bulk carrier between hopper and topside tanks, the cases 12 and 16 of Ch 8, Sec 5, Table 3 corresponding to the shorter edge of the plate panel clamped are to be considered together with a mean σ_y stress and $\Psi_y = 1$.

3.3 Stiffeners

3.3.1

The buckling strength of stiffeners or of side frames of single side skin bulk carriers is to satisfy the following criterion:

$\eta_{Stiffener} \leqslant \eta_{all}$

where:

$\eta_{Stiffener}$: Maximum stiffener utilisation factor, as defined in Ch 8, Sec 5, [2.3].

Note 1: This capacity check can only be fulfilled when the overall stiffened panel capacity, as defined in [3.1.1], is satisfied.

3.4 Vertically corrugated longitudinal bulkheads

3.4.1

The shear buckling strength of vertically corrugated longitudinal bulkheads is to satisfy the following criterion:

$\eta_{Shear} \leqslant \eta_{all}$

where:

η_{Shear} : Maximum shear corrugated bulkhead utilisation factor.

$$\eta_{Shear} = \frac{\tau_{bhd}}{\tau_c}$$

τ_{bhd} : Hull girder shear stress, in N/mm^2, in the longitudinal bulkhead as defined in [2.1.2].
τ_c: Shear critical stress, in N/mm^2, as defined in Ch 8, Sec 5, [2.2.3].

3.5 Horizontally corrugated longitudinal bulkhead

3.5.1

Each corrugation, within the extension of half flange, web and half flange, is to satisfy the following criterion:

$\eta \leqslant \eta_{all}$

where:

η : Overall column utilisation factor, as defined in Ch 8, Sec 5, [3.1].

3.6 Struts, pillars and cross ties

3.6.1

The compressive buckling strength of struts, pillars and cross ties is to satisfy the following criterion:

$\eta \leqslant \eta_{all}$

where:

η : Maximum buckling utilisation factor of struts, pillars or cross ties, defined in Ch 8, Sec 5, [3.1].

Section 4 BUCKLING REQUIREMENTS FOR DIRECT STRENGTH ANALYSIS

SYMBOLS

η_{all} : Allowable buckling utilisation factor, as defined in Ch 8, Sec 1, [3.3].

α : Aspect ratio of the plate panel, defined in Ch 8, Sec 5.

1 GENERAL

1.1 Scope

1.1.1

The requirements of this Section apply for the buckling assessment of direct strength analysis subjected to compressive stress, shear stress and lateral pressure.

1.1.2

All structural elements in the FE analysis carried out according to Ch 7 are to be assessed individually. The buckling checks have to be performed for the following structural elements:

- Stiffened and unstiffened panels, inclusive curved panels.
- Web plate in way of openings.
- Corrugated bulkhead.
- Vertically stiffened side shell of single side skin bulk carrier.
- Struts, pillars and cross ties.

2 STIFFENED AND UNSTIFFENED PANELS

2.1 General

2.1.1

The plate panel of hull structure is to be modelled as stiffened or unstiffened panel. Method A and Method B as defined in Ch 8, Sec 1, [3] are to be used according to Table 1 and Figure 1 to Figure 9.

2.1.2 Average thickness of plate panel

Where the plate thickness along a plate panel is not constant, the panel used for the buckling assessment is to be modelled according to Ch 7 with a weighted average thickness taken as:

$$t_{avr} = \frac{\sum_{1}^{n} A_i t_i}{\sum_{1}^{n} A_i}$$

where:

Ai : Area of the *i*-th plate element.

ti : Net thickness of the *i*-th plate element.

n : Number of finite elements defining the buckling plate panel.

Structural members **Table 1**

Structural elements	Assessment method	Normal panel definition
Longitudinal structure, see Figure 1, Figure 5 and Figure 7		
Longitudinally stiffened panels Shell envelope Deck Inner hull Hopper tank side Longitudinal bulkheads	SP-A	Length: between web frames Width: between primary supporting members
Double bottom longitudinal girders in line with longitudinal bulkhead or connected to hopper tank side	SP-A	Length: between web frames Width: full web depth

Structural elements	Assessment method	Normal panel definition
Web of double bottom longitudinal girders not in line with longitudinal bulkhead or not connected to hopper tank side	SP-B	Length: between web frames Width: full web depth
Web of horizontal girders in double side space connected to hopper tank side	SP-A	Length: between web frames Width: full web depth
Web of horizontal girders in double side space not connected to hopper tank side	SP-B	Length: between web frames Width: full web depth
Web of single skin longitudinal girders or stringers	UP-B	Plate between local stiffeners/face plate/PSM
Transverse structure, see Figure 2, Figure 6 and Figure 8		
Web of transverse deck frames including brackets	UP-B	Plate between local stiffeners/face plate/PSM
Vertical web in double side space	SP-B	Length: full web depth Width: between primary supporting members
Irregularly stiffened panels, e.g. web panels in way of hopper tank and bilge	UP-B	Plate between local stiffeners/face plate/PSM
Double bottom floors	SP-B	Length: full web depth Width: between primary supporting members
Vertical web frame including brackets	UP-B	Plate between vertical web stiffeners/face plate/PSM
Cross tie web plate	UP-B	Plate between vertical web stiffeners/face plate/PSM
Transverse oil-tight and watertight bulkheads, see Figure 3 and transverse wash bulkheads, see Figure 4		
Regularly stiffened bulkhead panels inclusive the secondary buckling stiffeners perpendicular to the regular stiffener (such as carlings)	SP-A	Length: between primary supporting members Width: between primary supporting members
Irregularly stiffened bulkhead panels, e.g. web panels in way of hopper tank and bilge	UP-B	Plate between local stiffeners/face plate
Web plate of bulkhead stringers including brackets	UP-B	Plate between web stiffeners /face plate
Transverse corrugated bulkheads and cross deck, see Figure 9		
Upper/lower stool including stiffeners	SP-A	Length: between internal web diaphragms Width: length of stool side
Stool internal web diaphragm	UP-B	Plate between local stiffeners /face plate / PSM

Structural elements	Assessment method	Normal panel definition
Cross deck	SP-A	Plate between local stiffeners/ PSM
Note1: SP and UP stand for stiffened and unstiffened panel respectively. Note2: A and B stand for Method A and Method B respectively.		

2.1.3 Yield stress of the plate panel

The panel yield stress R_{eH_P} is taken as the minimum value of the specified yield stresses of the elements within the plate panel.

2.2 Stiffened panels

2.2.1

To represent the overall buckling behaviour, each stiffener with attached plate is to be modelled as a stiffened panel of the extent defined in Table 1.

2.2.2

If the stiffener properties or stiffener spacing varies within the stiffened panel, the calculations are to be performed separately for all configurations of the panels, i.e. for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel.

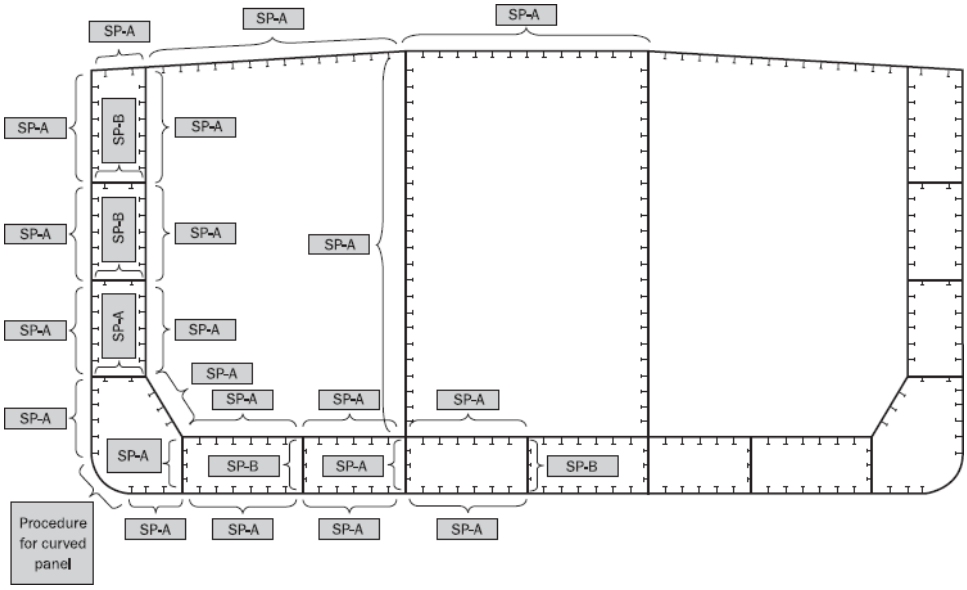


Figure 1 Longitudinal plates for oil tankers

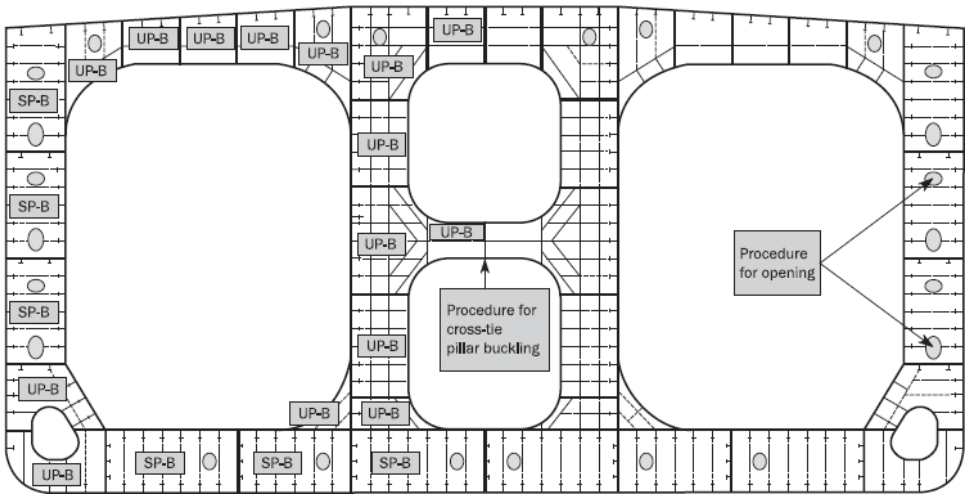


Figure 2 Transverse web frames for oil tankers

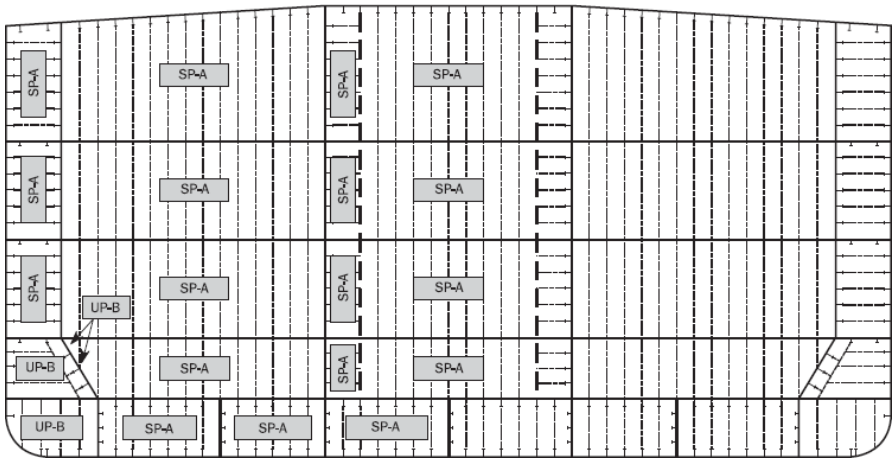


Figure 3 Transverse bulkhead for oil tankers

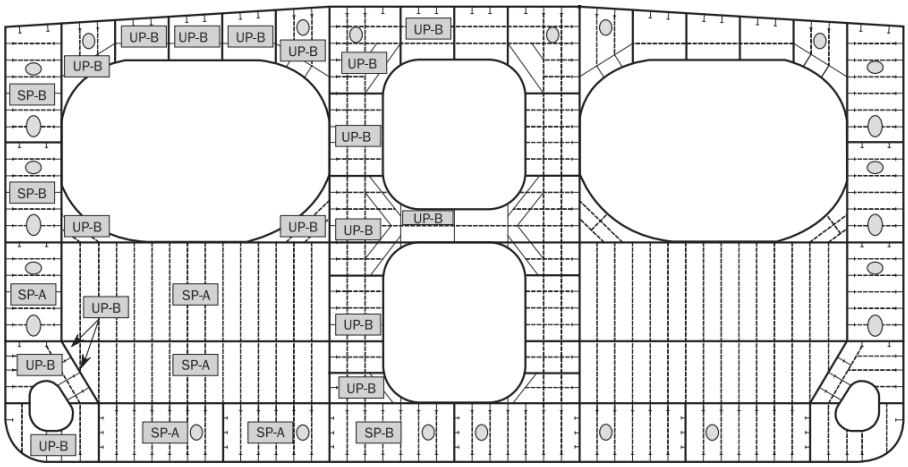


Figure 4 Cross tie

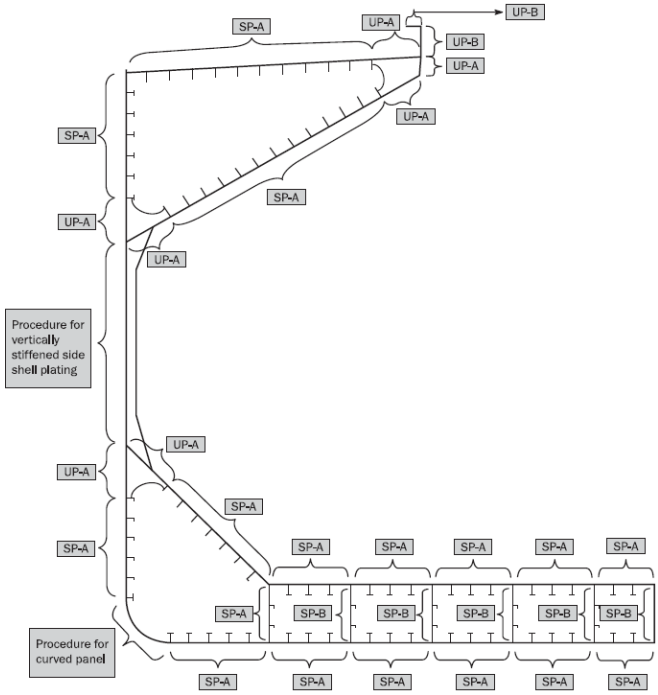


Figure 5 Longitudinal plates for single hull bulk carrier

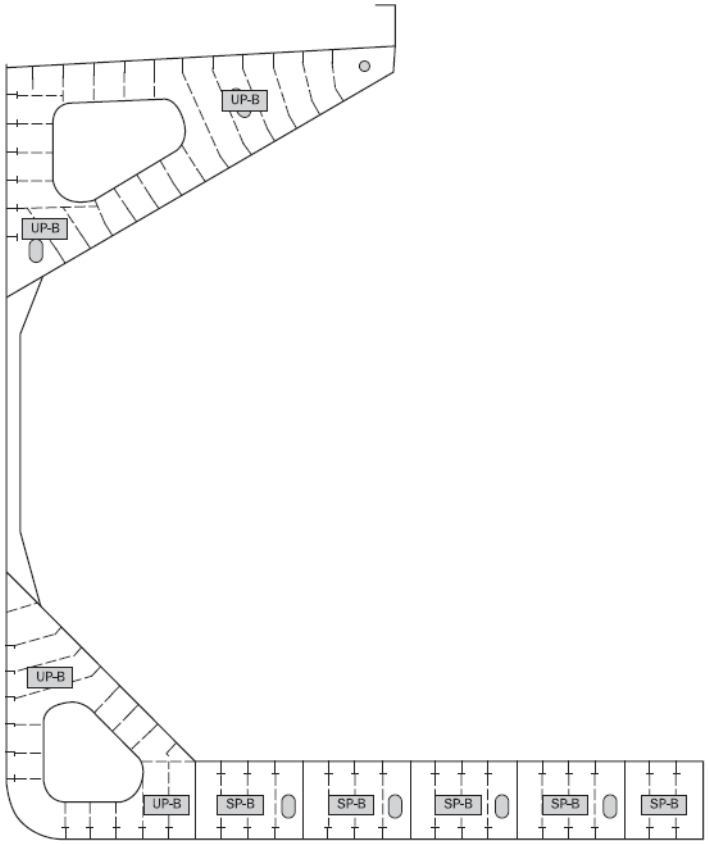


Figure 6 Transverse web frames for single hull bulk carrier

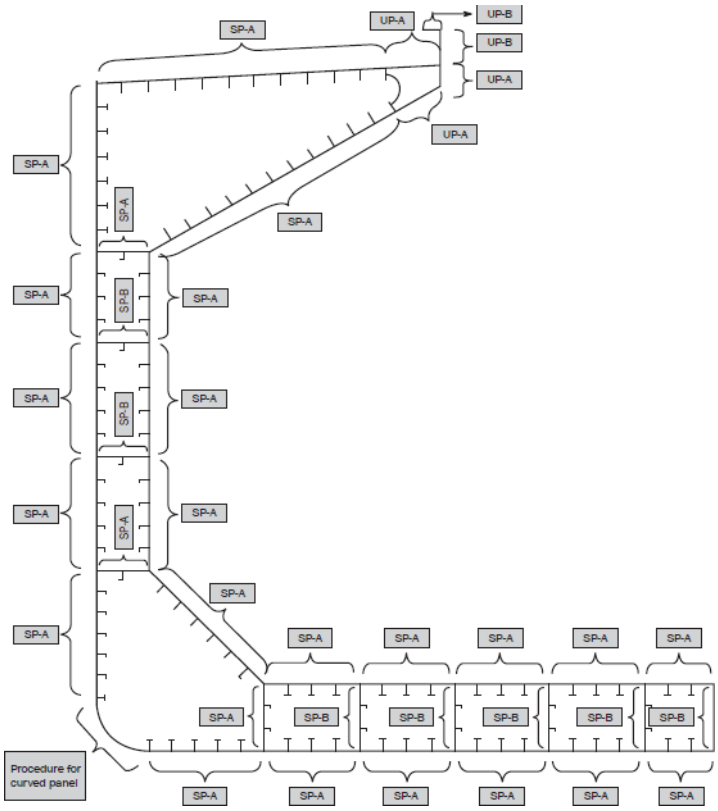


Figure 7 Longitudinal plates for double hull bulk carrier

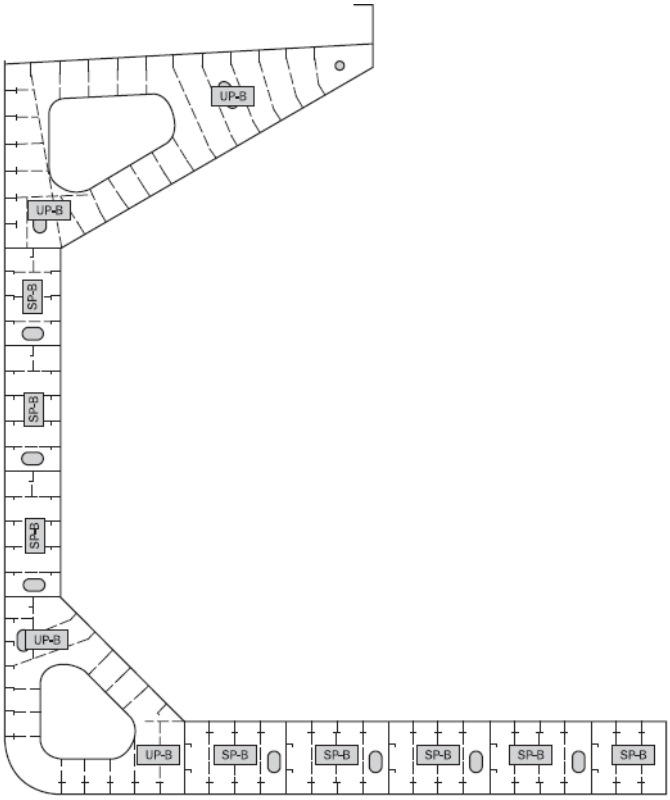


Figure 8 Transverse web frames for double hull bulk carrier

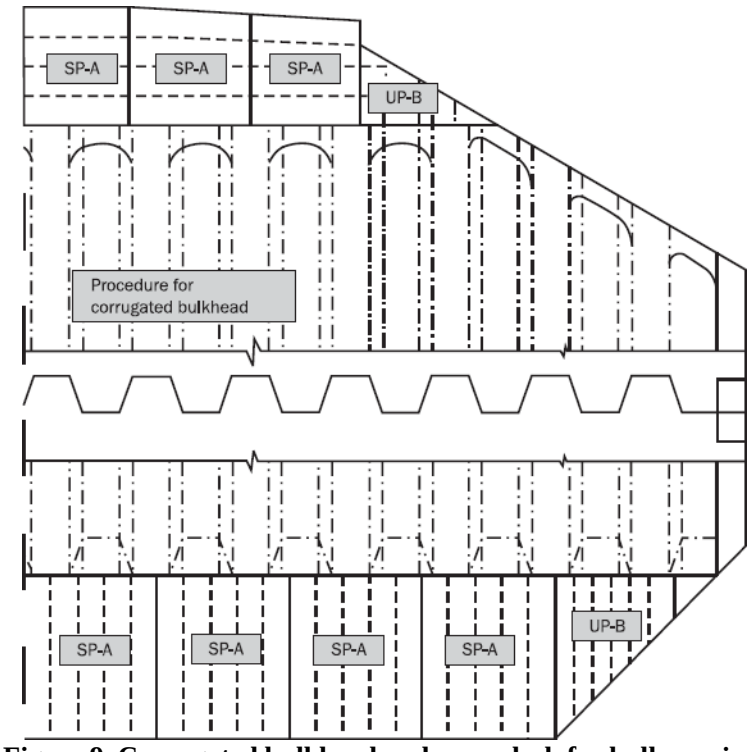


Figure 9 Corrugated bulkhead and cross deck for bulk carriers

2.3 Unstiffened panels

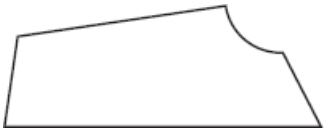
2.3.1 Irregular plate panel

In way of web frames, stringers and brackets, the geometry of the panel (i.e. plate bounded by web stiffeners/face plate) may not have a rectangular shape. In this case, an equivalent rectangular panel is to be defined according to [2.3.2] for irregular geometry and [2.3.3] for triangular geometry and to comply with buckling assessment.

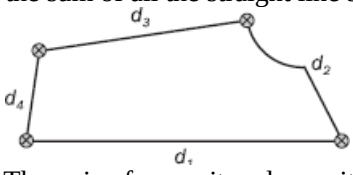
2.3.2 Modelling of an unstiffened panel with irregular geometry

Unstiffened panels with irregular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

a) The four corners closest to a right angle, 90 deg, in the bounding polygon for the plate are identified.

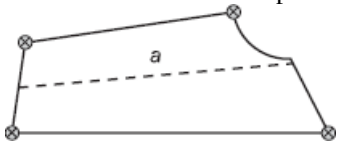


b) The distances along the plate bounding polygon between the corners are calculated, i.e. the sum of all the straight line segments between the end points.

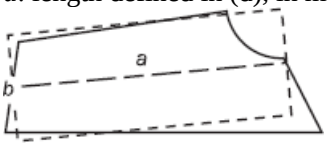


c) The pair of opposite edges with the smallest total length is identified, i.e. minimum of $d_1 + d_3$ and $d_2 + d_4$

d) A line joins the middle points of the chosen opposite edges (i.e. a mid point is defined as the point at half the distance from one end). This line defines the longitudinal direction for the capacity model. The length of the line defines the length of the capacity model, a measured from one end point.



e) The length of shorter side, b in mm, is to be taken as:
$b = A/a$
where:
A: Area of the plate, in mm^2
a: length defined in (d), in mm

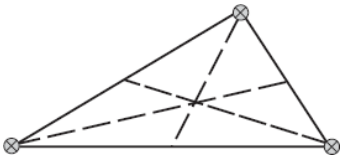


f) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.

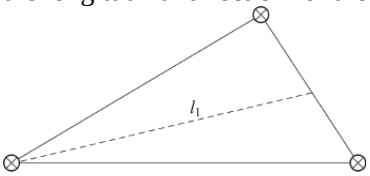
2.3.3 Modelling of an unstiffened plate panel with triangular geometry

Unstiffened panels with triangular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

a) Medians are constructed as shown below.

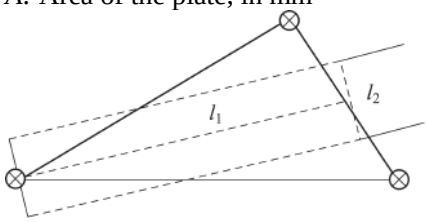


b) The longest median is identified. This median the length of which is l_1, in mm, defines the longitudinal direction for the capacity model.



c) The width of the model, l_2, in mm, is to be taken as:

$l_2 = A / l_1$
where:
A: Area of the plate, in mm^2



d) The lengths of shorter side, *b*, and of the longer side, *a*, in mm, of the equivalent rectangular plate panel are to be taken as:

$$b = \frac{l_2}{C_{tri}}$$

$a = l_1 C_{tri}$
where:

$$C_{tri} = 0.4\frac{l_2}{l_1} + 0.6$$

e) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel and are to be used for the buckling assessment of the equivalent rectangular panel.

2.4 Reference stress

2.4.1

The stress distribution is to be taken from the direct strength analysis and applied to the buckling model.

2.4.2

The reference stresses are to be calculated using the Stress based reference stresses as defined in App 1.

2.5 Lateral pressure

2.5.1

The lateral pressure applied to the direct strength analysis is also to be applied to the buckling assessment.

2.5.2

Where the lateral pressure is not constant over a buckling panel defined by a number of finite plate elements, an average lateral pressure, N/mm^2, is calculated using the following formula:

$$P_{avr} = \frac{\sum_{1}^{n} A_i P_i}{\sum_{1}^{n} A_i}$$

where:
A_i : Area of the *i*-th plate element, in mm^2.
P_i : Lateral pressure of the *i*-th plate element, in N/mm^2.
n : Number of finite elements in the buckling panel.

2.6 Buckling criteria

2.6.1 UP-A

The compressive buckling strength of UP-A is to satisfy the following criterion:

$\eta_{UP\text{-}A} \leqslant \eta_{all}$
where:
$\eta_{UP\text{-}A}$: Maximum plate utilisation factor, calculated according to Method A as defined in Ch 8, Sec 5, [2.2].

2.6.2 UP-B

The compressive buckling strength of UP-B is to satisfy the following criterion:

$\eta_{UP\text{-}B} \leqslant \eta_{all}$

where:

$\eta_{UP\text{-}B}$: Maximum plate utilisation factor, calculated according to Method B as defined in Ch 8, Sec 5, [2.2].

2.6.3 SP-A

The compressive buckling strength of SP-A is to satisfy the following criterion:

$\eta_{SP\text{-}A} \leqslant \eta_{all}$

where:

$\eta_{SP\text{-}A}$: Maximum stiffened panel utilisation factor taken as the maximum of:

- The overall stiffened panel capacity as defined in Ch 8, Sec 5, [2.1].
- The plate capacity calculated according to Method A as defined in Ch 8, Sec 5, [2.2].
- The stiffener buckling strength as defined in Ch 8, Sec 5, [2.3] considering separately the properties (thickness, dimensions), the pressures defined in [2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note1: The stiffener buckling capacity check can only be fulfilled when the overall stiffened panel capacity, as defined in Ch 8, Sec 5, [2.1], is satisfied.

2.6.4 SP-B

The compressive buckling strength of SP-B is to satisfy the following criterion:

$\eta_{SP\text{-}B} \leqslant \eta_{all}$

where:

$\eta_{SP\text{-}B}$: Maximum stiffened panel utilisation factor taken as the maximum of:

- The overall stiffened panel capacity as defined in Ch 8, Sec 5, [2.1].
- The plate capacity calculated according to Method B as defined in Ch 8, Sec 5, [2.2].
- The stiffener buckling strength as defined in Ch 8, Sec 5, [2.3] considering separately the properties (thickness, dimensions), the pressures defined in [2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note1: The stiffener buckling capacity check can only be fulfilled when the overall stiffened panel capacity, as defined in Ch 8, Sec 5, [2.1], is satisfied.

2.6.5 Web plate in way of openings

The web plate of primary supporting members with openings is to satisfy the following criterion:

$\eta_{opening} \leqslant \eta_{all}$

where:

$\eta_{opening}$: Maximum web plate utilisation factor in way of openings, as defined in Ch 8, Sec 5, [2.4].

3 CORRUGATED BULKHEAD

3.1 General

3.1.1

Three buckling failure modes are to be assessed on corrugated bulkheads:

- Corrugation overall column buckling.
- Corrugation flange panel buckling.
- Corrugation web panel buckling.

3.2 Reference stress

3.2.1

Each corrugation flange and web panel is to be assessed.

3.2.2

The membrane stresses at element centroid are to be used.

3.2.3

The maximum normal stress parallel to the corrugation, σ_x, is the maximum of the 2 following stresses:

- The normal stress parallel to the corrugation taken at $b/2$ from the corrugation ends,
- The normal stress parallel to the corrugation within the mid span of the corrugation.

When the corrugation end is fitted with a shedder plate, the normal stress parallel to the corrugation at end is to be taken at $b/2$ from the intersection of the shedder plate with the point at mid breadth of the flange or of the web, as the case may be.

The maximum shear stress is the shear stress which is maximum at the corrugation flange or web at the point

$b/2$ from ends as defined above for the normal stress parallel to the corrugation.

The in plane stresses, σ_x and σ_y, and shear stress, τ, are to be taken as the element stresses averaged over the width of the considered member (flange or web) at the considered location.

When the stress value at $b/2$ from ends cannot be obtained directly from FE element, the stress at this location is to be obtained by interpolation. This interpolation is to be made on elements extending over a distance equal to $3b$ to a point located at $b/2$ from the end of the corrugation or from the intersection of the shedder plate if fitted, measured at the mid breadth of the flange or of the web. The interpolation of the in plane stresses, σ_x and σ_y, are to be made in accordance with Ch 8, App 1, [2.1].

The shear stress at $b/2$ is obtained by linear interpolation between the elements most close to '$b/2$' location. For the application of this requirement, b is defined as follows:

b : Width of the considered member of the corrugation, i.e. flange or web.

3.2.4

Where more than one plate thicknesses are used for flange or web panel, maximum stress is to be obtained for each thickness range and to be checked with the buckling criteria for each thickness.

3.3 Overall column buckling

3.3.1

The overall buckling failure mode of corrugated bulkheads subjected to axial compression is to be checked for column buckling (e.g. horizontally corrugated bulkheads and vertically corrugated bulkheads subjected to local vertical forces).

Application of overall column buckling for corrugated bulkhead Table 2

Bulkhead orientation	Corrugation Orientation	
	Horizontal	Vertical
Longitudinal bulkhead	Required	Required, when subjected to local vertical forces (e.g. crane loads)
Transverse bulkhead	Required	

3.3.2

Each corrugation unit within the extension of half flange, web and half flange (i.e. single corrugation as shown in grey in Figure 10) is to satisfy the following criterion:

$\eta_{Overall} \leqslant \eta_{all}$

where:

$\eta_{Overall}$: Maximum overall column utilisation factor, as defined in Ch 8, Sec 5, [3.1.1] and Ch 8, Sec 5, [3.1.2], considered as a pillar with a unsupported length taken as the length of the corrugation.

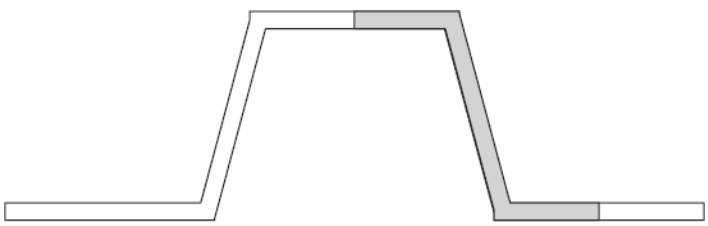


Figure 10 Single Corrugation

3.3.3
End constraint factor, f_{end} corresponding to pinned ends is to be applied except for fixed end support to be used in way of stool with width exceeding 2 times the depth of the corrugation.

3.4 Local buckling

3.4.1
The compressive buckling strength of a unit flange and a unit web of corrugation bulkheads is to satisfy the following criterion:

$\eta_{Corr} \leqslant \eta_{all}$

where:

η_{Corr} : Maximum unit flange or unit web utilisation factor, as defined in Ch 8, Sec 5, [3.2.1].

Two stress combinations are to be considered for the application of the above criterion:

- The maximum normal stress parallel to the corrugation, σ_x, combined with the stress perpendicular to the corrugation, σ_y, and with the shear stress, τ, at the location where the maximum normal stress parallel to the corrugation occurs.
- The maximum shear stress, τ, combined with the normal stress parallel to the corrugation, σ_x, and with the stress perpendicular to the corrugation, σ_y, at the location where the maximum shear stress occurs.

The buckling assessment is to be performed for an aspect ratio α equal to 2, and for the thicknesses of the member where the maximum compressive/shear stress occurs (see [3.2.4]).

4 VERTICALLY STIFFENED SIDE SHELL OF SINGLE SIDE SKIN BULK CARRIER

4.1 Buckling criteria

4.1.1 Side shell plating

The compressive buckling strength of the vertically stiffened side shell plating of single side skin bulk carrier is to satisfy the following criterion:

$\eta_{vss} \leqslant \eta_{all}$

where:

η_{vss}: Maximum vertically stiffened side shell plating utilisation factor calculated according to Method A as defined in Ch 8, Sec 5, [2.2.1] and considering the following boundary conditions and stress combinations:

- 4 edges simply supported (cases 1, 2 and 15 of Ch 8, Sec 5, Table 3):
  - Pure vertical stress:
    - The maximum vertical stress of stress elements is used with $\alpha = 1$ and $\Psi_x = 1$.
  - Maximum vertical stress combined with longitudinal and shear stress:
    - The maximum vertical stress in the buckling panel plus the shear and longitudinal stresses at the location where the maximum vertical stress occurs is used with $\alpha = 2$ and $\Psi_x = \Psi_y = 1$.
    - The plate thickness to be considered in the buckling strength check is the one where the maximum vertical stress occurs.
  - Maximum shear stress combined with longitudinal and vertical stress:
    - The maximum shear stress in the buckling panel plus the longitudinal and vertical stresses at the location where maximum shear stress occurs is used with $\alpha = 2$ and $\Psi_x = \Psi_y = 1$.
    - The plate thickness to be considered in the buckling strength check is the one where the maximum shear stress occurs.
- The 2 shorter edges of the plate panel clamped (cases 11, 12 and 16 of Ch 8, Sec 5, Table 3):
  - Distributed longitudinal stress associated with vertical and shear stress:
    - The actual size of the buckling panel is used to define α.
    - The average values for longitudinal, vertical and shear stresses are to be used.
    - $\Psi_x = \Psi_y = 1$.

- The plate thickness to be considered in the buckling strength check is the minimum thickness of the buckling panel.

4.1.2 Side frames

The buckling strength of side frames of single side skin bulk carriers is to satisfy the following criterion:

$\eta_{Stiffener} \leqslant \eta_{all}$

where:

$\eta_{Stiffener}$: Maximum stiffener utilisation factor, as defined in Ch 8, Sec 5, [2.3].

5 STRUTS, PILLARS AND CROSS TIES

5.1 Buckling criteria

5.1.1

The compressive buckling strength of struts, pillars and cross ties is to satisfy the following criterion:

$\eta_{Pillar} \leqslant \eta_{all}$

The buckling strength of elementary plate panels of cross ties is to satisfy the following criterion:

$\eta_{Pillar} \leqslant \eta_{all}$

where:

η_{Pillar} : Maximum utilisation factor of struts, pillars or cross ties, as defined in Ch 8, Sec 5, [3.1].

η_{Plate} : Maximum plate utilisation factor calculated according to UP-B, as defined in Ch 8, Sec 5, [2.2].

Section 5 BUCKLING CAPACITY

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

A_s : Net sectional area of the stiffener without attached plating, in mm^2.

A_p : Net sectional area of the stiffener attached plating, in mm^2, taken as:

$A_p = st_p$

a : Length of the longer side of the plate panel, in mm.

b : Length of the shorter side of the plate panel, in mm.

b_{eff} : Effective width of the attached plating of a stiffener, in mm, as defined in [2.3.5].

b_{eff1} :Effective width of the attached plating of a stiffener, in mm, without the shear lag effect taken as:

- For $\sigma_x > 0$
  - For prescriptive assessment:

$$b_{eff1} = \frac{C_{x1}b_1 + C_{x2}b_2}{2}$$

  - For FE analysis:

$b_{eff1} = C_x b$

- For $\sigma_x \leqslant 0$

$b_{eff1} = b$

b_f : Breadth of the stiffener flange, in mm.

b_1, b_2 : Width of plate panel on each side of the considered stiffener, in mm.

C_{x1},C_{x2} : Reduction factor defined in Table 3 calculated for the EPP1 and EPP2 on each side of the considered stiffener according to case 1.

d : Length of the side parallel to the axis of the cylinder corresponding to the curved plate panel as shown in Table 4, in mm.

d_f : Distance in mm, for the extension of flange for L2 profiles, as defined in Ch3, Sec2, Figure 3.

e_f : Distance from attached plating to centre of flange, in mm, as shown in Figure 1 to be taken as:

$e_f = h_w$ for flat bar profile.

$e_f = h_w - 0.5t_f$ for bulb profile.

$e_f = h_w + 0.5t_f$ for angle, L2 and Tee profiles.

F_{long} : Coefficient defined in [2.2.4].

F_{tran} : Coefficient defined in [2.2.5].

h_w : Depth of stiffener web, in mm, as shown in Figure 1.

l : Span, in mm, of stiffener equal to spacing between primary supporting members or span of side frame equal to the distance between the hopper tank and top wing tank as defined in Pt 2, Ch 1, Sec 2, Figure 2.

R : Radius of curved plate panel, in mm.

R_{eH_P} : Specified minimum yield stress of the plate in N/mm^2.

R_{eH_S} : Specified minimum yield stress of the stiffener in N/mm^2.

S : Partial safety factor to be taken as:

- S = 1.1 for structures which are exposed to local concentrated loads (e.g. container loads on hatch covers, foundations).
- S = 1.15 for bulk carrier stiffeners located on the hatchway coamings, the sloping plate of the topside and hopper tanks, the inner bottom, the inner side if any, the side shell of single side skin construction and the top and bottom stools of transverse bulkheads.
- S = 1.0 for all other cases.

t_p : Net thickness of plate panel, in mm.

t_w : Net stiffener web thickness, in mm.

t_f : Net flange thickness, in mm.

x axis : Local axis of a rectangular buckling panel parallel to its long edge.

y axis : Local axis of a rectangular buckling panel perpendicular to its long edge.

α : Aspect ratio of the plate panel, defined in Table 3 to be taken as:

$$\alpha = \frac{a}{b}$$

β : Coefficient taken as:

$$\beta = \frac{1 - \Psi}{\alpha}$$

ω : Coefficient taken as:

$\omega = \min(3; \sigma)$

σ_x : Stress applied on the edge along x axis of the buckling panel, in N/mm^2.

σ_y : Stress applied on the edge along y axis of the buckling panel, in N/mm^2.

σ_1 : Maximum stress, in N/mm^2.

σ_2 : Minimum stress, in N/mm^2.

σ_E : Elastic buckling reference stress, in N/mm^2 to be taken as:

- For the application of plate limit state according to [2.2.1]:

$$\sigma_E = \frac{\pi^2 E}{12(1-v^2)}\left(\frac{t_p}{b}\right)^2$$

- For the application of curved plate panels according to [2.2.6]:

$$\sigma_E = \frac{\pi^2 E}{12(1-v^2)}\left(\frac{t_p}{d}\right)^2$$

τ : Applied shear stress, in N/mm^2.

τ_c : Buckling strength in shear, in N/mm^2, as defined in [2.2.3].

ψ : Edge stress ratio to be taken as:

$$\psi = \frac{\sigma_2}{\sigma_1}$$

γ : Stress multiplier factor acting on loads. When the factor is such that the loads reach the interaction formulae, $\gamma = \gamma_c$.

γ_c : Stress multiplier factor at failure.

γ_{GEB} : Stress multiplier factor of global elastic buckling capacity.

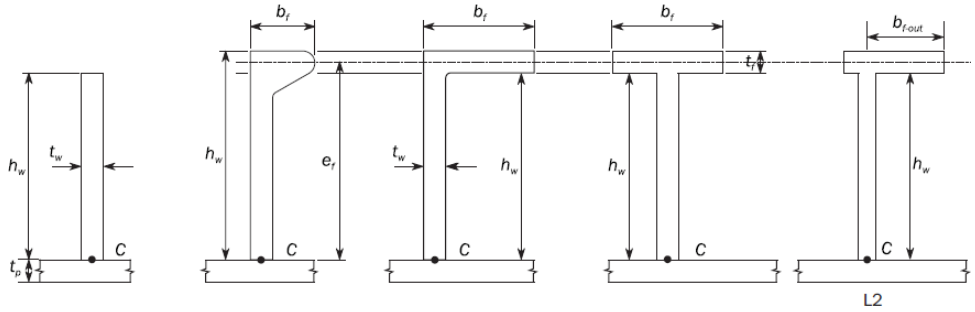


Figure 1 Stiffener cross sections

1 General

1.1 Scope

1.1.1

This section contains the methods for determination of the buckling capacity of plate panels, stiffeners, pri- mary supporting members, struts, pillars, cross ties and corrugated bulkheads.

1.1.2

For the application of this section, the stresses σ_x, σ_y and τ applied on the structural members are defined in:

- Ch 8, Sec 3 for prescriptive requirements.
- Ch 8, Sec 4 for FE analysis requirements.

1.1.3 Ultimate buckling capacity

The ultimate buckling capacity is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until the interaction formulae defined in [2.1.1], [2.2.1], and [2.3.4] are equal to 1.0.

1.1.4 Buckling utilisation factor

The buckling utilisation factor of the structural member is equal to the highest utilisation factor obtained for the different buckling modes.

1.1.5 Lateral pressure

The lateral pressure is to be considered as constant in the buckling strength assessment.

2 Buckling Capacity of Plates and Stiffeners

2.1 Overall stiffened panel capacity

2.1.1

The elastic stiffened panel limit state is based on the following interaction formula, which sets a precondition for the buckling check of stiffeners in accordance with [2.3.4]:

$$\frac{\gamma}{\gamma_{GEB}} = 1$$

where the stress multiplier factor corresponding to global elastic buckling capacity, γ_{GEB} , is to be calculated based on the following formulae:

$\gamma_{GEB} = \gamma_{GEB,bi+\tau}$ for $\tau \neq 0$ and ($\sigma x > 0$ or $\sigma y > 0$)

$\gamma_{GEB} = \gamma_{GEB,bi}$ for $\tau = 0$ and ($\sigma x > 0$ or $\sigma y > 0$)

$\gamma_{GEB} = \gamma_{GEB,\tau}$ for $\tau \neq 0$ and ($\sigma x \leqslant 0$ and $\sigma y \leqslant 0$)

where $\gamma_{GEB,bi+\tau}$, $\gamma_{GEB,bi}$, and $\gamma_{GEB,\tau}$ are stress multiplier factors for different load combinations as defined in [2.1.2], [2.1.3] and [2.1.4], respectively. For the calculation of $\gamma_{GEB,i+\tau}$, $\gamma_{GEB,bi}$, and $\gamma_{GEB,\tau}$, neither σ_x nor σ_y shall be taken less than 0.

σ_x, σ_y : Applied normal stresses to the plate panel, in N/mm^2, to be taken as defined in [2.2.7].

τ : Applied shear stress, in N/mm^2, to be taken as defined in [2.2.7].

2.1.2

The stress multiplier factor $\gamma_{GEB,i}$, for the stiffened panel subjected to biaxial loads is taken as:

$$\gamma_{GEB,bi} = \frac{\pi^2}{L_{B1}^2 L_{B2}^2} \frac{\left[D_{11} L_{B2}^4 + 2(D_{12} + D_{33}) n^2 L_{B1}^2 L_{B2}^2 + n^4 D_{22} L_{B1}^4 \right]}{L_{B2}^2 N_x + n^2 L_{B1}^2 N_y}$$

where:

N_x : Load per unit length applied on the edge along x axis of the stiffened panel, in N/mm, taken as

$$N_x = \sigma_{x,av}(A_p + A_s) / s$$

For stiffened panels fitted with U-type stiffeners, stiffener spacing s is taken as:

$$s = b_1 + b_2$$

Where b_1 and b_2 are as defined in Pt 2, Ch 1, Sec 5, Figure 1.

N_y : Load per unit length applied on the edge along y axis of the stiffened panel, in N/mm, taken as:

$N_y = c \sigma_y t_p$

L_{B1} : Stiffener span, in mm, equal to spacing between primary supporting members, i.e. $L_{B1} = l$. For vertically stiffened side shell of single side skin bulk carriers, $L_{B1} = 0.8l$.

L_{B2} : Width of the stiffened panel, in mm, taken as 6 times of the stiffener spacing, i.e. 6s.

n : Number of half waves along the direction perpendicular to the stiffener axis. The factor $\gamma_{GEB,i}$ is to be minimized with respect to the wave parameter n, i.e. to be taken as the smallest value larger than zero.

c : Factor taking into account the stresses in the attached plating acting perpendicular to the stiffener axis:

$c = 0.5(1 + \psi)$ for $0 \leqslant \Psi \leqslant 1$

$$c = \frac{1}{2(1 - \psi)} \quad \text{for } \Psi < 0$$

ψ : Edge stress ratio for case 2 according to Table 3.

$\sigma_{x,\mathrm{av}}$: Average stress for both plate and stiffener with Poisson correction, taken as:

$$\sigma_{x,\ av} = \sigma_x - vc\sigma_v A_s / (A_p + A_s) \geq 0 \quad \text{for } \sigma_x>0 \text{ and } \sigma_y>0$$

$$\sigma_{x,av}=\sigma_x \quad \text{for } \sigma_x\leqslant 0 \text{ or } \sigma_y\leqslant 0$$

D_{11},D_{12},D_{22},D_{33} : Bending stiffness coefficients, in Nmm, of the stiffened panel, defined in general as:

$$D_{11} = \frac{EI_{eff}10^4}{S}$$

$$D_{12} = \frac{Et_p{}^3 v}{12\left(1-v^2\right)}$$

$$D_{22} = \frac{Et_p{}^3}{12\left(1-v^2\right)}$$

$$D_{33} = \frac{Et_p{}^3}{12\left(1+v\right)}$$

For stiffened panels fitted with U-type stiffeners, D_{12} and D_{22} are defined as:

$$D_{22} = \frac{Et_p^3}{12(1-v^2)}\left[1.2+4.8\times \mathrm{Min}\left(1.0, \frac{b_1^2}{h_w(b_1+b_2)}\right)\times \mathrm{Min}\left(1.0, \left(\frac{t_w}{t_p}\right)^3\right)\right]$$

$$D_{12} = vD_{22}$$

h_w : Breadth of U-type stiffener web as defined in Pt 2, Ch 1, Sec 5, Figure 1.

I_{eff} : Moment of inertia, in cm^4, of the stiffener including effective width of attached plating, the same as I defined in [2.3.4].

2.1.3

The stress multiplier factor $\gamma_{GEB,\tau}$ for the stiffened panel subjected to pure shear load is taken as:

$$\gamma_{GEB,\tau} = \frac{\sqrt[4]{D_{11}^3 D_{22}}}{\left(L_{B1}/2\right)^2 N_{xy}}\left[8.125+5.64\sqrt{\frac{\left(D_{12}+D_{33}\right)^2}{D_{11}D_{22}}}-0.6\frac{\left(D_{12}+D_{33}\right)^2}{D_{11}D_{22}}\right] \quad \text{for } D_{11}D_{22}\geqslant(D_{12}+D_{33})^2$$

$$\gamma_{GEB,\tau} = \frac{\sqrt{2D_{11}\left(D_{12}+D_{33}\right)}}{\left(L_{B1}/2\right)^2 N_{xy}}\left[8.3+1.525\sqrt{\frac{D_{11}D_{22}}{\left(D_{12}+D_{33}\right)^2}}-0.493\frac{D_{11}{}^2 D_{22}{}^2}{\left(D_{12}+D_{33}\right)^4}\right] \text{ for } D_{11}D_{22}<(D_{12}+D_{33})^2$$

where

$N_{xy}=\tau t_p$

2.1.4

The stress multiplier factor $\gamma_{GEB,i+i}$ for the stiffened panel subjected to combined loads is taken as:

$$\gamma_{GEB,\mathrm{bi}+\tau} = \frac{1}{2}\gamma_{GEB,\tau}{}^2\left[-\frac{1}{\gamma_{GEB,bi}}+\sqrt{\frac{1}{\gamma_{GEB,bi}{}^2}+4\frac{1}{\gamma_{GEB,\tau}{}^2}}\right]$$

where $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are as defined in [2.1.2] and [2.1.3], respectively.

2.2 Plate capacity

2.2.1 Plate limit state

The plate limit state is based on the following interaction formulae:

$$\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}^{'}}\right)^{e_0} - B\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}^{'}}\right)^{e_0/2}\left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}^{'}}\right)^{e_0/2} + \left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}^{'}}\right)^{e_0} + \left(\frac{\gamma_{c1}|\tau|S}{\tau_c^{'}}\right)^{e_0} = 1$$

$$\left(\frac{\gamma_{c2}\sigma_x S}{\sigma_{cx}^{'}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_{c2}|\tau|S}{\tau_c^{'}}\right)^{2/\beta_p^{0.25}} = 1 \text{ for } \sigma_x\geqslant 0$$

$$\left(\frac{\gamma_{c3}\sigma_y S}{\sigma_{cx}^{'}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_{c3}|\tau|S}{\tau_c^{'}}\right)^{2/\beta_p^{0.25}} = 1 \text{ for } \sigma_y \geqslant 0$$

$$\frac{\gamma_{c4}|\tau|S}{\tau_c^{'}} = 1$$

with

$\gamma_c = \min(\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4})$

where:

σ_x, σ_y : Applied normal stress to the plate panel, in N/mm^2, to be taken as defined in [2.2.7].

τ : Applied shear stress to the plate panel, in N/mm^2.

$\sigma_{cx}^{'}$: Ultimate buckling stress, in N/mm^2, in direction parallel to the longer edge of the buckling panel as defined in [2.2.3].

$\sigma_{cy}^{'}$: Ultimate buckling stress, in N/mm^2, in direction parallel to the shorter edge of the buckling panel as defined in [2.2.3].

$\tau_c^{'}$: Ultimate buckling shear stresses, in N/mm^2, as defined in [2.2.3].

γ_{c1}, γ_{c2}, γ_{c3}, γ_{c4}: Stress multiplier factors at failure for each of the above different limit states. γ_{c1} and γ_{c2} are only to be considered when $\sigma_x \geqslant 0$ and $\sigma_y \geqslant 0$ respectively.

B : Coefficient given in Table 1.

e_0 : Coefficient given in Table 1.

β_p :Plate slenderness parameter taken as:

$$\beta_p = \frac{b}{t_p}\sqrt{\frac{R_{eH_P}}{E}}$$

Definition of coefficients *B* and e_0 **Table 1**

Applied Stress	B	e_0
$\sigma_x \geq 0$ and $\sigma_y \geq 0$	$0.7\text{-}0.3\beta_p/\alpha^2$	$2/\beta_p^{0.25}$
$\sigma_x < 0$ or $\sigma_y < 0$	1.0	2.0

2.2.2 Reference degree of slenderness

The reference degree of slenderness is to be taken as:

$$\lambda = \sqrt{\frac{R_{eH_P}}{K\sigma_E}}$$

where:

K : Buckling factor, as defined in Table 3 and Table 4.

2.2.3 Ultimate buckling stresses

The ultimate buckling stresses of plate panels, in N/mm^2, are to be taken as:

$$\sigma_{cx}' = C_x R_{eH_P}$$

$$\sigma_{cy}' = C_y R_{eH_P}$$

The ultimate buckling stress of plate panels subject to shear, in N/mm^2, is to be taken as:

$$\tau_c^{'} = C_\tau \frac{R_{eH_P}}{\sqrt{3}}$$

where:

C_x, C_y, C_τ :Reduction factors, as defined in Table 3

- For the 1st Equation of [2.2.1], when $\sigma_x < 0$ or $\sigma_y < 0$, the reduction factors are to taken as: $C_x = C_y = C_\tau = 1$.
- For the other cases:
  - For SP-A and UP-A, C_y is calculated according to Table 3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

  - For SP-B and UP-B, C_y is calculated according to Table 3 by using

$c_1 = 1$

- For vertically stiffened single side skin of bulk carrier, C_y is calculated according to Table 3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

- For corrugation of corrugated bulkheads, C_y is calculated according to Table 3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

The boundary conditions for plates are to be considered as simply supported, see cases 1, 2 and 15 of Table 3. If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of Table 3 subject to the agreement of the Society.

2.2.4 Correction factor Flong

The correction factor F_{long} depending on the edge stiffener types on the longer side of the buckling panel is defined in Table 2. An average value of F_{long} is to be used for plate panels having different edge stiffeners. For stiffener types other than those mentioned in Table 2, the value of c is to be agreed by the Society. In such a case, value of c higher than those mentioned in Table 2 can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate by the Society.

Correction factor F_{long} **Table 2**

<table>
<tr><th colspan="3">Structural element types</th><th>F_{long}</th><th>c</th></tr>
<tr><td colspan="3">Unstiffened Panel</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="7">Stiffened Panel</td><td colspan="2">Stiffener not fixed at both ends</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="5">Stiffener fixed at both ends</td><td>Flat bar (1)</td><td rowspan="4">$F_{long}=c$ for $\frac{t_w}{t_p} > 1$
$F_{long} = c\left(\frac{t_w}{t_p}\right)^3 + 1$ for $\frac{t_w}{t_p} \leq 1$</td><td>0.10</td></tr>
<tr><td>Bulb profile</td><td>0.30</td></tr>
<tr><td>Angle and L2 profiles</td><td>0.40</td></tr>
<tr><td>T profile</td><td>0.30</td></tr>
<tr><td>Girder of high rigidity (e.g. bottom transverse)</td><td>1.4</td><td>N/A</td></tr>
<tr><td>U-type profile fitted on hatch cover (2)</td><td>● Plate on which the U type profile is fitted, including EPP b_1 and EPP b_2
● For $b_2 < b_1$: $F_{long}=1$
● For $b_2 \geq b_1$: $F_{long} = \left(1.55 - 0.55\frac{b_1}{b_2}\right)\left[1 + c\left(\frac{t_w}{t_p}\right)^3\right]$
● Other plate of the U type profile: $F_{long}=1$</td><td>0.2</td></tr>
<tr><td colspan="5">(1) t_w is the net web thickness, in mm, without the correction defined in [2.3.2].
(2) b_1 and b_2 are defined in Pt 2, Ch 1, Sec 5,Figure 1.</td></tr>
</table>

CCS 2.2.4a The correction factor, F_{long} , of U type stiffened panel in hatch cover is calculated in accordance with the following formula:

$$F_{long} = \left(1.55 - 0.55\frac{b_1}{b_2}\right)\left[1 + c\left(\frac{t_w}{t_p}\right)^3\right]$$

where: b_1— width of opening of U type, in mm, see Figure CCS 2.2.4a;

b_2 — web spacing of two adjacent U type, in mm, see Figure CCS 2.2.4a;
c =0.2, when $b_2 \geqslant b_1$

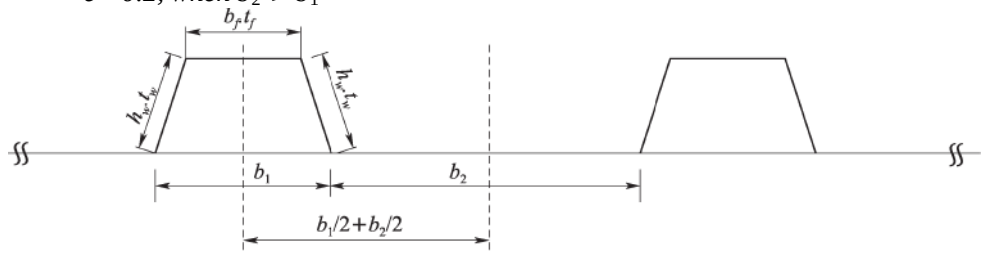


Figure CCS 2.2.4a U Type of Hatch Cover

2.2.5 Correction factor Ftran

The correction factor F_{tran} is to be taken as:

- For transversely framed EPP of single side skin bulk carrier, between the hopper and top wing tank:
  - F_{tran} = 1.25 when the two adjacent frames are supported by one tripping bracket fitted in way of the adjacent plate panels.
  - F_{tran} = 1.33 when the two adjacent frames are supported by two tripping brackets each fitted in way of the adjacent plate panels.
  - F_{tran} = 1.15 elsewhere.
- For the attached plate of a U-type stiffener fitted on a hatch cover:

  $$F_{tran} = \text{Max}\left(3 - 0.08(F_{tran0} - 6)^2, 1.0\right) \leq 2.25$$

  where,

  $$F_{tran0} = \text{Min}\left(\frac{b_2}{b_1} + \frac{6b_2^2}{\pi^2 h_w (b_1 + b_2)}\left(\frac{t_w}{t_p}\right)^3, 6\right) \text{ for EPP } b_2$$

  $$F_{tran0} = \text{Min}\left(\frac{b_1}{b_2} + \frac{6b_1^2}{\pi^2 h_w (b_2 + b_1)}\left(\frac{t_w}{t_p}\right)^3, 6\right) \text{ for EPP } b_1$$

  with b_1, b_2 and h_w as defined in Pt 2, Ch 1, Sec 5, Figure 1.
  Coefficient F defined in Case 2 of Table 3 is to be replaced by the following formula:

  $$F = \left[1 - \left(\frac{K_y}{0.91 F_{tran}} - 1\right) / \lambda_p^2\right] c_1 \geq 0$$

- For other cases: F_{tran} = 1

2.2.6 Curved plate panels

This requirement for curved plate limit state is applicable when $R/t_p \leq 2500$. Otherwise, the requirement for plate limit state given in [2.2.1] is applicable.
The curved plate limit state is based on the following interaction formula:

$$\left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}}\right)^{1.25} - 0.5\left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}}\right)\left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}}\right) + \left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}}\right)^{1.25} + \left(\frac{\gamma_c \tau \sqrt{3} S}{C_\tau R_{eH_P}}\right)^2 = 1.0$$

where:

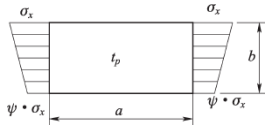
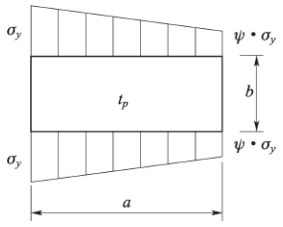
σ_{ax} : Applied axial stress to the cylinder corresponding to the curved plate panel, in N/mm^2.In case of tensile axial stresses, σ_{ax} = 0.

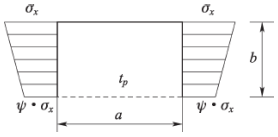
σ_{tg} : Applied tangential stress to the cylinder corresponding to the curved plate panel, in N/mm^2. In case of tensile tangential stresses, σ_{tg} = 0.

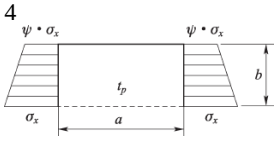
C_{ax}, C_{tg}, C_τ : Buckling reduction factor of the curved plate panel, as defined in Table 4.

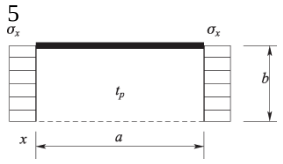
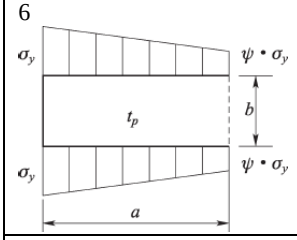
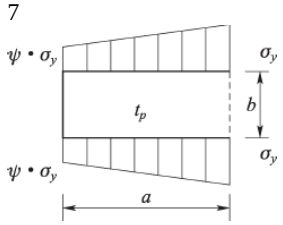
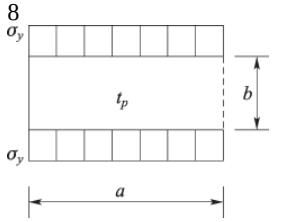
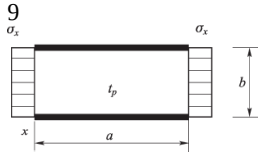
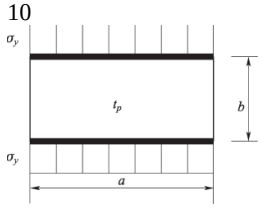
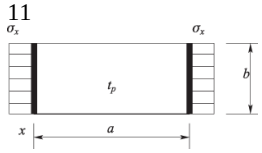
The stress multiplier factor, γ_c, of the curved plate panel need not be taken less than the stress multiplier factor, $\gamma_{c,}$ for the expanded plane panel according to [2.2.1].

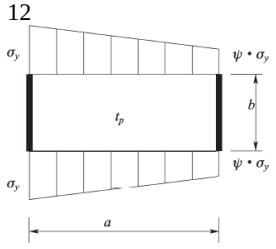
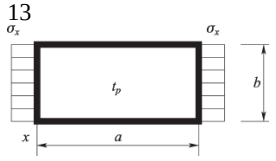
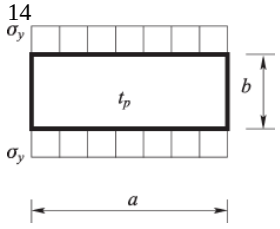
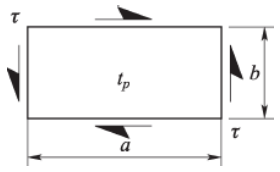
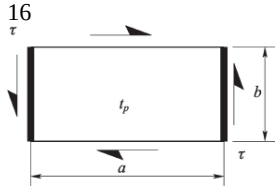
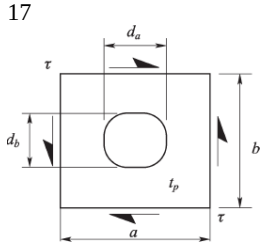
Buckling factor and reduction factor for plane plate panels **Table 3**

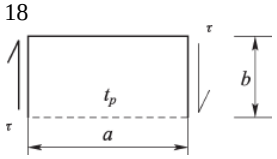
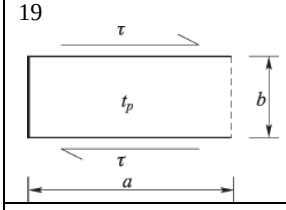
Case	Stress Ratio ψ	Aspect Ratio α	Buckling factor K	Reduction factor C
1  	$1 \geqslant \psi \geqslant 0$		$K_x = F_{longa}\dfrac{8.4}{\psi+1.1}$	When $\sigma_x \leqslant 0$ C_x=1 When σ_x >0 C_x = 1 for $\lambda \leqslant \lambda_c$ $C_x = c\left(\dfrac{1}{\lambda}-\dfrac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ where: $c = (1.25-0.12\psi) \leqslant 1.25$ $\lambda_c = \dfrac{c}{2}\left(1+\sqrt{1-\dfrac{0.88}{c}}\right)$
	$0 > \psi > -1$		$K_x = F_{long}[7.63-\Psi(6.26-10\psi)]$	
	$\psi \leqslant -1$		$K_x = F_{long}[5.975(1-\psi)^2]$	
2  	$1 \geqslant \psi \geqslant 0$		$K_y = F_{tran}\dfrac{2\left(1+\dfrac{1}{\alpha^2}\right)^2}{1+\psi+\dfrac{(1-\psi)}{100}\left(\dfrac{2.4}{\alpha^2}+6.9f_1\right)}$	When $\sigma_y \leqslant 0$ C_y=1; When σ_y >0 $C_y = c\left(\dfrac{1}{\lambda}-\dfrac{R+F^2(H-R)}{\lambda^2}\right)$ Where: c=(1.25-0.12Ψ)$\leqslant$1.25 $R = \lambda(1-\lambda/c)$ for $\lambda < \lambda_c$ R = 0.22 for $\lambda \geqslant \lambda_c$ $\lambda_c = 0.5c\left(1+\sqrt{1-0.88/c}\right)$ $F = \left(1-\left(\dfrac{K}{0.91}-1\right)\Big/\lambda_p^2\right)c_1 \geq 0$ $F = \left(1-\left(\dfrac{K}{0.91}-1\right)\Big/\lambda_p^2\right)c_1 \geq 0$ $\lambda^2{}_p = \lambda^2 - 0.5$ for $1 \leqslant \lambda^2{}_p \leqslant 3$ c_1 as defined in [2.2.3] $H = \lambda - \dfrac{2\lambda}{c(T+\sqrt{T^2-4})} \geq R$ $T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
		$\alpha \leqslant 6$	$f_1 = (1-\Psi)(\alpha-1)$	
		$\alpha > 6$	$f_1 = 0.6\left(1-\dfrac{6\psi}{a}\right)\left(a+\dfrac{14}{a}\right)$ but not greater than $14.5-\dfrac{0.35}{a^2}$	
	$0 > \psi \geqslant 1-\dfrac{4\alpha}{3}$		$K_y = \dfrac{200F_{tran}(1+\beta^2)^2}{(1-f_3)(100+2.4\beta^2+6.9f_1+23f_2)}$	
		$\alpha > 6(1-\psi)$	$f_1 = 0.6\left(\dfrac{1}{\beta}+14\beta\right)$ but not greater than $14.5-0.35\beta^2$ f_2=f_3=0	
		$3(1-\psi) \leqslant \alpha \leqslant 6(1-\psi)$	$f_1 = \dfrac{1}{\beta}-1$ f_2=f_3=0	

<table>
<tr><th>Case</th><th>Stress Ratio ψ</th><th>Aspect Ratio α</th><th>Buckling factor K</th><th>Reduction factor C</th></tr>
<tr><td></td><td></td><td>$1.5(1-\psi) \leqslant \alpha < 3(1-\psi)$</td><td>$f_1 = \frac{1}{\beta} - (2-\omega\beta)^4 - 9(\omega\beta-1)(\frac{2}{3}-\beta)$
f_2=f_3=0</td><td></td></tr>
<tr><td></td><td></td><td>$1-\psi \leqslant \alpha < 1.5(1-\psi)$</td><td>● For α >1.5
$f_1 = 2\left(\frac{1}{\beta} - 16\left(1-\frac{\omega}{3}\right)^4\right)(\frac{1}{\beta}-1)$
f_2=3β-2=0
f_3=0
● For $\alpha \leqslant$1.5
$f_1 = 2\left(\frac{1.5}{1-\psi}-1\right)\left(\frac{1}{\beta}-1\right)$
$f_2 = \frac{\psi(1-16f_4^2)}{1-\alpha}$
f_3=0
f_4= (1.5-Min(1.5;α))^2</td><td></td></tr>
<tr><td></td><td></td><td>$0.75(1-\psi) \leqslant \alpha < 1-\psi$</td><td>$f_1$=0
$f_2 = 1 + 2.31(\beta-1) - 48\left(\frac{4}{3}-\beta\right)f_4^2$
$f_3 = 3f_4(\beta-1) - \left(\frac{f_4}{1.81} - \frac{\alpha-1}{1.31}\right)$
f_4= (1.5-Min(1.5;α))^2</td><td></td></tr>
<tr><td></td><td>$\psi < 1 - \frac{4\alpha}{3}$</td><td colspan="2">$K_y = 5.972F_{tran}\frac{\beta^2}{1-f_3}$
where
$f_3 = f_5\left(\frac{f_5}{1.81} + \frac{1+3\psi}{5.24}\right)$
$f_5 = \frac{9}{16}(1+\mathrm{Max}(-1;\psi))^2$</td><td></td></tr>
<tr><td>3
 
</td><td>$1 \geqslant \psi \geqslant 0$</td><td colspan="2">$K_x = \frac{4(0.425+1/\alpha^2)}{3\psi+1}$</td><td rowspan="2">For UP-A:
C_x = 1 for $\lambda \leq 0.75$
$C_x = \frac{0.75}{\lambda}$ for λ>0.75

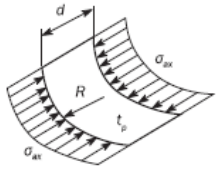
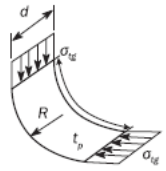
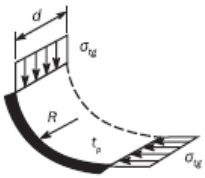
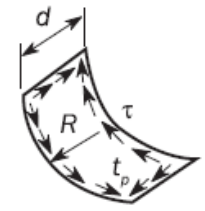
For UP-B:
C_x = 1 for $\lambda \leqslant 0.7$
$C_x = \frac{1}{\lambda^2+0.51}$ for λ > 0.7</td></tr>
<tr><td></td><td>$0 > \psi > -1$</td><td colspan="2">K_x=4(0.425+1/α^2)(1+ψ)-5ψ(1-3.42ψ)</td></tr>
<tr><td>4
 
</td><td>$1 \geqslant \psi \geqslant -1$</td><td colspan="2">$K_x = \left(0.425 + \frac{1}{\alpha^2}\right)\frac{3-\psi}{2}$</td><td></td></tr>
</table>

Case	Stress Ratio ψ	Aspect Ratio α	Buckling factor K	Reduction factor C
5 	—	$\alpha \geqslant 1.64$	K_x=1.28	
		$\alpha < 1.64$	$K_x = \frac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$	
6 	$1 \geqslant \psi \geqslant 0$	$K_y = \frac{4(0.425+\alpha^2)}{(3\psi+1)\alpha^2}$		For UP-A: C_y = 1 for $\lambda \leqslant 0.75$ $C_y = \frac{0.75}{\lambda}$ for $\lambda > 0.75$ For UP-B: C_x = 1 for $\lambda \leqslant 0.7$ $C_x = \frac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
	$0 > \psi \geqslant -1$	$K_y = 4(0.425+\alpha^2)(1+\psi)\frac{1}{\alpha^2} - 5\psi(1-3.42\psi)\frac{1}{\alpha^2}$		
7 	$1 \geqslant \psi \geqslant -1$	$K_y = (0.425+\alpha^2)\frac{(3-\psi)}{2\alpha^2}$		
8 	—	$K_y = 1 + \frac{0.56}{\alpha^2} + \frac{0.13}{\alpha^4}$		
9 	—	K_x=6.97		C_x = 1 for $\lambda \leqslant 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
10 	—	$K_y = 4 + \frac{2.07}{\alpha^2} + \frac{0.67}{\alpha^4}$		C_x = 1 for $\lambda \leqslant 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
11 	—	$\alpha \geqslant 4$	K_x= 4	C_x = 1 for $\lambda \leqslant 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ For $\lambda > 0.83$
		$\alpha < 4$	$K_x = 4 + 2.74\left[\frac{4-\alpha}{3}\right]^4$	

Case	Stress Ratio ψ	Aspect Ratio α	Buckling factor K	Reduction factor C
12 	—	K_y=K_y determined as per case 2		For $\alpha < 2$: C_y=C_{y2} For $\alpha \geqslant 2$ $C_y = \left(1.06 + \frac{1}{10\alpha}\right) C_{y2}$ Where: C_{y2} : C_y determined as per case 2
13 	—	$\alpha \geqslant 4$	K_x= 6.97	C_x = 1 for $\lambda \leqslant 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 6.97 + 3.1\left[\frac{4-\alpha}{3}\right]^4$	
14 	—	$K_y = \frac{6.97}{\alpha^2} + \frac{3.1}{\alpha^2}\left[\frac{4-1/\alpha}{3}\right]^4$		C_x = 1 for $\lambda \leqslant 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
15 	—	$K_\tau = \sqrt{3}\left[5.34 + \frac{4}{\alpha^2}\right]$		C_τ = 1 for $\lambda \leqslant 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
16 	—	$K_\tau = \sqrt{3}\left[5.34 + \text{Max}\left[\frac{4}{\alpha^2}; \frac{7.15}{\alpha^{2.5}}\right]\right]$		
17 	—	K_τ=$K_{\tau case15}$$r$ $K_{\tau case15}$: K_τ according to case 15 r : Opening reduction factor taken as $r = \left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$ With $\frac{d_a}{a} \leq 0.7$ and $\frac{d_b}{b} \leq 0.7$		

Case	Stress Ratio ψ	Aspect Ratio α	Buckling factor K	Reduction factor C
18 	—	$K_\tau = \sqrt{3}\left(0.6+4/\alpha^2\right)$		$C_\tau = 1$ for $\lambda \leqslant 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
19 	—	$K_\tau = 8$		
Edge boundary conditions: Plate edge free. Plate edge simply supported. Plate edge clamped.				
Note 1: Cases listed are general cases. Each stress component (σ_x, σ_y) is to be understood in local coordinates.				

Buckling and reduction factor for curved plate panel with $R/t_p \leqslant 2500$ Table 4

Case	Aspect ratio	Buckling factor K	Reduction factor C
1 	$\frac{d}{R} \le 0.5\sqrt{\frac{R}{t_p}}$	$K = 1 + \frac{2}{3}\frac{d^2}{Rt_p}$	For general application: C_{ax} =1 for $\lambda \leqslant 0.25$ C_{ax} =1.233-0.933λ for 0.25< $\lambda \leqslant 1$ C_{ax} =0.3/λ^2 for 1< $\lambda \leqslant 1.5$ C_{ax} =0.2/λ^2 for λ >1.5 For curved single fields, e.g. bilge plating, which are bounded by plane panels as shown in Ch 6, Sec 4, Figure 1: $C_{ax} = \frac{0.65}{\lambda^2} \le 1.0$
	$\frac{d}{R} > 0.5\sqrt{\frac{R}{t_p}}$	$K = 0.267\frac{d^2}{Rt_p}\left[3 - \frac{d}{R}\sqrt{\frac{t_p}{R}}\right] \ge 0.4\frac{d^2}{Rt_p}$	
2 	$\frac{d}{R} \le 1.63\sqrt{\frac{R}{t_p}}$	$K = \frac{d}{\sqrt{Rt_p}} + 3\frac{(Rt_p)^{0.175}}{d^{0.35}}$	For general application: C_{tg} =1 for $\lambda \leqslant 0.4$ C_{tg} =1.274-0.686λ for 0.4< $\lambda \leqslant 1.2$ $C_{tg} = \frac{0.65}{\lambda^2}$ for λ>1.2 For curved single fields, e.g. bilge plating, which are bounded by plane panels as shown in Ch6, Sec 4, Figure 1: $C_{tg} = \frac{0.8}{\lambda^2} \le 1.0$
	$\frac{d}{R} > 1.63\sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 2.25\left(\frac{R^2}{dt_p}\right)^2$	
3 	$\frac{d}{R} \le \sqrt{\frac{R}{t_p}}$	$K = \frac{0.6d}{\sqrt{Rt_p}} + \frac{\sqrt{Rt_p}}{d} - 0.3\frac{Rt_p}{d^2}$	As in load case 2a.
	$\frac{d}{R} > \sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 0.291\left(\frac{R}{dt_p}\right)^2$	
4 	$\frac{d}{R} \le 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\sqrt{28.3 + \frac{0.67d^3}{R^{1.5}t_p^{1.5}}}$	C_τ =1 for $\lambda \leqslant 0.4$ C_τ=1.274-0.686λ for 0.4< $\lambda \leqslant 1.2$ $C_\tau = \frac{0.65}{\lambda^2}$ for λ>1.2
	$\frac{d}{R} > 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\frac{0.28d^2}{R\sqrt{Rt_p}}$	
Explanations for boundary conditions: - - - - - - - - - - Plate edge free. ———————— Plate edge simply supported ▬▬▬▬▬▬▬▬ Plate edge clamped.			

2.2.7 Applied normal and shear stresses to plate panels

The normal stresses, σ_x and σ_y, in N/mm^2, to be applied for the overall stiffened panel capacity and the plate panel capacity calculations, as given in in [2.1.1] and [2.2.1] respectively, are to be taken as follows:

- For FE analysis, the reference stresses as defined in Ch 8, Sec 4, [2.4].

- For prescriptive assessment of the overall stiffened panel capacity and the plate panel capacity, the axial or transverse compressive stresses calculated according to Ch 8, Sec 3, [2.2.1], at load calculation points of the considered stiffener or the considered elementary plate panel, as defined in Ch 3, Sec 7, [3] and [2], respectively. However, in case of transverse stiffening arrangement, the transverse compressive stress used for the assessment of the overall stiffened panel capacity is to be taken as the compressive stress calculated at load calculation points of the stiffener attached plating, as defined in Ch 3, Sec 7, [2].
- For grillage analysis where the stresses are obtained based on beam theory, the stresses taken as:

$$\sigma_x = \frac{\sigma_{xb} + \nu\sigma_{yb}}{1-\nu^2}$$

$$\sigma_y = \frac{\sigma_{yb} + \nu\sigma_{xb}}{1-\nu^2}$$

Where:

σ_{xb}, σ_{yb} : Stress, in N/mm^2, from grillage beam analysis respectively along *x* or *y* axis of the plate attached to the PSM web.

The shear stress τ, in N/mm^2, to be applied for the overall stiffened panel capacity and the plate panel capacity calculations, as given in in [2.1.1] and [2.2.1] respectively ,are to be taken as follows:

- For FE analysis, the reference shear stresses as defined in Ch 8, Sec 4, [2.4].
- For prescriptive assessment of the plate panel capacity, the shear stresses calculated according to Ch 8, Sec 3, [2.2.1], at load calculation points of the considered elementary plate panel, as defined in Ch 3, Sec 7, [2].
- For prescriptive assessment of the overall stiffened panel capacity, the shear stresses calculated according to Ch 8, Sec 3, [2.2.1], at the following load calculation point:
  - At the middle of the full span, *ll*, of the considered stiffener.
  - At the intersection point between the stiffener and its attached plating.
- For grillage beam analysis, τ= 0 in the plate attached to the PSM web.

2.3 Stiffeners

2.3.1 Buckling modes

The following buckling modes are to be checked:

- Stiffener induced failure (*SI*).
- Associated plate induced failure (*PI*).

2.3.2 Web thickness of flat bar

For accounting the decrease of the stiffness due to local lateral deformation, the effective web thickness of flat bar stiffener, in mm, is to be used in [2.1] and [2.3.4] for the calculation of the net sectional area, *As*, the net section modulus, *Z*, and the moment of inertia, *I*, of the stiffener and is taken as:

$$t_{w_red} = t_w\left(1-\frac{2\pi^2}{3}\left(\frac{h_w}{s}\right)^2\left(1-\frac{b_{eff1}}{s}\right)\right)$$

2.3.3 Idealisation of bulb profile

Bulb profiles are to be considered as equivalent angle profiles, as defined in Ch 3, Sec 7, [1.4.1].

2.3.4 Ultimate buckling capacity

When $\sigma_a+\sigma_b+\sigma_w>0$ while initially setting γ = 1, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c\sigma_a + \sigma_B + \sigma_w}{R_{eH}} S = 1$$

where:

σ_a : Effective axial stress, in N/mm^2, at mid span of the stiffener, acting on the stiffener with its

attached plating.

$$\sigma_a = \sigma_x \frac{st_p + A_s}{b_{eff1} t_p + A_s}$$

σ_x : Nominal axial stress, in N/mm^2, acting on the stiffener with its attached plating.

- For FE analysis, σ_x is the FE corrected stress as defined in [2.3.6] in the attached plating in the direction of the stiffener axis.
- For prescriptive assessment, σ_x is the axial stress calculated according to Ch 8, Sec 3, [2.2.1] at load calculation point of the stiffener, as defined in Ch 3, Sec 7, [3].
- For grillage beam analysis, σ_x is the stress acting along the x-axis of the attached buckling panel.

R_{eH} : Specified minimum yield stress of the material, in N/mm^2:

$R_{eH} = R_{eH_S}$ for stiffener induced failure (*SI*).

$R_{eH} = R_{eH_P}$ for plate induced failure (*PI*).

σ_b : Bending stress in the stiffener, in N/mm^2:

$$\sigma_b = \frac{M_0 + M_1 + M_2}{1000Z}$$

Z : Net section modulus of stiffener, in cm^3, including effective width of plating according to [2.3.5], to be taken as:

- The section modulus calculated at the top of stiffener flange for stiffener induced failure (*SI*).
- The section modulus calculated at the attached plating for plate induced failure (*PI*).

C_{PI} : Plate induced failure pressure coefficient:

C_{PI} = 1 if the lateral pressure is applied on the side opposite to the stiffener.

C_{PI} = -1 if the lateral pressure is applied on the same side as the stiffener.

C_{SI} : Stiffener induced failure pressure coefficient:

C_{SI} = -1 if the lateral pressure is applied on the side opposite to the stiffener.

C_{SI} = 1 if the lateral pressure is applied on the same side as the stiffener.

M_2 : Bending moment, in Nmm, due to eccentricity of sniped stiffeners, to be taken as

M_2=0 for continuous stiffeners

$M_2=C_{snip} w_{na} \gamma \sigma_x (A_p+A_s)$ for stiffeners sniped at one or both ends.

C_{snip} : Coefficient to account for the end effect of the stiffener sniped at one or both ends, to be taken as

C_{snip}= -1.2 for stiffener induced failure (*SI*)

C_{snip}= 1.2 for plate induced failure (*PI*).

M_1 : Bending moment, in Nmm, due to the lateral load P:

$$M_1 = C_i \frac{|P| s l^2}{24 \times 10^3} \text{ for continuous stiffener}$$

$$M_1 = C_i \frac{|P| s l^2}{8 \times 10^3} \text{ for sniped stiffener}$$

$$M_1 = C_i \frac{|P| s l^2}{14.2 \times 10^3} \text{ for stiffener sniped at one end and continuous at the other end}$$

P : Lateral load, in kN/m^2.

- For FE analysis, P is the average pressure as defined in Ch 8, Sec 4, [2.5.2] in the attached plating.
- For prescriptive assessment, P is the pressure calculated at load calculation point of the stiffener, as defined in Ch 3, Sec 7, [3].

C_i : Pressure coefficient:

$C_i = C_{SI}$ for stiffener induced failure (*SI*).

$C_i = C_{PI}$ for plate induced failure (*PI*).

M_0 : Bending moment, in Nmm, due to the lateral deformation w of stiffener:

$$M_0 = F_E C_{sl} \frac{\gamma}{\gamma_{GEB} - \gamma} w_0 \quad \text{with precondition } \gamma_{GEB} - \gamma > 0$$

where γ_{GEB} is the stress multiplier factor of global elastic buckling capacity as defined in [2.1].

C_{sl} : Deformation reduction factor to account for global slenderness, to be taken as:

$$C_{sl} = 1 - \frac{1}{12}\lambda_G^4 \qquad \text{for } \lambda \leqslant 1.56$$

$$C_{sl} = 3/\lambda_G^4 \qquad \text{for } \lambda > 1.56$$

λ_G : The reference degree of global slenderness of the stiffened panel, to be taken as

$$\lambda_G = \sqrt{\frac{\gamma_{ReH}}{\gamma_{GEB}}} \text{ and } \gamma_{ReH} = \frac{\min(R_{eH_P}, R_{eH_S})}{\sqrt{\sigma_{x,av}^2 + \sigma_y^2 - \sigma_{x,av}\sigma_y + 3\tau_{xy}^2}}$$

F_E : Ideal elastic buckling force of the stiffener, in N.

$$F_E = \left(\frac{\pi}{l}\right)^2 EI \cdot 10^4$$

I : Moment of inertia, in cm^4, of the stiffener including effective width of attached plating according to
[2.3.5]. I is to comply with the following requirement:

$$I \geq \frac{st_p^3}{12 \cdot 10^4}$$

t_p : Net thickness of plate, in mm, to be taken as

- For prescriptive requirements: the mean thickness of the two attached plating panels,
- For FE analysis: the thickness of the considered EPP on one side of the stiffener.

w_0 : Assumed imperfection, in mm, to be taken as:
$w_0 = l/1000$

w_{na} : Distance from the mid-point of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating according to [2.3.5].

σ_w : Stress due to torsional deformation, in N/mm^2, to be taken as:

- For stiffener induced failure (*SI*)
  - For $\sigma_a > 0$

$$\sigma_w = E y_w e_f \Phi_0 \left(\frac{m_{tor}\pi}{l_{tor}}\right)^2 \left(\frac{1}{1 - \frac{\gamma\sigma_a}{\sigma_{ET}}} - 1\right) \text{ for with precondition } \sigma_{ET} - \gamma\sigma_a > 0$$

  - For $\sigma_a \leqslant 0$
    $\sigma_w = 0$
- For plate induced failure (*PI*)
  $\sigma_w = 0$

l_{tor} : Stiffener span, distance equal to spacing between primary supporting members, i.e. $l_{tor} = l$. When the stiffener is supported by tripping brackets, l_{tor} should be taken as the maximum spacing between the adjacent primary supporting members and fitted tripping brackets.

y_w : Distance, in mm, from centroid of stiffener cross section to the free edge of stiffener flange, to be taken as:

$$y_w = \frac{t_w}{2} \qquad \text{for flat bar}$$

$$y_w = b_f - \frac{h_w t_w^2 + t_f b_f^2}{2A_s} \qquad \text{for angle and bulb profiles}$$

$$y_w = b_{f-out} + 0.5t_w - \frac{h_w t_w^2 + t_f (b_f^2 - 2b_f d_f)}{2A_s} \qquad \text{for L2 profile}$$

$$y_w = \frac{b_f}{2} \qquad \text{for T profile.}$$

Φ_0 : Coefficient taken as:

$$\Phi_0 = \frac{l_{tor}}{m_{tor} h_w} 10^{-4}$$

σ_{ET} : Reference stress for torsional buckling, in N/mm^2:

$$\sigma_{ET} = \frac{E}{I_p}\left[\left(\frac{m_{tor}\pi}{l_{tor}}\right)^2 I_w \cdot 10^2 + \frac{1}{2(1+\nu)} I_T + \left(\frac{l_{tor}}{m_{tor}\pi}\right)^2 \varepsilon \cdot 10^{-4}\right]$$

I_P : Net polar moment of inertia of the stiffener, in cm^4, about point *C* as shown in Figure 1, as defined in Table 5.

I_T : Net St. Venant's moment of inertia of the stiffener, in cm^4, as defined in Table 5.

I_ω : Net sectorial moment of inertia of the stiffener, in cm^6, about point *C* as shown in Figure 1, as defined in Table 5

m_{tor} : Number of half waves within $lltttttt$, taken as a positive integer so as to give smallest reference stress for torsional buckling.

ε : Degree of fixation.

$$\varepsilon = \left(\frac{3b}{t_p^3} + \frac{2h_w}{t_w^3}\right)^{-1} \qquad \text{for bulb,angle,L2 ,L3 and T profiles;}$$

$$\varepsilon = \left(\frac{t_p^3}{3b}\right) \qquad \text{for flat bars.}$$

A_w : Net web area, in mm^2.

A_f : Net flange area, in mm^2.

Moments of inertia **Table 5**

	Flat bars (1)	Bulb, angle , L2 and T profiles
I_P	$\frac{h_w^3 t_w}{3\cdot 10^4}$	$\left(\frac{A_w (e_f - 0.5t_f)^2}{3} + A_f e_f^2\right) 10^{-4}$
I_T	$\frac{h_w t_w^3}{3\cdot 10^4}\left(1 - 0.63\frac{t_w}{h_w}\right)$	$\frac{(e_f - 0.5t_f) t_w^3}{3\cdot 10^4}\left(1 - 0.63\frac{t_w}{e_f - 0.5t_f}\right) + \frac{b_f t_f^3}{3\cdot 10^4}\left(1 - 0.63\frac{t_f}{b_f}\right)$
I_ω	$\frac{h_w^3 t_w^3}{36\cdot 10^6}$	For bulb, angle and L2 profiles(2). $\frac{A_f^3 + A_w^3}{36\cdot 10^6} + \frac{e_f^2}{10^6}\left(\frac{A_f b_f^2 + A_w t_w^2}{3} - \frac{\left(A_f (b_f - 2d_f) + A_w t_w\right)^2}{4\left(A_f + A_w\right)} - A_f d_f \left(b_f - d_f\right)\right)$ For T profiles $\frac{b_f^3 t_f e_f^2}{12\cdot 10^6}$

(1) t_w is the net web thickness, in mm. t_{w_red} as defined in [2.3.2] is not to be used in this table.
(2) d_f is to be taken as 0 for bulb and angle profiles.

2.3.5 Effective width of attached plating

The effective width of attached plating of stiffeners, b_{eff}, in mm, is to be taken as:

- For $\sigma_x > 0$:
  - For FE analysis,
    $b_{eff} = \min(C_x b, \chi_s s)$
  - For prescriptive assessment,

$$b_{eff} = \min\left(\frac{C_{x1}b_1 + C_{x2}b_2}{2}, \chi_s s\right)$$

- For $\sigma_x \leqslant 0$:
  - $b_{eff} = \chi_s s$

where:

χ_s : Effective width coefficient to be taken as:

$$\chi_s = \min\left[\frac{1.12}{1+\frac{1.75}{\left(\frac{l_{eff}}{s}\right)^{1.6}}};1.0\right]$$

l_{eff} : Effective length of the stiffener, in mm, taken as:

$l_{eff} = \frac{l}{\sqrt{3}}$ for stiffener fixed at both ends.

$l_{eff} = 0.75l$ for stiffener simply supported at one end and fixed at the other.

$l_{eff} = l$ for stiffener simply supported at both ends.

2.3.6 FE corrected stresses for stiffener capacity

When the reference stresses σ_x and σ_y obtained by FE analysis according to Ch 8, Sec 4, [2.4] are both com- pressive, σ_x is to be corrected according to the following formula:

- If $\sigma_x < \nu\sigma_y$:
  $\sigma_{xcor} = 0$
- If $\sigma_x \geqslant \nu\sigma_y$:
  $\sigma_{xcor} = \sigma_x - \nu\sigma_y$

2.4 Primary supporting members

2.4.1 Web plate in way of openings

The web plate of primary supporting members with openings is to be assessed for buckling based on the com- bined axial compressive and shear stresses.

The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in Table 6.

The interaction formulae of [2.2.1] are to be used with:

- $\sigma_x = \sigma_{av}$
- $\sigma_y = 0$
- $\tau = \tau_{av}$

where:

σ_{av} : Weighted average compressive stress, in N/mm^2, in the area of web plate being considered , i.e. P1, P2,or P3 as shown in Table 6.

For the application of the Table 6, the weighted average shear stress is to be taken as:

- Opening modelled in primary supporting members:
  τ_{av}: Weighted average shear stress, in N/mm^2, in the area of web plate being considered , i.e. P1, P2,or P3 as shown in Table 6.
- Opening not modelled in primary supporting members:
  τ_{av}: Weighted average shear stress, in N/mm^2, given in Table 6.

2.4.2 Reduction factors of web plate in way of openings

The reduction factors, C_x or C_y in combination with, C_τ of the plate panel(s) of the web adjacent to the opening is to be taken as shown in Table 6.

2.4.3

The equivalent plate panel of web plate of primary supporting members crossed by perpendicular

stiffeners is to be idealised as shown in Figure 2.

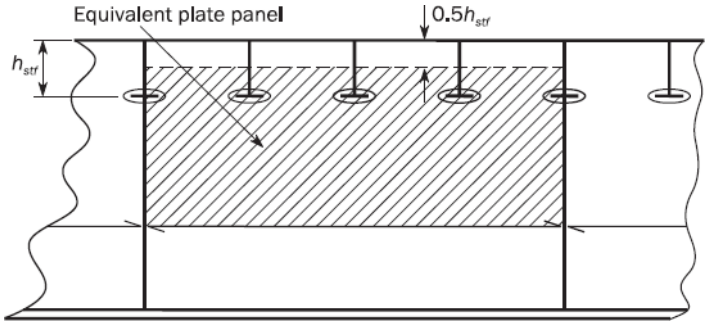
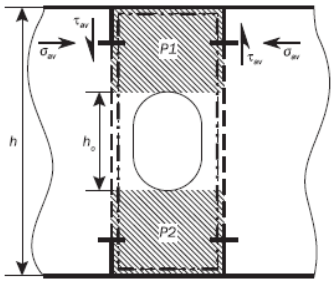
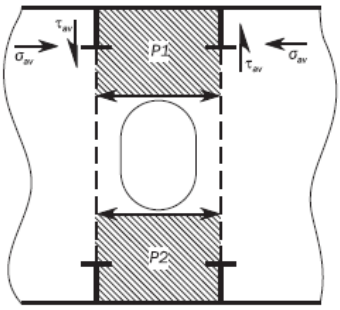
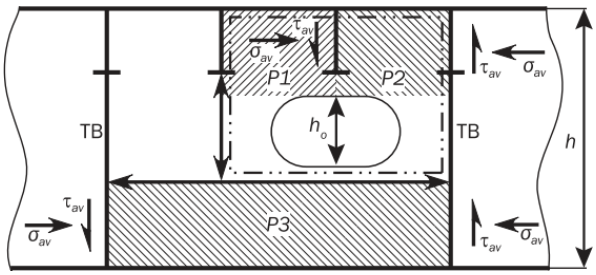


Figure 2 Web plate idealization

The correction of panel breadth is applicable also for other slot configurations provided that the web or collar plate is attached to at least one side of the passing stiffener.

Reduction factors **Table 6**

Configuration[1]	C_x, C_y	C_τ	
		Opening modelled in PSM	Opening not modelled in PSM
(a) Without edge reinforcements: [2]  	Separate reduction factors are to be applied to areas *P*1 and *P*2 using case 3 or case 6 in Table 3, with edge stress ratio: Ψ=1.0	Separate reduction factors are to be applied to areas *P*1 and *P*2 using case 18 or case 19 in Table 3	When case 17 of Table 3 is applicable: A common reduction factor is to be applied to areas *P1* and *P2* using case 17 in Table 3 with: $\tau_{av} = \tau_{av}$(web) When case 17 of Table 3 is not applicable: Separate reduction factors are to be applied to areas *P1* and *P2* using case 18 or case 19 in Table 3 with: $\tau_{av} = \tau_{av}(web)\ h/(h\text{-}h_0)$
(b) With edge reinforcements:  	Separate reduction factors are to be applied for areas *P*1 and *P*2 using C_x for case 1 or C_y for case 2 in Table 3 with stress ratio: Ψ=1.0	Separate reduction factors are to be applied for areas *P*1 and *P*2 using case 15 in Table 3.	Separate reduction factors are to be applied to areas *P*1 and *P*2 using case 15 in Table 3 with: $\tau_{av} = \tau_{av}(web)\ h/(h\text{-}h_0)$

Configuration(1)	C_x, C_y	C_τ	
		Opening modelled in PSM	Opening not modelled in PSM
(c) Example of hole in web:  		Panels *P*1 and *P*2 are to be evaluated in accordance with (a). Panel *P*3 is to be evaluated in accordance with (b).	

Where:
h : Height, in m, of the web of the primary supporting member in way of the opening.
h_0 : Height in m, of the opening measured in the depth of the web.
$\tau_{av}(web)$: Weighted average shear stress, in N/mm^2, over the web height h of the primary supporting member.
Note (1): Web panels to be considered for buckling in way of openings are shown shaded and numbered *P*1, *P*2, etc.
Note (2) : For a PSM web panel with opening and without edge reinforcements as shown in configuration (a), the applicable buckling assessment method depends on its specific boundary conditions. If one of the long edges along the face plate or along the attached plating is not subject to "inline support", i.e. the edge is free to pull in, Method B should be applied. In other cases, typically such as when the short plate edge is attached to the plate flanges, Method A is applicable.

3 Buckling capacity of other structures

3.1 Struts, pillars and cross ties

3.1.1 Buckling utilisation factor

The buckling utilisation factor, η, for axially compressed struts, pillars and cross ties is to be taken as:

$$\eta = \frac{\sigma_{av}}{\sigma_{cr}}$$

where:
σ_{av} : Average axial compressive stress in the member, in N/mm^2.
σ_{cr} : Minimum critical buckling stress, in N/mm^2, taken as:

$\sigma_{cr} = \sigma_E$ for $\sigma_E \leqslant 0.5R_{eH_S}$

$$\sigma_{cr} = \left(1 - \frac{R_{eH_S}}{4\sigma_E}\right) R_{eH_S} \text{ for } \sigma_E > 0.5R_{eH_S}$$

σ_E : Minimum elastic compressive buckling stress, in N/mm^2, according to [3.1.2] to [3.1.4].
R_{eH_S}: Specified minimum yield stress of the considered member, in N/mm^2. For built up members, the low-est specified minimum yield stress is to be used.

3.1.2 Elastic column buckling stress

The elastic compressive column buckling stress, σ_{EC} in N/mm^2 of members subject to axial compression is to be taken as:

$$\sigma_{EC} = \pi^2 E f_{end} \frac{I}{A l_{pill}^2} 10^{-4}$$

where:
I : Net moment of inertia about the weakest axis of the cross section, in cm^4.
A : Net cross sectional area of the member, in cm^2.
l_{pill} : Length of the member, in m, taken as:

- For pillar and strut: unsupported length of the member
- For cross tie:
  - In centre tank: distance between the flanges of longitudinal stiffeners on the

starboard and port longitudinal bulkheads to which the cross tie's horizontal stringer is attached.

- In wing tank: distance between the flanges of longitudinal stiffeners on the longitudinal bulkhead to which the cross tie's horizontal stringer is attached, and the inner hull plating.

f_{end} : End constraint factor, taken as:

- For pillar and strut:
  - f_{end} = 1.0 where both ends are simply supported.
  - f_{end} = 2.0 where one end is simply supported and the other end is fixed.
  - f_{end} = 4.0 where both ends are fixed.
- For cross tie:
  - f_{end} = 2.0

A pillar end may be considered fixed when brackets of adequate size are fitted. Such brackets are to be sup- ported by structural members with greater bending stiffness than the pillar.

3.1.3 Elastic torsional buckling stress

The elastic torsional buckling stress, σ_{ET}, in N/mm^2, with respect to axial compression of members is to be taken as:

$$\sigma_{ET} = \frac{GI_{sv}}{I_{pol}} + \frac{\pi^2 f_{end} E c_{warp}}{I_{pol} l_{pill}^2} 10^{-4}$$

where:

I_{sv} : Net St. Venant's moment of inertia, in cm^4, see Table 7 for examples of cross sections.

I_{pol} : Net polar moment of inertia about the shear centre of cross section, in cm^4

$$I_{pol} = I_y + I_z + A(y_0^2 + z_0^2)$$

c_{warp} : Warping constant, in cm6, see Table 7 for examples of cross sections.

l_{pill} : Length of the member, in m as defined in [3.1.2].

y_0 : Transverse position of shear centre relative to the cross sectional centroid, in cm, see Table 7 for examples of cross sections.

z_0 : Vertical position of shear centre relative to the cross sectional centroid, in cm, see Table 7 for exam- ples of cross sections.

A : Net cross sectional area, in cm^2, as defined in [3.1.2]

I_y : Net moment of inertia about y axis, in cm^4.

I_z : Net moment of inertia about z axis, in cm^4.

3.1.4 Elastic torsional/column buckling stress

For cross sections where the centroid and the shear centre do not coincide, the interaction between the tor- sional and column buckling mode is to be examined. The elastic torsional/column buckling stress, σ_{ETF}, with respect to axial compression is to be taken as:

$$\sigma_{ETF} = \frac{1}{2\zeta}\left[\left(\sigma_{EC} + \sigma_{ET}\right) - \sqrt{\left(\sigma_{EC} + \sigma_{ET}\right)^2 - 4\zeta\sigma_{EC}\sigma_{ET}} \right]$$

where:

ζ : Coefficient taken as:

$$\zeta = 1 - \frac{\left(y_0^2 + z_0^2\right) A}{I_{pol}}$$

y_0 : Transverse position of shear centre relative to the cross sectional centroid, in cm, as defined in [3.1.3].

z_0 : Vertical position of shear centre relative to the cross sectional centroid, in cm, as defined in [3.1.3].

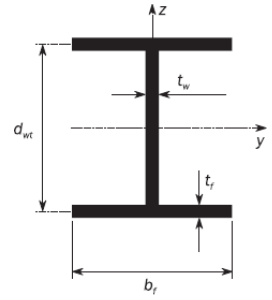
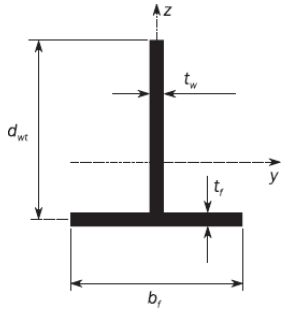
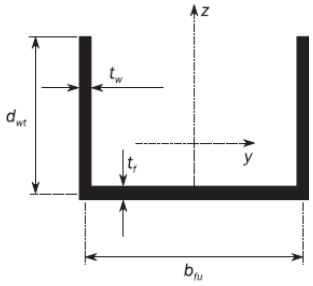
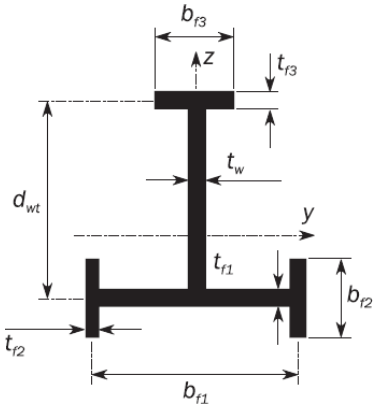
A : Net cross sectional area, in cm^2, as defined in [3.1.2].

I_{pol} : Net polar moment of inertia about the shear centre of cross section, in cm^4 as defined in [3.1.3].

σ_{EC} : Elastic column compressive buckling stress, as defined in [3.1.2].

σ_{ET} : Elastic torsional buckling stress, as defined in [3.1.3].

Cross sectional properties **Table 7**

	$I_{sv} = \frac{1}{3}\left(2b_f t_f^3 + d_{wt} t_w^3\right)10^{-4}$	cm^4
	$c_{warp} = \frac{d_{wt}^2 b_f^3 t_f}{24} 10^{-6}$	cm^6
	$I_{sv} = \frac{1}{3}\left(2b_f t_f^3 + d_{wt} t_w^3\right)10^{-4}$	cm^4
	$y_0 = 0$	cm
	$z_0 = -\frac{0.5 d_{wt}^2 t_w}{d_{wt} t_w + b_f t_f} 10^{-1}$	cm
	$c_{warp} = \frac{b_f^3 t_f^3 + 4 d_{wt}^3 t_w^3}{144} 10^{-6}$	cm^6
	$I_{sv} = \frac{1}{3}\left(b_{fu} t_f^3 + 2 d_{wt} t_w^3\right)10^{-4}$	cm^4
	$y_0 = 0$	cm
	$z_0 = -\frac{d_{wt}^2 t_w 10^{-1}}{2 d_{wt} t_w + b_{fu} t_f} - \frac{0.5 d_{wt}^2 t_w 10^{-1}}{d_{wt} t_w + b_{fu} t_f / 6}$	cm
	$c_{warp} = \frac{b_{fu}^2 d_{wt}^3 t_w (d_{wt} t_w + 2 b_{fu} t_f)}{12(6 d_{wt} t_w + b_{fu} t_f)} 10^{-6}$	cm^6
	$I_{sv} = \frac{1}{3}\left(b_{f1} t_{f1}^3 + 2 b_{f2} t_{f2}^3 + b_{f3} t_{f3}^3 + d_{wt} t_w^3\right)10^{-4}$	cm^4
	$y_0 = 0$	cm
	$z_0 = z_s - \frac{(b_{f3} d_{wt} t_{f3} + 0.5 d_{wt}^2 t_w)10^{-1}}{d_{wt} t_w + b_{f1} t_{f1} + 2 b_{f2} t_{f2} + b_{f3} t_{f3}}$	cm
	$C_{warp} = \left(I_{f1} Z_s^2 + \frac{I_{f2} b_{f1}^2}{200} + I_{f3} \left(\frac{d_{wt}}{10} - Z_s \right)^2 \right)$	cm^6
	$I_{f1} = \left(\frac{\left(b_{f1} - t_{f2}\right)^3 t_{f1}}{12} + \frac{b_{f2} t_{f2} b_{f1}^2}{2} \right) 10^{-4}$	cm^4
	$I_{f2} = \frac{b_{f2}^3 t_{f2}}{12} 10^{-4}$	cm^4
	$I_{f3} = \frac{b_{f3}^3 t_{f3}}{12} 10^{-4}$	cm^4
	$z_s = \frac{I_{f3} d_{wt}}{I_{f1} + I_{f3}} 10^{-1}$	cm

Note1: All dimensions are in mm.
Note2: Cross sectional properties are given for typical cross sections. Properties for other cross sections are to be determined by direct calculation.

3.2 Corrugated bulkhead

3.2.1

The buckling utilisation factor of flange and web of corrugation of corrugated bulkheads is based on the combination of in plane stresses and shear stress.

The interaction curve of [2.2.1] is to be used with the following coefficients:

- α=2
- $\psi_x = \psi_y = 1$

Appendix 1 STRESS BASED REFERENCE STRESSES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

a : Length, in mm, of the longer side of the plate panel as defined in Sec 5.

b : Length, in mm, of the shorter side of the plate panel as defined in Sec 5.

A_i : Area, in mm^2, of the i-th plate element of the buckling panel.

n : Number of plate elements in the buckling panel.

σ_{xi} : Actual stress, in N/mm^2, at the centroid of the i-th plate element in x direction, applied along the shorter edge of the buckling panel.

σ_{yi} : Actual stress, in N/mm^2, at the centroid of the i-th plate element in y direction, applied along the longer edge of the buckling panel.

Ψ : Edge stress ratio as defined in Sec 5.

τ_i : Actual membrane shear stress, in N/mm^2, at the centroid of the i-th plate element of the buckling panel.

1 STRESS BASED METHOD

1.1 Introduction

1.1.1

This section provides a method to determine stress distribution along edges of the considered buckling panel by 2nd order polynomial curve, by linear distribution using least square method and by weighted average approach. This method is called Stress based Method.

The reference stress is the stress components at centre of plate element transferred into the local system of the considered buckling panel.

1.1.2 Definition

A regular panel is a plate panel of rectangular shape. An irregular panel is plate panel which is not regular, as detailed in Ch 8, Sec 4, [2.3.1].

1.2 Stress application

1.2.1 Regular panel

The reference stresses are to be taken as defined in [2.1] for a regular panel when the following conditions are satisfied:

- At least, one plate element centre is located in each third part of the long edge a of a regular panel and
- This element centre is located at a distance in the panel local x direction not less than $a/4$ to at least one of the element centres in the adjacent third part of the panel.

Otherwise, the reference stresses are to be taken as defined in [2.2] for an irregular panel.

1.2.2 Irregular panel and curved panel

The reference stresses of an irregular panel or of a curved panel are to be taken as defined in [2.2].

2 REFERENCE STRESSES

2.1 Regular Panel

2.1.1 Longitudinal stress

The longitudinal stress σ_x applied on the shorter edge of the buckling panel is to be calculated as follows:

- For plate buckling assessment, the distribution of $\sigma_x(x)$ is assumed as 2nd order polynomial curve as:

  $\sigma_x = Cx^2 + Dx + E$

  The best fitting curve $\sigma_x(x)$ is to be obtained by minimising the square error Π considering the area of each element as a weighting factor.

  $$\prod = \sum_{i=1}^{n} A_i \left[\sigma_{xi} - \left(Cx^2 + Dx + E \right) \right]^2$$

  The unknown coefficients C, D and E must yield zero first derivatives, $\partial \Pi$ with respect

to C, D and E
respectively.

$$\frac{\partial \prod}{\partial C} = 2\sum_{i=1}^{n} A_i x_i^2 \left[\sigma_{xi} - (Cx_i^2 + Dx_i + E) \right] = 0$$

$$\frac{\partial \prod}{\partial D} = 2\sum_{i=1}^{n} A_i x_i \left[\sigma_{xi} - (Cx_i^2 + Dx_i + E) \right] = 0$$

$$\frac{\partial \prod}{\partial E} = 2\sum_{i=1}^{n} A_i \left[\sigma_{xi} - (Cx_i^2 + Dx_i + E) \right] = 0$$

The unknown coefficients C, D and E can be obtained by solving the 3 above equations.

$$\sigma_{x1} = \frac{1}{b}\int_0^b \sigma_x(x)\mathrm{d}x = \frac{b^2}{3}C + \frac{b}{2}D + E$$

$$\sigma_{x2} = \frac{1}{b}\int_{a-b}^{a} \sigma_x(x)\mathrm{d}x = \left(a^2 - ab + \frac{b^2}{3}\right)C + \left(a - \frac{b}{2}\right)D + E$$

If $-D/2C < b/2$ or $-D/2C > a-b/2$, σ_{x3} is to be ignored. Otherwise, σ_{x3} is taken as:

$$\sigma_{x3} = \frac{1}{b}\int_{x\min}^{x\max} \sigma_x(x)\mathrm{d}x = \frac{b^2}{12}C - \frac{D^2}{4C} + E$$

where:

$$x_{\min} = -\frac{b}{2} - \frac{D}{2C}$$

The longitudinal stress is to be taken as:
$\sigma_x = \max(\sigma_{x1}; \sigma_{x2}; \sigma_{x3})$
The edge stress ratio is to be taken as:
$\psi_x = 1$

- For overall stiffened panel buckling and stiffener buckling assessments, $\sigma_x(x)$ applied on the shorter edge of the attached plate is to be taken as:

$$\sigma_x = \frac{\sum_{1}^{n} A_i \sigma_{xi}}{\sum_{1}^{n} A_i}$$

The edge stress ratio ψ_x for the stress σ_x is equal to 1.0.

2.1.2 Transverse stress

The transverse stress σ_y applied along the longer edges of the buckling panel is to be calculated by extrapolation of the transverse stresses of all elements up to the shorter edges of the considered buckling panel.

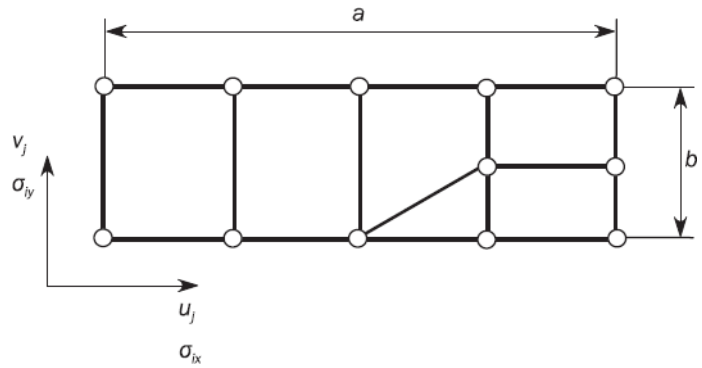


Figure 1 Buckling panel

The distribution of $\sigma_y(x)$ is assumed as straight line. Therefore:
$\sigma_y(x) = A+Bx$

The best fitting curve $\sigma_y(x)$ is to be obtained by the least square method minimising the square error Π considering area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^{n} A_i \left[\sigma_{yi} - (A + Bx_i) \right]^2$$

The unknown coefficients *A* and *B* must yield zero first partial derivatives, $\partial\Pi$ with respect to *A* and *B*, respectively.

$$\frac{\partial \Pi}{\partial A} = 2\sum_{i=1}^{n} A_i \left[\sigma_{yi} - (A + Bx_i) \right] = 0$$

$$\frac{\partial \Pi}{\partial B} = 2\sum_{i=1}^{n} A_i x_i \left[\sigma_{yi} - (A + Bx_i) \right] = 0$$

The unknown coefficients A and *B* are obtained by solving the 2 above equations and are given as follow:

$$\begin{cases} A = \dfrac{\left(\sum_{i=1}^{n} A_i \sigma_{yi}\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i x_i \sigma_{iy}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2} \\ B = \dfrac{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i \sigma_{iy}\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i \sigma_{iy}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2} \end{cases}$$

$\sigma_y = \max(A, A+Ba)$

$$\psi_y = \frac{\min(A, A + Ba)}{\max(A, A + Ba)} \text{ for } \sigma_y \geqslant 0$$

$\Psi_y = 1$ for $y < 0$

2.1.3 Shear stress

The shear stress τ is to be calculated using a weighted average approach, and is to be taken as:

$$\tau = \frac{\sum_{1}^{n} A_i \tau_i}{\sum_{1}^{n} A_i}$$

2.2 Irregular panel and curved panel

2.2.1 Reference stresses

The longitudinal, transverse and shear stresses are to be calculated using a weighted average approach. They are to be taken as:

$$\sigma_x = \frac{\sum_{1}^{n} A_i \sigma_{xi}}{\sum_{1}^{n} A_i}$$

$$\sigma_y = \frac{\sum_{1}^{n} A_i \sigma_{yi}}{\sum_{1}^{n} A_i}$$

$$\tau = \frac{\sum_{1}^{n} A_i \tau_i}{\sum_{1}^{n} A_i}$$

The edge stress ratios are to be taken as

$\Psi_x = 1$

$\Psi_y = 1$

Chapter 9 FATIGUE

Section 1 GENERAL CONSIDERATIONS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

T_{DF}: Design fatigue life, in year, specified by the designer, but not to be taken less than 25 years.

1 RULE APPLICATION FOR FATIGUE REQUIREMENTS

1.1 Scope

1.1.1 General

This chapter provides requirements applicable to ships having rule a freeboard length L_{LL} between 150 m and 500 m to evaluate fatigue strength of the ship's structural details considering an operation time in North Atlantic environment equal to the design fatigue life, T_{DF}.

1.1.2 Assessed area

Fatigue assessment is performed for structural details located in the ship's cargo hold region in order to prevent the following types of fatigue failure:

- Fatigue cracks initiating from the toe of the weld and propagating into the plate.
- Fatigue cracks initiating from free edge of non-welded details.

1.1.3 Structural details to be assessed

The structural details required for fatigue assessment are given in Ch 9, Sec 2:

- Structural details to be checked are listed in:
  - Ch 9, Sec 2, [1] for simplified stress analysis according to Ch 9, Sec 4, or
  - Ch 9, Sec 2, [2] for finite element stress analysis according to Ch 9, Sec 5.
- Structural details to be checked by screening fatigue assessment are listed in Ch 9, Sec 2, Table 2.

Additional specific details may be requested to be checked on a case-by-case basis by the Society.

CCS 1.1.3a Where the fatigue strength of details other than those specified in Section 2 of this Chapter needs to be verified, fatigue assessment may be carried out in accordance with the requirements of this Chapter.

1.1.4 Detail design standard

Detail design standard given in Ch 9, Sec 6 provides welding requirement at critical structural details in order to prevent the following types of fatigue failure:

- Fatigue cracks initiating from the weld toe into the base material.
- Fatigue cracks initiating from the weld root and propagating into the plate section under the weld.
- Fatigue cracks initiating from the weld root and propagating through the weld throat.
- Fatigue cracks initiating from surface irregularity or notch at the free edge into the base material.

1.1.5 Material

The fatigue assessment is applicable for steel material with specified minimum yield stress less than or equal to 390 N/mm^2. For steel with specified minimum yield stress value higher than 390 N/mm^2 and for steels with improved fatigue performance, the S-N curves to be used are considered by the Society on a case-by-case basis.

CCS 1.1.5a S-N curves in Chapter 9 of this PART or those in air and/or corrosive environment in IIW, HSE or ISO standards may be used, taking into account the applicability of the minimum yield stress. S-N curves obtained from testing may also be used and the probability of survival is not to be less than 97.7%.

CCS 1.1.5b Where S-N curves of other standards are used, relevant technical documents are to

be submitted as audit basis.
CCS 1.1.5c Where S-N curves obtained from testing are used, relevant testing reports are to be submitted as audit basis and the qualification proof of testing organization is also to be submitted.
CCS 1.1.5d Where S-N curves in corrosive environment are obtained from testing, the evidence demonstrating that the corrosive environment used in testing is equivalent to that of sea water is also to be submitted.

1.1.6 Wave loads
Fatigue assessment is based on quasi-static wave loads.

1.1.7 Loads other than wave loads
Fatigue induced by low cycle loads such as cargo variations or impact loads such as sloshing in partially filled tanks which may induce fatigue damage is disregarded in this chapter.

2 DEFINITION

2.1 Hot spots

2.1.1
Hot spots are locations in the structure where fatigue cracks may initiate due to the combined effect of nominal structural stress fluctuation and stress raising effects due to the weld geometry or similar effects due to notch in the base material.
Hot spots may be located at:

- Weld toe.
- Weld root of partial penetration or fillet weld.
- Base material at free edge of plate.

2.2 Nominal stress

2.2.1
Nominal stress is the stress in a structural component taking into account macro-geometric effect but disregarding the stress concentration due to structural discontinuities and the presence of welds. Nominal stress is to be obtained either using coarse or fine mesh FE analysis, as required in Ch 9, Sec 5 or using analytical calculation based on beam theory, as required in Ch 9, Sec 4.

2.3 Hot spot stress

2.3.1
Hot spot stress is the stress at the weld toe taking into account the stress concentration due to structural discontinuities and presence of welded attachments but disregarding the non-linear stress peak caused by the notch at the weld toe. The hot spot stresses to be considered correspond to the two principal stresses on the surface plating at the weld toe. The first principal stress acts within $\pm 45°$, perpendicular to the weld and the second principal stress acts outside $\pm 45°$.
The hot spot stress is to be obtained by multiplying the nominal stress by a Stress Concentration Factor (SCF), according to Ch 9, Sec 4, [5] or directly by a very fine mesh FE analysis, according to Ch 9, Sec 5, [3] and Ch 9, Sec 5, [4].

2.4 Local stress at free edge

2.4.1
Local stress at free edge is the stress at the plate free edge derived using finite element analysis according to Ch 9, Sec 5, [3.2].

2.5 Fatigue stress

2.5.1
Fatigue stress is the stress relevant for fatigue assessment purpose,i.e.:

- Maximum of the two principal hot spot stress for weld toe with the mean stress effect and thickness effect corrections.
- Local stress at free edge with corrections due to the base material surface finishing, mean stress effect, thickness effect and material strength.

3 ASSUMPTIONS

3.1 General

3.1.1

The following assumptions are made in the fatigue assessment:

a) A linear cumulative damage model, i.e. Palmgren-Miner's Rule, given in Ch 9, Sec 3, [5], has been used in connection with the design S-N curves, given in Ch 9, Sec 3, [4].
b) Design fatigue life, T_{DF}, is taken not less than 25 years.
c) Rule quasi-static wave induced loads are based on North Atlantic wave environment. They are determined at 10^{-2} probability level of exceedance by the Equivalent Design Wave (EDW) concept.
d) Net thickness t_{n50} approach is used, according to [5].
e) Type of stress used for crack initiating at the weld toe is the hot spot stress. Type of stress used for crack initiating at free edge of non-welded details is local stress at free edge.
f) Fatigue stress range $\Delta\sigma_{FS}$ may be calculated by simplified stress analysis or by finite element stress analysis for details with more complex geometry.
g) Long term distribution of stress range of a structural detail is assumed to follow a two-parameter Weibull distribution. Weibull shape parameter is equal to 1 and the fatigue stress range $\Delta\sigma_{FS}$ is given at the reference probability level of exceedance equal to 10^{-2}.
h) The acceptance criteria for fatigue checking are the total fatigue damage D to be less than 1 for the design fatigue life, as required in Ch 9, Sec 3, [2].

4 METHODOLOGY

4.1 Principles

4.1.1 General

Appropriate fatigue strength of structural details is ensured by use of:

- Detail design standards given in Ch 9, Sec 6, providing specific design requirements.
- Fatigue strength assessment by fatigue life calculation, based on three different methods for hot spot stress calculation: simplified stress analysis, very fine mesh finite element stress analysis and fatigue screening assessment.

4.2 Simplified stress analysis

4.2.1

Procedure based on simplified stress analysis, required in Ch 9, Sec 4, is used to determine the hot spot stress at weld toe of longitudinal stiffener end connections, given in Ch 9, Sec 2, [1.1].

Nominal stresses are calculated by using analytical method based on beam theory according to Ch 9, Sec 4, [3] and Ch 9, Sec 4, [4]. Hot spot stresses are obtained by multiplying nominal stresses by stress concentration factors (SCF) of the considered detail according to Ch 9, Sec 4, [5.2].

4.3 Finite element stress analysis

4.3.1

Procedure based on finite element stress analysis, required in Ch 9, Sec 5, is used to determine hot spot stress at weld toe of specified structural details, from very fine mesh models.

The hot spot stress is generally highly dependent on the finite element model used for representing the structure.

General procedure for the calculation of hot spot stress at weld toe for any welded details except for web stiffened cruciform joints is given in Ch 9, Sec 5, [3.1]. Procedure for the calculation of hot spot stress at the flange connections for web stiffened cruciform joints is given in Ch 9, Sec 5, [4]. Calculation of local stress for non-welded area is provided in Ch 9, Sec 5, [3.2].

A list of details for which the fatigue assessment is to be made through a compulsory very fine mesh finite element analysis or through the compliance with the design standard given in Ch 9, Sec 6 if a very fine mesh finite element analysis is omitted, is given respectively in Ch 9, Sec 2, Table 1 and Ch 9, Sec 2, Table 3.

4.4 Fatigue screening assessment

4.4.1

A fatigue screening procedure is used to assess the fatigue strength of specified structural details, given in Ch 9, Sec 2, [2.1.3]. The screening procedure is based on screening hot spot stress at

weld toe of specified structural details determined by multiplying the stresses obtained from a local fine mesh finite element model, required in Ch 7, Sec 3, by stress magnification factor of the considered detail, given in Ch 9, Sec 5, Table 2.

4.5 Fatigue design standards

4.5.1

Detail design standards given in Ch 9, Sec 6 are provided to ensure improved fatigue performance of critical structural details. Alternative detail design configurations may be accepted subject to demonstration of satisfactory fatigue performance.

5 CORROSION MODEL

5.1 Net thickness

5.1.1 General

The fatigue assessment should be performed based on net thicknesses according to Ch 3, Sec 2.

5.1.2 Stress correction

The hull girder stresses for simplified stress analysis and stresses calculated by FE analysis are to be corrected by multiplying the calculated stress by f_c, correction factor taken as:

f_c =0.95

6 LOADING CONDITIONS

6.1 Description

6.1.1

Fatigue analyses are to be carried out for representative loading conditions according to the intended ship's operation as given in [6.2] and [6.3].

6.2 Loading conditions for oil tankers

6.2.1

The loading conditions to be considered for oil tankers and corresponding fraction of time for each loading condition, $\alpha_{(j)}$, are defined in Table 1. The standard loading conditions for fatigue assessment of oil tankers are provided in Ch 4, Sec 8, [5.1].

Fraction of time in each loading condition for oil tanker **Table 1**

Loading conditions	$\alpha_{(j)}$
Full Load condition (Homogeneous)	0.5
Normal ballast condition	0.5

6.3 Loading conditions for bulk carriers

6.3.1

The loading conditions to be considered for bulk carriers and corresponding fraction of time for each loading condition, $\alpha_{(j)}$, are defined respectively in Table 2 and Table 3 depending on the ship's type (BC-A, BC-B, BC-C). The standard loading conditions for fatigue assessment of bulk carriers are provided in Ch4, Sec 8, [5.2].

Loading conditions for bulk carriers **Table 2**

Ship type	Full load condition		Ballast condition	
	Homogeneous	Alternate	Normal ballast	Heavy ballast
BC-A	X	X	X	X
BC-B	X	-	X	X
BC-C	X	-	X	X

7 LOAD CASES

7.1 Assumptions

7.1.1

The load cases to be considered for fatigue assessment are given in Ch 4, Sec 2, [3].

The design load scenario for fatigue assessment is defined in Ch 4, Sec 7, Table 3.

For each loading condition defined in [6], all fatigue load cases are to be considered to generate the combination of dynamic loads for fatigue assessment

7.1.2 Predominant load case

The predominant load case for each loading condition (*j*) is defined as load case where the fatigue stress range for the critical location is the maximum among all fatigue load cases.

Fraction of time for each loading condition of bulk carriers **Table 3**

Ship length	Loading conditions	$\alpha_{(j)}$	
		BC-A	BC-B, BC-C
L < 200 m	Homogeneous	0.60	0.70
	Alternate	0.10	-
	Normal ballast(1)	0.15	0.05
	Heavy ballast(1)	0.15	0.25
$L \geqslant$ 200 m	Homogeneous	0.25	0.50
	Alternate	0.25	-
	Normal ballast	0.20	0.20
	Heavy ballast	0.30	0.30

(1) For BC-B and BC-C without heavy ballast cargo hold, fraction of time $\alpha_{(j)}$ for normal ballast is 0.30 and for heavy ballast 0.

Section 2 STRUCTURAL DETAILS TO BE ASSESSED

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.
EA : Empty cargo hold in alternate loading condition.
FA : Full cargo hold in alternate loading condition.

1 SIMPLIFIED STRESS ANALYSIS

1.1 Structural details to be assessed

1.1.1

Critical structural details to be checked over the full extent of the cargo region for fatigue assessment by simplified stress analysis according to Ch 9, Sec 1 are:

- End connections of longitudinal stiffeners to transverse bulkheads, including swash bulkheads,
- End connections of longitudinal stiffeners to floors and web frames.

2 FINITE ELEMENT ANALYSIS

2.1 Structural details to be assessed

2.1.1 General

Critical structural details to be checked for fatigue by finite element analysis according to Ch 9, Sec 5 are given in [2.1.2] to [2.1.4].
Table 4 to Table 19 give the list of hot spots for structural details.

CCS 2.1.1a The requirements in Table 16 apply to the hot spots corresponding to the 6th item in Table 3 of Section 2, Chapter 9. Fatigue assessment of the following hot spots is to be carried out, see Figure CCS 2.1.1a.

(1) in way of corner of curvature of free edge of the cut-out, see hot spots 1, 2 and 3 in Figure CCS 2.1.1a;
(2) *intersection of web of transverse frame to longitudinal web, see hot spots 4 and 5 in Figure CCS 2.1.1a;*
(3) *intersection of lug plate to longitudinal web, see hot spots 6 and 7 in Figure CCS 2.1.1a;*
(4) *intersection of web of transverse frame to lug plate, see hot spots 8, 9, 10 and 11 in Figure CCS 2.1.1a (where hot spots 10 and 11 are located near the middle point of side length);*
(5) *intersection of web of transverse frame to attached plating of longitudinal, see hot spots 12 and 13 in Figure CCS 2.1.1a.*

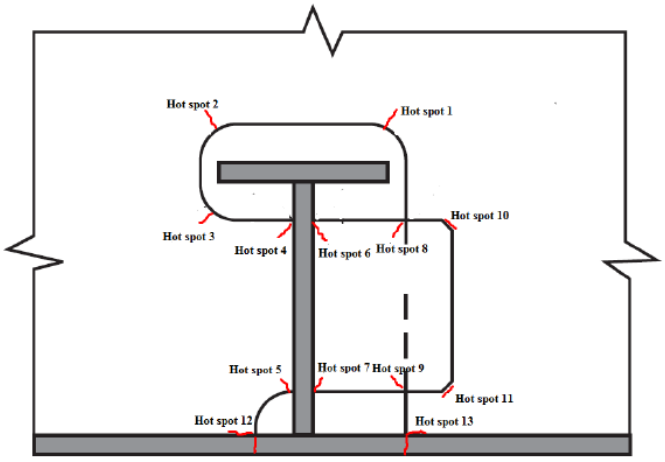


Figure CCS 2.1.1a Critical Hot Spot

CCS 2.1.1b The general requirements for FE modeling of Table 16 are given in 2.1.1 to 2.1.7 of Section 5.
CCS 2.1.1c The FE modeling requirements in way of the cut-out in Table 16 are given in CCS 2.2.1a of Section 6. In way of hot spots 10 and 11, the number of mesh along the side length is not

to be less than 4.
CCS 2.1.1d The fatigue assessment method in Table 16 is given in Sections 1 and 3.

2.1.2 Details to be checked by very fine mesh analysis

Critical structural details to be assessed for fatigue by very fine mesh analysis according to Ch 9, Sec 5, [1] to Ch 9, Sec 5, [4] are provided in Table 1, irrespective of their compliance with the design standard given in Ch 9, Sec 6.

2.1.3 Details to be checked by screening fatigue assessment

The structural details listed in Table 2 for which FE fine mesh models have been analysed according to yielding requirements given in Ch 7, Sec 3 are to be assessed using the screening fatigue procedure as given in Ch 9, Sec 5, [6]. or to be assessed by very fine mesh analysis according to Ch 9, Sec 5, [1] to [4].

2.1.4 Details in accordance with detail design standard

Table 3 gives critical structural details for which fatigue assessment by very fine mesh analysis can be omitted if their design is in accordance with detail design standard given in Ch 9, Sec 6.

Structural details to be assessed by very fine mesh analysis **Table 1**

No	Critical detail	Applicability	
		Oil tanker	Bulk carrier
1	Welded lower hopper knuckle connection (intersection of hopper sloping plate, inner bottom plate, longitudinal girder, floor and transverse web) at the most critical frame location. (1)	One cargo tank (4)	Ballast hold
2	Radiused lower hopper knuckle connection (intersection of knuckled inner bottom plate, longitudinal girder, floor and transverse web) at the most critical frame location. (1)	One cargo tank (4)	Ballast hold
3	Welded upper knuckle connection (intersection of hopper sloping plate, inner hull longitudinal bulkhead, transverse web and side stringer) where the angle between hopper plate and inner hull longitudinal bulkhead is less than 130 deg, at the most critical frame location. (1)	One cargo tank (4)	Ballast hold of double side bulk carrier
4	Connections of transverse bulkhead lower stools to the inner bottom plating in way of double bottom girders. (2) (3)	One cargo tank (4)	Ballast hold
5	Upper side frame bracket toe in case of flat bottom of top wing tank. (1)	N/A	FA hold (4), EA hold (4) and ballast hold of single skin bulk carrier
6	Deck plating and longitudinal hatch coaming end bracket toe.	N/A	Two aftermost holds, midship hold and two foremost holds

(1) The most critical frame position is generally, but not necessarily, located closest to the mid length of the hold. Where a swash bulkhead is fitted, this is generally located closest to the mid length between the swash bulkhead and the oil-tight bulkhead.
(2) Stool connections at each end of the hold are to be checked unless these are symmetrical about mid-hold.
(3) Position at the mid breadth location of the largest hold.
(4) Cargo hold located closest to the midship.

Structural details for screening fatigue assessment **Table 2**

No	Critical detail	Applicability	
		Oil tanker	Bulk carrier
1	Bracket toe of transverse web frame	Applicable (1)	N/A
2	Toe of horizontal stringer	Applicable (1)	N/A

No	Critical detail	Applicability	
		Oil tanker	Bulk carrier
3	Lower hopper knuckle connection in EA hold (2) and in FA hold (2) not assigned as a ballast hold	N/A	Applicable (1)
4	Connections of transverse bulkhead lower stool to inner bottom in EA hold (2) and in FA hold (2) where the ballast hold is not assigned to the ship	N/A	Applicable (1)

(1) For details assessed by fine mesh analysis according to Ch 7, Sec 3, [3.2].
(2) Cargo hold located closest to the midship.

Structural details to be assessed by very fine mesh analysis if not designed in accordance with detail design standard Table 3

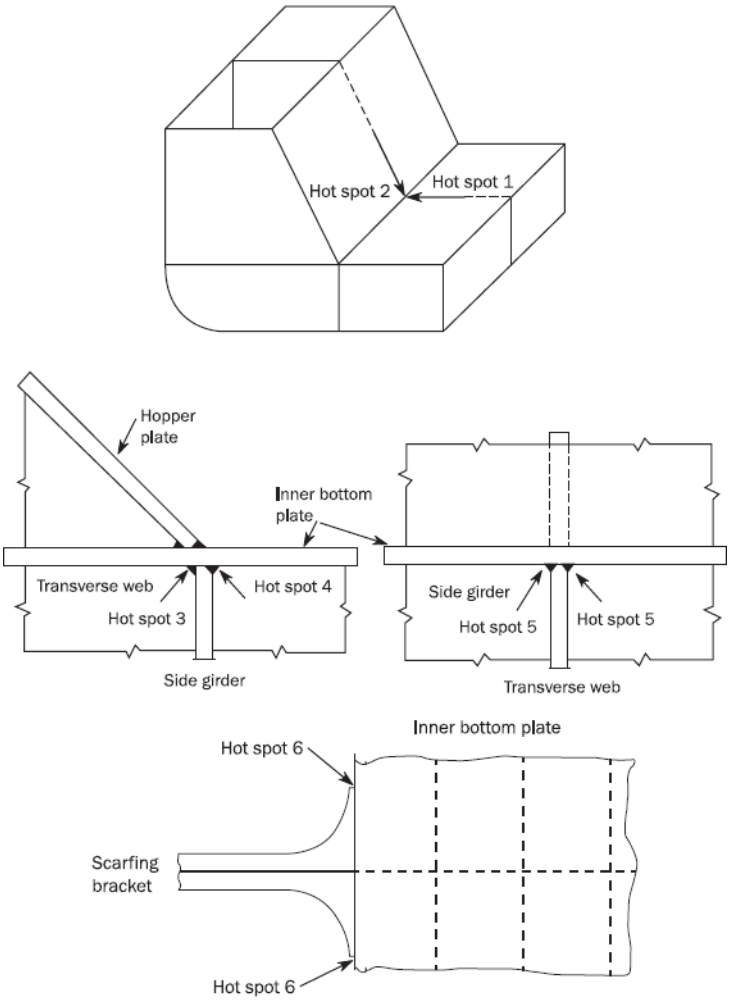
No	Critical detail	Corresponding detail design standard	Applicability	
			Oil tanker	Bulk carrier
1	Radiused upper hopper knuckle connection (intersection of knuckled inner side plate, side girder and transverse web) at the most critical frame location. (1)	Ch 9, Sec 6, [4]	One cargo tank (4)	Ballast hold of double side bulk carrier
2	Corrugations of bulkheads to lower stool or inner bottom plating connection. (2) (3)	Ch 9, Sec 6, [6] and Ch 9, Sec 6, [7]	One cargo tank (4)	Ballast hold
3	Corrugations of transverse bulkheads to upper stool. (2) (3)	Ch 9, Sec 6, [6]	N/A	Ballast hold
4	Cruciform heel connections between side stringers in double side and transverse bulkhead horizontal stringers, for the stringer closest to the mid depth and for the uppermost one.	Ch 9, Sec 6, [5]	One cargo tank	N/A
5	Lower and upper side frame bracket toes at the most critical frame position. (1)	Ch 9, Sec 6, [8]	N/A	FA hold (4), EA hold (4) and ballast hold of single skin bulk carrier
6	Cut out for longitudinal stiffeners in web-frame without web stiffener connection.	Ch 9, Sec 6, [2.1]	One cargo tank (4)	FA hold (4), EA hold (4) and ballast hold
7	Scallops in way of block joints on strength deck close to mid hold (and down to 0.1D from deck corner).	Ch 9, Sec 6, [3]	One cargo tank (4)	FA hold (4), EA hold (4) and ballast hold

(1) The most critical frame position is generally, but not necessarily, located closest to the mid length of the hold. Where a swash bulkhead is fitted, this is generally located closest to the mid length between the swash bulkhead and the oil-tight bulkhead.
(2) Stool connections at each end of the hold are to be checked unless these are symmetrical about mid-hold.
(3) Position at the mid breadth or length location of the largest hold in the considered transverse section or longitudinal section.
(4) Cargo hold located closest to the midship.

Hot spots for welded lower hopper knuckle connection Table 4

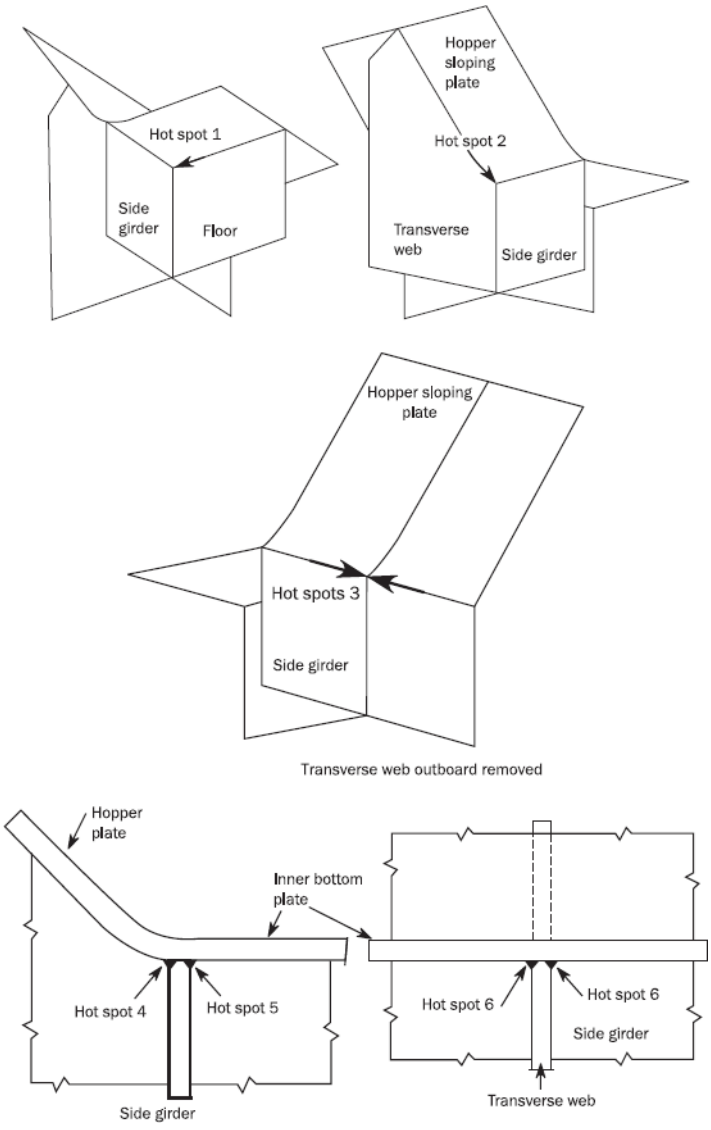
Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner bottom plate, on cargo tank side Hot spot 2: Hopper sloping plate, on cargo tank side	Ch 9, Sec 5, [4.2]

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 3: Hopper web, outboard of side girder Hot spot 4: Double bottom floor, inboard the side girder Hot spot 5: Side girder	Ch 9, Sec 5, [4.3]
Hot spot 6: Scarfing bracket to the inner bottom plate	Ch 9, Sec 5, [3.1], type '*b*'



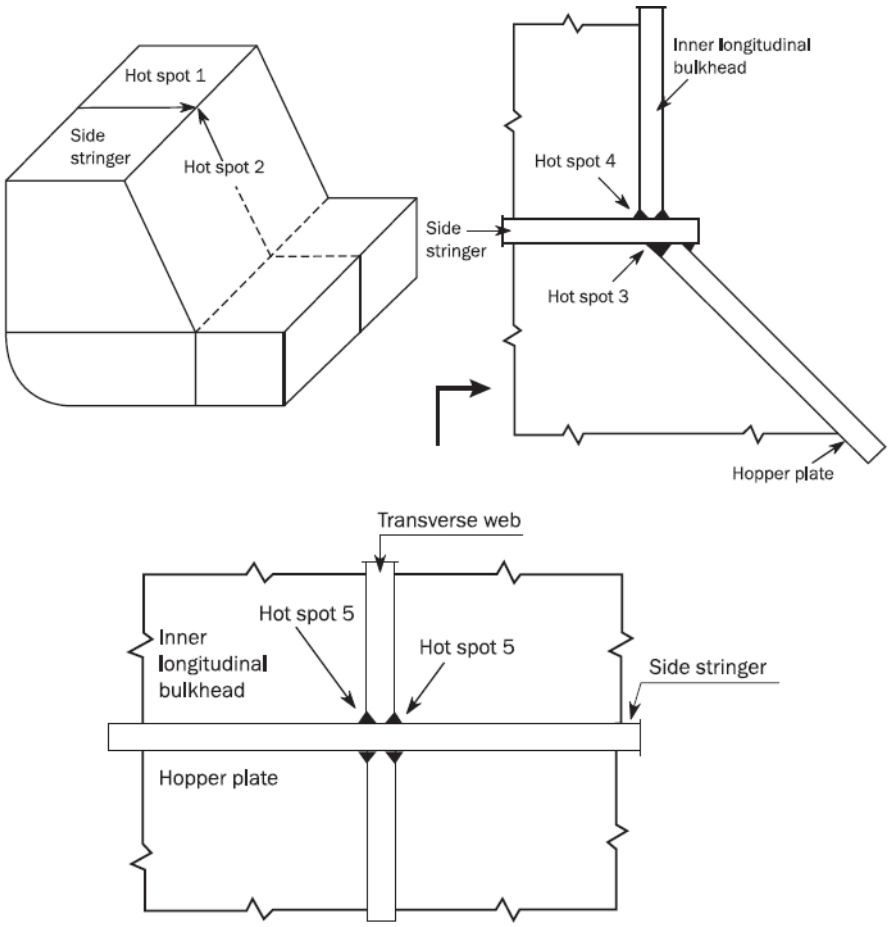
Hot spots for radiused lower hopper knuckle connection **Table 5**

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner bottom plate on ballast tank side, inboard of the side girder Hot spot 2: Radiused hopper sloping plate on ballast tank side outboard of the side girder Hot spot 3: Radiused hopper sloping plate on ballast tank side, outboard of the side girder, towards transverse web Hot spot 4: Hopper web, outboard of side girder Hot spot 5: Double bottom floor, inboard of the side girder Hot spot 6: Side girder	Ch 9, Sec 5, [3.3]



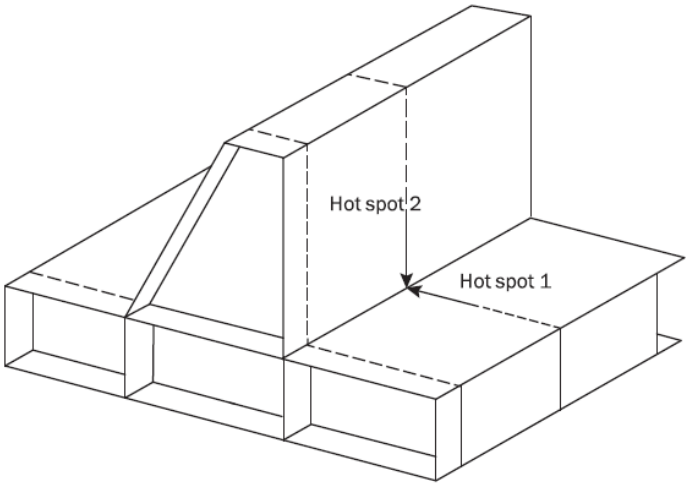
Hot spots for welded upper knuckle connection **Table 6**

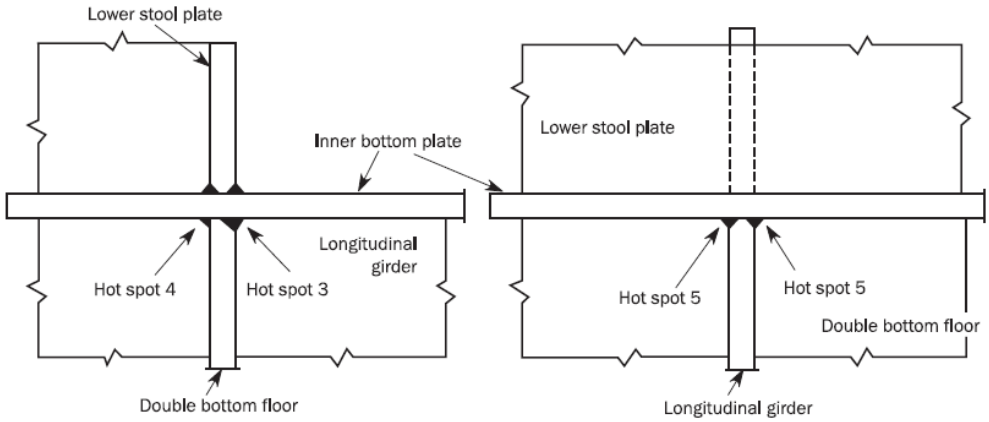
Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Side stringer on ballast tank side Hot spot 2: Hopper sloping plate, on ballast tank side	Ch 9, Sec 5, [4.2]
Hot spot 3: Transverse web, below stringer. Hot spot 4: Transverse side web, above stringer Hot spot 5: Inner hull longitudinal bulkhead on ballast tank side	Ch 9, Sec 5, [4.3]



Hot spots for connections of transverse bulkhead lower stools to the inner bottom plating in way of double bottom girders **Table 7**

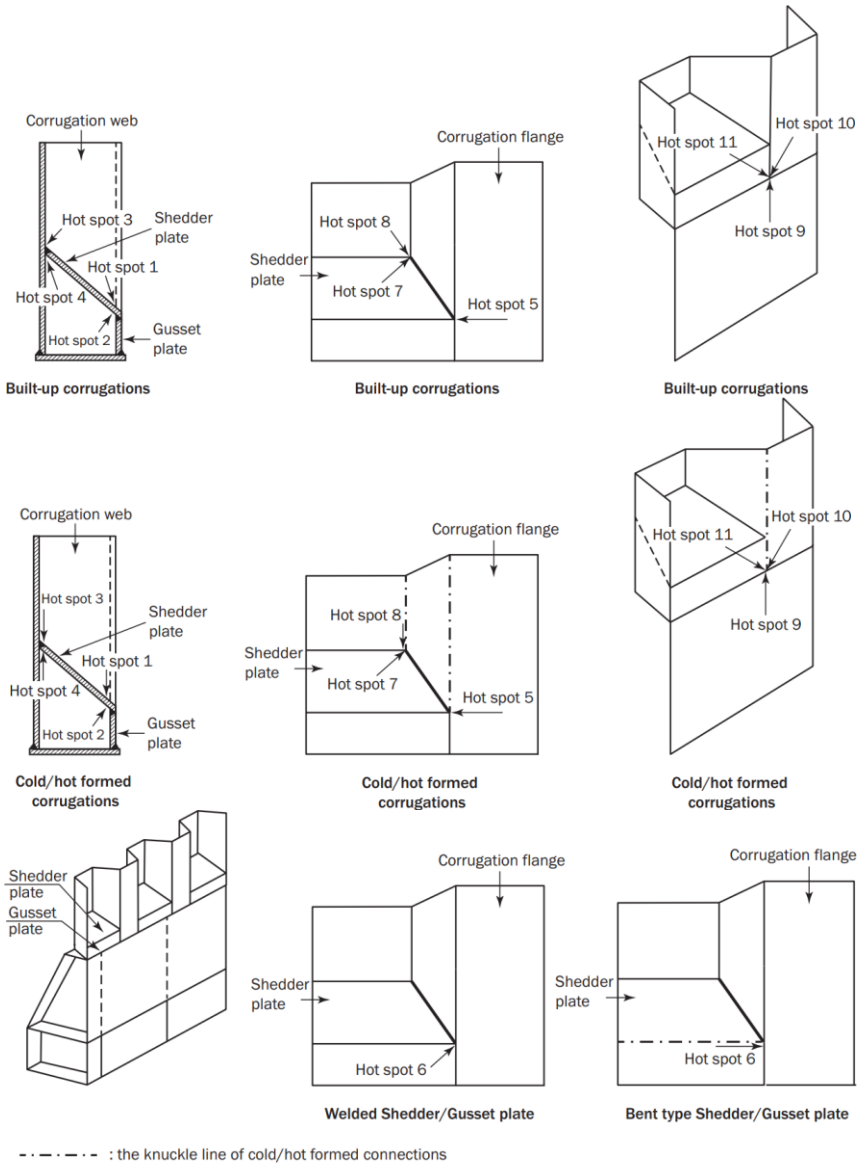
Hot spot ocation	Procedure for calculation of hot spot stress
Hot spot 1: Inner bottom plate, on cargo hold side Hot spot 2: Stool sloping plate, on cargo hold side	Ch 9, Sec 5, [4.2]
Hot spot 3: Longitudinal girder, under hold, to supporting floor in line with stool plate Hot spot 4: Longitudinal girder, under stool space to supporting floor in line with stool plate Hot spot 5: Double bottom supporting floor in line with stool plate	Ch 9, Sec 5, [4.3]



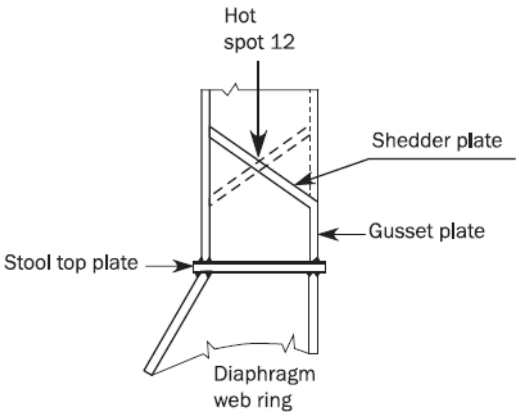
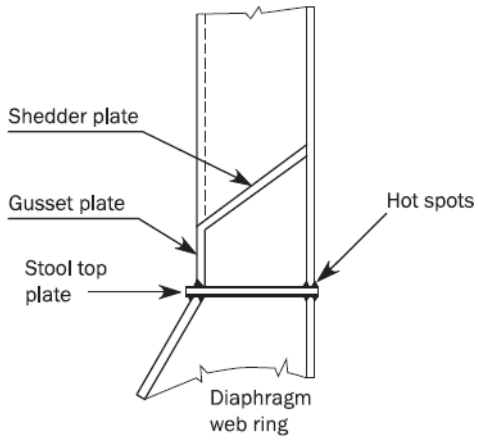


Hot spots for corrugated bulkhead to lower stool connection **Table 8**

Hot spot location		Procedure for calculation of hot spot stress	
		Cold/hot formed corrugations (Bent type)	Built-up corrugations (welded)
Hot spots 1 and 3: Corrugation web above shedder plate Hot spot 4: Corrugation web below shedder plate Hot spot 8: Corrugation flange		Ch 9, Sec 5, [3.1], type 'a'	Ch 9, Sec 5, [4.3]
Hot spot 2: Corrugation web below shedder plate Hot spot 7: Shedder plate Hot spot 10: Corrugation corner to stool top plate Hot spot 11: Gusset plate in way of corrugation corner		Ch 9, Sec 5, [4.3]	
Hot spot 5: Corrugation flange Hot spot 9: Lower stool plate to stool top plate		Ch 9, Sec 5 [3.1], type 'a'	
Hot spot 6: Gusset plate in case of:	welded gusset plate/shedder plate	Ch 9, Sec 5, [4.3]	
	bent type gusset plate/shedder plate	Ch 9, Sec 5, [3.1], type 'a'	



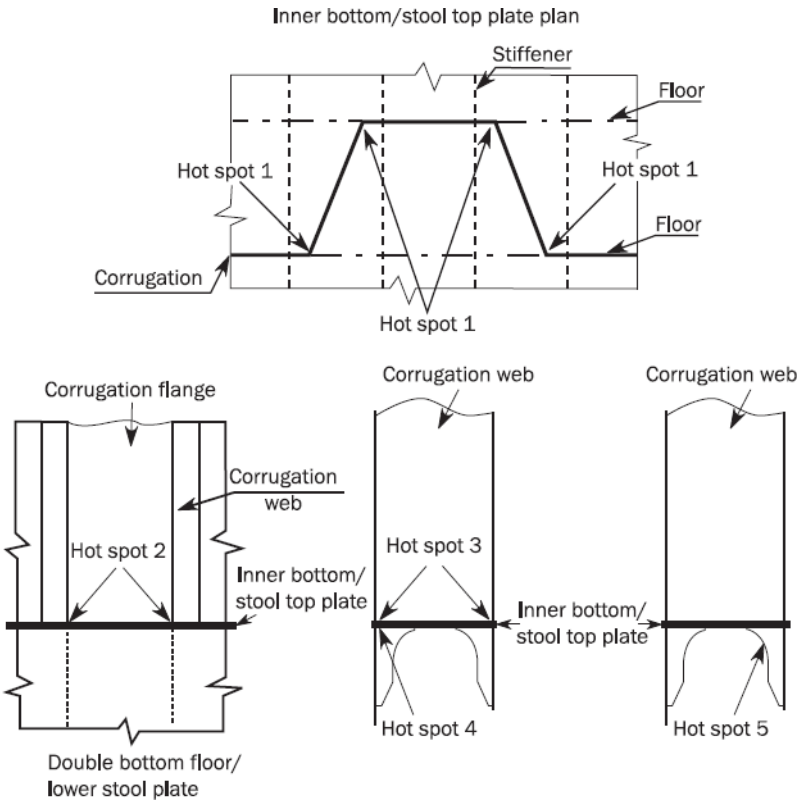
Hot spots for corrugated bulkhead to lower stool - Intersecting shedder plates and single sided shedder plate **Table 9**

Hot spot location	Procedure for calculation of hot spot stress
Intersecting shedder plates	
Hot spot 12: Intersection of shedder plates	Ch 9, Sec 5, [3.1], type '*a*'
	
Single sided shedder plate	
Welded connection of web and flange of corrugation to lower stool top For details of hot spots see Table 10, hot spots 1-3 If supported brackets are fitted, see Table 10 for hot spots 4	Ch 9, Sec 5, [3.1], type '*a*'
	

Hot spots for corrugated bulkhead to lower stool or inner bottom plating connection

Table 10

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1 : Inner bottom/lower stool top Hot spot 2: Corner of corrugation flange in way of inner bottom/lower stool top Hot spot 3: Corner of corrugation web in way of inner bottom/lower stool top Hot spot 4: Inner bottom/lower stool top in way of brackets supporting corrugation web	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 5: Edge of supporting brackets	Ch 9, Sec 5, [3.2].



Hot spots for connections of corrugated longitudinal bulkhead to lower stool top Table 11

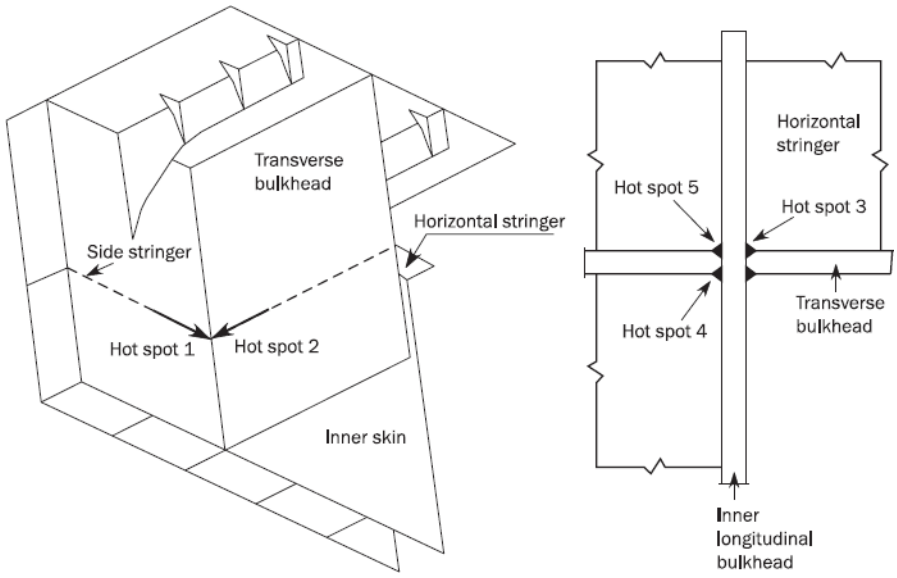
Hot spot location	Procedure for calculationof hot spot stress
See Table 9	Ch 9, Sec 5, [3.1], type '*a*'

Hot spots for connections of corrugated transverse bulkhead to upper stool bottom plate or to deck plate for tanker design without top stool Table 12

Hot spot location	Procedure for calculation of hot spot stress
See Table 8 and Table 9 Additional bending stresses in the deck stiffeners in way of corrugation flange induced by the bulkhead need to be considered	

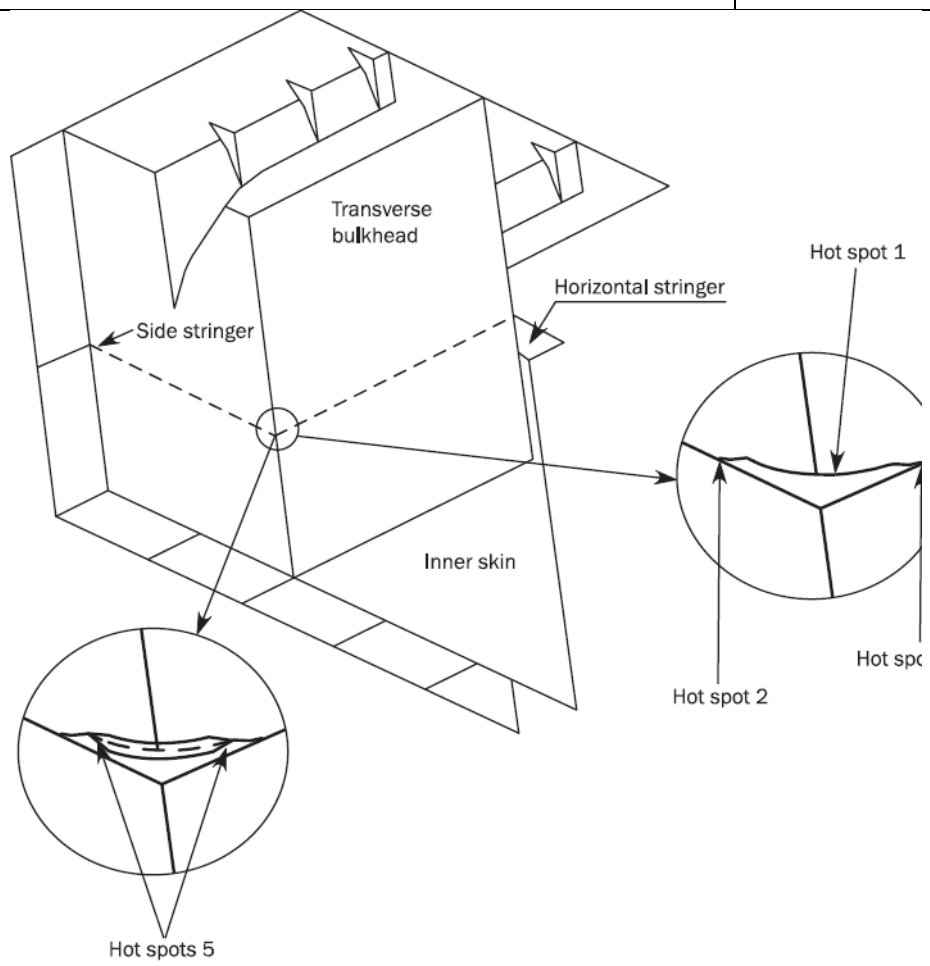
Hot spots for connection between transverse bulkhead and inner hull longitudinal bulkhead in way of transverse bulkhead horizontal stringer and side stringer without backing bracket at stringer heel **Table 13**

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner hull longitudinal bulkhead plate on cargo tank side connection to plane side of transverse bulkhead (i.e. opposite side to stiffening) at heel of transverse bulkhead horizontal stringer Hot spot 2: Transverse bulkhead plate on plane side (i.e. opposite stiffening) at heel of transverse bulkhead horizontal stringer	Ch 9, Sec 5, [4.2]
Hot spot 3: Heel of transverse bulkhead horizontal stringer Hot spot 4: Side stringer in double side diagonally opposite horizontal stringer Hot spot 5: Side stringer in double side in line with horizontal stringer	Ch 9, Sec 5, [4.3]



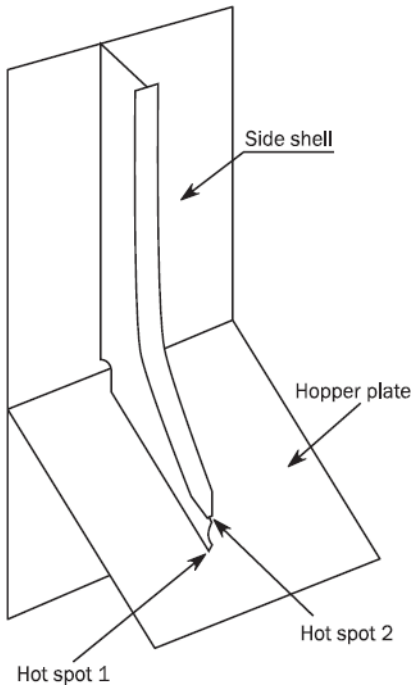
Hot spots for connection between transverse bulkhead and inner hull longitudinal bulkhead in way of transverse bulkhead horizontal stringer and side stringer, with backing bracket at stringer heel **Table 14**

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Bracket edge where a face plate is not fitted to the bracket Hot spot 4: Radius of bracket toe	Ch 9, Sec 5, [3.2]
Hot spot 2: Inner longitudinal bulkhead at bracket toe Hot spot 3: Transverse bulkhead at bracket toe Hot spot 6: Side stringer, in way of bracket toe Hot spot 7: Horizontal stringer in way of bracket toe	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 5: Where a face plate is fitted to the bracket, the weld connection of face plate to bracket in way of the face plate termination	Ch 9, Sec 5, [3.1], type '*b*'



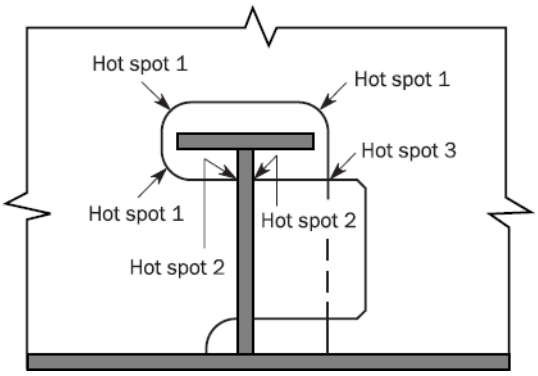
Hot spots for lower side frame bracket toe **Table 15**

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Hopper sloping plate in way of hold frame toe	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 2: Hold frame toe in way of face plate termination	Ch 9, Sec 5, [3.1], type '*b*'

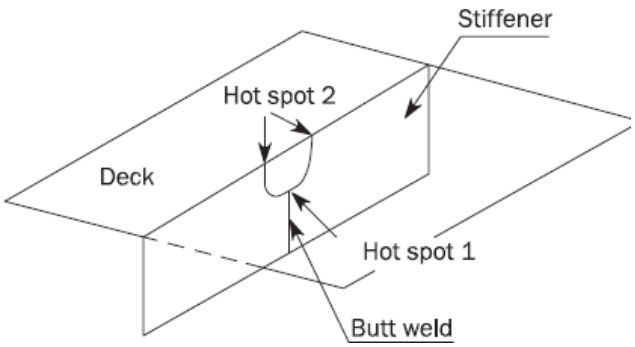


Hot spots for connection of longitudinal stiffener and transverse web including cut-outs and lug plates **Table 16**

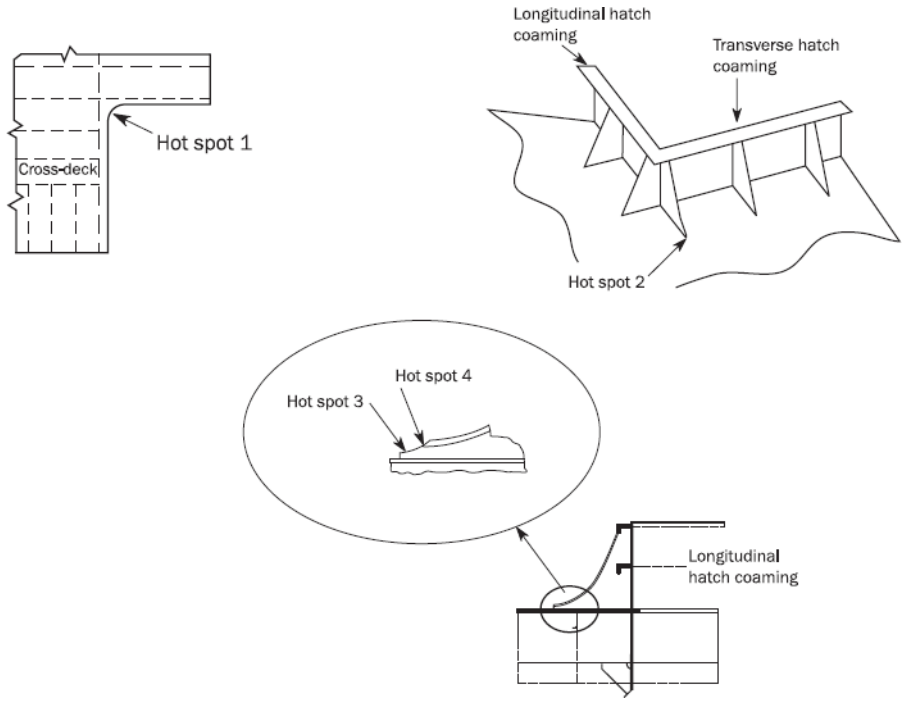
Hot spot location	Procedure for calculation of hot spot stress
The critical hot spot has to be decided for each design in agreement with the Society. Typically the following three hot spot types are to be considered:	
Hot spot 1: Corners of the cut-out edge	Ch 9, Sec 5, [3.2].
Hot spot 2: Connection of transverse web/lug-plate to longitudinal stiffener web in way of slot Hot spot 3: Overlapping connection between transverse web and lug plate	Ch 9, Sec 5, [3.1], type '*b*'



Hot spots for scallops in way of block connections joints at deck Table 17

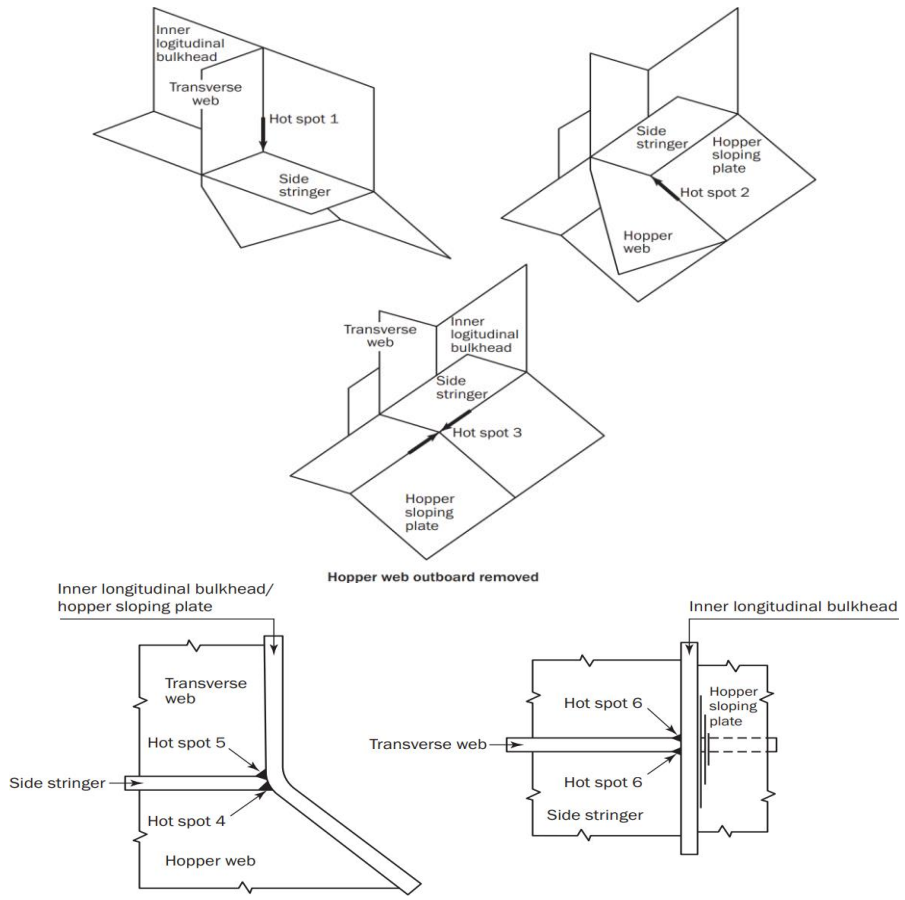
Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Butt weld in longitudinal stiffener web in way of scallop. Hot spot 2: Deck plate in way of scallop.	Ch 9, Sec 5, [3.1], type '*a*'
	

Hot spots for deck plating and longitudinal hatch coaming end bracket toe Table 18

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Hatch corner radiused edge Hot spot 3: Radius of hatch coaming bracket toe	Ch 9, Sec 5, [3.2]
Hot spot 2: Deck plating in way of hatch coaming bracket toe	Ch 9, Sec 5, [3.1], type '*a*'
Hot spot 4: Where a face plate is fitted to the bracket, the weld connection of face plate to bracket in way of the face plate termination	Ch 9, Sec 5, [3.1], type '*b*'
	

Hot spots for radiused upper hopper knuckle connection **Table 19**

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner longitudinal bulkhead plate on ballast tank side, above side stringer Hot spot 2: Radiused hopper sloping plate on ballast tank side, below side stringer Hot spot 3: Radiused hopper sloping plate on ballast tank side, below side stringer, towards hopper web Hot spot 4: Hopper web, below side stringer Hot spot 5: Transverse web, above side stringer Hot spot 6: Side stringer, to transverse web	Ch 9, Sec 5, [3.3]



Section 3 FATIGUE EVALUATION

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

(i) : Suffix which denotes load case HSM, FSM, BSR-P, BSR-S, BSP-P, BSP-S, OST-P or OST-S specified in Ch 4, Sec 2, [3].

'*i1*' denotes load case: HSM-1, FSM-1, BSR-1P, BSR-1S, BSP-1P, BSP-1S, OST-1P or OST-1S.

'*i2*' denotes load case: HSM-2, FSM-2, BSR-2P, BSR-2S, BSP-2P, BSP-2S, OST-2P or OST-2S.

(j) : Suffix which denotes loading condition:

Full load or normal ballast for oil tankers as defined in Ch 9, Sec 1, [6.2].

Full load homogeneous, full load alternate, normal ballast or heavy ballast for bulk carriers as defined in Ch 9, Sec 1, [6.3].

T_C : Time in corrosive environment, in years, according to Table 5.

T_D : Design life, in years, to be taken as 25 years.

T_{DF} : Design fatigue life, in year, as defined in Ch 9, Sec 1.

T_F : Fatigue life, in year, calculated according to [5].

m :Inverse slope of the design S-N curve, as given in Table 2 for in-air environment and in Table 3 for corrosive environment.

The inverse slope for S-N curves in-air environment changes from m to m+2 at $N = 10^7$ cycles.

n_{LC} : Number of applicable loading conditions, as defined in Ch 9, Sec 1, [6.2] and Ch 9, Sec 1, [6.3].

fc : Correction factor as defined in Ch 9, Sec 1, [5.1.2].

f_{thick} : Correction factor for plate thickness effect given in [3.3].

$f_{mean,\ i(j)}$: Correction factor for mean stress effect given in [3.2].

1 FATIGUE ANALYSIS METHODOLOGY

1.1 Cumulative damage

1.1.1

The fatigue assessment of the structure is based on the application of the Palmgren-Miner cumulative damage D taken as:

$$D = \sum_{i-1}^{n_{tot}} \frac{n_i}{N_i}$$

where:

n_i : Number of cycles at stress range $\Delta\sigma_i$.

N_i : Number of cycles to failure at stress range $\Delta\sigma_i$.

n_{tot} : Total number of stress range blocks.

i : Stress range block index.

1.1.2

As the long term stress range distribution of a structural detail in a ship can be described by a two-parameter Weibull distribution, as given in Ch 9, Sec 1, [3.1.1], fatigue damage can be obtained by means of a closed- form equation, as given in [5].

1.2 Fatigue strength assessment

1.2.1

Assessment of the fatigue strength of structural members according to [2] includes the following three steps:

a) Calculation of stress ranges, according to [3].
b) Selection of the design S-N curve, according to [4].
c) Calculation of the cumulative damage and the fatigue life calculation, according to [5].

2 ACCEPTANCE CRITERIA

2.1 Fatigue life and acceptance criteria

2.1.1

The calculated fatigue life, T_F, is to comply with the following formula:

$T_F \geqslant T_{DF}$

3 REFERENCE STRESSES FOR FATIGUE ASSESSMENT

3.1 Fatigue stress range

3.1.1

The fatigue stress range for each load case of each loading condition is defined in [3.1.2] for welded joints and in [3.1.3] for base material free edge.

The stress range of each loading condition *(j)* to be considered is the stress range obtained from the predominant load case, according to Ch 9, Sec 1, [7.1.2].

$$\Delta\sigma_{FS,(j)} = \max_i(\Delta\sigma_{FS,i(j)})$$

where:

$\Delta\sigma_{FS,i(j)}$: Fatigue stress range, in N/mm², for load case *(i)* of loading condition *(j)*, as defined in [3.1.2] for welded joints and in [3.1.3] for base material free edge.

3.1.2 Welded joints

For welded joints, the fatigue stress range $\Delta\sigma_{FS,i(j)}$, in N/mm², corrected for mean stress effect, thickness effect and warping effect, is taken as:

- For simplified stress analysis:

$$\Delta\sigma_{FS,i(j)} = f_{mean,i(j)} \cdot f_{thick} \cdot f_{warp} \cdot \Delta\sigma_{HS,i(j)}$$

- For FE analysis:
  - For web-stiffened cruciform joints:

$$\Delta\sigma_{FS,i(j)} = f_w \cdot f_s \cdot \max(\Delta\sigma_{FS1,i(j)}, \Delta\sigma_{FS2,i(j)})$$

  - For other joints:

$$\Delta\sigma_{FS,i(j)} = \max_{(SideL,SideR)}[\max(\Delta\sigma_{FS1,i(j)}, \Delta\sigma_{FS2,i(j)})]$$

where:

f_w : correction factor for the effect of stress gradient along weld line given as 0.96

f_s : correction factor for the effect of supporting member given as 0.95

$\Delta\sigma_{HS,i(j)}$: Hot spot stress range, in N/mm^2, due to dynamic loads in load case (*i*) of loading condition *(j)* given in Ch 9, Sec 4, [2.1.1].

$\Delta\sigma_{FS1,i(j)}$: Fatigue stress range, in N/mm^2,due to the principal hot spot stress range $\Delta\sigma_{HS1,i(j)}$

$$\Delta\sigma_{FS1,(j)} = f_{mean1,i(j)} \cdot f_{thick} \cdot f_c \cdot \Delta\sigma_{HS1,i(j)}$$

$\Delta\sigma_{FS2,i(j)}$: Fatigue stress range, in N/mm^2,due to the principal hot spot stress range $\Delta\sigma_{HS2,i(j)}$

$$\Delta\sigma_{FS2,i(j)} = 0.9 \cdot f_{mean2,i(j)} \cdot f_{thick} \cdot f_c \cdot \Delta\sigma_{HS2,i(j)}$$

SideL, *SideR*: Left and right side respectively of the line A-A as shown in Ch 9, Sec 5, Figure 15 and Ch 9, Sec5, Figure 16.

$f_{mean1,\,i(j)}$: Correction factor for mean stress effect given in [3.2].

$f_{mean2,\,i(j)}$: Correction factor for mean stress effect given in [3.2].

f_{warp} : Correction factor due to warping effect, taken as:

- f_{warp} = 1.07 for the deck longitudinal stiffener of bulk carrier, the closest to the longitudinal hatch coaming in way of the hatch corner as shown in Figure 1, except f_{warp} =1.0 when OST is not the dominant load case for all loading conditions
- f_{warp} = 1.04 for following deck longitudinal stiffeners of bulk carrier, except f_{warp} =1.0 when OST is not the dominant load case for all loading conditions
  - The closest stiffener to the longitudinal hatch coaming at one web frame away from the hatch corner, in way of the hatch opening as shown in Figure 1,
  - The second closest stiffener away from the longitudinal hatch coaming in way of the hatch corner as shown in Figure 1,
- f_{warp} = 1.0 for the other cases.

$\Delta\sigma_{HS1,i(j)}$: Principal hot spot stress ranges, in N/mm^2, due to dynamic loads for load case (*i*) of loading condition *(j)* which acts within $\pm 45°$ of the perpendicular to the weld toe,

determined in Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [3.3.2] and Ch 9, Sec 5, [4.2.3] for the two types of shell elements (4-node or 8- node).

$\Delta\sigma_{HS2,i(j)}$: Principal hot spot stress ranges, in N/mm^2, due to dynamic loads for load case (*i*) of loading condition *(j)* which acts outside $\pm 45°$ of the perpendicular to the weld toe, determined in Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [3.3.2] and Ch 9, Sec 5, [4.2.3] for the two types of shell elements (4-node or 8- node).

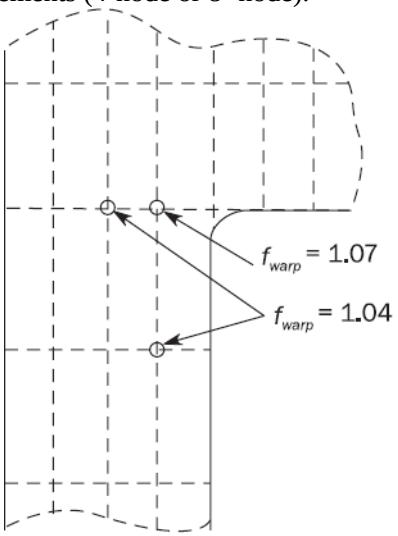


Figure 1 Warping effect on deck longitudinal stiffeners of bulk carrier

3.1.3 Base material free edge

For base material free edge, the fatigue stress range, $\Delta\sigma_{FS,i(j)}$ in N/mm^2, is taken as the local stress range at free edge, $\Delta\sigma_{BS,i(j)}$, as defined in Ch 9, Sec 1, [2.4] with correction factors:

$$\Delta\sigma_{FS,i(j)} = K_{sf} \cdot f_{material} \cdot f_{mean,i(j)} \cdot f_{thick} \cdot f_c \cdot \Delta\sigma_{BS,i(j)}$$

where:

K_{sf} : Surface finishing factor for base material given in [4.2.3].

$f_{material}$: Correction factor for material strength, taken as:

$$f_{material} = \frac{1200}{965 + R_{eH}}$$

$\Delta\sigma_{BS,i(j)}$: Local stress range, in N/mm^2, due to dynamic loads in load case (*i*) of loading condition *(j)* taken as:

$$\Delta\sigma_{BS,i(j)} = \left|\sigma_{BS,i1(j)} - \sigma_{BS,i2(j)}\right|$$

$\sigma_{BS,i(j)}$, $\sigma_{BS,i(j)}$: Local stress, in N/mm^2, in load case '*i1*' and '*i2*' of loading condition *(j)*, obtained by very fine mesh FE analysis specified in Ch 9, Sec 5.

3.2 Mean stress effect

3.2.1 Correction factor for mean stress effect

The mean stress correction factor to be considered for each principal hot spot stress range of welded joint, $\Delta\sigma_{HS,i(j)}$, or for local stress range at free edge, $\Delta\sigma_{BS,i(j)}$, is taken as:

a) For welded joint:

$$f_{mean,i(j)} = \begin{cases} \min[1.0, 0.9 + 0.2\dfrac{\sigma_{mCor,i(j)}}{2\Delta\sigma_{HS,i(j)}}] & \text{for} \quad \sigma_{mCor,i(j)} \geq 0 \\ \max[0.3, 0.9 + 0.8\dfrac{\sigma_{mCor,i(j)}}{2\Delta\sigma_{HS,i(j)}}] & \text{for} \quad \sigma_{mCor,i(j)} < 0 \end{cases}$$

b) For base material:

$$f_{mean,i(j)} = \begin{cases} \min[1.0, 0.8 + 0.4\dfrac{\sigma_{mCor,i(j)}}{2\Delta\sigma_{BS,i(j)}}] & \text{for} \quad \sigma_{mCor,i(j)} \geq 0 \\ \max[0.3, 0.8 + \dfrac{\sigma_{mCor,i(j)}}{2\Delta\sigma_{BS,i(j)}}] & \text{for} \quad \sigma_{mCor,i(j)} < 0 \end{cases}$$

where:

$$\sigma_{mCor,i(j)} = \begin{cases} \sigma_{mean,i(j)} & \text{for} \ \ \sigma_{max} \leq R_{eEq} \\ R_{eEq} - \sigma_{max} + \sigma_{mean,i(j)} & \text{for} \ \sigma_{max} > R_{eEq} \end{cases}$$

$$\sigma_{max} = \begin{cases} \max_{i,(j)}(\Delta\sigma_{HS,i(j)} + \sigma_{mean,i(j)}) & \text{for welded joint} \\ \max_{i,(j)}(\Delta\sigma_{BS,i(j)} + \sigma_{mean,i(j)}) & \text{for base material} \end{cases}$$

R_{eEq}= *max* (315 ; R_{eH})

$\sigma_{mean,\ i(j)}$: Fatigue mean stress, in N/mm^2, for base material calculated according to [3.2.2] or welded joint calculated according to [3.2.3] or [3.2.4] as applicable.

3.2.2 Mean stress for base material free edge

The fatigue mean stress for base material free edge, $\sigma_{mean,i(j)}$, in N/mm^2, due to static and dynamic loads case '*i1*' and '*i2*' of loading condition (*j)* is calculated by the following formula based on local stress:

$$\sigma_{mean,i(j)} = \frac{\sigma_{BS,i1(j)} + \sigma_{BS,i2(j)}}{2}$$

3.2.3 Mean stress for simplified method

The fatigue mean stress to be considered for welded joint assessed by the simplified stress analysis is to be obtained from Ch 9, Sec 4, [2.2].

3.2.4 Mean stress for FE analysis

The fatigue mean stresses for welded joint due to static and dynamic loads, $\sigma_{mean,i(j),pX}$, and$\sigma_{mean,i(j),pY}$, in N/mm^2, for load cases '*i1*' and '*i2*' of loading condition (j) ,belonging to the two principal hot spot stress range directions, *pX* and *pY*, is calculated by the following formula based on hot spot stress components as defined in Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [3.3.2] and Ch 9, Sec 5, [4.2.3]:

$$\sigma_{mean,i(j)pX} = \frac{(\sigma_{HS,i1(j)})_{xx} + (\sigma_{HS,i2(j)})_{xx} + (\sigma_{HS,i1(j)})_{yy} + (\sigma_{HS,i2(j)})_{yy}}{4} +$$

$$(\frac{(\sigma_{HS,i1(j)})_{xx} + (\sigma_{HS,i2(j)})_{xx} - (\sigma_{HS,i1(j)})_{yy} - (\sigma_{HS,i2(j)})_{yy}}{4}) \cdot \cos 2\theta + (\frac{(\sigma_{HS,i1(j)})_{xy} + (\sigma_{HS,i2(j)})_{xy}}{4}) \cdot \sin 2\theta$$

$$\sigma_{mean,i(j)pY} = \frac{(\sigma_{HS,i1(j)})_{xx} + (\sigma_{HS,i2(j)})_{xx} + (\sigma_{HS,i1(j)})_{yy} + (\sigma_{HS,i2(j)})_{yy}}{4} -$$

$$(\frac{(\sigma_{HS,i1(j)})_{xx} + (\sigma_{HS,i2(j)})_{xx} - (\sigma_{HS,i1(j)})_{yy} - (\sigma_{HS,i2(j)})_{yy}}{4}) \cdot \cos 2\theta - (\frac{(\sigma_{HS,i1(j)})_{xy} + (\sigma_{HS,i2(j)})_{xy}}{4}) \cdot \sin 2\theta$$

θ :Angle between the direction x of the element coordinate system and the principal direction *pX* of the principal hot spot stress range coordinate system (Ch 9, Sec 5, [3.1.2], Ch 9, Sec 5, [4.2.3]). The direction x of the element coordinate system is defined as the normal to the weld toe.

The one of the two mean stresses $\sigma_{mean,i(j),pX}$ and $\sigma_{mean,i(j),pY}$ which has a principal stress direction with an absolute value less than 45 ° is defined as $\sigma_{mean1,i(j)}$ belonging to $\Delta\sigma_{HS1,i(j)}$ The other mean stress is defined as$\sigma_{mean2,i(j)}$ belonging to $\Delta\sigma_{HS2\ ,i(j)}$.

3.3 Thickness effect

3.3.1

Plate thickness primarily influences the fatigue strength of welded joints through the effect of geometry, and through-thickness stress distribution. The correction factor, f_{thick},, for plate thickness effect is taken as:

- For $t_{n50} \leqslant 22$ mm, $f_{thick} = 1.0$.
- For $t_{n50} > 22$ mm, $f_{thick} = (t_{n50} /22)^n$

where:

t_{n50} : Net thickness of the considered member in way of the hot spot for welded joints or base material free edge, in mm.

- For simplified stress analysis, the net thickness to be considered for stiffeners is as follows:
  - Flat bar and Bulb profile: no correction,
  - Angle bar and T-bar: flange net thickness.
- For FE analysis, the net thickness to be considered is the net thickness of the member where the crack is likely to initiate and propagate.
  For 90 ° attachments, i.e. cruciform welded joints, transverse T-joints and plates with transverse attachment, the net thickness to be considered is to be taken as:

$$t_{n50} = \min\left(\frac{d}{2}, t_{1n50}\right)$$

n : Thickness exponent provided in Table 1 and Table 4 respectively for welded and non-welded joints. n is to be selected according to the considered stress direction. For this selection, $\Delta\sigma_{HS1}$ and $\Delta\sigma_{HS2}$ are considered perpendicular and parallel to the weld respectively.

d : Toe distance, in mm, as shown in Figure 2, taken as:
$d = t_{2n50} + 2\, l_{leg}$

t_{1n50} : Net thickness, in mm, of the continuous plate as shown in Figure 2.

t_{2n50} : Net thickness, in mm, of the transverse attach plate where the hot spot is assessed, as shown in Figure 2.

l_{leg} : Fillet weld leg length, in mm.

When post-weld treatment methods are applied to improve the fatigue life of considered welded joint, the thickness exponent is provided in [6].

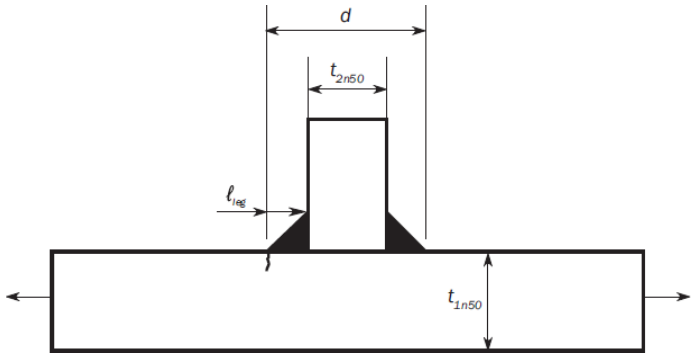


Figure 2 Toe distance for cruciform welded joints, transverse T-joints and plates with transverse attachment

4 S-N CURVES

4.1 Basic S-N curves

4.1.1 Capacity

The capacity of welded steel joints and steel base material with respect to fatigue strength is defined by S-N curves which provide the relationship between the stress range applied to the detail and the number of constant amplitude load cycles to failure.

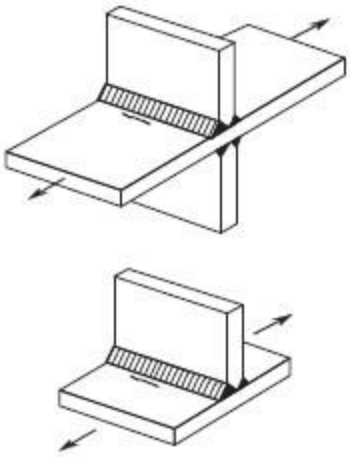
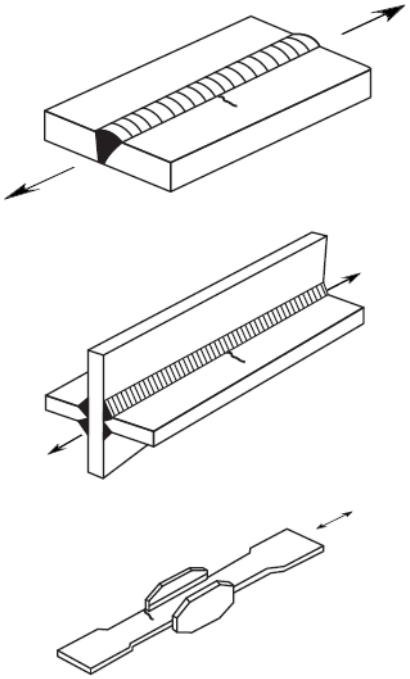
4.1.2 Design S-N curves

The fatigue assessment is based on use of S-N curves which are obtained from fatigue tests. The design S-N curves are established at two standard deviations below the mean S-N curves corresponding to 50% of probability of survival for relevant experimental data. Design S-N curves given in Table 2 and Table 3 correspond to a probability of survival of 97.7%.

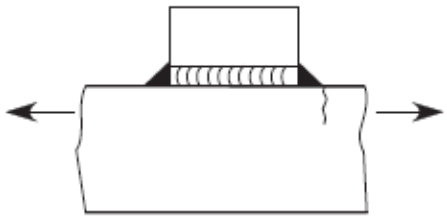
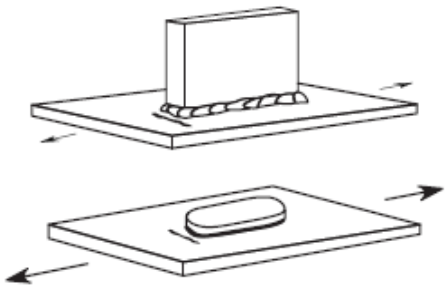
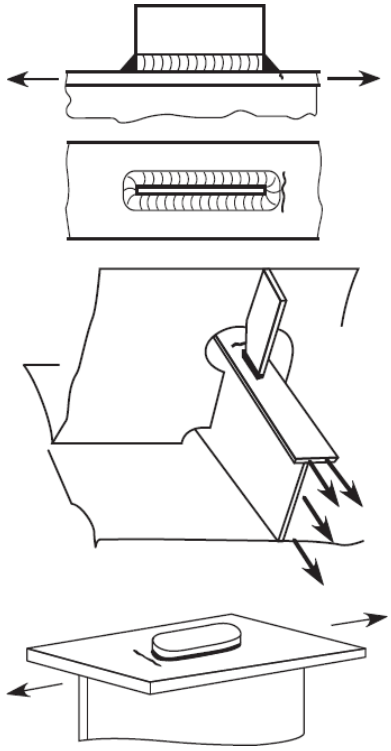
4.1.3 S-N curve scope of application

The S-N curves are applicable to normal and high strength steels up to a specified minimum yield stress equal to 390 N/mm^2.

Welded joints: thickness exponents **Table 1**

No	Joint category description	Geometry	Condition	*n*
1	Cruciform joints, transverse T-joints, plates with transverse attachments		As-welded	0.25
			Weld toe treated by post-weld improvement method	0.2
2	Transverse butt welds		As-welded	0.2
			Ground flush or weld toe treated by post-weld improvement method	0.1
3	Longitudinal welds or attachments to plate edges		Any	0.1
			Weld toe treated by post-weld improvement method	0.1

(1) No benefit applicable for post-weld treatment of longitudinal end connections.

No	Joint category description	Geometry	Condition	*n*
4	Longitudinal attachments on the flat bar or bulb profile		Any	0
			Weld toe treated by post-weld improvement method (1)	0
5	Longitudinal attachments and doubling plates		As-welded	0.2
			Weld toe treated by post-weld improvement method	0.1
6	Longitudinal attachments and doubling plates supported longitudinally		As-welded	0.1
			Weld toe treated by post-weld improvement method (1)	0
(1) No benefit applicable for post-weld treatment of longitudinal end connections.				

4.1.4 In-air environment

The basic design curves in-air environment shown in Figure 3 are represented by linear relationships between log ($\Delta\sigma$) and log (N) as follows:

log (N)=log(K_2)– m log ($\Delta\sigma$)

where:

log (K_2) = log (K_1) – 2 log(δ)

K_1 : Constant related to mean S-N curve, as given in Table 2.
K_2 : Constant related to design S-N curve, as given in Table 2.
δ : Standard deviation of log (N), as given in Table 2.
$\Delta\sigma_q$: Stress range at N = 107 cycles related to design S-N curve, in N/mm2, as given in Table 2.

Basic S-N curve data, in-air environment **Table 2**

Class	K_1		m	Standard deviation δ	K_2	Design stress range at 10^7 cycles	Design stress range at 2×10^6 cycles
	K_1	$\log_{10}K_1$		$\log_{10}\delta$	K_2	$\Delta\sigma_q$ N/mm^2	N/mm^2
B	2.343E15	15.3697	4.0	0.1821	1.01E15	100.2	149.9
C	1.082E14	14.0342	3.5	0.2041	4.23E13	78.2	123.9
D	3.988E12	12.6007	3.0	0.2095	1.52E12	53.4	91.3

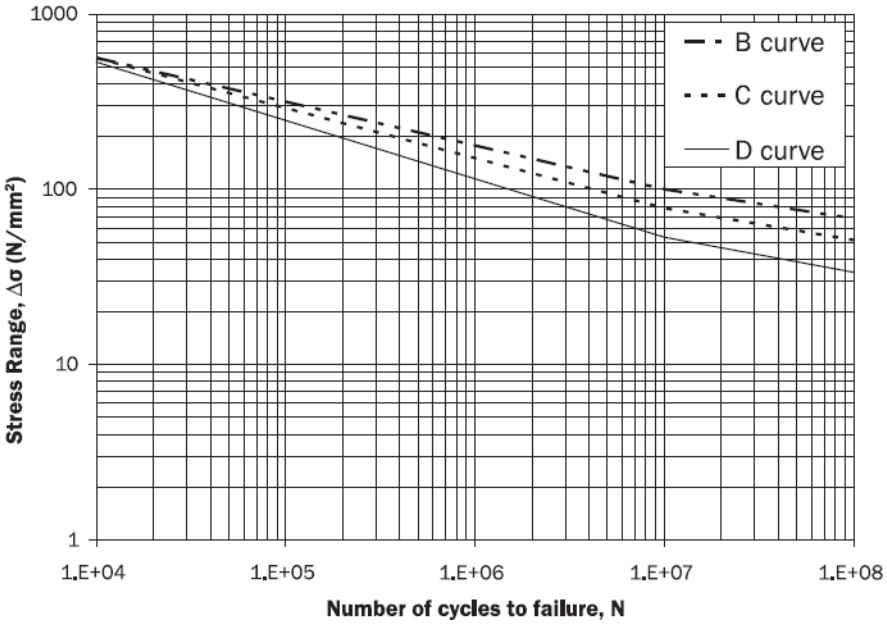


Figure 3 Basic design S-N curves, in-air environment

4.1.5 Corrosive environment

The basic design curves for corrosive environment shown in Figure 4 are represented by linear relationships between log ($\Delta\sigma$) and log (N) as follows:

log (N)=log(K_2)– m log ($\Delta\sigma$)

N : Predicted number of cycles to failure under stress range .

K_2 : Constant related to design S-N curve as given in Table 3.

Basic S-N curve data, corrosive environment **Table 3**

Class	K_2	m	Design stress range at 2×10^6 cycles, N/mm^2
B_{corr}	5.05×10^{14}	4.0	126.1
C_{corr}	2.12×10^{13}	3.5	101.6
D_{corr}	7.60×10^{11}	3.0	72.4

4.2 Selection of S-N curves

4.2.1 Welded joints

For fatigue assessment of welded joints exposed to in-air environment, S-N curve D as defined in Table 2 is to be used. For corrosive environment, S-N curve D_{corr} as defined in Table 3 is to be used.

4.2.2 Base material free edge

For fatigue assessment of base material at free edge exposed to in-air environment, S-N curves B

or C as defined in Table 2 are to be used. For corrosive environment, S-N curves B_{corr} or C_{corr} as defined in Table 3 are to be used.

4.2.3 Surface finishing factor

The S-N curve *C* is applicable to most of non-welded locations taking into account the likelihood of some notching from corrosion, wear and tear in service with surface finishing factor as given in Table 4.

Higher surface finishing quality may be applied in using S-N curve *B* as given in Table 4, provided adequate protective measures are taken against wear, tear and corrosion and finite element analysis according Sec 5, [2] is carried out.

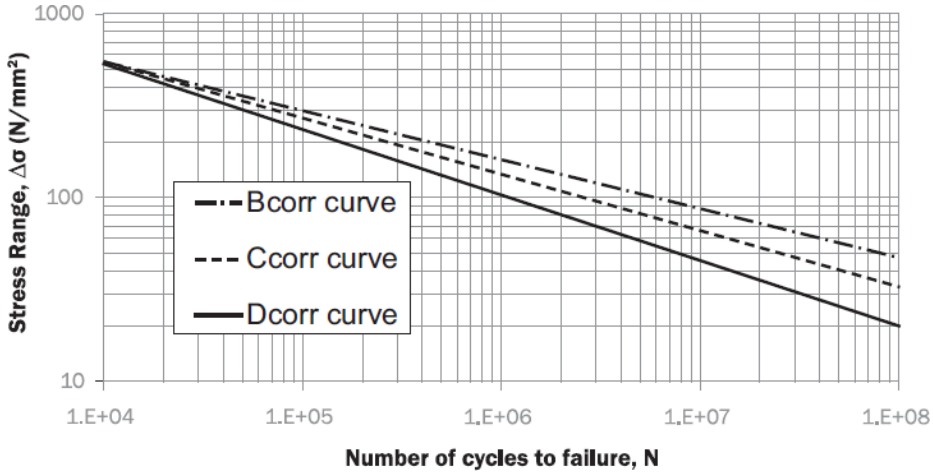
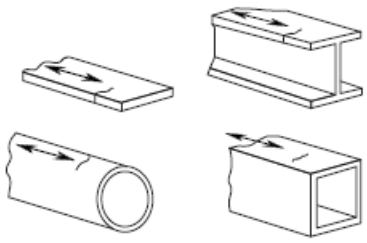
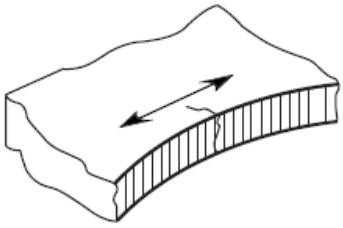


Figure 4 Basic design S-N curves, corrosive environment

CCS 4.2.3a Surface finishing factors are to be selected according to the joint configurations in Table 4, Section 3, Chapter 9 of this PART and submitted to CCS as the basis for selection of such factors corresponding to joint configurations. For the surface finishing factor corresponding to joint configuration 2, edge cutting process, edge treatment and surface finishing are to be taken into account.

Non-welded joints: thickness exponent and surface finishing factor **Table 4**

	Joint configuration, fatigue crack location and stress direction	Edge Cutting process	Edge treatment	Surface finishing	n	K_{sf}	S-N curve
1	Rolled or extruded plates and sections as well as seamless pipes, no surface or rolling defects 	N/A	N/A	No surface nor roll defect(1), (2)	0	0.94	B

Joint configuration, fatigue crack location and stress direction		Edge Cutting process	Edge treatment	Surface finishing	n	K_{sf}	S-N curve
2	Cut edges 	Machine-cutting e.g. by a thermal process. or sheared edge cutting.	Cutting edges chamfered or rounded by means of smooth grinding, groove direction parallel to the loading direction	Smooth surface free of cracks and notches[(1), (2)]	0.1	1.00	B
			Cutting edges broken or rounded.	Smooth surface free of cracks and notches. [(1), (2)]	0.1	1.07	B
			No edge treatment	Surface free of cracks and severe notches (inspection procedure) [(1), (2)]	0.1	1.0	C
		Manually thermally cut e.g. by flame cutting	No edge treatment	Surface free of cracks and severe notches (inspection procedure) [(1), (2)]	0.1	1.24	C
Note1: Stress increase due to geometry of cut-outs to be considered. Note2: Fine mesh FE analysis according to Sec 5, [2].							

5 FATIGUE DAMAGE CALCULATION

5.1 General

5.1.1

The design fatigue life is divided into a number of time periods due to different loading conditions and due to limitation of the corrosion protection.

It is assumed that the corrosion protection (i.e. coating system) is only effective for a limited number of years during which the structural details are protected, i.e. in-air environment. During the remaining part of the design life as specified in Table 5, the structural details are unprotected i.e. exposed to corrosive environment.

5.1.2

The elementary fatigue damage, given in [5.2], is the damage accumulated during a specific loading condition *(j)* associated with a specific environmental condition either protected condition, i.e. in-air environment, or unprotected condition, i.e. corrosive environment.

The combined fatigue damage, given in [5.3], is the combination of damage accumulated for a specific loading condition *(j)* for the in-air and corrosive environment time.

Total fatigue damage, given in [5.4], is the sum of the combined fatigue damages obtained for all loading conditions.

5.2 Elementary fatigue damage

5.2.1

The elementary fatigue damage for each fatigue loading condition *(j)* is to be calculated

independently for both protected in-air environment and unprotected corrosive environment, based on the fatigue stress range obtained for the predominant load case as follows:

$$D_{E(j)} = \frac{\alpha_{(j)} \cdot N_D}{K_2} \frac{\Delta\sigma_{FS,(j)}^m}{\left(\ln N_R\right)^{m/\xi}} \cdot \mu_{(j)} \cdot \Gamma\left(1+\frac{m}{\xi}\right)$$

where:

N_D : Total number of wave cycles experienced by ship during the design fatigue life, taken as:
N_D= 31.557 ×106 ($f_0 T_D$) / (4 log L)

f_0 :Factor taking into account time in seagoing operations excluding time in loading and unloading, repairs, etc.
f_0 = 0.85.

$\alpha_{(j)}$: Fraction of time in each loading condition given in Ch 9, Sec 1, Table 1 for oil tanker and in Ch 9, Sec1, Table 3 for bulk carrier.

$\Delta\sigma_{FS,i(j)}$: Fatigue stress range at the reference probability level of exceedance of 10^{-2}, in N/mm^2.

N_R : Number of cycles corresponding to the reference probability of exceedance of 10^{-2}.
N_R = 100.

ξ : Weibull shape parameter,
ξ= 1.

$\Gamma(x)$: Complete Gamma function.

K_2 : Constant of the design S-N curve, as given in Table 2 for in-air environment and in Table 3 for corrosive environment.

$\mu_{(j)}$: Coefficient taking into account the change of inverse slope of the S-N curve, m,

- For in-air environment:

$$\mu_{(j)} = 1 - \frac{\left\{\gamma\left(1+\frac{m}{\xi}, \nu_{(j)}\right) - \nu_{(j)}^{-\Delta m/\xi} \cdot \gamma\left(1+\left(\frac{m+\Delta m}{\xi}\right), \nu_{(j)}\right)\right.}{\Gamma\left(1+\frac{m}{\xi}\right)}$$

$$\nu_{(j)} = \left(\frac{\Delta\sigma_q}{\Delta\sigma_{FS,(j)}}\right)^{\xi} \ln N_R$$

- For corrosive environment:
$\mu_{(j)}$ =1.0

$\gamma(a,x)$: Incomplete Gamma function.

$\Delta\sigma_q$: Stress range, in N/mm^2, corresponding to the intersection of the two segments of design S-N curve at N=10^7 cycles, as given in Table 2.

Δm : Change in inverse slope of S-N curve at N=10^7 cycles.
Δm = 2

5.3 Combined fatigue damage

5.3.1

The combined fatigue damage in protected in-air environment and unprotected corrosive environment for each loading condition *(j)* is to be calculated as follows:

$$D_{(j)} = D_{E,air(j)} \cdot \frac{T_D - T_C}{T_D} + D_{E,corr(j)} \cdot \frac{T_C}{T_D}$$

where:

$D_{E,air(j)}$: The elementary fatigue damage for in-air environment for loading condition *(j)* given in [5.2.1].

$D_{E,corr(j)}$: The elementary fatigue damage for corrosive environment for loading condition *(j)* as calculated in [5.2.1].

5.4 Total fatigue damage

5.4.1

The total fatigue damage for all applicable loading conditions is calculated as follows:

$$D = \sum_{j=1}^{n_{LC}} D_{(j)}$$

where:

$D_{(j)}$: Combined fatigue damage for each applicable loading condition, as given in [5.3].

Time in corrosive environment, T_C **Table 5**

Location of weld joint or structural detail	Time in corrosive environment T_C, in years
Water ballast tank	10
Oil cargo tank	
Lower part (1) of bulk cargo hold and water ballast cargo hold	
Bulk cargo hold and water ballast cargo hold except lower part (1)	5
Void space Other areas	
(1) Lower part means cargo hold part below a horizontal level located at a distance of 300 mm below the frame end bracket for holds of single side skin construction or 300 mm below the hopper tank upper end for holds of double side skin construction (see Pt 2, Ch 1, Sec 2, Figure 1).	

5.5 Fatigue life calculation

5.5.1

The fatigue life, T_F, is taken as:

$$T_F = \frac{T_D}{D_{air}} \qquad \text{if} \quad \frac{T_D}{D_{air}} \le \left(T_D - T_C\right)$$

$$T_F = T_D - T_C + \left(\frac{T_D}{D_{air}} - T_D + T_C\right)\frac{D_{air}}{D_{corr}} \qquad \text{otherwise.}$$

where:

D_{air} : Total fatigue damage for all loading conditions in-air environment taken as:

$$D_{air} = \sum_{j=1}^{n_{LC}} D_{E,air(j)}$$

D_{corr} : Total fatigue damage for all loading conditions in corrosive environment taken as:

$$D_{corr} = \sum_{j=1}^{n_{LC}} D_{E,corr(j)}$$

6 WELD IMPROVEMENT METHODS

6.1 General

6.1.1

Post-weld fatigue strength improvement methods are to be considered as a supplementary means of achieving the required fatigue life, and subjected to quality control procedures and corrosion protection in accordance with Pt 1, Ch 3, Sec 4.

6.1.2 Limitation of the benefit of post-weld treatment

For structural details where the benefit of post-weld treatment is applicable, the calculated fatigue life at the design stage for the considered structural detail excluding the post-weld treatment effects, is not to be less than T_{DF} / 1.47.

However, for structural details inside a bulk cargo hold the calculated fatigue life at design stage excluding post-weld treatment effects is not to be less than 25 years.

Note1: When T_{DF} is taken equal to 25 years, the calculated fatigue life at the design stage for the considered structural detail excluding the post-weld treatment effects, is not to be less than 17 years.

6.1.3 Post-weld treatment at fabrication stage

There is one basic post-weld treatment method considered in these Rules to improve fatigue strength at the fabrication stage, i.e. weld geometry control and defect removal method by burr grinding.

6.1.4 Weld toe

The improvement method is applied to the weld toe. Thus, it is intended to increase the fatigue life of the weld from the viewpoint of a potential fatigue failure arising at the weld toe. The possibility of failure initiation at other locations is always to be considered. If the failure is shifted from the weld toe to the root by applying post- weld treatment, there may be no significant improvement in the overall fatigue performance of the joint. Improvements of the weld root cannot be expected from treatment applied to weld toe.

A brief description of the method and the degree of improvement which can be achieved is given in [6.2].

6.1.5 Weld type for post-weld treatment

When weld improvements are planned, full or partial penetration welds with a minimum root face according to Ch 12, Sec 3, [2.4] are to be used to mitigate or to eliminate the possibility of cracking at the weld root.

6.2 Weld toe burr grinding

6.2.1

The weld may be machined using a burr grinding tool to produce a favourable shape to reduce stress concentrations and remove defects at the weld toe, see Figure 5. In order to eliminate defects, such as intrusions, undercuts and cold laps, the material in way of the weld toe is to be removed. The depth of grinding shall be at least 0.5mm below the bottom of any visible undercut. The total depth of the burr grinding is not to be greater than the lesser of 2 mm and of 7% the local gross thickness of the machined plate. Any undercut not complying with this requirement is to be repaired by an approved method.

6.2.2

To avoid introducing a detrimental notch effect due to small radius grooves, the burr diameter is to be scaled to the plate thickness at the weld toe being ground. The diameter is to be in the 10 to 25 mm range for application to welded joints with plate thickness from 10 to 50 mm. The resulting root radius of the groove is to be no less than 0.25 t_{as_built}. The weld throat thickness and leg length after burr grinding must comply with the rule requirements or any increased weld sizes as indicated on the approved drawings.

The inspection procedure is to include a check of the weld toe radius, the depth of burr grinding, and confirmation that the weld toe undercut has been removed completely.

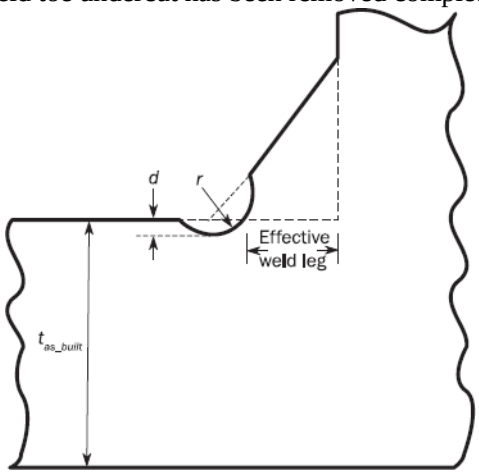


Figure 5 Details of ground weld toe geometry

6.3 Fatigue improvement factor

6.3.1

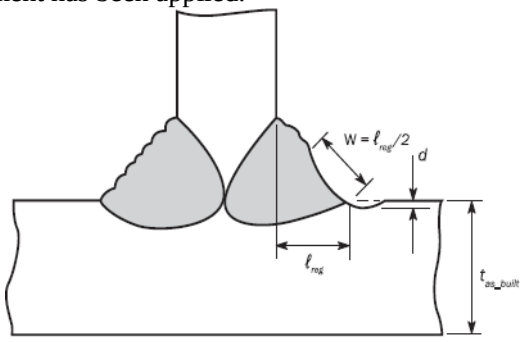
The benefit of burr grinding corresponds to an increase in fatigue strength by a factor of 1.3 (i.e. a reduction of the effective stress range by 1.3), reducing the damage in air to D_{air} / 2.2,
where:
D_{air} : Fatigue damage in air as given in Ch 9, Sec 3, [5.3.1].

6.4 Applicability

6.4.1

The application of post-weld improvement and fatigue improvement factor provided in this section is subject to following limitations:

- The weld type complies with [6.1.5].
- The weld improvement is effective in improving the fatigue strength of structural details under high cycle fatigue conditions therefore the fatigue improvements factors do not apply to low-cycle fatigue conditions, i.e. when N≤5×104, where N is the number of life cycles to failure.
- Unless otherwise specifically stated, the fatigue improvement factor is to be used for welds, joining steel plates which are between 6 and 50 mm thick.
- Fatigue improvement factor is to be applied to as-welded transverse butt welds, as-welded T-joint and cruciform welds and as-welded longitudinal attachment welds excluding longitudinal end connections.
- In way of areas prone to mechanical damage, fatigue improvement may only be granted if these are adequately protected.
- Treatment of inter-bead toes is required for large multi-pass welds as shown in Figure 6.
- The builder is to provide the list of details and their locations on the ship for which the post-weld treatment has been applied.



l_{leg}: Weld leg length.
W : Width of groove.
d : Depth of grinding.

Figure 6 Extent of weld toe burr grinding to remove inter-bead toes on weld face

7 WORKMANSHIP

7.1 Application

7.1.1

In general, the fatigue performance of structural details can be improved by adopting enhanced workmanship standards, which include building alignment and weld control.

7.2 Workmanship control for construction details

7.2.1 Building alignment and tolerance control

Building alignment exceeding construction tolerance could introduce additional stress concentration for structural details, reducing the fatigue performance. The builder is responsible to comply with the construction requirements given in Ch 12, Sec 1.

7.2.2 Weld profile control

Poor weld geometry could introduce additional stress concentration; therefore special attention should be given to achieving a favourable geometry and smooth transition at the weld toe. Weld profile control, i.e. enhanced workmanship may be required by the Society in way of critical weld toe locations.
The weld notch stress concentration is a direct function of the weld flank angle and the weld toe

radius.
The validity of the aforementioned S-N curves is based on a weld flank angle with a maximum mean value of 50 deg and on a weld toe radius with a minimum mean value of 0.5 mm. Welding details may be requested to be submitted for approval for some critical areas considering the calculated fatigue life.

CCS 7.2.2a For weld toe in critical locations, reference may be made to the requirements of 3.3.1 of CCS Guidelines for Construction Monitoring of Hull Structures.

7.2.3 Post-weld treatment methods
Post-weld treatment methods may be used to improve fatigue resistance of structural detail, as specified in [6].
At the design stage, the calculated fatigue life should not generally take into account any benefit that may be derived from such treatment. This benefit should only be considered in exceptional cases when the design fatigue life can not reasonably be achieved by adopting alternative design measures such as improvement of the shape of the cut-outs, soft brackets toes, local increase in thickness or other changes in geometry of the structural detail. This is to be considered on a case-by-case basis by the Society.

CCS 7.2.3a Where the benefit derived from the post-weld treatment is taken into account, the relevant workmanship requirements of post-weld treatment need to be approved by CCS.
CCS 7.2.3b Where grinding is applied, the following requirements are to be complied with: The grinding standard of structural details including the extent, smoothness particulars, final weld profile, grinding workmanship and quality acceptance criteria are to be clearly shown on the applicable drawings and submitted for review together with supporting calculations. The applicable conditions, methods and workmanship requirements for grinding are to be in accordance with paragraph 6, Section 3, Chapter 9 of this PART. Grinding has to extend to areas well outside the high stress region.

7.2.4 Detail design standard
Requirements for improved design of structural details are provided in Ch 9, Sec 6. The detail design standard also includes workmanship and welding requirements.

Section 4 SIMPLIFIED STRESS ANALYSIS

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

(i) : Suffix which denotes dynamic load case HSM, FSM, BSR-P, BSR-S, BSP-P, BSP-S, OST-P or OST-S specified in Ch 4, Sec 2, [3.1].

'i1' denotes dynamic load case HSM-1, FSM-1, BSR-1P, BSR-1S, BSP-1P, BSP-1S, OST-1P or OST-1S

'i2' denotes dynamic load case HSM-2, FSM-2, BSR-2P, BSR-2S, BSP-2P, BSP-2S, OST-2P or OST-2S.

(j) : Suffix which denotes loading condition:

'Full load' or 'Normal ballast' for oil tankers, as defined in Ch 9, Sec 1, [6.2].

'Full load homogeneous', 'Full load alternate', 'Normal ballast' or 'Heavy ballast' for bulk carriers, as defined in Ch 9, Sec 1, [6.3].

l_{bdg} : Effective bending span of stiffener, in m, as defined in Ch 3, Sec 7.

$I_{y\text{-}n50}$: Net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4.

$I_{z\text{-}n50}$: Net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m^4.

y : Transverse coordinate of the load calculation point under consideration, in m.

z : Vertical coordinate of the load calculation point under consideration, in m.

z_n : Distance from the baseline to the horizontal neutral axis, in m.

f_c : Correction factor as defined in Ch 9, Sec 1, [5.1.2].

f_{NA} : Correction factor taken as:

- For bulk carrier:
  - f_{NA} = 1.0 for $0 < z \leqslant D/2$
  - f_{NA} = 0.95 for $z = D$
  - f_{NA} : linear interpolation for other values of z
- For oil tanker: f_{NA} = 1.0

K_a : Geometrical stress concentration factor for stress due to axial load given in [5.2].

K_b : Geometrical stress concentration factor for stress due to lateral pressure given in [5.2].

K_n : Stress concentration factor due to unsymmetrical stiffener geometry, as defined in [5.1].

1 GENERAL

1.1 Application

1.1.1

This section defines the procedure for a simplified stress assessment which is to be used to evaluate the fatigue strength of the longitudinal stiffener end connections.

1.1.2

The hot spot stress ranges and hot spot mean stresses in way of each end connection of longitudinal stiffener, as shown in Figure 2 are to be evaluated at the flange of the longitudinal stiffener in the following locations:

a) Transverse webs or floors other than those located
   - At transverse bulkhead including swash bulkhead of cargo hold or
   - In way of stool,

   such that additional hot spot stress due to the relative displacement is not to be considered.

b) Transverse webs or floors located
   - At transverse bulkhead including swash bulkhead of cargo hold or
   - In way of stool,

   such that additional hot spot stress due to the relative displacement are to be considered.

Stress concentration factors due to unsymmetrical stiffener geometry according [5.1] and due to the stiffener end connection geometry at point 'A' and 'B' according to [5.2] are to be applied.

1.2 Assumptions

1.2.1
The following assumptions are made in the fatigue assessment for longitudinal stiffener end connections:

a) The hot spot stress is based on:
- Nominal stresses.
- Stress concentration factors given in [5].
- Loading conditions specified in Ch 9, Sec 1, [6].

b) The longitudinal stiffener end connection types are described in [5.2].

1.2.2
The end connections given in [5.2] are based on typical joint geometry under axial and lateral loadings. When a structural detail is different from those shown in Table 4, a finite element analysis is to be used to demonstrate the adequacy of the detail in terms of fatigue strength, according to [5.3].

2 HOT SPOT STRESS

2.1 Hot spot stress range

2.1.1
The hot spot stress range, in N/mm^2, due to dynamic loads for load case (*i*) of loading condition (*j*) is obtained from the following formula:

$$\Delta\sigma_{HS,i(j)} = \left|\left(\sigma_{GD,i1(j)} + \sigma_{LD,i1(j)} + \sigma_{dD,i1(j)}\right) - \left(\sigma_{GD,i2(j)} + \sigma_{LD,i2(j)} + \sigma_{dD,i2(j)}\right)\right|$$

where:

$\sigma_{GD,i1(j)}$,$\sigma_{GD,i2(j)}$: Stresses due to global hull girder wave bending moments, in N/mm^2, as defined in [3.1.1].

$\sigma_{LD,i1(j)}$,$\sigma_{LD,i2(j)}$: Stresses due to local dynamic pressure, in N/mm^2, as defined in [4.1.1].

$\sigma_{dD,i1(j)}$,$\sigma_{dD,i2(j)}$: Stresses due to relative displacement in wave, in N/mm^2, as defined in [4.2.4] and [4.2.5].

2.2 Hot spot mean stress

2.2.1
The hot spot mean stress, in N/mm^2, due to static and dynamic loads for load case (*i*) of loading condition (*j*) is obtained from the following formula:

$$\Delta\sigma_{mean,i(j)} = \sigma_{GS,(j)} + \sigma_{LS,(j)} + \sigma_{dS,(j)} + \sigma_{mLD,i(j)} + \sigma_{mGD,i(j)}$$

where for the load case (*i*) of loading condition (*j*):

$\sigma_{GS,(j)}$: Stress due to still water hull girder bending moment, in N/mm^2, as defined in [3.2.1].

$\sigma_{LS,(j)}$: Stress due to local static pressure, in N/mm^2, as defined in [4.1.2].

$\sigma_{dS,(j)}$: Stress due to relative displacement in still water, in N/mm^2, as defined in [4.2.7].

$\sigma_{mLD,i(j)}$: Mean stress due to local dynamic pressure, in N/mm^2, as defined as:

$$\sigma_{mLD,i(j)} = \frac{\sigma_{LD,i1(j)} + \sigma_{LD,i2(j)}}{2}$$

$\sigma_{LD,i1(j)}$, $\sigma_{LD,i2(j)}$: Stress due to local dynamic pressure, in N/mm^2, as defined in [4.1.1].

$\sigma_{mGD,i(j)}$: Mean stress due to global wave bending moment, in N/mm ², as defined as:

$$\sigma_{mGD,i(j)} = \frac{\sigma_{GD,i1(j)} + \sigma_{GD,i2(j)}}{2}$$

$\sigma_{GD,i1(j)}$, $\sigma_{GD,i2(j)}$: Stress due to global wave bending moment, in N/mm^2, as defined in [3.1.1].

3 HULL GIRDER STRESS

3.1 Stress due to hull girder wave bending moments

3.1.1
The hull girder hot spot stress, in N/mm^2, for load cases *i1* and *i2* of loading condition (*j*) is obtained from the following formula:

$$\sigma_{GD,ik(j)} = f_c \cdot K_a \left(\frac{M_{wv-LC,ik}}{I_{y-n50}} (z - z_n) \cdot f_{NA} - \frac{M_{wh-LC,ik}}{I_{z-n50}} y \right) 10^{-3}$$

where:

$M_{wv\text{-}LC,\ ik}$: Vertical wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, at the hull girder load calculation point of the considered longitudinal position for the loading condition (*j*) for *ik* being equal to *i*1 and *i*2.

$M_{wh\text{-}LC,\ ik}$: Horizontal wave bending moment, in kNm, of the considered dynamic load case, as defined in Ch 4, Sec 4, at the hull girder load calculation point of the considered longitudinal position for the loading condition (*j*) for *ik* being equal to *i*1 and *i*2.

3.2 Stress due to still water hull girder bending moment

3.2.1

The hull girder hot spot stress due to still water bending moment, in N/mm^2, in loading condition (*j*) is obtained from the following formula:

$$\sigma_{GS,(j)} = \frac{f_c \cdot f_{NA} \cdot K_a \cdot \beta_{(j)} \cdot M_{sw} \cdot (z - z_n)}{I_{y-n50}} 10^{-3}$$

where:

M_{sw} : Permissible still water vertical bending moment, in kNm, as defined in Ch 4, Sec 4 at the hull girder load calculation point of the considered longitudinal position.

$\beta_{(j)}$: Fraction of permissible still water vertical bending moment, as defined in Table 1.

Fraction of permissible still water vertical bending moments, $\beta_{(j)}$ **Table 1**

Ship type	Loading conditions	Longitudinal position on the considered section	$\beta_{(j)}$
Oil tankers	Homogeneous	N/A	0.60 in sagging condition
	Normal ballast		0.80 in hogging condition
Bulk carriers	Homogeneous		0.40 in sagging condition
	Alternate		0.75 in hogging condition
	Normal ballast		0.80 in hogging condition
	Heavy ballast (See Figure 1)	Ballast hold	0.75 in sagging condition
		Cargo holds adjacent to ballast hold	Linear interpolation between 0.75 in sagging condition and 0.45 in hogging condition
		Other cargo holds	0.45 in hogging condition

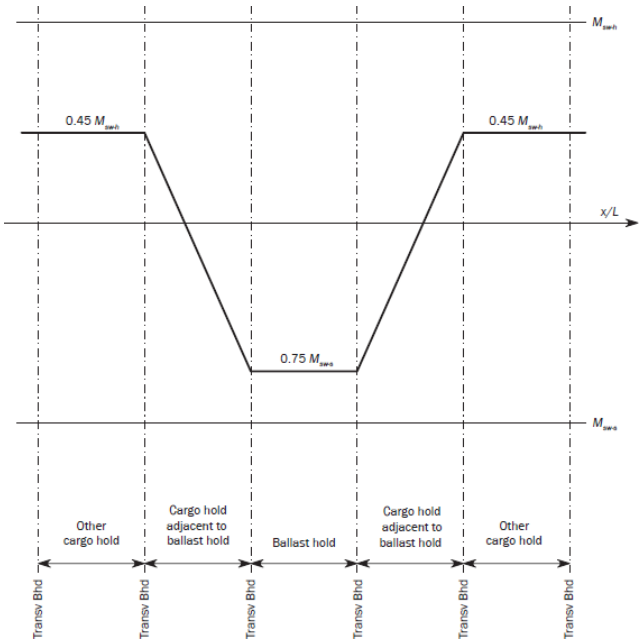


Figure 1 Distribution of still water bending moment for fatigue assessment in way of ballast hold

4 LOCAL STIFFENER STRESS

4.1 Stress due to stiffener bending

4.1.1 Stress due to dynamic pressure

The hot spot stress, in N/mm^2, due to local dynamic pressure in load case *i*1 and *i*2 for loading condition (*j*) is obtained from the following formula:

$$\sigma_{LD,ik(j)} = \frac{K_b K_n s l_{bdg}^2 (\eta_W f_{NL} P_{W,ik(j)} + \eta_{ld} P_{Id,ik(j)} + \eta_{bd} P_{bd,ik(j)}) \left(1 - \frac{6x_e}{l_{bdg}} + \frac{6x_e^2}{l_{bdg}^2}\right)}{12 Z_{eff-n50}}$$

where:

$P_{W, ik(j)}$: Dynamic wave pressure, at the mid span, in kN/m^2, specified in Ch 4, Sec 5, [1.4], in load case *i*1 and *i*2 for loading condition (*j*).

$P_{ld, ik(j)}$: Dynamic liquid tank pressure, at the mid span, in kN/m^2, as specified in Ch 4, Sec 6, [1.1.1], in load case *i*1 and *i*2 for loading condition (*j*).

Pressure acting on both sides of the stiffener, i.e. applied on the attached plate on stiffener side or on opposite side to the stiffener, could be simultaneously considered if relevant in the loading condition.

For the deck longitudinal stiffeners of bulk carriers, no internal pressure from the topside tank is considered.

$P_{bd, ik(j)}$: Dynamic dry bulk cargo pressure at the mid span, in kN/m^2, as specified in Ch 4, Sec 6, [2.4.1], in load case *i*1 and *i*2 for loading condition (*j*).

η_w, η_{ld}, η_{bd}: Pressure normal coefficients, taken as:

η = 1 when the considered pressure is applied on the stiffener side,

η = -1 otherwise.

f_{NL} : Correction factor for the non-linearity of the wave pressure taken as:

$f_{NL} = 1$ $\quad z > T_{LC} + 2h_w$

$f_{NL} = 2.5\frac{z - T_{LC}}{h_w} - 4$ $\quad T_{LC} + 1.8h_w < z \le T_{LC} + 2h_w$

$f_{NL} = 0.5\frac{z - T_{LC}}{h_w} - 0.4$ $\quad T_{LC} + 1.6h_w < z \le T_{LC} + 1.8h_w$

$f_{NL} = 0.4$ $\quad T_{LC} + 1.2h_w < z \le T_{LC} + 1.6h_w$

$f_{NL} = 0.7 - 0.25\frac{z - T_{LC}}{h_w}$ $\quad T_{LC} + 0.6h_w < z \le T_{LC} + 1.2h_w$

$f_{NL} = 1 - 0.75\frac{z - T_{LC}}{h_w}$ $\quad T_{LC} - 0.2h_w < z \le T_{LC} + 0.6h_w$

$f_{NL} = 0.1875\frac{z - T_{LC}}{h_w} + 1.1875$ $\quad T_{LC} - h_w < z \le T_{LC} - 0.2h_w$

$f_{NL} = 1$ $\quad z \le T_{LC} - h_w$

h_w : Water head equivalent to the pressure at waterline, in m, as defined in Ch 4, Sec 5.

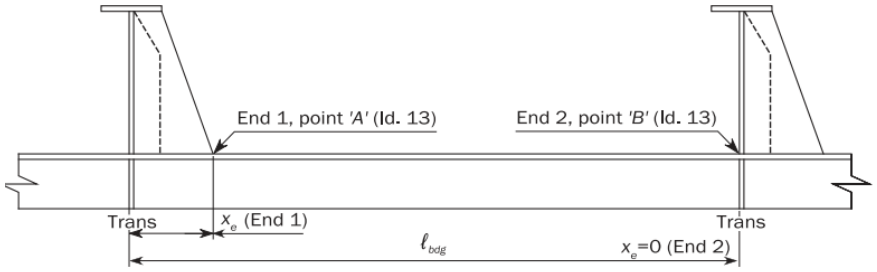
x_e : Distance, in m, to the hot spot from the closest end of the span l_{bdg}, as defined in Figure 2.

$Z_{eff-n50}$: Net section modulus, in cm^3, of the considered stiffener calculated considering an effective breadth b_{eff} of attached plating.

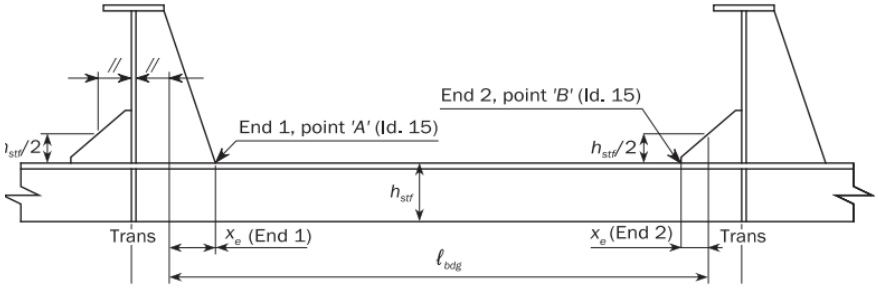
b_{eff} : Effective breadth, in mm, of attached plating specified at the ends of the span and in way of end brackets and supports, taken as:

$$b_{eff} = s \cdot \min\left[\frac{1.04}{1 + \frac{3}{\left(\frac{l_{bdg}}{s}\left(1 - \frac{1}{\sqrt{3}}\right) \cdot 10^3\right)^{1.35}}}; 1.0\right] \quad \text{for} \quad \frac{l_{bdg}}{s}\left(1 - \frac{1}{\sqrt{3}}\right) \times 10^3 \ge 1$$

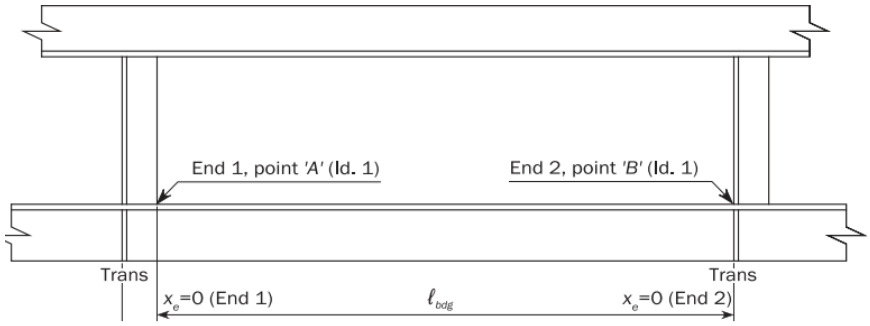
$$b_{eff} = 0.26 l_{bdg}\left(1-\frac{1}{\sqrt{3}}\right)\times 10^3 \quad \text{for} \quad \frac{l_{bdg}}{s}\left(1-\frac{1}{\sqrt{3}}\right)\times 10^3 < 1$$



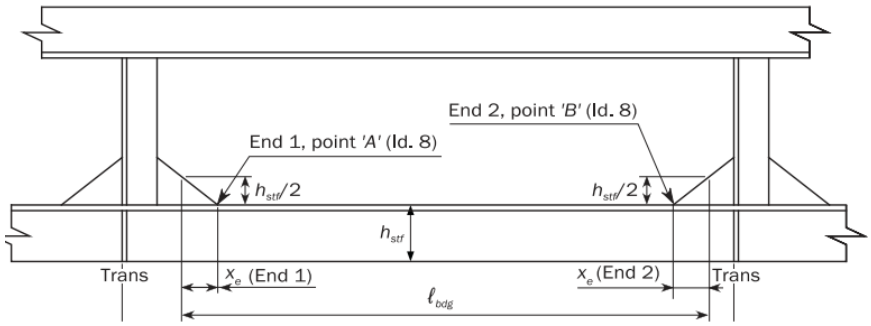
Supported by free flange transverses



Supported by free flange transverses



Supported by double skin/transverse bulkheads



Supported by double skin/transverse bulkheads

Figure 2 Definition of effective span and x_e for hot spot

4.1.2 Stress due to static pressure

The hot spot stress due to local static pressure, in N/mm2, for loading condition (*j*) is obtained from the following formula:

$$\sigma_{LS,(j)} = \frac{K_b K_n s l_{bdg}^2 (\eta_s P_{s,(j)} + \eta_{ls} P_{Is,(j)} + \eta_{bs} P_{bs,(j)}) \left(1 - \frac{6x_e}{l_{bdg}} + \frac{6x_e^2}{l_{bdg}^2}\right)}{12 Z_{eff-n50}}$$

where:

$P_{S,(j)}$: Static external pressure, in kN/m^2, in loading condition (j) specified in Ch 4, Sec 5, [1.2].

$P_{ls,(j)}$:Static liquid tank pressure, in kN/m^2, in loading condition (j) specified in Ch 4, Sec 6, [1.1.1].Pressure acting on both sides could be simultaneously considered if relevant in the loading condition.

$P_{bs,(j)}$: Static dry bulk cargo pressure, in kN/m^2, in loading condition (j) specified in Ch 4, Sec 6, [2.4.1].

η_s, η_{ls}, η_{bs} : Pressure normal coefficients, taken as:

η = 1 when the considered pressure is applied on the stiffener side,

η = -1 otherwise.

4.2 Stress due to relative displacement

4.2.1 General

For longitudinal stiffener end connections fitted on transverse web or floor located

- At transverse bulkhead including swash bulkhead of cargo hold or
- In way of stool,

the additional hot spot stress due to the relative displacement is to be considered.

4.2.2 Relative displacement definition

The relative displacement is defined as follows.

- For longitudinals penetrating floors in way of stool the relative displacement is defined as the displacement of the longitudinal measured at the first floor forward (*Fwd*) or afterward (*Aft*) relative to the displacement of the longitudinal at the floor in way of stool.
- For other longitudinals, the relative displacement is defined as the displacement of the longitudinal measured at the first transverse web frame (or floor) forward (*Fwd*) or afterward (*Aft*) relative to the displacement of the longitudinal at the transverse bulkhead including swash bulkhead.

4.2.3 Sign convention

Where the stress at the hot spot location, i.e. at the flange of longitudinal, due to relative displacement is in tension, the sign of the relative displacement is positive.

4.2.4 Oil tankers

The additional hot spot stress due to relative displacement for load case $i1$ and $i2$ of loading condition (j) for an oil tanker is to be accounted for either using finite element method as described in [4.2.6] or by applying a stress factor on the local dynamic stress component as described in the following:

$$\sigma_{dD,ik(j)} = (K_d - 1) \cdot \sigma_{LD,ik(j)}$$

where:

$\sigma_{LD,ik(j)}$: Local dynamic stress defined in [4.1.1].

K_d : Bending stress factor for longitudinal stiffeners caused by relative displacement between supports, shown on Figure 3, as given in Table 2.

Bending stress factor of longitudinals due to relative displacement between transverse bulkhead (including swash bulkhead) and adjacent web frames (floors) Table 2

Location		K_d factor	
		Full load condition	Ballast condition
Bottom longitudinal	Mid position between longitudinal bulkhead, bottom girders or buttress structure	1.50	
	At longitudinal bulkhead, bottom girders (except centre line girder) or buttress structure	1.15	
	At centre line girder	1.30	
	Intermediate position between above bottom positions	Linear interpolation	
Side longitudinals	Mid position between lowest side stringer and deck at side	1.30	1.15
	Lowest side stringer and deck at side	1.15	1.15
	Intermediate positions	Linear interpolation	1.15
Other longitudinals		1.15	

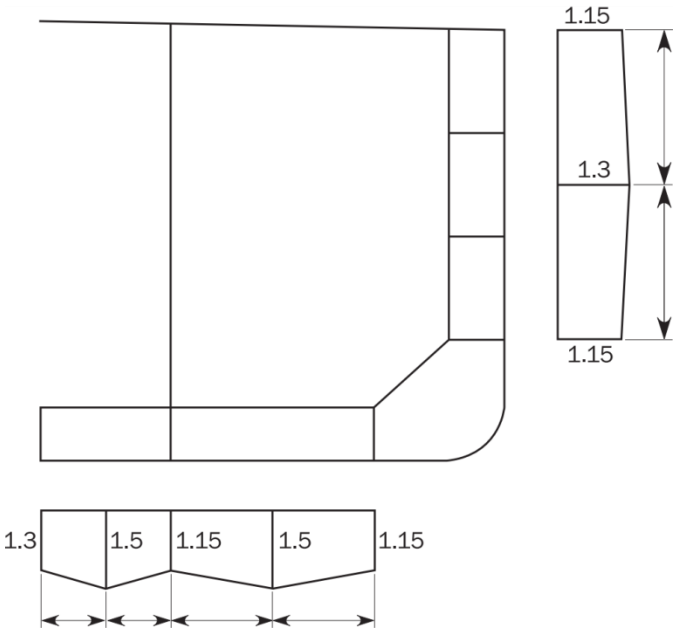


Figure 3 K_d factor in full load condition for oil tanker with two longitudinal bulkheads

4.2.5 Bulk carriers

The additional hot spot stress due to relative displacement for load case *i1* and *i2* of loading condition (*j*) for a bulk carrier is to be calculated using finite element method as described in [4.2.6].

4.2.6 Stress due to relative displacement derived using FE method

The following procedure is based on a cargo hold model complying with Ch 7, Sec 2, [2] to calculate the stress due to relative displacements. The stress due to relative displacements, in N/mm2, for load case *i1* and *i2* of loading condition (*j*) for both locations "*a*" and "*f*" is to be calculated directly using the following expression:

$$\sigma_{dD,ik(j)} = \begin{cases} K_b\sigma_{dFwd-a,ik(j)} + K_b\sigma_{dAft-a,ik(j)} & \text{for location "}a\text{"} \\ K_b\sigma_{dFwd-f,ik(j)} + K_b\sigma_{dAft-f,ik(j)} & \text{for location "}f\text{"} \end{cases} \quad (k = 1,2)$$

where:

a, f : Suffix which denotes the location as indicated in Figure 4.

Aft, Fwd : Suffix which denotes the direction, afterward (*Aft*) or forward (*Fwd*), from the transverse bulkhead. as shown in Figure 4.

K_b : Stress concentration factor due to bending for the location '*a*' or '*f*' which may correspond to points '*A*' or '*B*' as defined in Table 4.

$\sigma_{dFwd\text{-}a,ik(j)}, \sigma_{dAft\text{-}a,ik(j)}, \sigma_{dFwd\text{-}f,ik(j)}, \sigma_{dAftd\text{-}f,ik(j)}$: Additional stress at location '*a*' and '*f*', in N/mm^2, due to the relative displacement between the transverse bulkhead including swash bulkhead or floors in way of stool and the forward (*Fwd*) and afterward (*Aft*) transverse web or floor respectively for load case *i1* and *i2* of loading condition (*j*), taken as:

$$\sigma_{dFwd-a,ik(j)} = \frac{3.9\delta_{Fwd,ik(j)} EI_{Aft-n50} I_{Fwd-n50}}{Z_{Aft-n50} l_{Fwd} \left(l_{Aft} I_{Fwd-n50} + l_{Fwd} I_{Aft-n50}\right)} \left(1 - 1.15 \frac{|x_{eAft}|}{l_{Aft}}\right) 10^{-5}$$

$$\sigma_{dAft-a,ik(j)} = \left[\frac{3.9\delta_{Aft,ik(j)} EI_{Aft-n50} I_{Fwd-n50}}{Z_{Aft-n50} l_{Aft} \left(l_{Aft} I_{Fwd-n50} + l_{Fwd} I_{Aft-n50}\right)} \left(1 - 1.15 \frac{|x_{eAft}|}{l_{Aft}}\right) - \frac{0.9\delta_{Aft,ik(j)} EI_{Aft-n50} |x_{eAft}|}{Z_{Aft-n50} l_{Aft}^3}\right] 10^{-5}$$

$$\sigma_{dFwd-f,ik(j)} = \left[\frac{3.9\delta_{Fwd,ik(j)} EI_{Aft-n50} I_{Fwd-n50}}{Z_{Fwd-n50} l_{Fwd} \left(l_{Aft} I_{Fwd-n50} + l_{Fwd} I_{Aft-n50}\right)} \left(1 - 1.15 \frac{|x_{eFwd}|}{l_{Fwd}}\right) - \frac{0.9\delta_{Fwdt,ik(j)} EI_{Fwd-n50} |x_{eFwd}|}{Z_{Fwd-n50} l_{Fwd}^3}\right] 10^{-5}$$

$$\sigma_{dAft-f,ik(j)} = \frac{3.9\delta_{Aft,ik(j)} EI_{Aft-n50} I_{Fwd-n50}}{Z_{Fwdt-n50} l_{Aft} \left(l_{Aft} I_{Fwd-n50} + l_{Fwd} I_{Aft-n50}\right)} \left(1 - 1.15 \frac{|x_{eFwd}|}{l_{Fwd}}\right) 10^{-5}$$

$I_{Fwd\text{-}n50}$, $I_{Aft\text{-}n50}$: Net moment of inertia, in cm^4, of forward (*Fwd*) and afterward (*Aft*) longitudinal.

$Z_{Fwd\text{-}n50}$, $Z_{Aft\text{-}n50}$: Net section modulus of forward (*Fwd*) and afterward (*Aft*) stiffener, in cm^3.

l_{Fwd}, l_{Aft} : Span, in m, of forward (*Fwd*) and afterward (*Aft*) longitudinal, as shown in Figure 4.

x_{eFwd}, x_{eAft} : Distance, in m, as shown in Figure 2, to the hot spot in location '*a*' or '*f*' from the closest end of l_{Fwd} and l_{Aft} respectively.

$\delta_{Fwd,ik(j)}$, $\delta_{Aft,ik(j)}$: Relative displacement in the direction perpendicular to the attached plate, in mm, between the transverse bulkhead (including swash bulkhead or floor in way of stools) and the forward (*Fwd*) or afterward (*Aft*) transverse web (or floor) as shown in Figure 4.

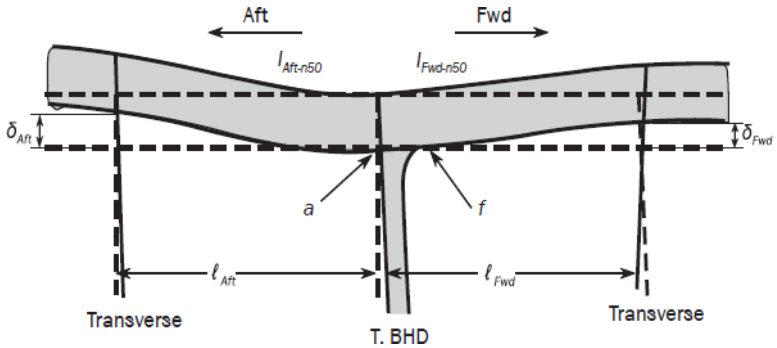


Figure 4 Definition of the relative displacement (example of the side longitudinal)

4.2.7 Stress due to relative displacement in still water

The additional hot spot stress, in N/mm^2, in still water, due to the relative displacement in the direction perpendicular to the attached plate between the transverse bulkhead including swash bulkhead or floor in way of stools and the adjacent transverse web or floor is to be obtained according to procedures of [4.2.4] and [4.2.5] for oil tankers and bulk carriers respectively, replacing dynamic local stress σ_{LD} and dynamic pressure with static local stress σ_{LS} and static pressure.

5 STRESS CONCENTRATION FACTORS

5.1 Unsymmetrical stiffener

5.1.1

The stress concentration factor K_n for unsymmetrical flange of built-up and rolled angle stiffeners under lateral load, calculated at the web's mid-thickness position, as shown in Figure 5, is to be taken as:

$$K_n = \frac{1+\lambda\beta^2}{1+\lambda\beta^2\psi_z}$$

where:

$$\lambda = \frac{3\left(1+\frac{\eta}{280}\right)}{1+\frac{\eta}{40}}$$

$$\eta = \frac{l_{bdg}^4 \cdot 10^{12}}{b_{f-n50}^3 \cdot t_{f-n50} \cdot h_{stf-n50}^2 \cdot \left(\frac{4 \cdot h_{stf-n50}}{t_{w-n50}^3} + \frac{s}{t_{p-n50}^3}\right)}$$

$\beta = 1 - \frac{2b_{g-n50}}{b_{f-n50}}$ for built-up profiles

$\beta = 1 - \frac{t_{w-n50}}{b_{f-n50}}$ for rolled angle profiles.

$b_{g\text{-}n50}$: Eccentricity of the stiffener equal to the distance from flange's edge to web's centreline, in mm, as shown in Figure 6.

$b_{f\text{-}n50}$: Net breadth of flange, in mm, as shown in Figure 6.

$t_{f\text{-}n50}$: Net flange thickness, in mm, as shown in Figure 6.

$h_{stf\text{-}n50}$: Net stiffener height, including face plate, in mm, as shown in Figure 6.

$t_{w\text{-}n50}$: Net web thickness, in mm, as shown in Figure 6.

$h_{w\text{-}n50}$: Net web's height stiffener, in mm, as shown in Figure 6.

$t_{p\text{-}n50}$: Net thickness of attached plating, in mm, as shown in Figure 6.

Ψ_z : Coefficient given as:

$$\psi_z = \frac{h_{w-n50}^2 t_{w-n50}}{4Z_{n50}} 10^{-3}$$

Z_{n50} : Net section modulus, in cm^3, of stiffener with an attached plating breadth equal to the stiffener spacing.

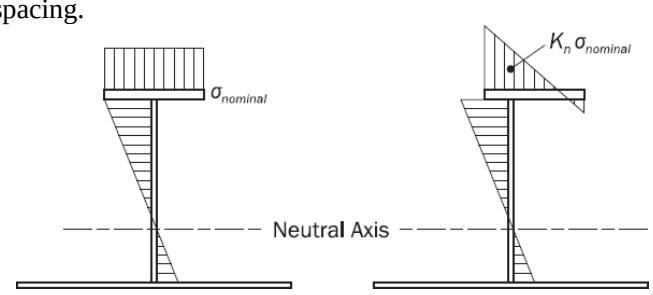


Figure 5 Bending stress in stiffener with symmetrical and unsymmetrical flange

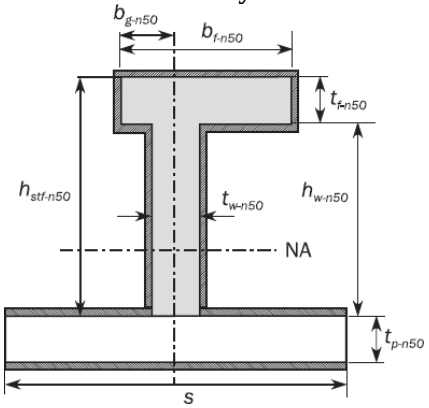


Figure 6 Stiffener - net scantling

5.1.2 Bulb profiles

For bulb profiles K_n factor is to be calculated using the equivalent built-up profile as shown in Figure 7. The flange of the equivalent built-up profile is to have the same properties as the bulb flange, i.e. same cross sectional area and moment of inertia about the vertical axis and neutral axis position.

For HP bulb profiles, examples of the equivalent built up profile dimensions are listed in Table 3.

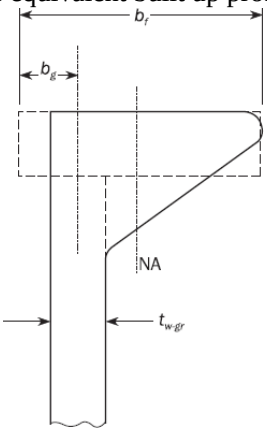


Figure 7 Bulb profile and equivalent built-up profile

HP equivalent built-up profile dimensions **Table 3**

HP-bulb		Equivalent built-up flange in gross thickness		
Height (mm)	Gross web thickness, $t_{w\text{-}gr}$ (mm)	b_f (mm)	$t_{f\text{-}gr}$ (mm)	b_g (mm)
200	9 – 13	$t_{w\text{-}gr}$ + 24.5	22.9	($t_{w\text{-}gr}$ + 0.9)/2
220	9 – 13	$t_{w\text{-}gr}$ + 27.6	25.4	($t_{w\text{-}gr}$ + 1.0)/2
240	10 – 14	$t_{w\text{-}gr}$ + 30.3	28.0	($t_{w\text{-}gr}$ + 1.1)/2
260	10 – 14	$t_{w\text{-}gr}$ + 33.0	30.6	($t_{w\text{-}gr}$ + 1.3)/2
280	10 – 14	$t_{w\text{-}gr}$ + 35.4	33.3	($t_{w\text{-}gr}$ + 1.4)/2
300	11 – 16	$t_{w\text{-}gr}$ + 38.4	35.9	($t_{w\text{-}gr}$ + 1.5)/2
320	11 – 16	$t_{w\text{-}gr}$ + 41.0	38.5	($t_{w\text{-}gr}$ + 1.6)/2
340	12 – 17	$t_{w\text{-}gr}$ + 43.3	41.3	($t_{w\text{-}gr}$ + 1.7)/2
370	13 – 19	$t_{w\text{-}gr}$ + 47.5	45.2	($t_{w\text{-}gr}$ + 1.9)/2
400	14 – 19	$t_{w\text{-}gr}$ + 51.7	49.1	($t_{w\text{-}gr}$ + 2.1)/2
430	15 – 21	$t_{w\text{-}gr}$ + 55.8	53.1	($t_{w\text{-}gr}$ + 2.3)/2

5.2 Longitudinal stiffener end connections

5.2.1

The stress concentration factors K_a and K_b are given in Table 4 for end connection of stiffeners subjected to axial and lateral loads. The values given in Table 4 for soft toe are valid provided the toe geometry complies with the requirements given in [5.2.5]. The stress concentration factor K_b given for lateral loads are to be used also for stress due to relative displacements.

5.2.2 Other connection types

When connection types other than those given in Table 4 are proposed, the fatigue strength for the proposed connection type is to be assessed either by performing a very fine mesh FE analysis as described in Ch 9, Sec 5 to obtain directly the hot spot stress, or by calculating the stress concentration factor using FE analysis according to [5.3].

5.2.3 Overlapped connection

Overlapped connection types for longitudinal stiffeners, i.e. attachments welded to the web of the longitudinals, are not to be used in the cargo hold region.

5.2.4 End stiffener without connection to web stiffener

Where the web stiffener is omitted or not connected to the longitudinal flange in way of:

- Side shell below 1.1 T_{sc}.
- Bottom.
- Inner hull longitudinal bulkhead below 1.1 T_{sc}.
- Hopper.
- Topside tank sloping plating below 1.1 T_{sc}.
- Inner bottom.

the following is required:

- A complete collar as defined in Figure 8 (i.e. connection type ID 31 of Table 4), or,
- A detail design for cut-outs as described in Ch 9, Sec 6, [2.1].

Equivalence to cut-outs given in Ch 9, Sec 6, [2.1] may be accepted provided it is assessed for fatigue by using comparative FE analysis which is based on hot spot stress around the cut-out in the web plate of the primary supporting member inclusive of the collar, as given in Ch 9, Sec 6, [2.2].

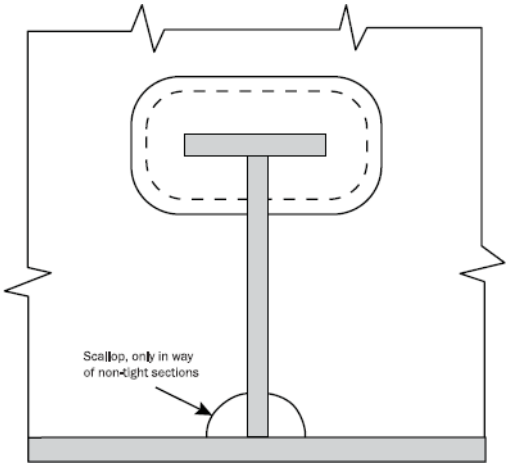


Figure 8 Complete collar

5.2.5 Soft toe of web stiffener and backing bracket

The toe geometry end connection of web stiffener and backing bracket is to comply with the following:

$\theta \leqslant 20$

$h_{toe} \leqslant \max(t_{bkt\text{-}gr}; 15)$

where:

θ : Angle of the toe, in deg, as shown in Figure 9.

h_{toe} : Height of the toe, in mm, as shown in Figure 9.

$t_{bkt\text{-}gr}$: Gross thickness of the bracket, in mm.

5.2.6 Recommended detail designs

Recommended detail designs for longitudinal end connections with soft toes and backing brackets are given in Figure 9.

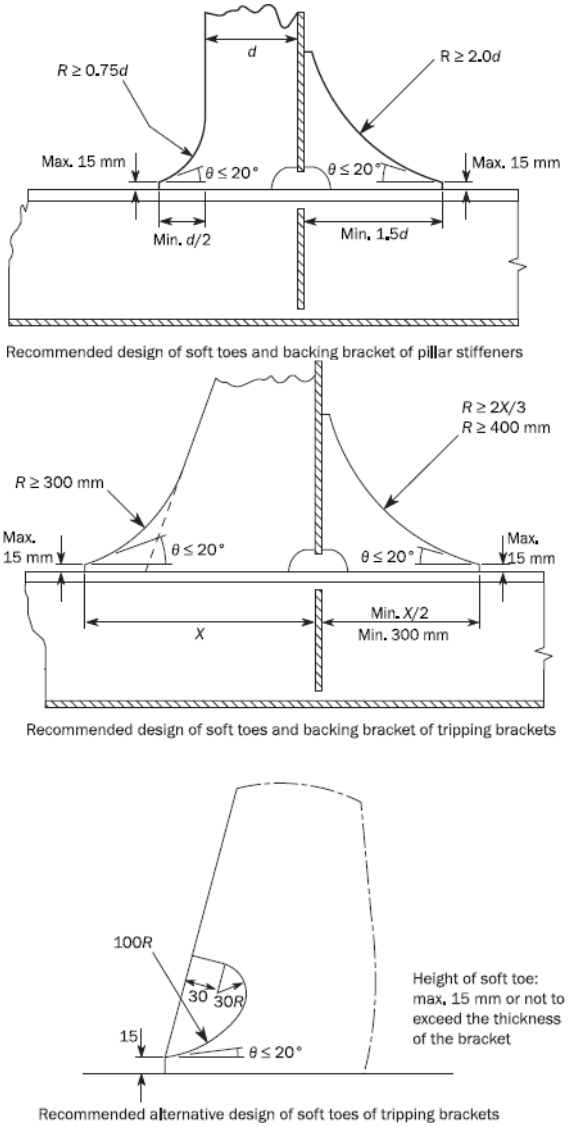
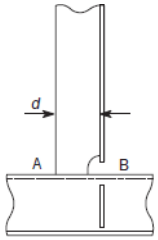
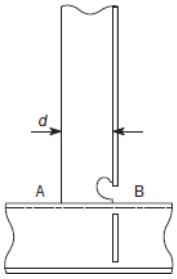
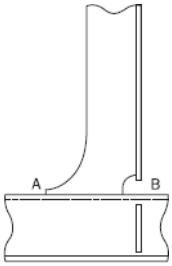
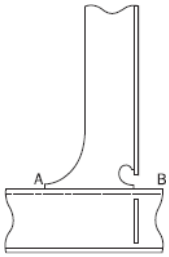
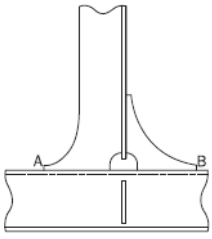
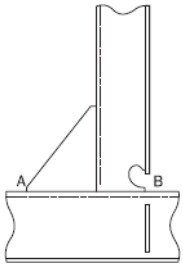
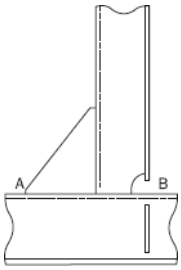
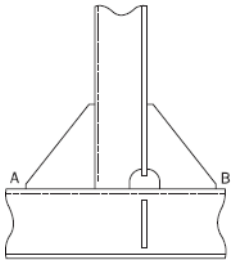
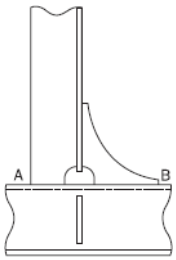
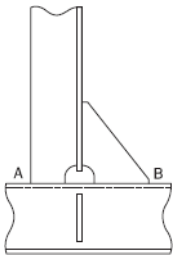
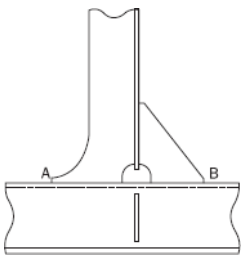
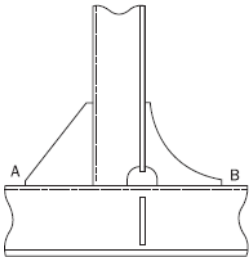
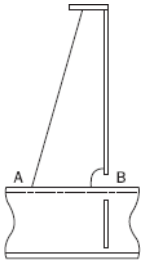
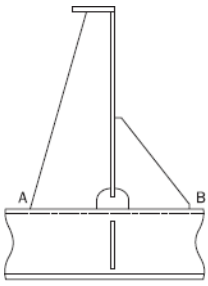
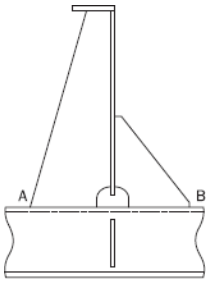
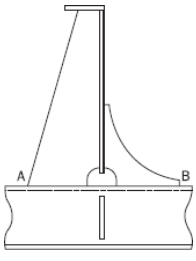
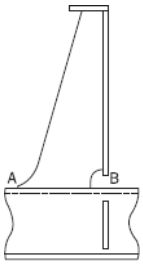


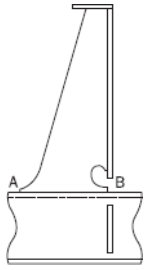
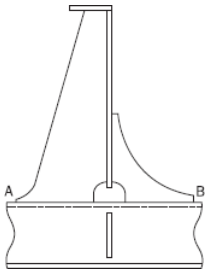
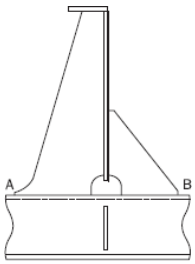
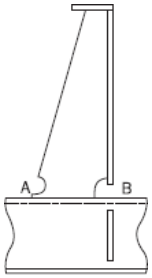
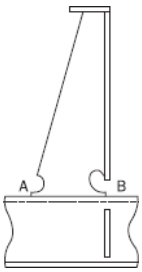
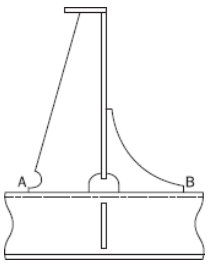
Figure 9 Detail design for soft toes and backing brackets

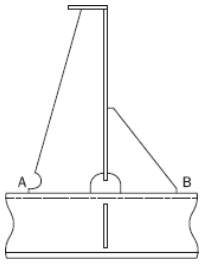
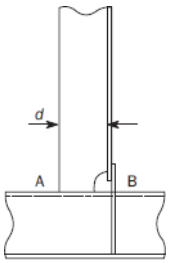
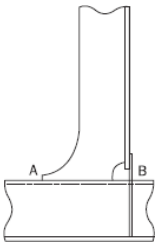
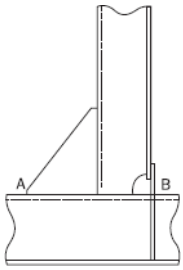
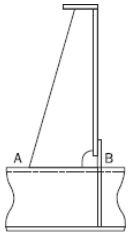
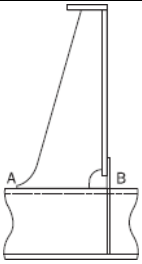
Stress concentration factors **Table 4**

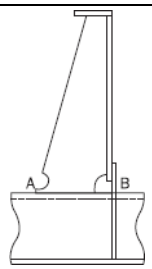
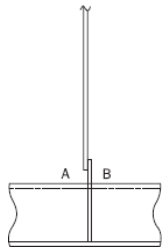
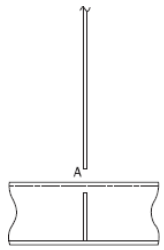
ID	Connection type [2] [3]	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
1 [1]		1.28 for $d \leqslant 150$ 1.36 for $150 < d \leqslant 250$ 1.45 for $d > 250$	1.40 for $d \leqslant 150$ 1.50 for $150 < d \leqslant 250$ 1.60 for $d > 250$	1.28 for $d \leqslant 150$ 1.36 for $150 < d \leqslant 250$ 1.45 for $d > 250$	1.60
2 [1]		1.28 for $d \leqslant 150$ 1.36 for $150 < d \leqslant 250$ 1.45 for $d > 250$	1.40 for $d \leqslant 150$ 1.50 for $150 < d \leqslant 250$ 1.60 for $d > 250$	1.14 for $d \leqslant 150$ 1.24 for $150 < d \leqslant 250$ 1.34 for $d > 250$	1.27
3		1.28	1.34	1.52	1.67
4		1.28	1.34	1.34	1.34
5		1.28	1.34	1.28	1.34

ID	Connection type [2] [3]	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
6		1.52	1.67	1.34	1.34
7		1.52	1.67	1.52	1.67
8		1.52	1.67	1.52	1.67
9		1.52	1.67	1.52	1.34
10		1.52	1.67	1.52	1.67
11		1.28	1.34	1.52	1.67

ID	Connection type [2] [3]	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
12		1.52	1.67	1.28	1.34
13		1.52	1.67	1.52	1.67
14		1.52	1.67	1.34	1.34
15		1.52	1.67	1.52	1.67
16		1.52	1.67	1.28	1.34
17		1.28	1.34	1.52	1.67

ID	Connection type [2] [3]	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
18		1.28	1.34	1.34	1.34
19		1.28	1.34	1.28	1.34
20		1.28	1.34	1.52	1.67
21		1.28	1.34	1.52	1.67
22		1.28	1.34	1.34	1.34
23		1.28	1.34	1.28	1.34

ID	Connection type [2] [3]	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
24		1.28	1.34	1.52	1.67
25[1]		1.28 for $d \leqslant 150$ 1.36 for $150 < d \leqslant 250$ 1.45 for $d > 250$	1.40 for $d \leqslant 150$ 1.50 for $150 < d \leqslant 250$ 1.60 for $d > 250$	1.14 for $d \leqslant 150$ 1.24 for $150 < d \leqslant 250$ 1.34 for $d > 250$	1.25 for $d \leqslant 150$ 1.36 for $150 < d \leqslant 250$ 1.47 for $d > 250$
26		1.28	1.34	1.34	1.47
27		1.52	1.67	1.34	1.47
28		1.52	1.67	1.34	1.47
29		1.28	1.34	1.34	1.47

ID	Connection type (2) (3)	Point '*A*'		Point '*B*'	
		K_a	K_b	K_a	K_b
30		1.28	1.34	1.34	1.47
31 (4)		1.13	1.20	1.13	1.20
32 (4) (5) (6)		1.13	1.14	N/A	N/A

(1) The attachment length *d*, in mm, is defined as the length of the welded attachment on the longitudinal stiffener flange without deduction of scallop.
(2) Where the longitudinal stiffener is a flat bar and there is a web stiffener/bracket welded to the flat bar stiffener, the stress concentration factor listed in the table is to be multiplied by a factor of 1.12. when the thickness of attachment is thicker than the 0.7 times thickness of flat bar stiffener This also applies to unsymmetrical profiles where there is less than 8 mm clearance between the edge of the stiffener flange and the attachment, e.g. bulb or angle profiles where the clearance of 8 mm cannot be achieved.
(3) Designs with overlapped connection / attachments, see [5.2.3].
(4) ID 31 and 32 refer to details where web stiffeners are omitted or not connected to the longitudinal stiffener flange. See [5.2.4]
(5) For connection type ID 32 with no collar and/or web plate welded to the flange, the stress concentration factors provided in this table are to be used irrespective of slot configuration.
(6) The fatigue assessment point 'A' is located at the connection between the stiffener web and the transverse web frame or lug plate.

5.3 Alternative design

5.3.1 Derivation of alternative stress concentration factors

Upon agreement by the Society, the geometrical stress concentration factors for alternative designs are to be calculated by a very fine mesh FE analysis according to the requirements given in Ch 9, Sec 5. Additional requirements for derivation of geometrical stress concentration factors for stiffener end connections using very fine mesh FE analysis are given below:

a) FE model extent: the FE model, as shown in Figure 10, is to cover at least four web frame spacings in the longitudinal stiffener direction with the detail to be considered located at the middle frame. The same type of end connection is to be modelled at all the web frames. In the transverse direction, the model may be limited to one stiffener spacing.
b) Load application: in general, two loading cases are to be considered:
c) Axial loading by enforced displacement applied to the model ends and
d) Lateral loading by unit pressure load applied to the shell plating.
e) Boundary conditions:
f) Symmetry conditions are applied along the longitudinal cut of the plate flange, along

transverse and vertical cuts on web frames and on top of the web stiffener.

g) For lateral pressure loading: the model is to be fixed in all degrees of freedom at both forward and aft ends.

h) For axial loading: the model is to be fixed for displacement in the longitudinal direction at the aft end of the model while enforced axial displacement is applied at the forward end, or vice versa.

i) FE mesh density: At the location of the hot spots under consideration, the element size is to be in the order of the thickness of the stiffener flange. or 10mm depending on the type of stiffener In the remaining part of the model, the element size is to be in the order of s/10, where s is the stiffener spacing.

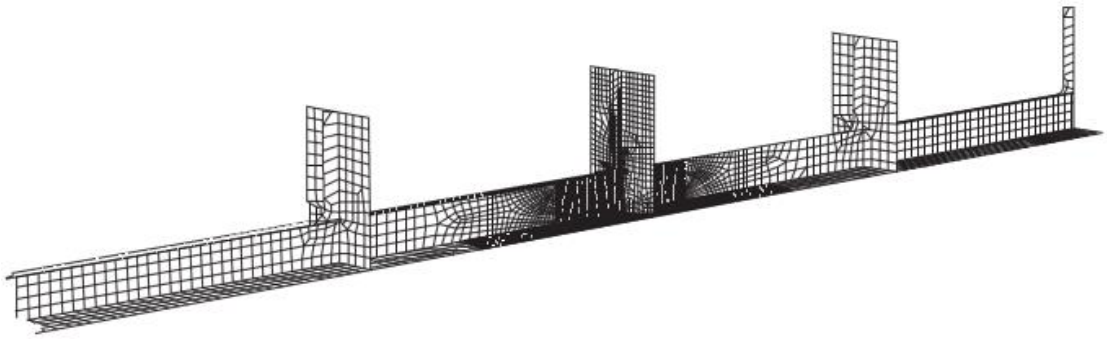


Figure 10 Fine mesh finite element model for derivation of geometrical stress concentration factor(example of stiffener with flange)

For the 2 loading cases specified above, the stress concentration factors are determined as follows:

- For the axial loading case:

$$K_a = \frac{\sigma_{HSAx}}{\sigma_{NomAx}}$$

- For the bending loading case:

$$K_b = \frac{\sigma_{HSBd}}{\sigma_{NomBd}}$$

σ_{HSAx} : Hot spot stress, in N/mm^2, determined at the stiffener flange for the axial load.

σ_{NomAx}: Nominal axial stress, in N/mm^2, calculated at the stiffener flange according to [3.1] for the axial load applied for the FE calculation.

σ_{HSBd} : Hot spot stress, in N/mm^2, determined at the stiffener flange for the unit pressure load.

σ_{NomBd}: Nominal bending stress, in N/mm^2, calculated at the stiffener flange according to [4.1] in way of the hot spot for the unit pressure load applied for the FE calculation.

The derivation of geometrical stress concentration factors for alternative designs is to be documented and provided to the Society.

CCS 5.3.1a FE model extent

(1) FE model extent

The FE model, as shown in Figure CCS 5.3.1a(1), is to cover at least four web frame spacings in the longitudinal stiffener direction with the detail to be considered located at the middle web frame. The same type of end connection is to be modeled at all the web frames. In the transverse direction, the model is to cover at least half the stiffener spacing on both sides; in the vertical direction, it is to maintain at least half the web height.

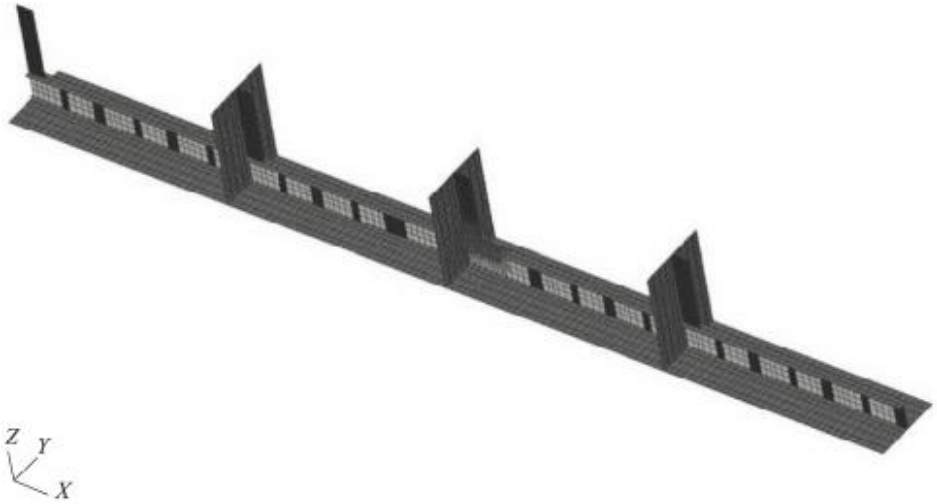


Figure CCS 5.3.1a(1) Longitudinal Extent of Fine Mesh Finite Element Model

(2) FE mesh size

At the location of the hot spots under consideration, the mesh size of at least 10 elements is to be the same as the thickness of the flange of longitudinals. In the remaining part of the model, the mesh size is to be taken as1/10 of the spacing of longitudinals. Attention is to be given to the smooth transition of mesh size. It is recommended to use mm as the length unit during modeling.

(3) Load case

Axial load case: enforced displacement of 1 mm applied to the model ends.

Lateral load case: uniformly distributed unit load applied to the attached plating of longitudinal, in 1 kN/m^2, i.e. 0.001 Mpa.

(4) Boundary conditions

Symmetry conditions:

a) *angular displacement $\theta_x = 0$, displacement $\delta_y = 0$ along the longitudinal edge of the attached plate, see Figure CCS 5.3.1a(2);*
b) *angular displacement $\theta_z = 0$, displacement $\delta_y = 0$ along vertical edge on web frames, see Figure CCS 5.3.1a(3);*
c) *angular displacement $\theta_y = 0$, displacement $\delta_z = 0$ along transverse edge on top of web frames, see Figure CCS 5.3.1a(4);*
d) *angular displacement $\theta_x = 0$, displacement $\delta_z = 0$ on top of the web stiffener, see Figure CCS 5.3.1a(5).*

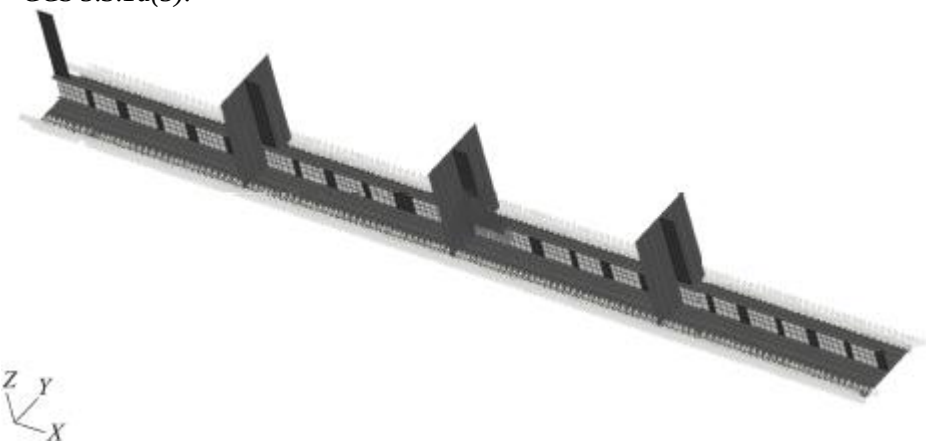


Figure CCS 5.3.1a(2) Boundary Condition of Fine Mesh Finite Element Model (a)

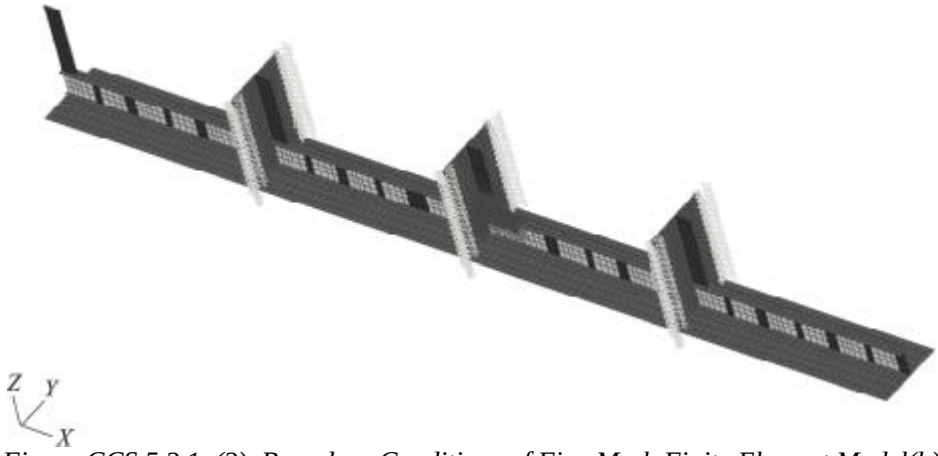


Figure CCS 5.3.1a(3) Boundary Conditions of Fine Mesh Finite Element Model(b)

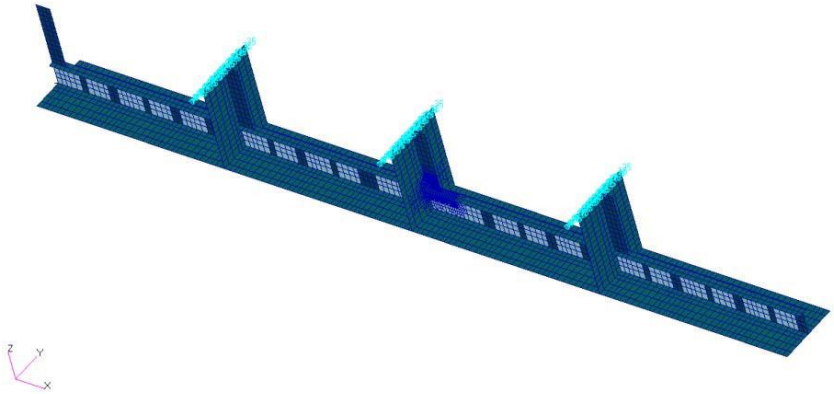


Figure CCS 5.3.1a(4) Boundary Conditions of Fine Mesh Finite Element Model(c)

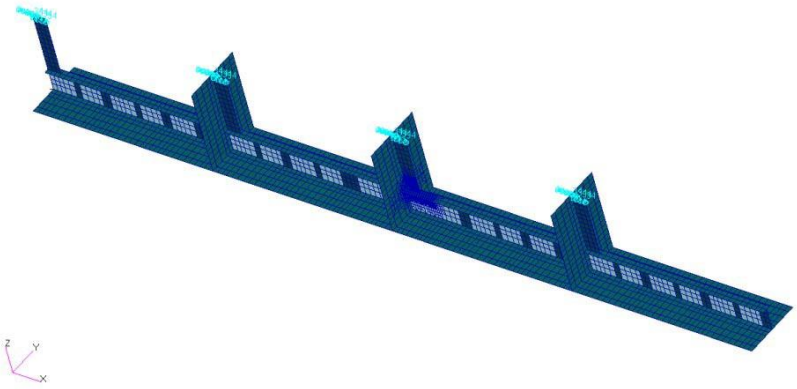


Figure CCS 5.3.1a(5) Boundary Conditions of Fine Mesh Finite Element Model (d)

For axial load case: the model is to be fixed for displacement in the longitudinal direction at the aft end of the model while enforced axial displacement is applied at the forward end, or vice versa. For lateral load case: the model is to be fixed in all degrees of freedom at both forward and aft ends.

CCS 5.3.1b Calculation of stress concentration factors

(1) The geometrical stress concentration factor, K_g , is calculated in accordance with the following formula:

$$K_g = \frac{\sigma_{HS}}{\sigma_{nom}}$$

where:

σ_{HS} : hot spot stress, in N/mm^2, to be calculated in accordance with (2) of this paragraph;

σ_{nom}: nominal stress, in N/mm^2, to be calculated in accordance with (3) of this paragraph and taken as σ_{axial} or $\sigma_{lateral}$.

(2) Hot spot stress σ_{HS}, in N/mm^2, is calculated in accordance with the following formula according to the process as specified in 3.1, Section 5 of Chapter 9:

$$\sigma_{HS} = 1.12\sigma$$

where:

σ : longitudinal stress obtained from interpolation of FE calculation, in N/mm^2.

(3) Calculation of nominal stress

a) The nominal stress σ_{axial}, in N/mm^2, of axial load case is calculated in accordance with the following formula:

$$\sigma_{axial} = \frac{\Delta l}{l} E$$

where:

Δl: axial enforced displacement, in mm;

l : length of FE model, in mm;

E : Young's modulus of elasticity, 2.06×10^5 N/mm^2.

b) The nominal stress $\sigma_{lateral}$, in N/mm^2, of bending load case under lateral load is calculated in accordance with the following formula:

$$\sigma_{lateral} = \frac{sl^2(1-\frac{6x_e}{l}+\frac{6x_e^{\ 2}}{l^2})}{12Z_{eff-n50}}10^3$$

where:

s : spacing of longitudinals, in m;

l : full length, in m, see definition of l in Symbols of Section 7, Chapter 3;

$Z_{eff\text{-}n50}$:section modulus, in cm^3,deducting corrosion addition of $0.5t_c$ and considering attached plating;

x_e :distance, in m, from the hot spot to the closest end of full length l.

Section 5 FINITE ELEMENT STRESS ANALYSIS

1 GENERAL

1.1 Applicability

1.1.1

This section applies to fatigue assessment by finite element stress analysis. The methods are based on the hot spot stress approach and requirements are given for both welded and non-welded hot spots. The hot spot stress takes into account structural discontinuities due to the structural detail of the welded joint, but not taking into account the notch effect at the weld toe.

1.1.2

The hot spot stress is generally highly dependent on the finite element model used for representation of the structure and the procedure used to calculate the hot spot stress. No other methods than those described in this Section is to be adopted for calculation of FE based hot spot stress.

1.1.3

Two types of hot spots, denoted '*a*' and '*b*' are described in Table 1. These are defined according to their location on the plate and their orientation to the weld toe as illustrated in Figure 1.

Types of hot spots **Table 1**

Type	Description
a	Hot spot at the weld toe on plate surface
b	Hot spot at the weld toe around the plate edge

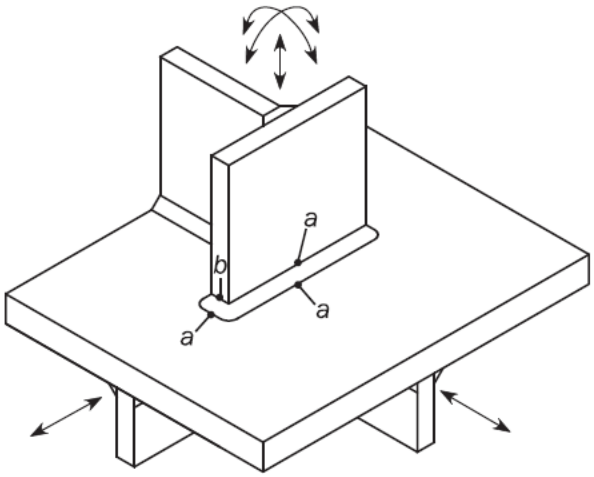


Figure 1 Types of hot spots

1.1.4

The method for calculation of hot spot stress at weld toe for any welded details is given in [3.1] except for web- stiffened cruciform joints. The method for calculation of local stress for non-welded area is given in [3.2].

1.1.5

The method for calculation of hot spot stress at web-stiffened cruciform joints such as hopper knuckle connection, transverse bulkhead lower stool to inner bottom connection and horizontal stringer heel is given in [4].

1.1.6

Attention is to be given to limitations of the hot spot stress methodology for simple connections given in [5].

2 FE MODELLING

2.1 General

2.1.1

Evaluation of hot spot stresses for fatigue assessment requires the use of very fine finite element meshes in way of areas of high stress concentration. These very fine mesh zones may be incorporated into the global model as shown in Figure 2. The coarse mesh model of the cargo holds is to be made according to Ch 7, Sec 2, [2.4]. Alternatively, this very fine mesh analysis can be carried out by means of separate local finite element models with very fine mesh zones in conjunction with the boundary conditions obtained from a global model of the cargo holds. Typical local finite element models of a hopper knuckle with very fine mesh are shown in Figure 3, Figure 4, and Figure 5.

2.1.2 Corrosion model

The very fine mesh finite element models used for fatigue assessment are to be made using net thickness, t_{n50}, in accordance with Ch 9, Sec 1, [5.1].

2.1.3 Separate local FE model

Where a separate local finite element model is used, the extent of the local model is to be such that the calculated stresses are not significantly affected by the imposed boundary conditions and application of loads. The boundary of the fine mesh model is to be taken at adjacent primary supporting members such as girders, stringers and floors in the cargo hold model as far as practicable. Transverse web frames, stringer plates and girders at the boundaries of the local model need not be represented in the local model.

2.1.4

The evaluation of hot spot stress for '*a*' type hot spot is to be based on shell element of mesh size t_{n50}, $\times t_{n50}$, where t_{n50}, is the net thickness of the plate in way of the considered hot spot. The evaluation of hot spot stress for a '*b*' type hot spot is to be based on shell element of mesh size 10×10 mm. The aforementioned mesh size is to be maintained within the very fine mesh zone, extending over at least 10 elements in all directions from the fatigue hot spot position. The transition of element size between the coarser mesh and the very fine mesh zone is to be done gradually and an acceptable mesh quality is to be maintained. This transition mesh is to be such that a uniform mesh with regular shape gradually transitions from smaller elements to larger ones. An example of the mesh transition in way of the side frame bracket toe is shown in Figure 6.

2.1.5

Four-node shell elements with adequate bending and membrane properties are to be used inside the very fine mesh zone. The four node element is to have a complete linear field of in-plane stresses and hence pure in- plane bending of the element can be exactly represented. In case of steep stress gradients, 8 node thin shell elements are to be used if deemed practical. The shell elements are to represent the mid plane of the plating. For practical purposes, adjoining plates of different thickness may be assumed to be median line aligned, i.e. no staggering in way of thickness change is required. The geometry of the weld and construction misalignment is not required to be modelled.

2.1.6

All structure in close proximity to the very fine mesh zones is to be modelled explicitly with shell elements. Triangular elements are to be avoided where possible. Use of extreme aspect ratio (e.g. aspect ratio greater than 3) and distorted elements (e.g. element's corner angle less than 60 deg or greater than 120 deg) are to be avoided.

2.1.7

Where stresses are to be evaluated on a free edge, such as cut-outs for stiffener connections at web frames, edge of plating and hatch corners, beam elements having the same depth as the adjoining plate thickness and negligible width is to be used to obtain the required local edge stress values.

2.2 Hopper knuckle welded connection

2.2.1
In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of bilge hopper lower-knuckle and upper-knuckle welded connections.

2.2.2
Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover two web frame spaces (i.e. one web frame space extending either side of the transverse web frame of interest). Transverse web frames at the end of the local model need not be represented in the local model.
b) Vertically, the model is to extend from the baseline to the lower stringer in the double side water ballast tank for tankers and double skin bulk carriers. For single skin bulk carriers, the model is to extend from the baseline to the top of the hopper ballast tank. Where a fatigue assessment is also carried out for the upper knuckle connection, the model is to be extended to four longitudinal spaces above the lower stringer in the double side ballast tank.
c) Transversely, for the hopper lower knuckle, the model is to extend from the ship side to 4 longitudinal spaces inboard of the double bottom side girder. For the upper hopper knuckle, the model is to extend from the ship side to the double bottom side girder.

2.2.3
Any scarfing brackets on the web frame adjoining the inner bottom plating, the first longitudinal stiffeners away from the knuckle hot spot as well as any carlings and brackets offset from the main frames are to be modelled explicitly using shell elements. Longitudinal stiffeners further away from the knuckle may be modelled by beam elements. The inner bottom plate 'overhang' outboard of the girder is to be modelled using shell elements up to the extent of the scarfing bracket. Away from the scarfing bracket in longitudinal direction, the inner bottom plate 'overhang' may be modelled using line elements of equivalent the area. Any perforations, such as cut-outs for cabling, pipes and access that are within one stiffener space from the knuckle point are to be modelled explicitly.

2.2.4
Figure 3, Figure 4 and Figure 5 show typical local finite element models of the hopper knuckle connection and close-up views of the $t_{n50} \times t_{n50}$ mesh zone.

2.3 Horizontal stringer heel connection
2.3.1
In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of horizontal stringer heel connections.

2.3.2
Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover one web frame space away from the stringer heel to at least one web frame space ahead of the stringer toe. Transverse web frames at the end of the local model need not be represented in the local model.
b) Vertically, the model is to extend at least to the next stringer level above and below the concerned stringer heel location.
c) Transversely, the model is to extend from the ship side to a half of the tank width in case of a stringer heel located at the inner hull longitudinal bulkhead. In case of stringer heel located at other longitudinal bulkheads the model is to extend transversely up to half the tank width on either side of the concerned stringer heel.

2.3.3
Shell elements are to be used for modelling the stringer heel connection and adjacent stiffeners. The first longitudinal and vertical stiffeners away from the heel hot spot are to be modelled explicitly using shell elements. Longitudinal and vertical stiffeners further away from the hot spot

may be modelled by beam elements. Figure 7 shows a typical finite element model of the stringer heel connection with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.4 Lower stool – inner bottom connection

2.4.1

In addition to [2.1], the modelling requirements in this sub-article are applicable to the assessment of the connection between lower stool plate and inner bottom plate.

2.4.2

The minimum extent of the local model is as follows:

a) Vertically, from the bottom shell to a level at least 2 m above the inner bottom or up to the connection of the corrugation to the upper shelf plate of the lower stool, whichever is greater.

b) The local model is to be extended transversely to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. to the adjacent double bottom girder). The end diaphragms need not be modelled.

c) Longitudinally, the model is to cover one floor space aft of the aft lower stool – inner bottom connection and one floor space forward of the forward lower stool – inner bottom connection.

2.4.3

Diaphragm webs, brackets inside the lower stool and stiffeners on the stool plates are to be modelled at their actual positions within the extent of the local model. Shell elements are to be used for modelling of diaphragms and brackets. The first vertical or horizontal stiffeners on the lower stool plate and the first longitudinal stiffeners on the inner bottom are to be represented by shell elements, other stiffeners may be represented by beam elements. Figure 8 shows a typical finite element model of the lower stool - inner bottom connection with very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.5 Lower stool – corrugated bulkhead connection

2.5.1

In addition to [2.1], the modelling requirements in this sub-article are applicable to the assessment of the connection between lower stool plate and corrugated bulkhead.

2.5.2

The minimum extent of the local model is as follows:

a) Vertically, from the bottom of the lower stool to a level at least 2 m above the upper shelf plate of the lower stool.

b) The local model is to be extended transversely to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. to the adjacent double bottom girder). The end diaphragms need not be modelled.

c) Longitudinally, the model is to cover one floor space aft of the aft lower stool – inner bottom connection and one floor space forward of the forward lower stool – inner bottom connection.

2.5.3

Diaphragm webs, brackets inside the lower stool and stiffeners on the stool plates are to be modelled at their actual positions within the extent of the local model. Shell elements are to be used for modelling of diaphragms, and bracket. The first vertical or horizontal stiffeners on the lower stool plate are to be represented by shell elements, other stiffeners may be represented by beam elements. Figure 9 shows a typical finite element model of the lower stool - corrugated bulkhead connection with very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.6 Side frame bracket to hopper sloping plate connections

2.6.1

In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of a side frame to hopper sloping plate bracket connections.

2.6.2
Shell elements are to be used for modelling the side frame bracket, hopper tank sloping plate and adjacent stiffeners. Figure 10 shows a typical finite element model of the side frame bracket to hopper sloping plate connection with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.6.3
Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover two web frame spaces (i.e. one web frame space extending either side of the bracket connection of interest). Transverse web frames at the end of the local model need not be represented in the local model.
b) Vertically, the model is to extend from the baseline to the bottom of the topside tank sloping plate.
c) Transversely, the model is to extend from the ship side to the adjacent double bottom side girder.

2.7 Side frame bracket to the upper sloping / flat bottom wing tank connections
2.7.1
In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of a side frame bracket to upper sloping/flat bottom wing tank connections.

2.7.2
Shell elements are to be used for modelling the side frame bracket, upper sloping or flat bottom plate and adjacent stiffeners. Figure 11 shows a typical finite element model of the side frame bracket to upper sloping wing tank with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.7.3
Where a separate local finite element model is used, the minimum extent of the local model is to be according to the following:

a) Longitudinally, the model is to cover two web frame spaces (i.e. one web frame space extending either side of the bracket connection of interest). Transverse web frames at the end of the local model need not be represented in the local model.
b) Vertically, the model is to extend from the deck level to the top of the hopper sloping plate.
c) Transversely, the model is to extend from the ship side to the end of upper sloping/flat bottom wing tank.

2.8 Hatch corners and hatch coaming end bracket
2.8.1
In addition to the general requirements in [2.1], the modelling requirements in this sub-article are applicable to the modelling of hatch corners/hatch coaming end bracket. The selection of hatch corners / hatch coaming end bracket for fatigue analysis is to be determined based on the level of stresses obtained from the cargo hold FE analysis.

2.8.2
Where separate local finite element models are used, the model extents are to be according to the following:

a) Transversely, over the half-breadth of the ship,
b) Longitudinally, from the midpoint of the cargo hold in which the concerned hatch corners/hatch coaming end bracket is located to the adjacent cargo hold up to and including the full width of the cross deck nearest to the concerned hatch corners/hatch coaming end bracket.
c) Vertically, from the top plate of coaming to the intersection of the topside tank sloping plate with the side or inner side shell.

2.8.3
The primary supporting members and coaming stays are to be represented by shell finite elements having both membrane and bending properties. Figure 12 shows a typical FE model of the toe connection of a longitudinal hatch coaming end bracket to the deck plating with the very fine mesh zone having $t_{n50} \times t_{n50}$ mesh size.

2.8.4
The level of FE mesh refinement is to be such as to enable stress concentrations arising from the hatch corner geometry to be captured in the hot spot stress. The plate edge of hatch opening corners at the level of upper deck and cross deck structure is to be assessed. The free edge of hatch coaming end bracket and bracket toe welded connection to the deck plating are also to be assessed. Beam elements having the same depth as the adjoining plate thickness and negligible width are to be used at a plate edge of hatch opening corners or free edge of the hatch coaming end bracket to obtain the required local edge stress values as outlined in [2.1.7].

2.8.5
The local structural geometry, particularly in the areas of concern, is to be represented. The hatch corner area is to be meshed using elements with a sufficiently small size to capture the local stress on the edge. In general, a minimum of 15 elements in a 90 degree arc are to be used to describe the curvature of the hatchway radius plating for a rounded corner (see Figure 13). For an elliptical or parabolic corner, a minimum of 15 elements are to be used from the inboard radius end to a point on the edge located at half the longitudinal distance of the semi- major axis. A total of 20 elements are to be used at the elliptical edge of the hatch corner (see Figure 14). However, the element edge dimensions along the free edge of the radius need not be less than the thickness of the plating being represented and also should not be greater than 5 times the thickness of the plating being represented. Except where necessary from practical meshing considerations, this level of idealisation is to be maintained over the bracket plating and is to extend into the stringer plating, deck plating and coaming. Mesh transitions should not be arranged close to bracket toes.

2.9 Boundary conditions
2.9.1 Cargo hold model
The boundary conditions to be applied to the ends of the cargo hold model are to be in accordance with Ch 7, Sec 2, [2.5].

2.9.2 Separate local finite element model
Where a separate local finite element model is used for evaluating the hot spot stress range, the boundary conditions and application of loads are to be in accordance with Ch 7, Sec 3, [4.2].

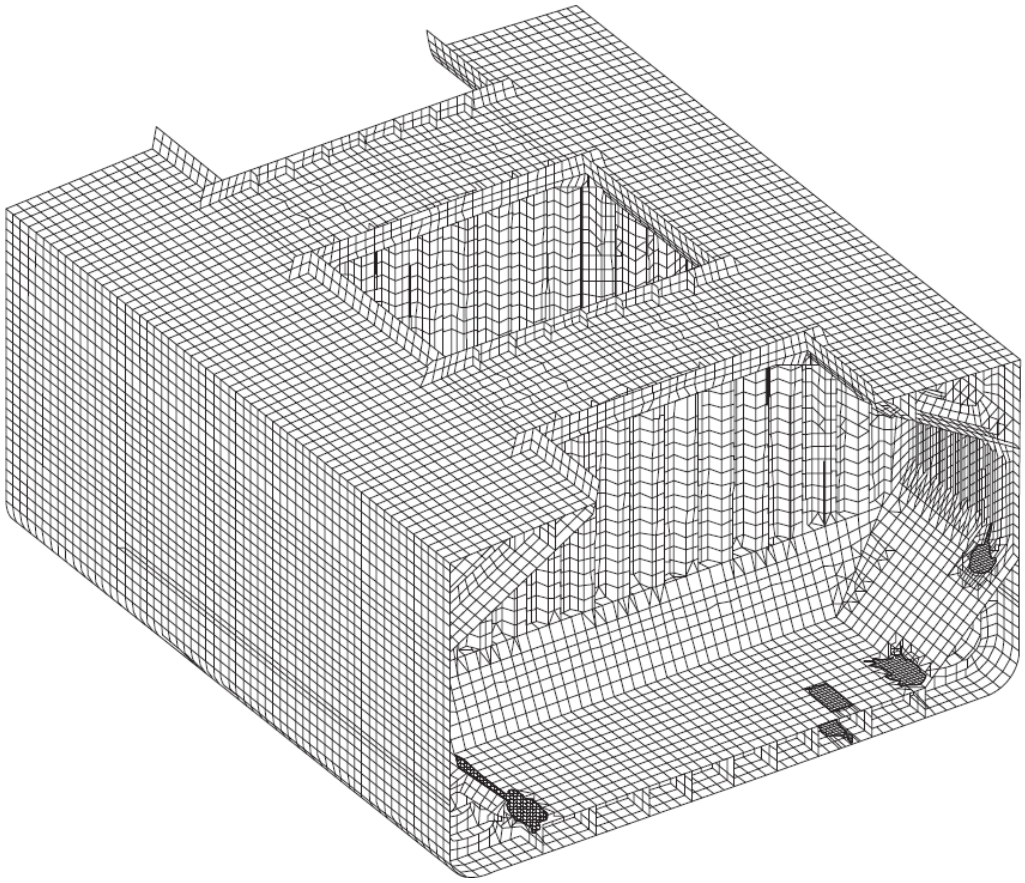


Figure 2 Very fine mesh areas incorporated

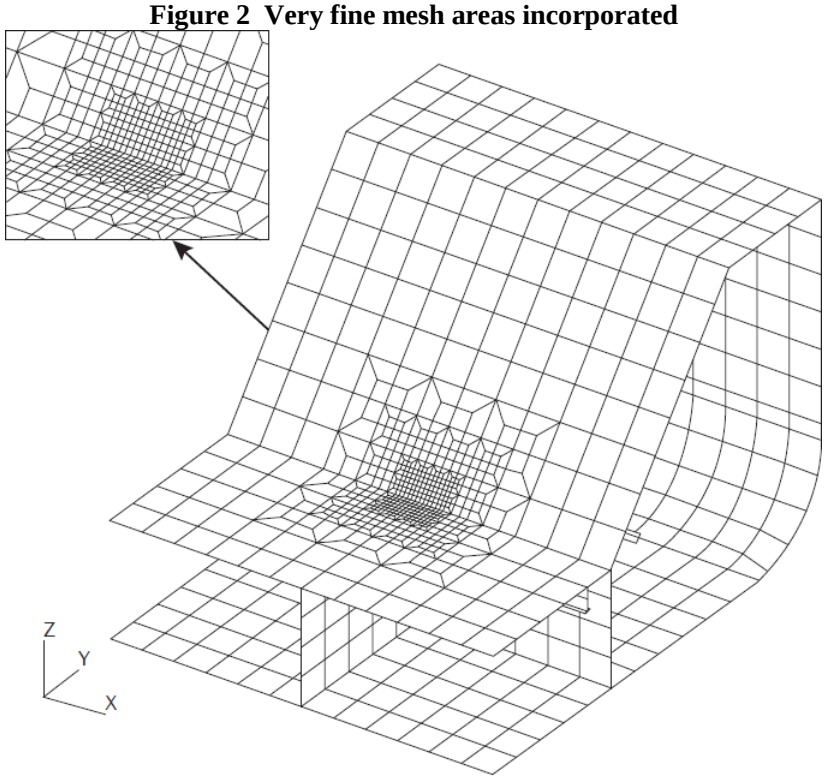


Figure 3 Local very fine mesh model ($t_{n50} \times t_{n50}$) of hopper knuckle connection between inner bottom and hopper plate

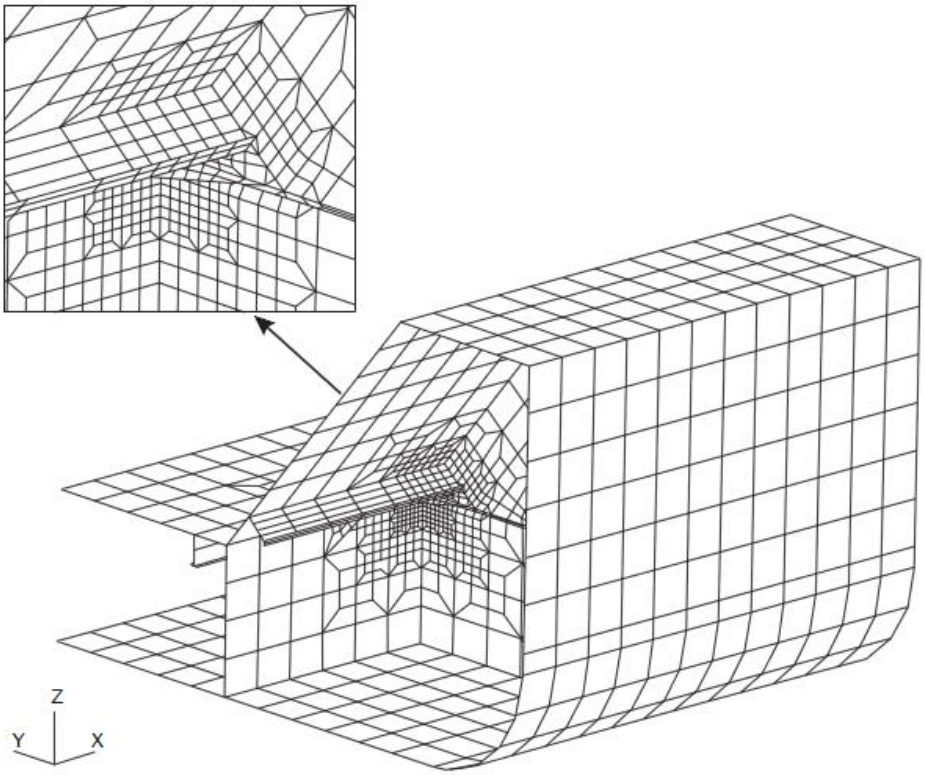


Figure 4 Local very fine mesh model ($t_{n50} \times t_{n50}$) of hopper knuckle connection between inner bottom, hopper plate, web frame, girder and bracket

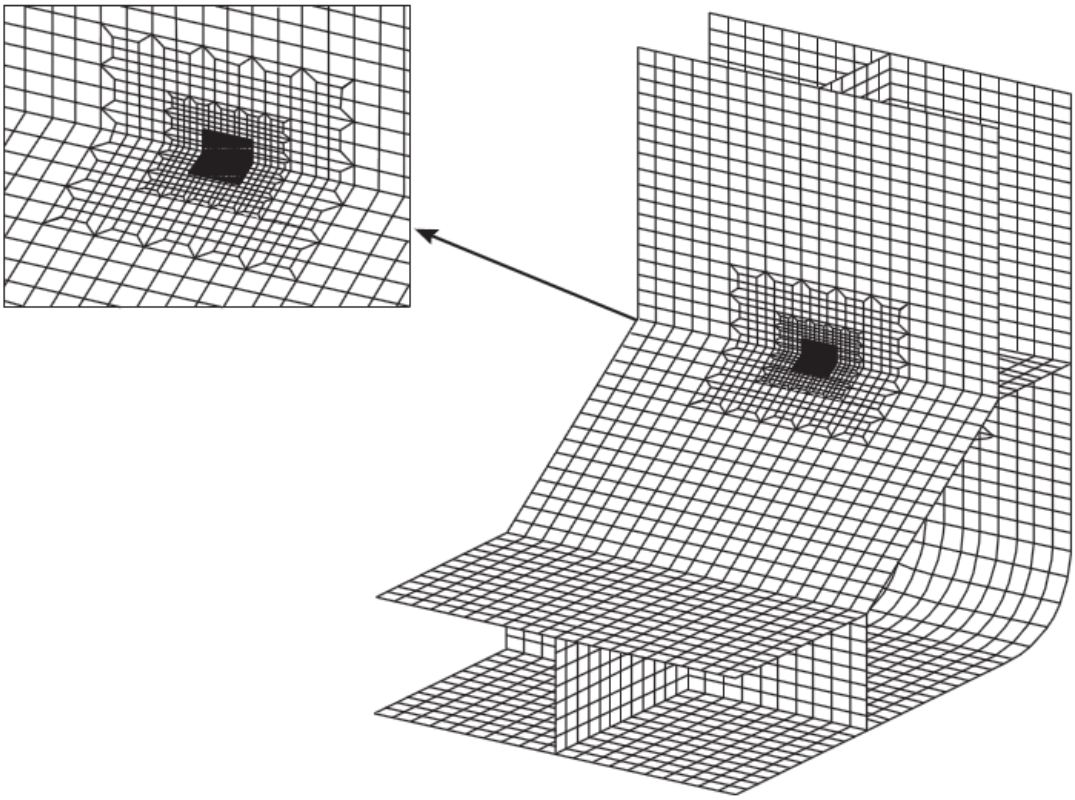


Figure 5 Local very fine mesh model ($t_{n50} \times t_{n50}$) of upper hopper knuckle connection between inner side shell and hopper plate

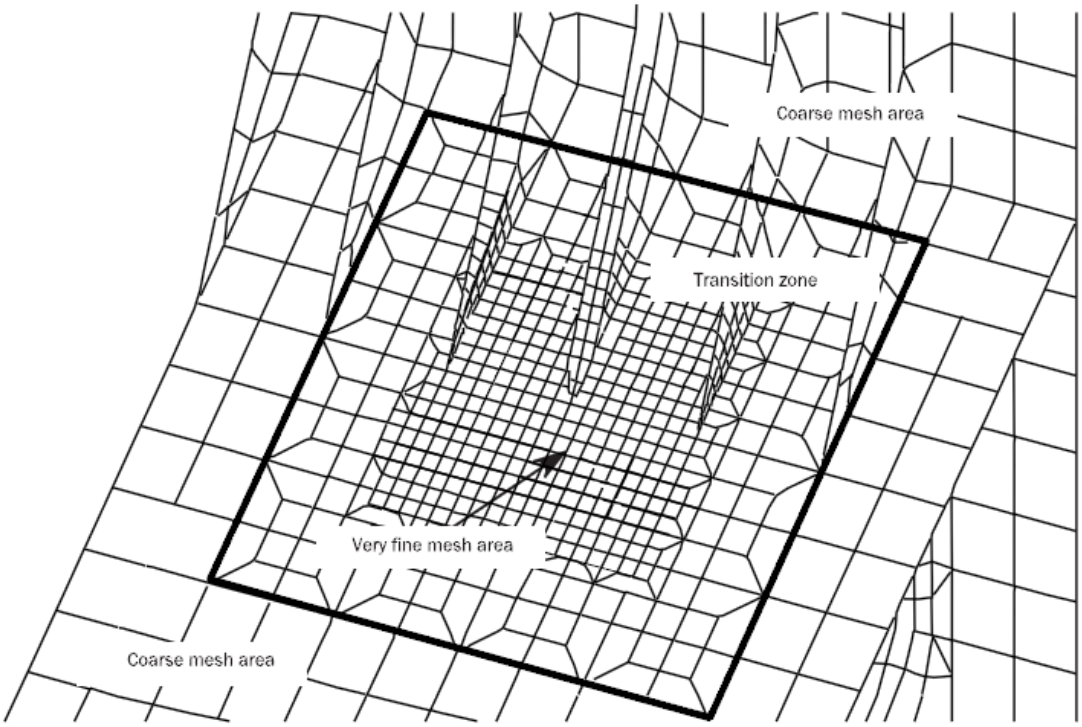


Figure 6 Transition area between coarse and very fine mesh

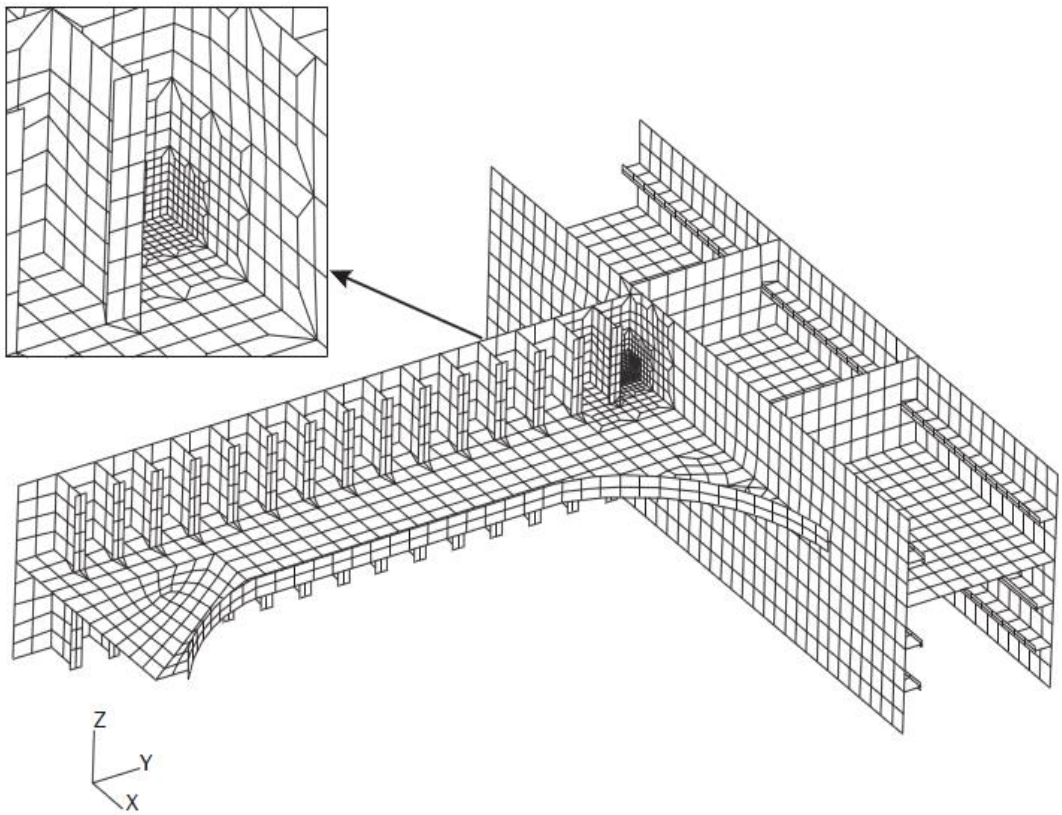


Figure 7 Finite element model of stringer heel connection

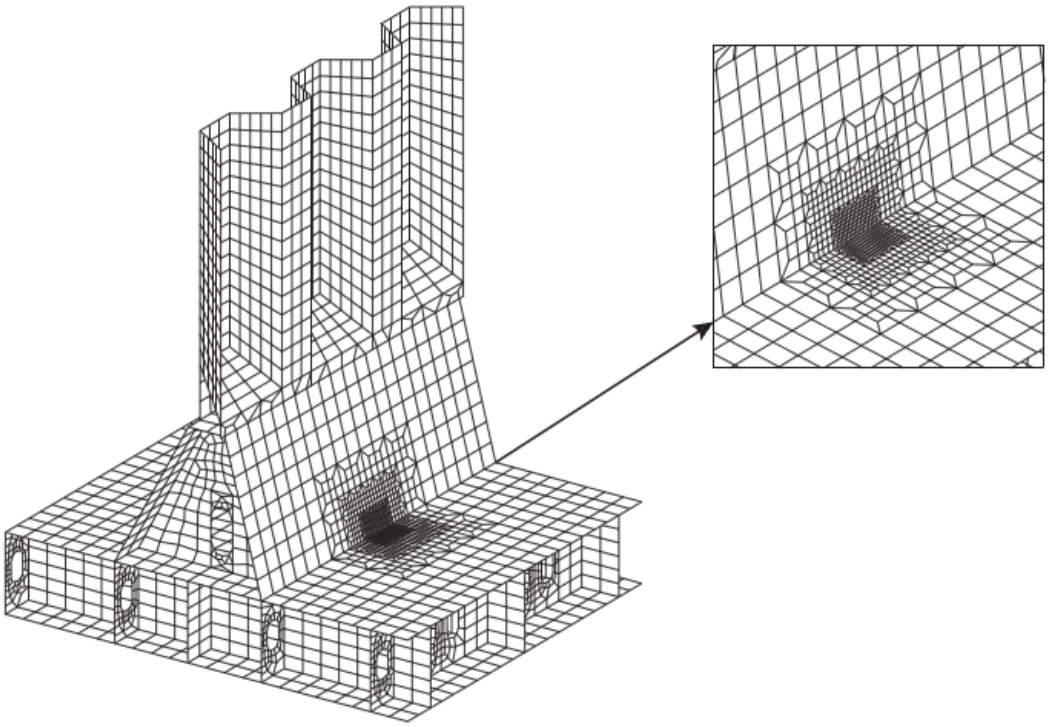


Figure 8 Local FE model of lower stool connection between inner bottom and lower stool plate, $t_{n50} \times t_{n50}$ mesh

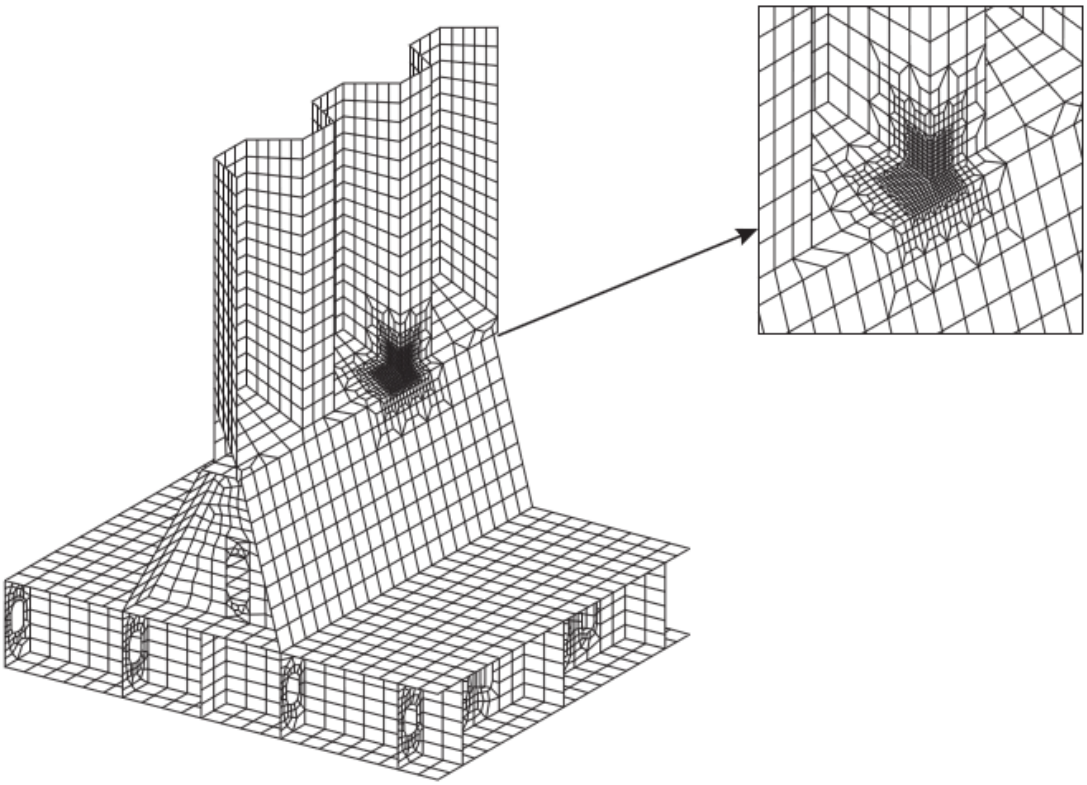


Figure 9 Local finite element model of lower stool - corrugated bulkhead connection between corrugated bulkhead and lower stool plate, $t_{n50} \times t_{n50}$ mesh

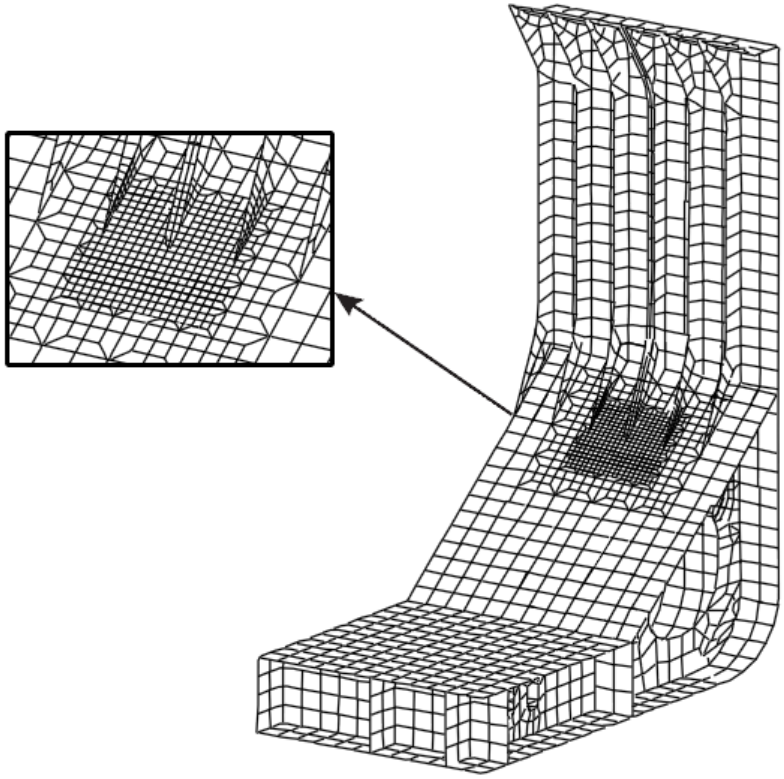


Figure 10 Local finite element model of side frame bracket, $t_{n50} \times t_{n50}$ mesh

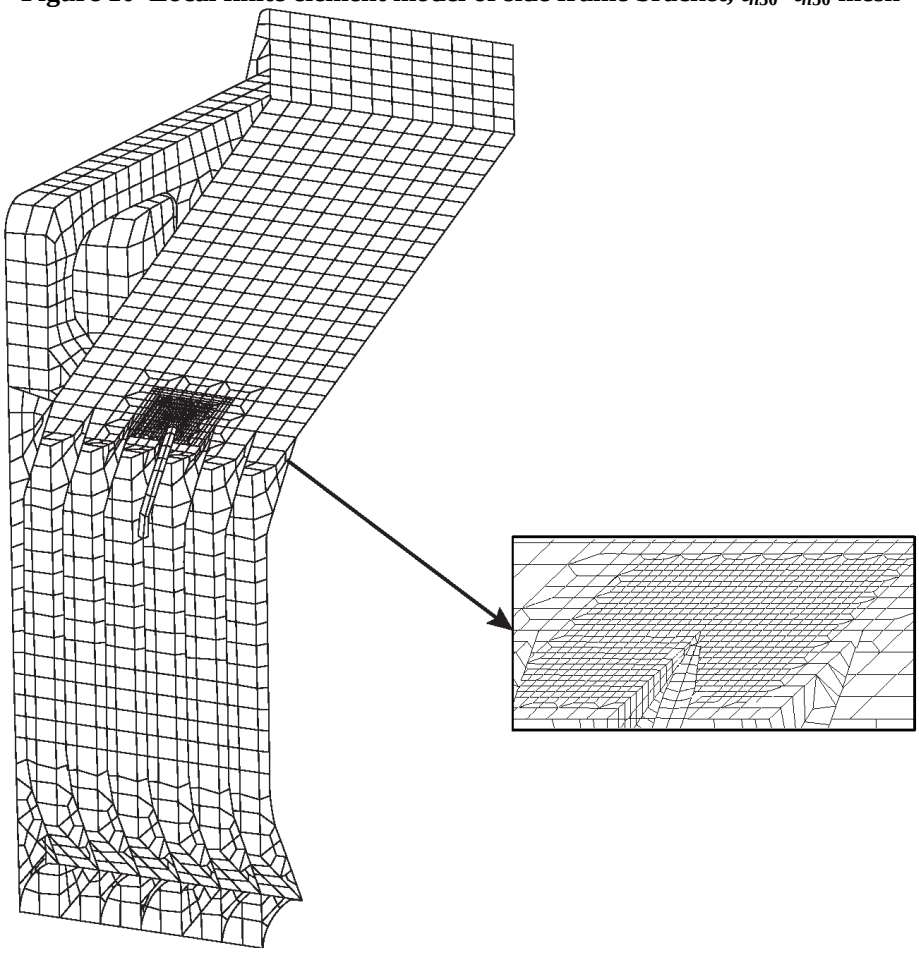


Figure 11 Local FE modelof upper side frame bracket $t_{n50} \times t_{n50}$ mesh

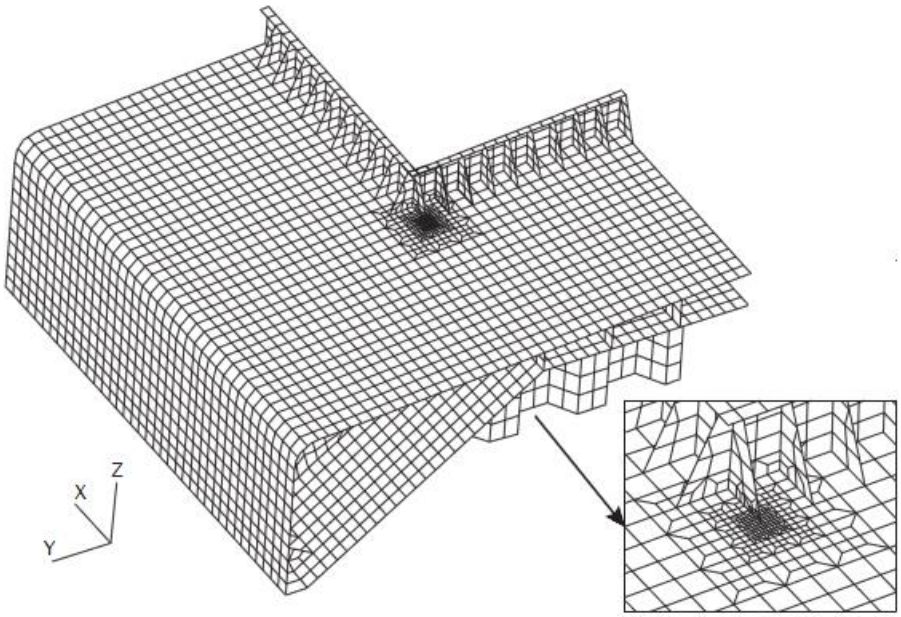


Figure 12 Local FE model of longitudinal hatch coaming end bracket to the deck plating with very fine mesh zone, $t_{n50} \times t_{n50}$ mesh

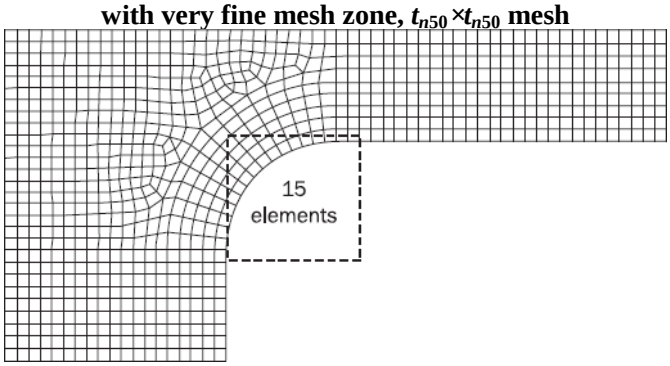


Figure 13 Mesh density for rounded hatch corner

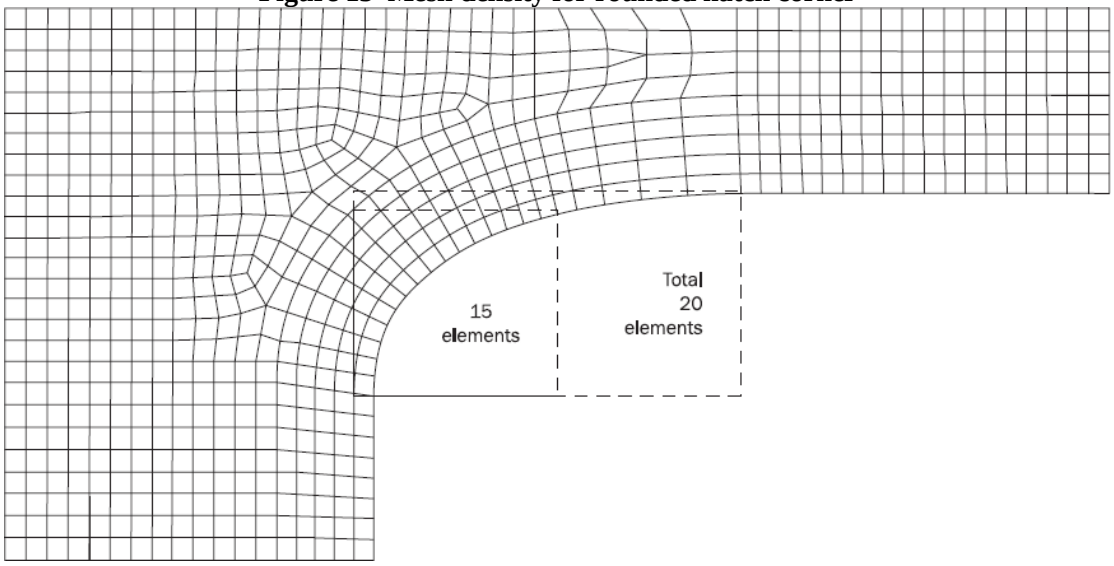


Figure 14 Mesh density for elliptical hatch corner

3 HOT SPOT STRESS FOR DETAILS DIFFERENT FROM WEB-STIFFENED CRUCIFORM JOINTS

3.1 Welded details

3.1.1

For hot spot type '*a*', the structural hot spot stress, σ_{HS} is calculated from a finite element analysis

with t_{n50} ×t_{n50} mesh density and is obtained by the following formula:
σ_{HS} = 1.12 σ
where:
σ : Surface principal stress, in N/mm^2, read out at a distance t_{n50}/2 away from the intersection line.
t_{n50} *:* Plate net thickness, in mm, in way of the weld toe.
At structural details where the hot spot type '*a*' is classified as a web-stiffened cruciform joint, the stress read out procedure of [4.2] is to be applied.
For hot spot type '*b*', the stress distribution is not dependent on the plate thickness; the structural hot spot stress, σ_{HS}, is derived from a finite element analysis with mesh density 10×10 mm and is obtained by the following formula:
σ_{HS} = 1.12 σ
where:
σ : Surface principal stress, in N/mm^2, read out at an absolute distance from the intersection line of 5 mm.

3.1.2 Stress read out methods

Depending on the element type, one of the following stress read out method is to be used:

- With 4-node shell element:
  Element surface stress components at the centre points are linearly extrapolated to the line A-A as shown in Figure 15 to determine the stress components for load case '*i*1' and '*i*2' at the stress read out point located at a distance t_{n50} from the intersection line for type 'a' hot spot. Two principal hot spot stress ranges are determined at the stress read out point from the stress components tensor differences (between load case '*i*1' and '*i*2') calculated from each side (side L, side R) of line A-A. The angle θ between the direction x of the element co-ordinate system and the principal direction *pX* of the principal hot spot stress range co-ordinate system has to be determined.
- With 8-node shell element:
  With a t_{n50} × t_{n50} element mesh using 8-node element type, the element mid-side node is located on the line A-A at a distance *tn50* for type '*a*' hot spots. This node coincides with the stress read out point. The element surface stress components for load case '*i*1' and '*i*2' can be used directly without extrapolation within each adjacent element located on each side (side L, side R) of the line A-A as illustrated in Figure. 16. Two principal hot spot stress ranges are determined at the stress read out point from the stress components tensor difference (between load case '*i*1' and '*i*2') calculated from each side of line A-A. The angle θ between the direction x of the element coordinate system and the principal direction *pX* of the principal hot spot stress range coordinate system has to be determined.

For fatigue assessment of type '*b*' hot spots, a beam element is to be used to obtain the fatigue stress range. The stress range is to be based on axial and bending stress in the beam element. The beam element is to have the same depth as the connecting plate thickness while the in-plane width is negligible.

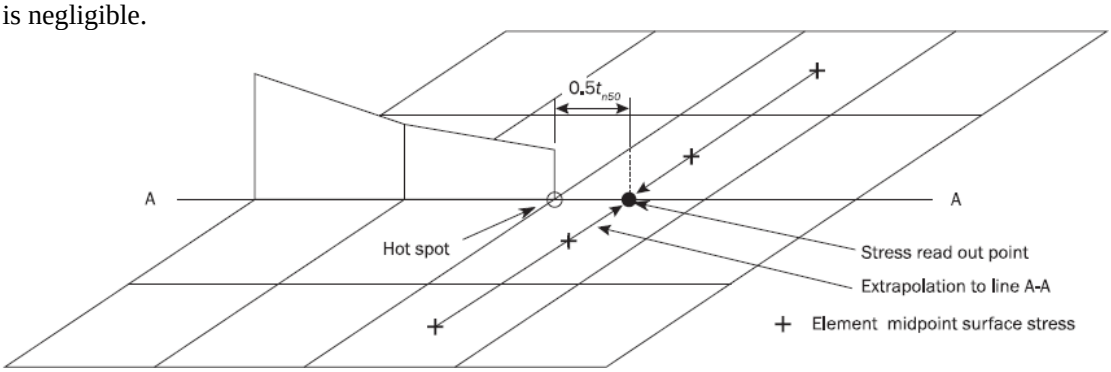


Figure 15 Determination of stress read out points and hot spot stress for 4-node element

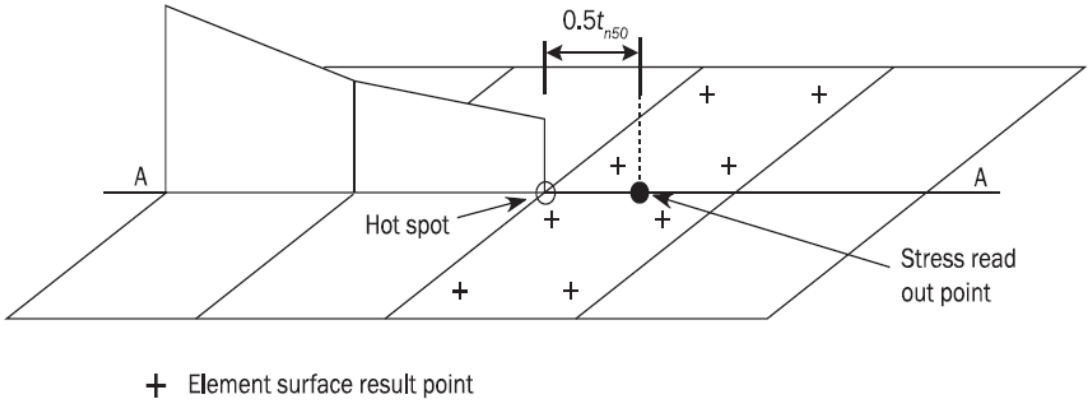


Figure 16 Determination of stress read out points and hot spot stress for 8-node element

3.1.3
The above read out procedure is based on element surface stresses. Generally, in FE software the element stresses are calculated at the Gaussian integration points located inside the element. Depending on the element type implemented in the FE software, it may be necessary to perform several interpolations in order to determine the actual stress at the considered stress read out point at the surface of the element mid-point or element edge.

3.2 Base material
3.2.1
For fatigue assessment at a free plate edge, a beam element is to be used to obtain the fatigue stress range. The beam element is to have the same depth as the connecting plate thickness while the in-plane width should be negligible.

3.3 Bent hopper knuckle
3.3.1
The hot spot stress at the inner bottom/hopper sloping plate and inner hull/hopper sloping plate in transverse, vertical and longitudinal directions (i.e. hot spots 1, 2 and 3 defined in Ch 9, Sec 2, Table 5 and Ch 9, Sec 2, Table 19) of a bent hopper knuckle is to be taken as the surface principal stress read out from a point shifted away from the intersection line between the considered member and abutting member by the weld leg length.
The hot spot stress, in N/mm^2, is obtained by the following formula:
$\sigma_{HS} = \sigma_{shift}$
where:
σ_{shift} : Surface principal stress, in N/mm^2, at the shifted read out position as defined in [4.2.1] and taken as:
$\sigma_{shift} = \sigma_{membrane}\,(x_{shift}) + \sigma_{bending}(x_{shift})$
$\sigma_{bending}\,(x_{shift})$: Bending stress, in N/mm^2, at x_{shift} position.
$\sigma_{membrane}(x_{shift})$: Membrane stress at x_{shift} position, in N/mm^2.

3.3.2
The procedure for calculation of hot spot stress at flange such as inner bottom /hopper sloping plate and inner hull/hopper sloping plate is the same that for web-stiffened cruciform joints as described in [4.2.1]. The procedure that applies for hot spots on the ballast tank side of the inner bottom/hopper plate and inner hull/hopper sloping plate in way of a bent hopper knuckle is in principle the same as that applied on the cargo tank side of the inner bottom plate for welded knuckle in Figure 18 and Figure 19. The intersection line is taken at the mid-thickness of the joint assuming median alignment. The plate angle correction factor and the reduction of bending stress as applied for a web-stiffened cruciform joint in [4.2.2] are not to be applied for the bent hopper knuckle type.

3.3.3
The stress at hot spots located in way of the web such as transverse web, side stringer and side girder (i.e. hot spots 4, 5 and 6 defined in Ch 9, Sec 2, Table 5 and Ch 9, Sec 2, Table 19) at a bent

hopper knuckle type is to be derived as described for web-stiffened cruciform joints in [4.3.1].

4 HOT SPOT STRESS FOR WEB-STIFFENED CRUCIFORM JOINT

4.1 Applicability

4.1.1

Among the structural details to be assessed listed in Ch 9, Sec 2, Table 3 the following structural details are considered as a web-stiffened cruciform joint:

a) Welded hopper knuckle connection, shown in Figure 17.
b) Heel of horizontal stringer, shown in Figure 17.
c) Lower stool – inner bottom connection.

Two kinds of hot spots relative to the web-stiffened cruciform joints are to be assessed:

- Hot spots at the flange of web-stiffened cruciform joint,
- Hot spots in way of the web of web-stiffened cruciform joint.

4.1.2

The procedure for calculating hot spot stress at flange of web-stiffened cruciform joint is given in [4.2].

4.1.3

The procedure for calculating hot spot stress in way of the web of the web-stiffened cruciform joint is given in [4.3].

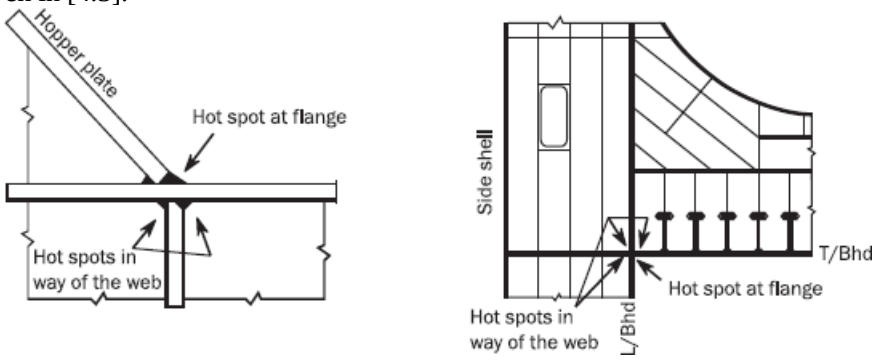


Figure 17 Web-stiffened cruciform joints

4.2 Calculation of hot spot stress at the flange

4.2.1

For hot spot at the flange of web-stiffened cruciform joints, the surface principal stress is to be read out from a point shifted away from the intersection line between the considered member and abutting member to the position of the actual weld toe and multiplied by 1.12. The intersection line is taken at the mid-thickness of the cruciform joint assuming a median alignment.

The hot spot stress, in N/mm^2, is to be obtained as:

$\sigma_{HS} = 1.12\sigma_{shift}$

where:

σ_{shift}: Surface principal stress, in N/mm^2, at shifted stress read out position. The stress read out point shifted away from the intersection line is obtained as:

$$x_{shift} = \frac{t_{1-n50}}{2} + x_{wt}$$

where:

$t_{1\text{-}n50}$: Net plate thickness of the plate number 1, in mm, as shown in Figure 18.

x_{wt} : Extended fillet weld leg length, in mm, as defined in Figure 18, not taken larger than $t_{1\text{-}n50}$.

4.2.2

The stress at the shifted position is derived according to the following formula and illustrated in Figure 19:

$$\sigma_{shift} = \left[\sigma_{membrane}(x_{shift}) + 0.6 \cdot \sigma_{membrane}(x_{shift})\right] \cdot \beta$$

where:

$\sigma_{bending}(x_{shift})$: Bending stress, in N/mm^2, at the shifted position taken as:

$\sigma_{bending}(x_{shift}) = \sigma_{surface}(x_{shift}) - \sigma_{membrane}(x_{shift})$

$\sigma_{surface}(x_{shift})$: Total surface stress at x_{shift} position (including membrane stress and bending stress), in N/mm^2.

$\sigma_{membrane}(x_{shift})$: Membrane stress at x_{shift} position, in N/mm^2.

β : Plate angle hot spot stress correction factor, taken as:

- For α = 135°:

$$\beta = 0.96 - 0.13\frac{x_{wt}}{t_1} + 0.20(\frac{x_{wt}}{t_1})^2$$

- For α= 120°:

$$\beta = 0.97 - 0.14\frac{x_{wt}}{t_1} + 0.32(\frac{x_{wt}}{t_1})^2$$

- For α= 90°:

$$\beta = 0.96 + 0.031\frac{x_{wt}}{t_{1-n50}} + 0.24(\frac{x_{wt}}{t_{1-n50}})^2$$

α : Angle, in deg, between the plates forming a web-stiffened cruciform joint as shown in Figure 19.

Correction factors for connections with plate angles intermediate to those given should be derived based on a linear interpolation of the above values. The calculated hot spot stress is to be used in conjunction with the hot spot S-N curve for weld toe connections according to Ch 9, Sec 3, [4.2].

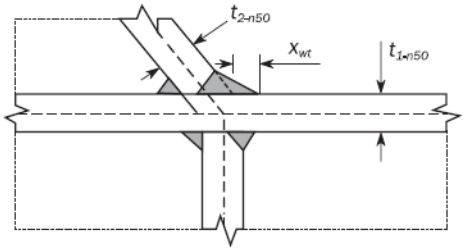


Figure 18 Geometrical parameters of web-stiffened cruciform connections

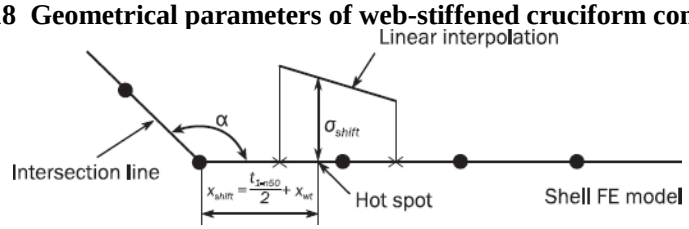


Figure 19 Procedure for calculation of hot spot stress at web-stiffened cruciform connections

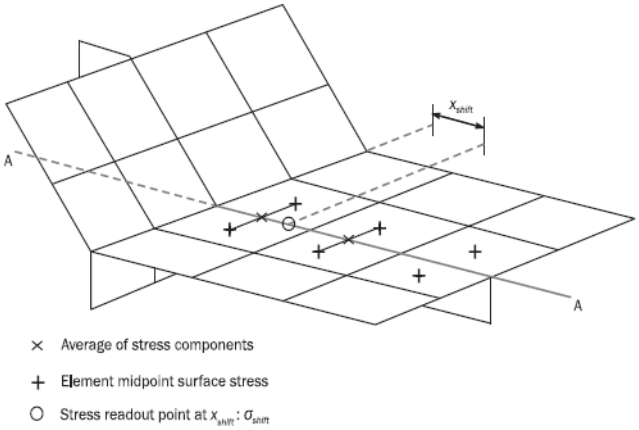


Figure 20 Determination of stress read out points for web-stiffened cruciform connections

4.2.3

Surface principal stresses at the centre point of the two first elements on left and right side of the line A-A are averaged and taken as the surface principal stresses in way of the web position (line A-A). The surface principal stresses for load case '*i1*' and '*i2*' are linearly interpolated along the

line A-A in order to determine hot spot principal stresses at the stress read out point located at the x_{shift} position as shown in Figure 20. The two principal hot spot stress ranges are determined at the stress read out point between load case '*i1*' and '*i2*'.

4.3 Calculation of hot spot stress in the web

4.3.1

Hot spots located in way of the web as indicated in Figure 21 are to be checked with the hot spot stress defined from the maximum principal surface stress at the intersection offset by the distance x_{shift} from the vertical and horizontal element intersection lines as illustrated in Figure 21. The intersection line is taken at the mid thickness of the cruciform joint assuming a median alignment. The hot spot stress, in N/mm^2, is to be obtained as:

$\sigma_{HS} = \sigma_{shift}$

where:

σ_{shift} : Maximum principal surface stress, in N/mm^2, at the intersection offset by the distance x_{shift}.

The stress read out point at the intersection offset is obtained as:

$$x_{shift} = \frac{t_{3-n50}}{2} + x_{wt}$$

where:

$t_{3\text{-}n50}$: Net plate thickness of the web, in mm, as shown in Figure 21

x_{wt} : Extended fillet weld leg length, in mm, , taken as:

$x_{wt} = \min(l_{leg1}, l_{leg2})$

l_{leg1},l_{leg2} : Leg length, in mm, of the vertical and horizontal weld lines as shown in Figure 21.

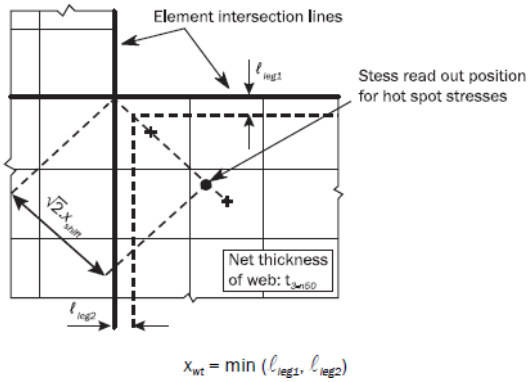


Figure 21 Hot spots in way of web

5 LIMITATIONS OF HOT SPOT STRESS APPROACH

5.1 Scope of application of hot spot stress approach

5.1.1

The hot spot stress approach given in Ch 9, Sec 1, [2.3.1] is not applicable for simple cruciform joints and simple T-joints when the stress flow in direction I as shown in Figure 22 is considered. For stresses in the direction normal to the weld at hot spot location "*c*" (direction I) there is no stress flow into the transverse plating as it is represented only by one plane in the shell model. However, it attracts stresses for in-plane direction (direction II) at hot spot location "*a*".

In situations where a bracket is fitted behind the transverse plate as shown in Figure 1, acting with stiffness in the direction normal to the transverse plate, stresses flow also into the transverse plate and the hot spot methodology is considered applicable.

5.1.2

The hot spot stress at position '*c*' for simple cruciform joints and simple T-joints is to be determined by the stress read out procedure given in [3.1] multiplied by a geometrical stress concentration factor of 1.3 and is taken as:

$\sigma_{HS} = 1.3 \cdot 1.12\sigma$

6 SCREENING FATIGUE ASSESSMENT

6.1 Screening procedure

6.1.1 Assumptions

The screening fatigue procedure is based on:

- Screening hot spot stress obtained by multiplying the stresses calculated from fine mesh analysis according to Ch 7, Sec 3 by the stress magnification factor of the considered structural detail.
- Mean stress effect and thickness effect are used according to Ch 9, Sec 3, [3.2] and Ch 9, Sec 3, [3.3].

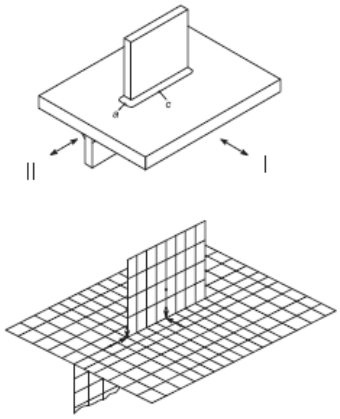


Figure 22 Illustration of check points in way of a welded attachment under orthogonal applied in plane loads

6.1.2 Procedure

The screening fatigue procedure includes the following three phases:

a) Phase 1: Calculation of fatigue stress.
   - Stresses are calculated at the stress read out point from the fine mesh element analysis with elements size of 50 × 50 mm, according to Ch 7, Sec 3 for all fatigue load cases defined in Ch 9, Sec 1, [7], for all loading conditions. Stresses to be used are element average membrane components stress defined in [6.2.3].
   - Hot- spot surface stress components are calculated for each load case '*i*1' and '*i*2' from the stresses multiplied by the stress magnification factor η, taken as:
     - $\sigma_{HS,\, i1(j)} = \eta \sigma_{S,\, i1(j)}$
     - $\sigma_{HS,\, i2(j)} = \eta \sigma_{S,\, i2(j)}$
   - Hot spot principal surface stress ranges are the difference of hot spot stress components obtained for each load case '*i1*' and '*i2*'.
   - Fatigue stress ranges for welded joints are determined from hot spot principal surface stress ranges with correction factor for mean stress and thickness effect.

   where:

   $\sigma_{S,\, i1(j)}$: Stress calculated from the fine mesh analysis in load case '*i1*' of loading condition (*j*) defined in [6.2].

   $\sigma_{S,\, i2(j)}$: Stress calculated from the fine mesh analysis in load case '*i*2' of loading condition (*j*) defined in [6.2].

   η : Stress magnification factor given in Table 2.

b) Phase 2: Selection of S-N curve.
   The S-N curve D defined in Ch 9, Sec 3, [4] is to be used with the fatigue stress range of weld toe in screening fatigue procedure.

c) Phase 3: Calculation of fatigue damage and fatigue life according to [6.1.3].

Stress magnification factor **Table 2**

Ship type	Structural detail category		Bulk hold	Stress magnification factor η
Oil tanker	Toe of stringer		-	2.45
	Bracket toe of transverse web frame		-	1.65
Bulk carrier	Lower hopper welded knuckle		FA(1)	2.28
			EA or C(1)	2.00
	Lower stool -Inner bottom	Non vertical (knuckle angle > 90°)	FA(1)	1.81
			EA or C(1)	1.47
		Vertical (knuckle angle = 90°)	FA(1)	2.09
			EA or C(1)	2.75
(1) FA and EA means "full cargo hold in alternate loading condition" and "empty cargo hold in alternate loading condition" respectively, C means cargo hold of BC-B and BC-C bulk carriers.				

6.1.3 Screening fatigue criteria

The total fatigue damage and the fatigue life of screened details are to comply with the criteria given in Ch 9, Sec 3, [2].

Structural details that do not comply with the acceptance criteria are to be checked with respect to fatigue strength using a very fine mesh finite element analysis as described in Ch 9, Sec 5.

6.2 Stress read out procedure

6.2.1 Bracket toe

For bracket toe, the stress read out point is located at a 50 mm distance away from the bracket toe as shown in Figure 23.

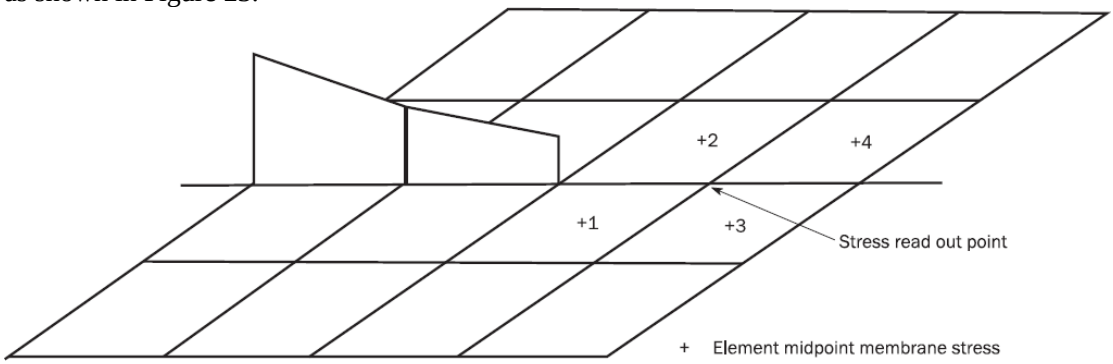


Figure 23 Stress read out point at bracket toe

6.2.2 Knuckle detail

For the lower hopper knuckle and for the connection between transverse bulkhead lower stool and inner bottom, the stress read out point is located at a 50 mm distance away from the knuckle line (i.e. model intersection line) as shown in Figure 24.

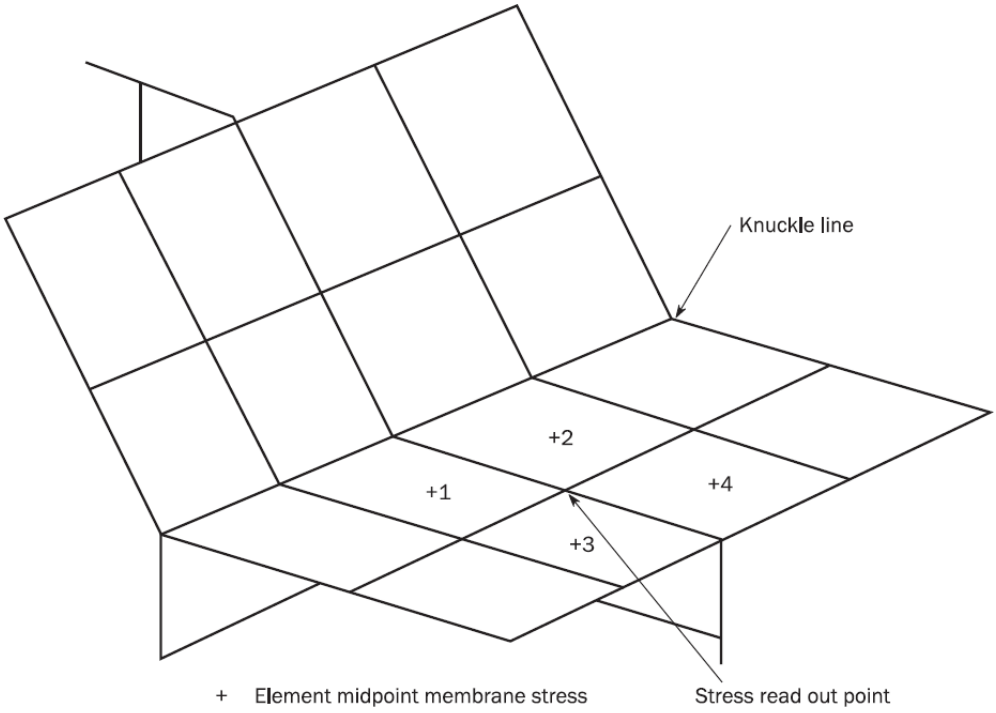


Figure 24 Stress read out point of knuckle detail

6.2.3 Read out point stress

The average of membrane stress components at the centre of four elements, modelled with elements size of 50 × 50 mm connected to the stress read out point (or node) can be used as read out point stress.

When the element size is less than 50 × 50 mm, the stress of read out point can be derived using elements in an equivalent area as shown in Figure 25.

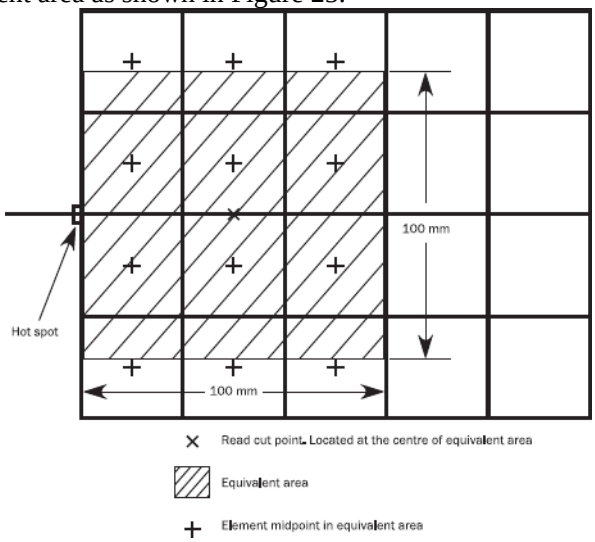


Figure 25 Equivalent area for element size less than 50 × 50 mm

Section 6 DETAIL DESIGN STANDARD

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.

1 GENERAL

1.1 Purpose

1.1.1
Design standard provides fatigue resistant detail design at an early stage in the structural design process by giving consideration to the following aspects:

- Application of fatigue design principles.
- Construction tolerances and other practical considerations.
- In-service experience and fatigue performance.

1.1.2
The design standard is to be applied to the design of ship structural details in following steps:

- Highlighting potential critical areas within the ship structure.
- Identification of the fatigue hot spot locations for each of the critical structural details.
- Provision of a set of alternative improved configurations from which a suitable solution can be selected.
- Requirements on geometrical configurations, scantlings, welding requirements and construction tolerances.
- Post fabrication method of improving fatigue life, such as weld toe grinding.

1.2 Application

1.2.1
The structural details described in this section are to be designed according to the given design standard but alternative detail design configurations may be accepted subject to demonstration of satisfactory fatigue performance.
For the details given in Ch 9, Sec 2, Table 3, the fatigue assessment by very fine mesh finite element analysis may be omitted if the detail is designed in accordance with the design standard given in this section.

2 STIFFENER-FRAME CONNECTIONS

2.1 Design standard A

2.1.1
Designs for cut outs in cases where web stiffeners are omitted or not connected to the longitudinals are required to adopt tight collar or the improved design standard "*A*" as shown in Table 1 or equivalent, for the following members:

- Side shell below $1.1T_{sc}$.
- Bottom.
- Inner hull longitudinal bulkhead below $1.1\ T_{sc}$.
- Topside tank sloping plating below $1.1\ T_{sc}$.
- Hopper.
- Inner bottom.

2.1.2
Designs that are different from those shown in Table 1 are acceptable subject to demonstration of satisfactory fatigue performance, e.g. by using comparative finite element analysis. The comparative FE analysis is to be performed following the modelling guidance given in Figure 1.

2.2 Equivalent design of stiffener-frame connections

2.2.1
If the required designs for stiffener-frame connections in [2.1] are not followed, the alternative design is to be verified to have equivalent fatigue strength to the design standard "A" or to be verified to have satisfactory fatigue performance. The alternative design is to be verified

according to the procedure given in [2.2.2] to [2.2.5] and documentation of results is to be submitted to the Society.

CCS 2.2.1a FE modeling

(1) FE model of standard design is to be established according to Table 1 of [2.1], and FE model of alternative design is also to be established according to the modeling method in [2.2.3].

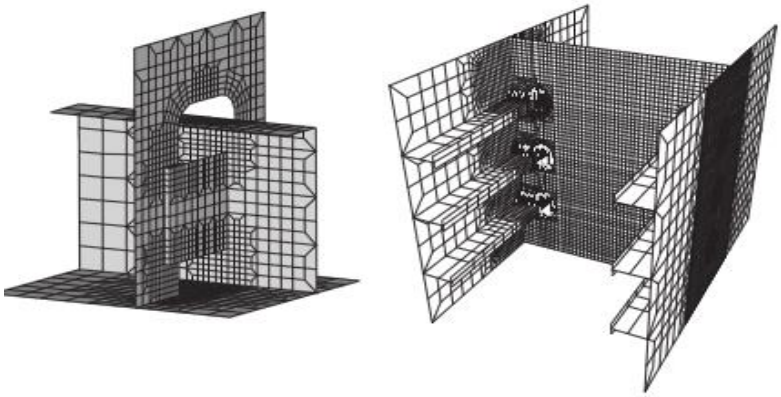


Figure 1 Finite element model for verification of equivalent design

(2) The mesh size in way of hot spot is in general to be t × t. When the hot spots are classified as hot spot type "b" as specified in 1.1.3 of Section 5 and Table 16 of Section 2, the mesh size is to be 10 ×10 mm. The mesh size is to extend at least five elements in all directions. Outside this area, the mesh size may gradually be increased in accordance with the requirements in 2 of Section 5.

(3) Simulated beam elements are to be fitted in way of the edge of cut-out and hot spot type "b". The height of the simulated beam elements is to be consistent with plate thickness of web, the width may be neglected and the area is taken as 1 mm^2.

(4) Shell elements are to be used in the overlap scope of web of transverse frame and lug plates. In order to simulate fillet welds, web of transverse frame and lug plates are to be connected by shell elements in way of the boundary of overlap scope. The height of shell element is to be the distance between mid-layers of web of transverse frame and lug plates having a thickness equal to 2 times the net thickness of web plate, see Figure 2.2.1a(4).

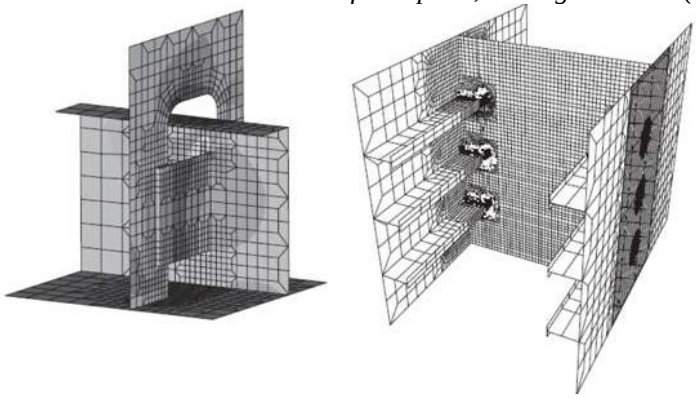


Figure 2.2.1a(1) FE Model of Equivalent Alternative Design

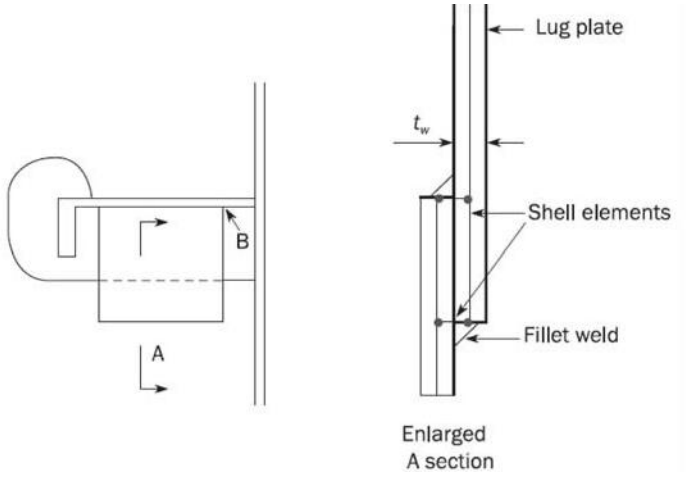


Figure 2.2.1a(4) Element Modeling of Overlap of Lug Plate and Web of Transverse Frame

CCS 2.2.1b Load case

(1) Three load cases are to be applied to the models of the standard design and alternative designs:

LC1: External pressure of unit value, fixed boundary conditions at top and bottom of model.

LC2: Shear stress by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.

LC3: Axial load by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.

(2) The forward and aft part of the model are to have symmetry condition in a double hull structure. Load application and boundary conditions are shown in Figure CCS 2.2.1b(2).

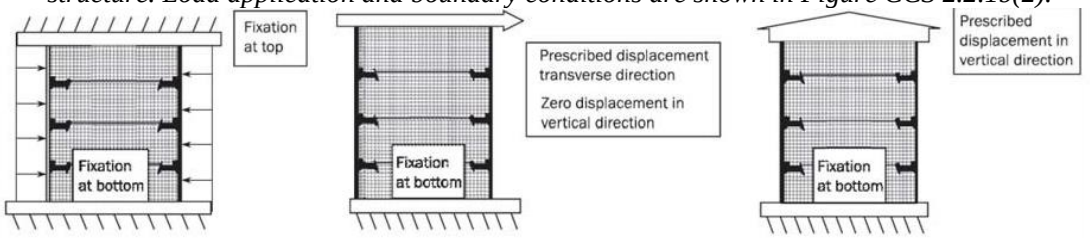


Figure CCS 2.2.1b(2) Load Application and Boundary Conditions

CCS 2.2.1c Reference stress

The stress for assessment is the maximum of the combination of axial and bending stress of simulated beam.

CCS 2.2.1d Assessment criteria of equivalent design

The reference stress (see CCS 2.2.1c) in way of critical hot spots around the cut-out of equivalent design is not greater than the corresponding value of standard design.

2.2.2

The procedure of [2.2.3] and [2.2.4] is provided to verify the alternative design to have equivalent fatigue strength with respect to any position in the transverse ring, i.e. double bottom and double side. The hot spot stress of the alternative design and that of the required design is to be compared to the critical hot spots in way of the cut-out. The critical hot spots depend on the detail design and are to be selected in agreement with the Society. The hot spot stress is to be derived according to Ch 9, Sec 5, [3.1] and Ch 9, Sec 5, [3.2]. It is to be noted that welded hot spots at the free edge are classified as hot spot type "*b*". Example of typical hot spots for checking is shown in Ch 9, Sec 2, [2].

CCS 2.2.2a The critical hot spots in way of the cut-out of alternative design for connection of stiffeners to transverse frames are selected as follows, see Figure CCS 2.2.2a:

(1) in way of corner of curvature of free edge of the cut-out, see hot spots 1, 2 and 3 in Figure

CCS 2.2.2a;

(2) intersection of web of transverse frame to longitudinal web, see hot spots 4 and 5 in Figure CCS2.2.2a;

(3) intersection of lug plate to longitudinal web, see hot spots 6 and 7 in Figure CCS 2.2.2a;

(4) intersection of web of transverse frame to lug plate, see hot spots 8, 9, 10 and 11 in Figure CCS 2.2.2a (where hot spots 10 and 11 are located near the middle point of side length);

(5) intersection of web of transverse frame to attached plating of longitudinal, see hot spots 12 and 13 in Figure CCS 2.2.2a.

CCS 2.2.2b In way of hot spots 10 and 11, the number of mesh along the side length is not to be less than4

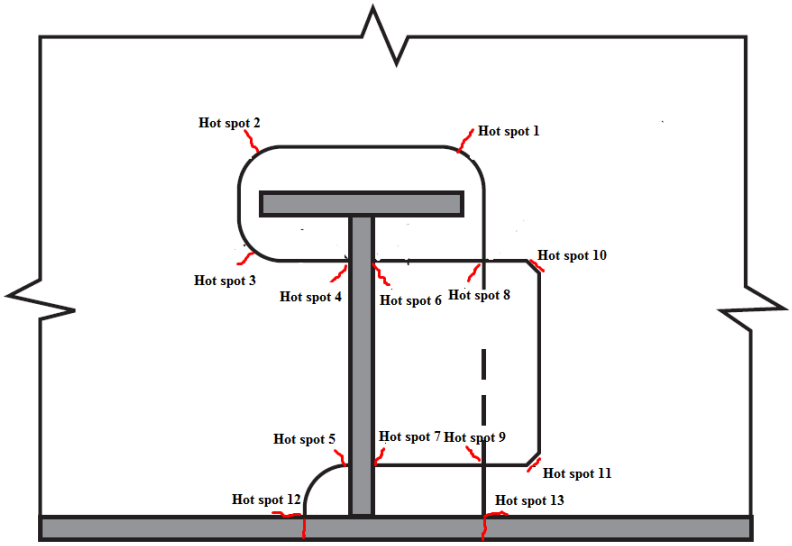
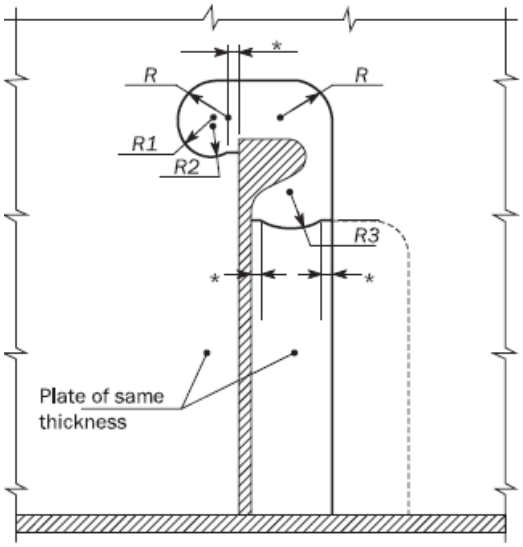
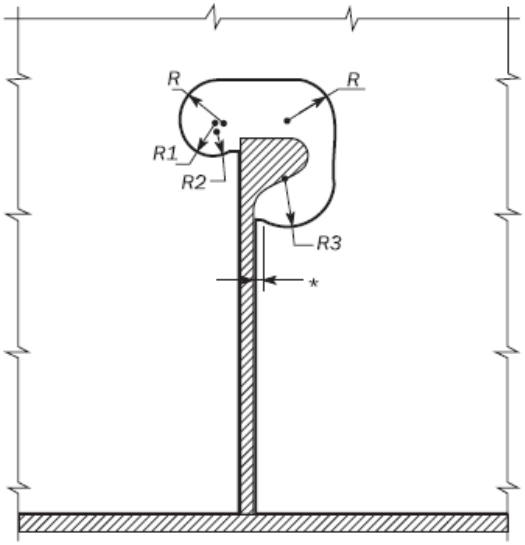
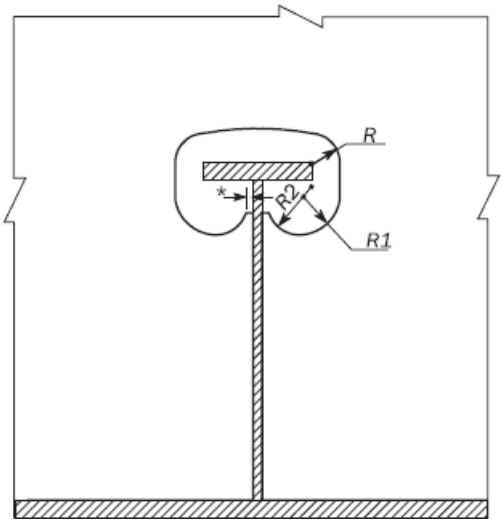
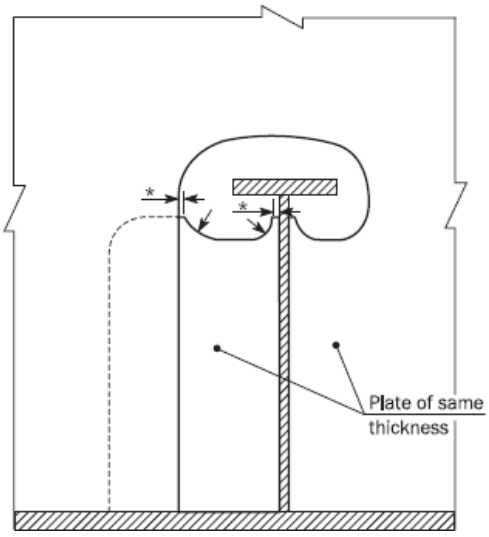


Figure CCS 2.2.2a Selection of Critical Hot Spot in way of Cut-out

Design standard A – stiffener-frame connection **Table 1**

Cut outs for longitudinals in transverse webs where web stiffeners are omitted or not connected to the longitudinal flange	
Design standard *A*	
1	2
	
3	4
	
Note1: Soft toes marked '*' are to be dimensioned to suit the weld leg length such that smooth transition from the weld to the curved part can be achieved. Maximum 15 mm or thickness of transverse web/collar plates/lug plates whichever is the greater. Note2: Configurations 1 and 4 indicate acceptable lapped lug plate connections.	
Critical location	Locations around cut-out with high stress concentration and locations in way of weld terminations
Detail design standard	Improved slot shape to avoid high stress concentrations in transverse webs due to shear loads and local pressure loads transmitted via welded joints
Building tolerances	Ensure alignment of all connecting members and accurate dimensional control of cut-outs according to IACS Recommendation No. 47.
Welding requirements	A wraparound weld, free of undercut or notches, around the transverse web connection to longitudinal stiffener web.

2.2.3

The very fine mesh finite element models are made to analyse the behaviour in way of double side or double bottom. The models should have an extent of 3 stiffeners in cross section, i.e. 4 stiffener spacings, and the longitudinal extent is to be one half frame spacing in both forward and aft direction. A typical model is shown in Figure 1. No cut-outs for access openings are to be included in the models. Connection between the lug or the web-frame to the longitudinal stiffener web, connections of the lug to the web-frame and free edges on lugs and cut-outs in web-frame are to be modelled with elements of net plate thickness size ($t_{n50} \times t_{n50}$). The mesh with net plate thickness size should extend at least five elements in all directions. Outside this area, the mesh size may gradually be increased in accordance with the requirements in Ch 9, Sec 5, [2]. The eccentricity of the lapped lug plates is to be included in the model. Transverse web and lug plates are to be connected by eccentricity elements (transverse plate elements). The height of eccentricity element is to be the distance between mid-layers of transverse web and lug plates having a thickness equal to 2 times the net thickness of web-frame plate $t_{w\text{-}n50}$ Eccentricity elements representing fillet welds are shown in Figure 2.

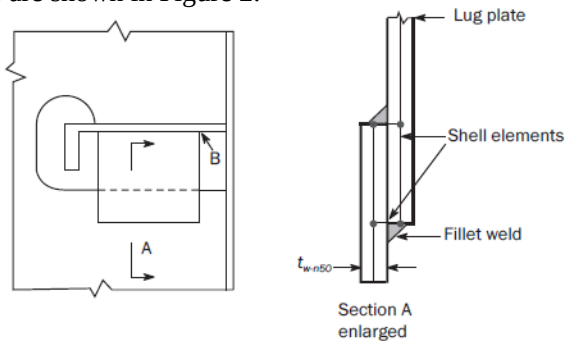


Figure 2 Modelling of eccentric lug plate by shell elements

2.2.4

Three load cases are to be applied to the models of the design standard and alternative designs:

- External pressure of unit value, fixed boundary conditions at top and bottom of model.
- Shear stress by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.
- Axial load by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.

The forward and aft part of the model should have symmetry condition describing the behaviour in a double hull structure. Load application and boundary conditions are provided in Figure 3.

2.2.5

The alternative design may also be verified to have satisfactory fatigue performance using sub-modelling technique where a very fine mesh model of the alternative design located at the actual position of the stiffener-frame connection is analysed. The alternative design is considered acceptable if the fatigue acceptance criterion of Ch 9, Sec 1 is achieved. The fatigue acceptance criterion is checked by applying the methodology described in Ch 9, Sec 1, Ch 9, Sec 3 and Ch 9, Sec 5. The alternative design is considered acceptable only for the particular position where it is analysed.

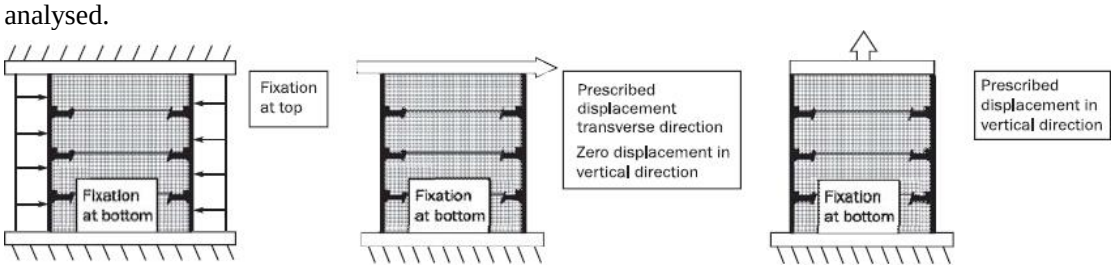


Figure 3 Load application and boundary conditions – FE model for verification of alternative design

3 SCALLOPS IN WAY OF BLOCK JOINTS

3.1 Design standard B

3.1.1
Scallops in way of block joints in the cargo tank/hold region, located on the stiffeners fitted on strength deck, and side above 0.9*D* from the baseline, are required to be designed according to the design standard B as shown in Table 2.

4 HOPPER KNUCKLE CONNECTION

4.1 Design standard C to H

4.1.1
The welded knuckle between hopper plating and inner bottom plating for double-hull oil tankers is to be designed according to the design standard C in Table 3. The design standard D in Table 4 may be used as an alternative to increase fatigue strength at the hopper connection.

4.1.2
The welded knuckle between hopper plating and inner bottom plating for bulk carriers is to be designed according to the design standard E in Table 5.

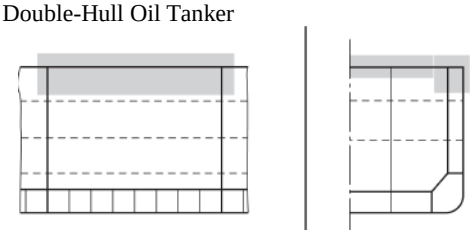
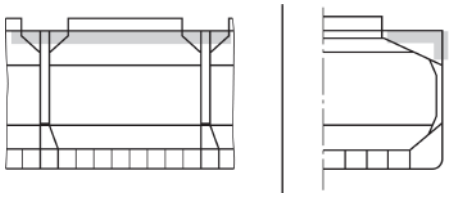
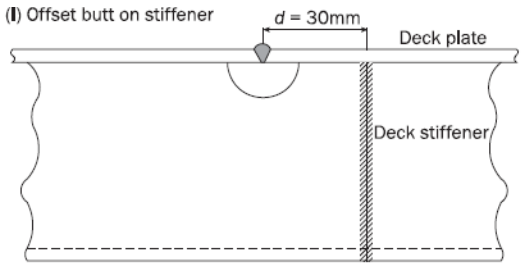
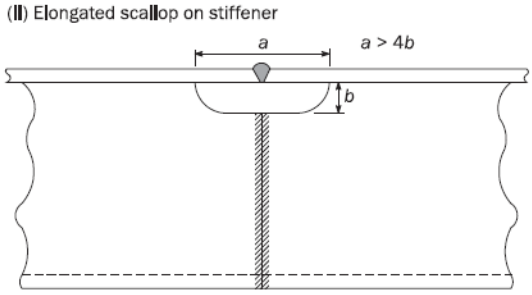
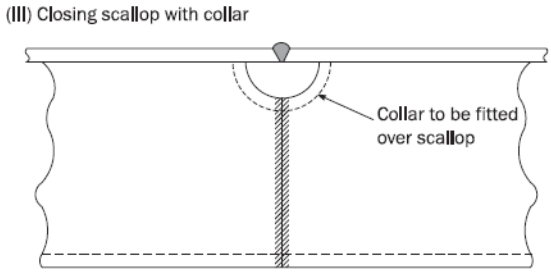
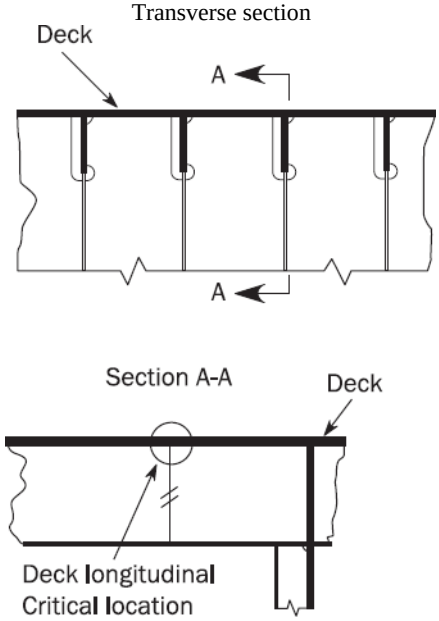
4.1.3
The radiused knuckle between hopper plating and inner bottom plating is to be designed according to the design standard F in Table 6 for double hull oil tankers.
Alternative structural arrangements may be accepted based on verification in accordance with Ch 9, Sec 5, [3.3].

4.1.4
The radiused knuckle between hopper plating and inner bottom plating for bulk carriers is to be designed according to the design standard G in Table 7.

4.1.5
The radiused knuckle between hopper plating and inner side plating for oil tankers and double side bulk carriers is to be designed according to the design standard H in Table 8.

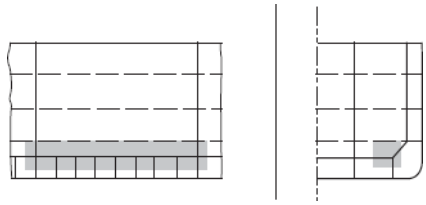
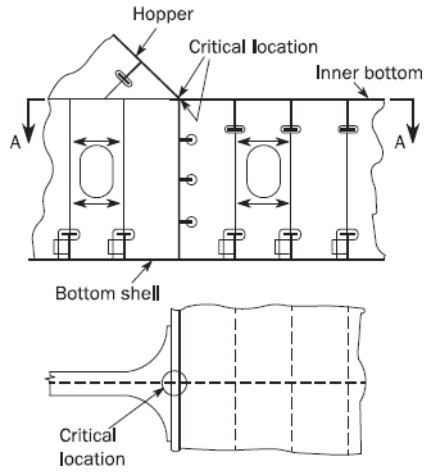
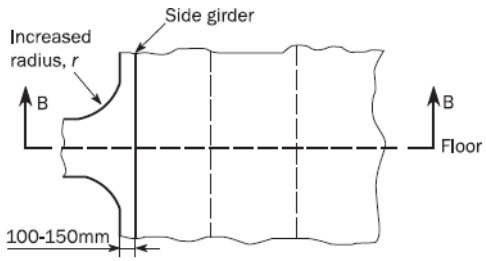
4.1.6
In general, the prescribed minimum requirements for welding, weld dressing and building tolerances as given in Table 3 to Table 8 are to be followed. Alternative positioning and/or dispensation of some support structure, such as transverse and longitudinal brackets may be accepted subject to demonstration of acceptable fatigue lives. Inserts and/or weld dressing additional to those prescribed may be required as a consequence of hot spot fatigue analysis.

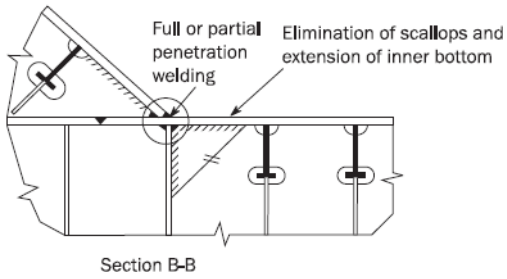
Design standard B – scallops in way of block joints **Table 2**

<table>
<tr><td colspan="2">Welding of deck stiffeners in way of block joints</td></tr>
<tr><td>Critical areas Design standard B</td><td>Critical areas Design standard B</td></tr>
<tr><td>Double-Hull Oil Tanker
 
Bulk Carrier
  </td><td rowspan="3"> 
 
 
Note1: Alternative scallop geometry to that shown in option II may be accepted subject to demonstration of satisfactory fatigue life based on hull girder loads taking into account additional stress concentration factor in way of weld</td></tr>
<tr><td>Critical locations</td></tr>
<tr><td>Transverse section
  </td></tr>
</table>

Critical location	Welding of deck stiffeners in way of block joints in cargo tank region, the strength deck and side above 0.9*D* from the baseline.
Detail design standard	All scallops are to be fitted according to detail design standard B.
Building tolerances	Ensure alignment of all structural members according to IACS Recommendation No. 47.
Welding requirements	Full penetration butt weld, free of undercut or notches, around the web and flange of the longitudinal stiffener at block joints, particularly in way of the weld termination at the scallop for option II.

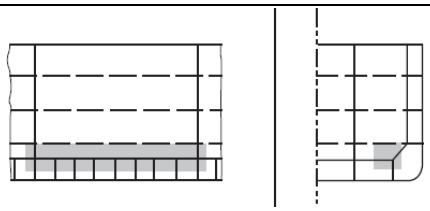
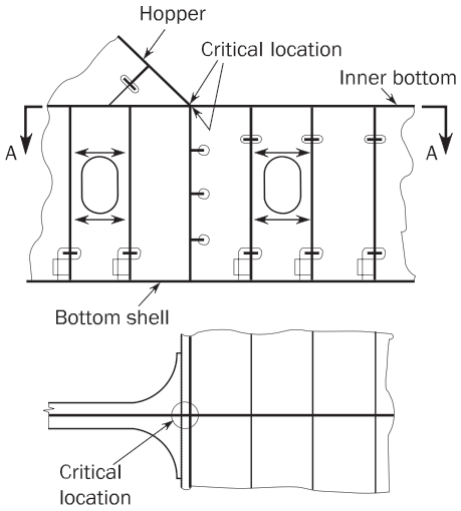
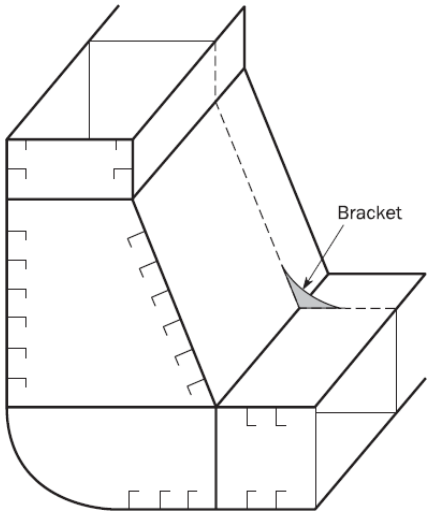
Design standard C – hopper knuckle connection detail, welded, without bracket, double hull oil tanker **Table 3**

<table>
<tr><td colspan="2">Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing welded inner bottom and hopper sloping plating</td></tr>
<tr><td>Critical areas</td><td>Design standard C</td></tr>
<tr><td> 
Critical locations
 
</td><td> 

 
</td></tr>
</table>

Minimum requirement	As a minimum, detail design standard C or D is to be fitted. The ground surface is to be protected by a stripe coat of suitable paint composition, where the lower hopper knuckle region of cargo tanks is not coated.
Critical location	Hopper sloping plating connections to inner bottom plating in way of floors. Floor connections to inner bottom plating and side girder in way of hopper corners.
Detail design standard	Elimination of scallops in way of hopper corners, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket thickness is to be close to that of the inner bottom in way of the knuckle.
Building tolerances	Median line of hopper sloping plate is to be in line with the median line of the girder with an allowable tolerance of $t_{as\text{-}built}/3$ or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the as-built side girder thickness. The allowable tolerance is to be measured parallel to the inner bottom.
Welding requirements	Full or partial penetration welding is to be applied to hopper sloping plating and inner bottom plating connection. Partial penetration welding is to be applied to connections of side girder to inner bottom plating, to connections of floors to inner bottom plating and to side girder, to connections of hopper transverse webs to sloping plating, to inner bottom and to side girder in way of the hopper knuckle. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3 Weld between hopper plating and inner bottom plating to be enlarged and ground smooth. Visible undercuts are to be removed, see Ch 9, Sec 3, [6]. Weld enlargement and grinding are applicable to minimum 200 mm on each side of the floor.

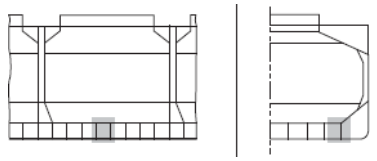
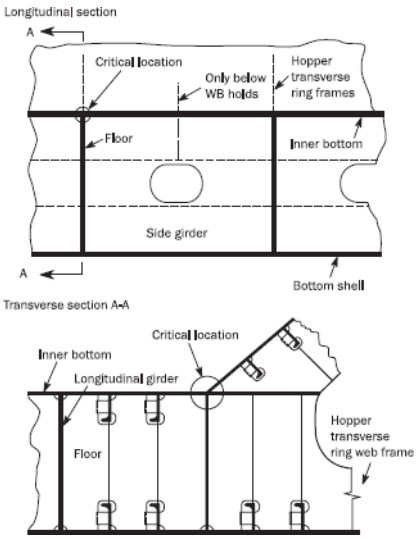
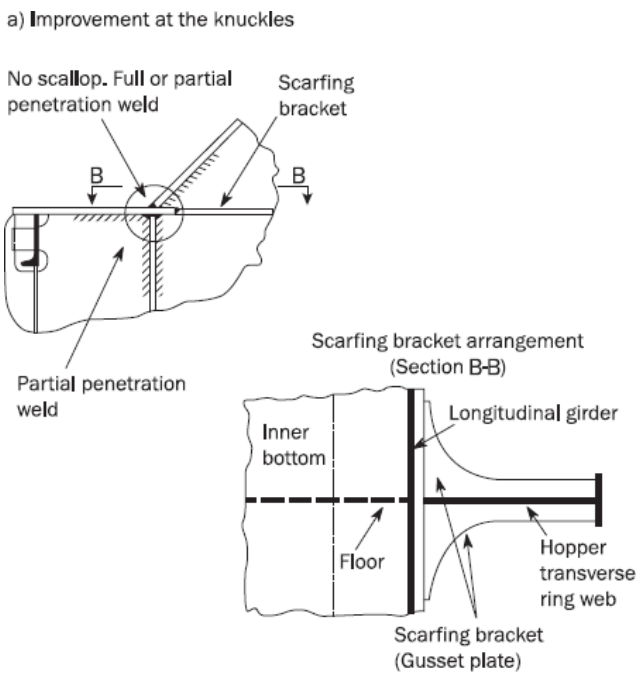
Design standard D – hopper knuckle connection detail, welded, with bracket, double hull oil Tanker Table 4

<table>
<tr><td colspan="2">Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing welded inner bottom and hopper sloping plating</td></tr>
<tr><td>Critical areas</td><td>Design standard D</td></tr>
<tr><td> 
Critical locations
 
</td><td> 

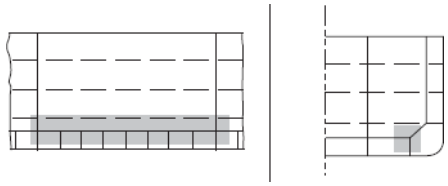
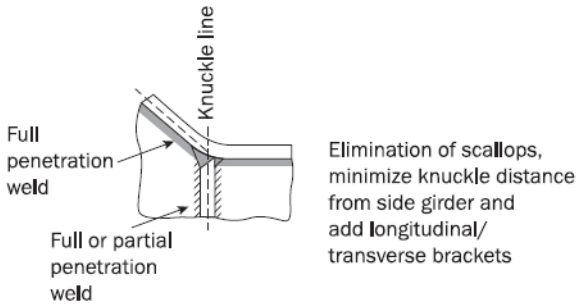
Note1: Bracket to be fitted inside cargo tank.
Note2: Bracket to extend approximately to the first longitudinal.
Note3: The bracket toes are to have a soft nose design.
Note4: Bracket material to be same as that of inner bottom.
Note5: Slenderness of bracket to be in accordance with Ch 8, Sec 2, [5.2].</td></tr>
</table>

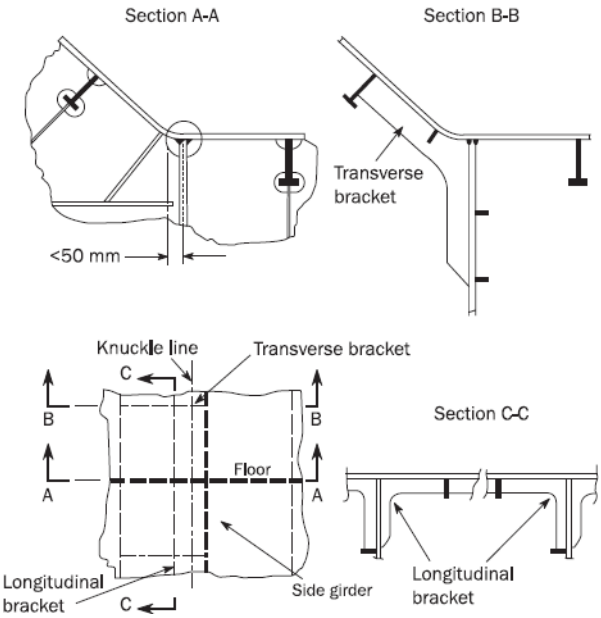
Minimum requirement	As a minimum, detail design standard C or D is to be applied.
Critical location	Hopper sloping plating connections to inner bottom plating in way of floors. Floor connections to inner bottom plating and side girder in way of hopper corners. The bracket connection to inner bottom and hopper sloping plate.
Detail design standard	Elimination of scallops in way of hopper corners, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket thickness similar to that of the inner bottom in way of the knuckle.
Building tolerances	Median line of hopper sloping plate is to be in line with the median line of girder with an allowable tolerance of $t_{as\text{-}built}$ /3 or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the as-built side girder thickness.
Welding requirements	Partial penetration welding is to be applied to hopper sloping plating and inner bottom plating connection, to connections of side girder to inner bottom plating, to connections of floors to inner bottom plating and to side girder, to connections of hopper transverse webs to sloping plating, to inner bottom and to side girder in way of the hopper knuckle. Partial penetration welding is to be applied to the bracket connections to inner bottom and hopper sloping plate, full penetration welding is to be applied at bracket toes. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.

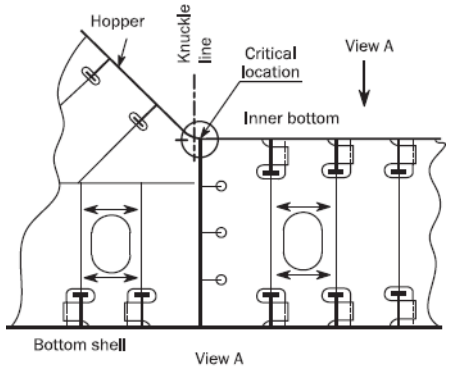
Design standard E – hopper knuckle connection detail, welded, bulk carrier Table5

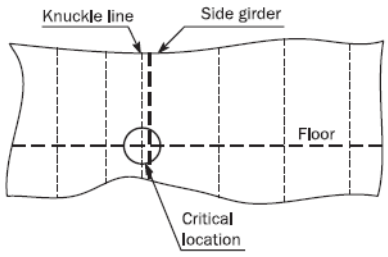
<table>
<tr><td colspan="2">Connections of floors in double bottom tanks to hopper tanks
Welded knuckle connection of hopper tank sloping plating to inner bottom plating</td></tr>
<tr><td>Critical areas</td><td>Design standard E</td></tr>
<tr><td> 
Critical locations
 
</td><td> 
</td></tr>
<tr><td>Minimum requirement</td><td>As a minimum, detail design standard E is to be fitted.
Ballast holds: No scallops or close scallops with collars; scarfing bracket; intermediate bracket if floor spacing greater than 2.5 m.
Dry holds: No scallop or close scallops with collars and scarfing bracket.</td></tr>
<tr><td>Critical location</td><td>Hopper sloping plating connections to inner bottom plating in way of the floors. Floor connections to inner bottom plating and side girder in way of the hopper knuckle.</td></tr>
<tr><td>Detail design standard</td><td>Elimination of scallops in way of hopper knuckle, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket net thickness is to be minimum 80% of that of the inner bottom in way of knuckle and steel material to be of the same yield strength.</td></tr>
<tr><td>Building tolerances</td><td>Median line of hopper sloping plate is to be in line with the median line of girder with an allowable tolerance of $t_{as\text{-}built}/3$ or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the as-built side girder thickness.</td></tr>
<tr><td>Welding requirements</td><td>Full or partial penetration welding is to be applied to hopper sloping plating and inner bottom plating connection for the length of the cargo hold. Partial penetration welding is to be applied to connections of side girder to inner bottom plating, to connections of floors to inner bottom plating and to side girder, to connections of hopper transverse webs to sloping plating, to inner bottom and to side girder in way of the hopper knuckle. Weld between hopper plating and inner bottom plating is to be enlarged and ground smooth. Visible undercuts are to be removed. Weld enlargement and grinding are applicable to minimum 200 mm on each side of the floor. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.</td></tr>
</table>

Design standard F – hopper knuckle connection detail, radiused type, for double hull oil tanker **Table 6**

<table>
<tr><td colspan="2">Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating</td></tr>
<tr><td>Critical areas</td><td>Design standard F</td></tr>
<tr><td>  </td><td rowspan="3"> 

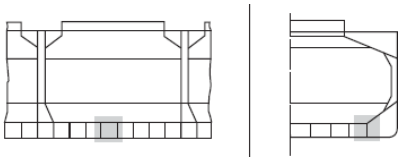
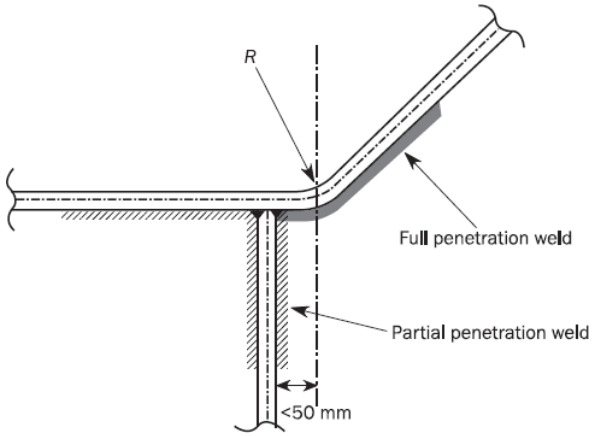


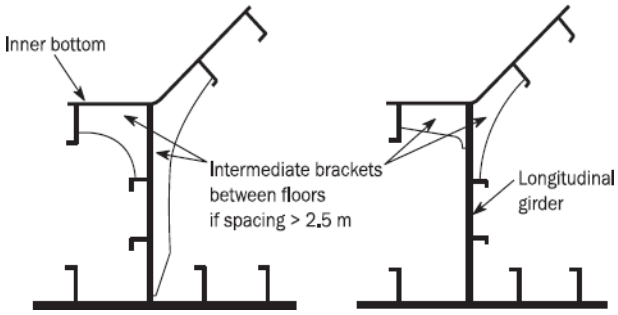
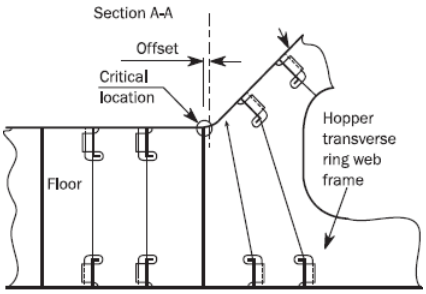
Note1: Distance from side girder to centre of knuckle is to be as small as practicable, but is not to exceed 50 mm.
Note2: The knuckle radius is not to be less than 4.5 $t_{as\text{-}built}$ or 100 mm, whichever is the greater, where $t_{as\text{-}built}$ is the as-built thickness of the knuckle part.
Note3: Additional transverse brackets offset at a suitable distance on either side of transverse floor/hopper connection.
Note4: Additional longitudinal bracket on the side of sloping plate.
Note5: Longitudinal and/or transverse brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line, i.e. that fatigue requirements according to Ch 9, Sec 5 and local strength analysis requirements according to Ch 7, Sec 3 are fulfilled.</td></tr>
<tr><td>Critical locations</td></tr>
<tr><td> 

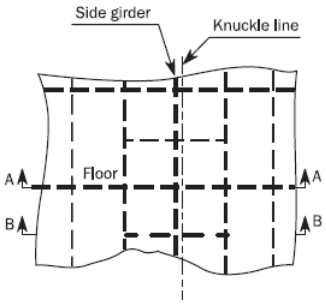

</td></tr>
<tr><td>Critical location</td><td colspan="2">Floor and hopper transverse web connections to inner bottom plating and hopper sloping plate, respectively and to side girder in way of hopper knuckle. Side girder connections to inner bottom plating in way of floors.</td></tr>
</table>

Connections of floors in double bottom tanks to hopper tanks Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating	
Detail design standard	Elimination of scallops in way of hopper/girder connection and additional transverse and longitudinal brackets to reduce peak and range of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure, and hull girder global loading, and provide additional support to sloping plate.
Building tolerances	The nominal distance between the centres of thickness of the two abutting members (e.g. floor and hopper web plate) is not to exceed 1/3 of the as-built thickness of the side girder.
Welding requirements	Full penetration welding is to be applied to connections of floors to hopper/inner bottom plating in way of radiused hopper knuckle. Partial penetration welding is to be applied to connections of floors/hopper transverse webs to the side girder in way of hopper corner, and to connections of side girder to hopper/inner bottom plating. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3. In order to improve the fatigue strength, weld enlargement and grinding are applicable to full and partial penetration welds with a minimum distance of 300 mm from the intersection point between the radiused knuckle, the floor and the side girder.

Design standard G – hopper knuckle connection detail, radiused type, bulk carrier Table 7

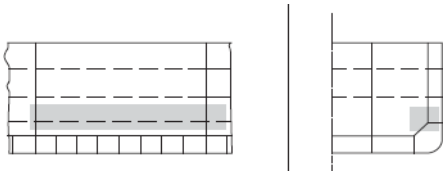
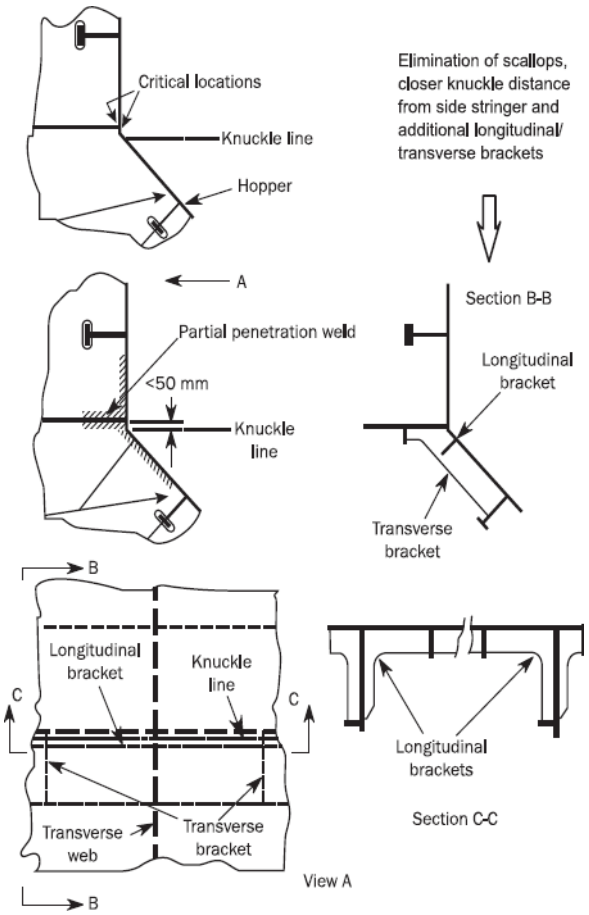
<table>
<tr><td colspan="3">Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating</td></tr>
<tr><td>Critical areas</td><td colspan="2">Design standard G</td></tr>
<tr><td>  </td><td colspan="2" rowspan="2"> 

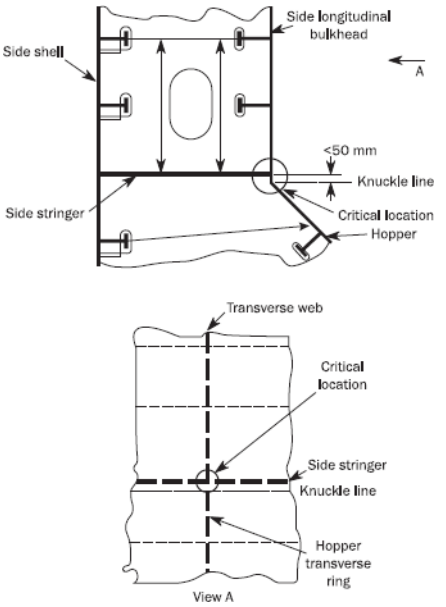
Intermediate bracket arrangement (Section B-B).
Two intermediate brackets at both sides of floor/transverse web.
 
</td></tr>
<tr><td>Critical locations</td></tr>
<tr><td> 


</td><td colspan="2">Note1: Distance from side girder to centre of knuckle is to be as small as practicable, but is not to exceed 50 mm.
Note2: The knuckle radius is not to be less than 4.5 $t_{as\text{-}built}$ or 100 mm, whichever is the greater, in cases where $t_{as\text{-}built}$ is the as-built thickness of the knuckle part.
Note3: Additional transverse brackets on both side of transverse floor/hopper connection.
Note4: Transverse brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line, i.e. that fatigue requirements according to Ch 9, Sec 5 and local strength analysis requirements according to Ch 7, Sec 3 are fulfilled.</td></tr>
<tr><td>Critical location</td><td colspan="2">Side girder connections to inner bottom plating in way of floors. Floor and hopper transverse web connections to inner bottom plating and hopper sloping plate, respectively, and to side girder in way of hopper corners.</td></tr>
<tr><td>Detail design standard</td><td colspan="2">Elimination of scallops in way of hopper/girder connection.
Ballast holds: Intermediate brackets fitted at approximately 0.5 floor space from floor/hopper web.
Dry holds: Intermediate brackets fitted at 0.5 floor space from floor/hopper web if floor spacing is equal to or greater than 2.5 m.</td></tr>
<tr><td>Building tolerances</td><td colspan="2">The nominal distance between the centres of thickness of the two abutting members (e.g. floor and hopper web plate and additional supporting brackets) should not exceed 1/3 of the as-built thickness of the side girder.</td></tr>
</table>

Connections of floors in double bottom tanks to hopper tanks Hopper corner connections employing radiused knuckle between inner bottom and hopper sloping plating	
Welding requirements	Full penetration welding is to be applied to connections of floors to hopper /inner bottom plating in way of radiused hopper knuckle. Partial penetration welding is to be applied to connections of floors/hopper transverse webs to side girder in way of hopper corners, to connections of side girder to hopper /inner bottom plating. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.

Design standard H – upper hopper knuckle connection detail, radiused type, oil tankers and double side bulk carrier **Table 8**

<table>
<tr><td colspan="2">Connections of transverse webs in double side tanks to hopper tanks
Hopper corner connections employing radiused knuckle between side longitudinal bulkhead and hopper sloping plating</td></tr>
<tr><td>Critical areas</td><td>Design standard H</td></tr>
<tr><td>  </td><td rowspan="3"> 

Note1: Distance from side stringer to centre of knuckle is to be as small as practicable, but is not to exceed 50 mm.
Note2: The knuckle radius is not to be less than 4.5 $t_{as\text{-}built}$ or 100 mm, whichever is the greater, where $t_{as\text{-}built}$ is the as-built thickness of the knuckle part, according to Ch 12 Sec 1 [3] & [4].
Note3: Additional transverse brackets offset at a suitable distance on either side of transverse floor/hopper connection.
Note4: Additional longitudinal bracket on the side of sloping plate.
Note5: Longitudinal and/or transverse brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line, i.e. that fatigue requirements according to Ch 9, Sec 5 and local strength analysis requirements according to Ch7, Sec 3 are fulfilled.</td></tr>
<tr><td>Critical locations</td></tr>
<tr><td> 
</td></tr>
<tr><td>Critical location</td><td colspan="2">Side stringer connections to side longitudinal bulkhead in way of transverse webs. Double side tank transverse web and hopper transverse web connections to side longitudinal bulkhead and to side stringers in way of hopper corners.</td></tr>
</table>

Connections of transverse webs in double side tanks to hopper tanks Hopper corner connections employing radiused knuckle between side longitudinal bulkhead and hopper sloping plating	
Detail design standard	Elimination of scallops in way of hopper corners, closer knuckle distance from side stringers. Additional longitudinal / transverse brackets to reduce peak and range of resultant stresses arising from cyclic external hydrodynamic pressure and cargo inertia pressure.
Building tolerances	The nominal distance between the centres of thickness of the two abutting members should not exceed 1/3 of the as-built thickness of the side stringer.
Welding requirements	Partial penetration welding is applied to connection of side stringers to side longitudinal bulkhead, connection of double side tank transverse webs to side longitudinal bulkhead and to side stringers, connection of hopper transverse webs to sloped side longitudinal bulkhead and to side stringers in way of hopper corners. Small scallops of suitable shape, which are to be closed by welding after completion of the continuous welding of side stringers to longitudinal bulkhead, are to be provided where scallops are eliminated. Definition of full and partial penetration welding and their required extent are given in Ch 12, Sec 3.

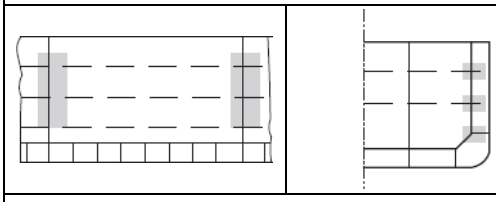
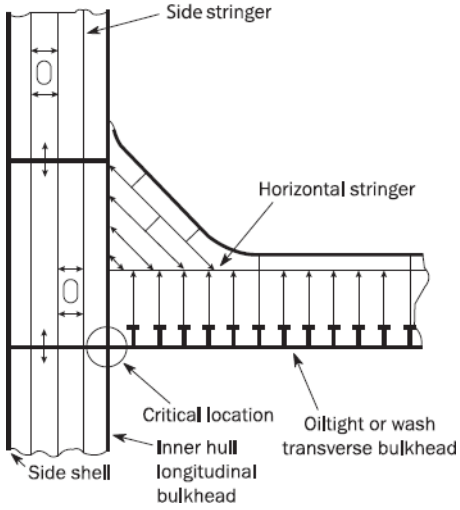
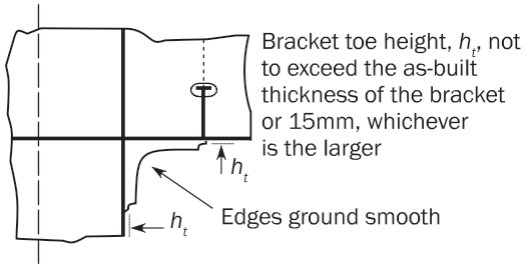
5 HORIZONTAL STRINGER HEEL

5.1 Design standard I

5.1.1

The horizontal stringer heel location between transverse oil-tight/swash bulkhead plating and inner hull longitudinal bulkhead plating for double hull oil tankers are required to be designed according to design standard I, as shown in Table 9.

Design Standard I – transverse bulkhead horizontal stringer heel **Table 9**

<table>
<tr><td colspan="2">Connections of horizontal stringer on plane oil-tight transverse bulkheads or wash bulkheads to inner hull longitudinal bulkheads</td></tr>
<tr><td>Critical areas</td><td>Design standard I</td></tr>
<tr><td> 
Critical locations
 
</td><td> 

Note1: Where a face plate is considered necessary, it is recommended that design features be adopted to reduce the stress concentration at the face plate termination (e.g. taper and soft nose). Adequate fatigue life of the weld on the bracket edge in way of such terminations is to be confirmed.
Note2: ‘Slit type cut-outs are to be adopted in way of the bracket toe as shown. Alternatively, cut-outs with insert type collars will be accepted. Scallops are to be avoided.’</td></tr>
<tr><td>Critical location</td><td colspan="2">Intersections of webs of transverse bulkhead horizontal stringer and double side tank side stringer forming square corners.</td></tr>
<tr><td>Detail design standard</td><td colspan="2">A soft toe backing bracket is to be fitted. The following bracket sizes are recommended:
● VLCC: 800×800×30, R600 with soft toe as shown in figure above,
● Other tankers: 800×600×25, R550 with soft toe as shown in figure above, where the longer arm length is in way of the inner skin.
The specified minimum yield stress for the bracket is not to be less than 315 N/mm^2. The free edge is to be ground smooth with corners rounded.</td></tr>
<tr><td>Building tolerances</td><td colspan="2">The nominal distance between the centres of thickness of the two abutting members should not exceed 1/3 of the as-built plate thickness of the inner hull longitudinal bulkhead.</td></tr>
<tr><td>Welding requirements</td><td colspan="2">Vertical weld between the inner hull plating and transverse bulkhead plating, fillet welding having minimum weld factor 0.44.
Welding between the backing bracket and the adjoining plates is to be double sided fillet welding having minimum weld factor 0.44 except in way of the bracket toes. Full penetration welding is to be used for the connection of bracket toes to the inner hull and transverse bulkhead plating for a distance of 200 mm from the toes and the weld toes are to be ground smooth in way.</td></tr>
</table>

6 BULKHEAD CONNECTION TO LOWER AND UPPER STOOL

6.1 Design standard J, K and L

6.1.1

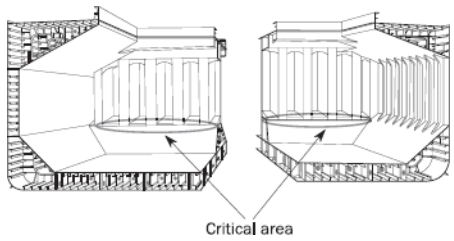
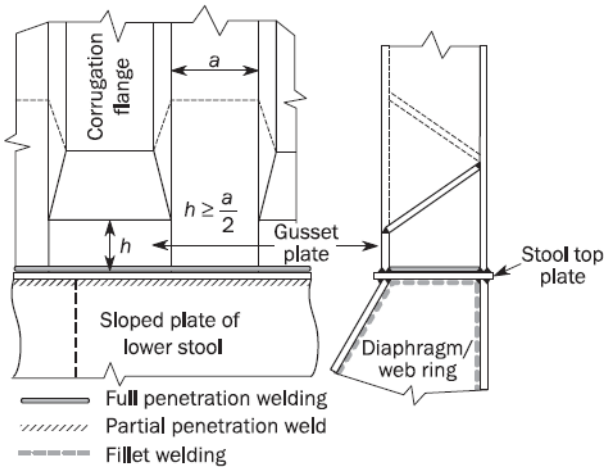
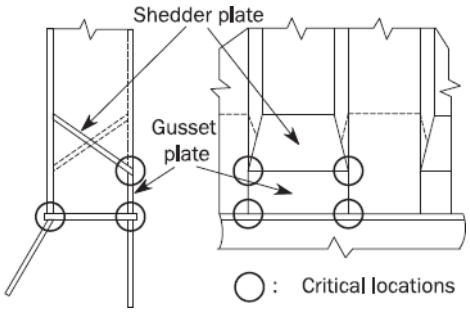
The welded connection of bulkhead to lower stool of bulk carriers and oil tankers are to be designed according to the design standard J and K respectively, as shown in Table 10 and Table 11.

6.1.2

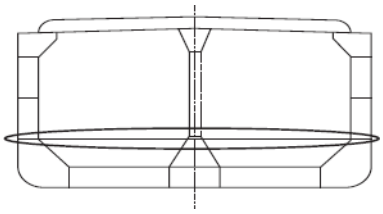
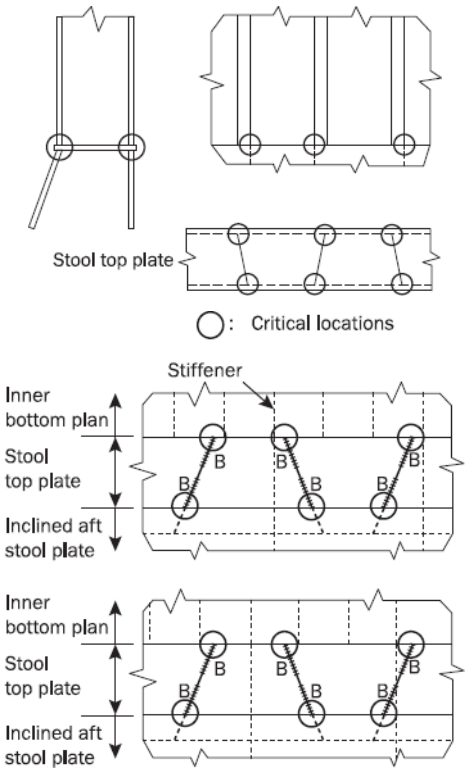
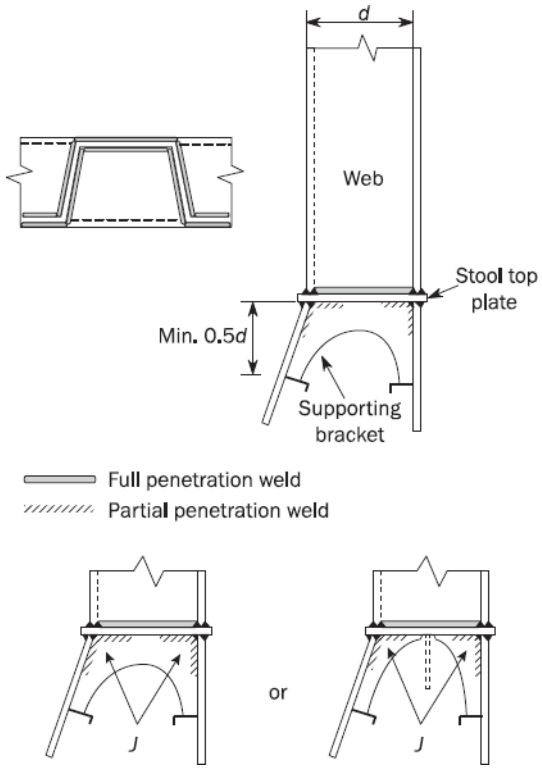
The welded connection of bulkhead to upper stool of bulk carriers are to be designed according to the design standard L, as shown in Table 12.

Design standard J – transverse bulkhead connection detail, bulk carrier (Ballast hold)

Table 10

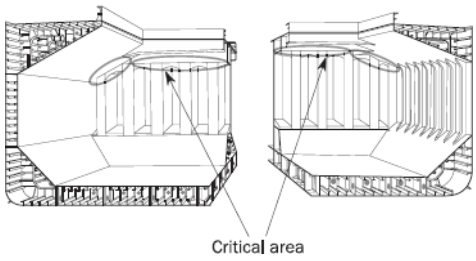
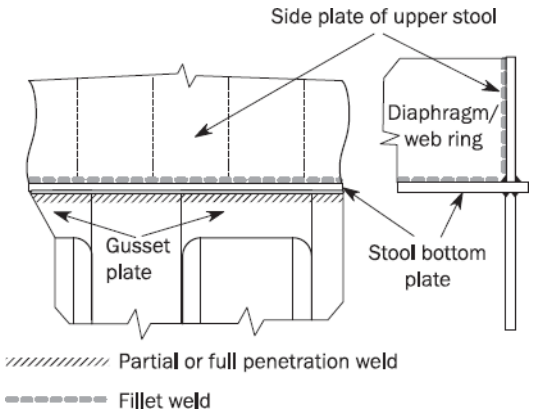
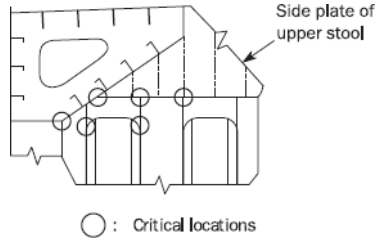
<table>
<tr><td colspan="2">Connections of transverse bulkhead with lower stool</td></tr>
<tr><td>Critical areas</td><td>Design standard J</td></tr>
<tr><td> 
</td><td rowspan="2"> 
</td></tr>
<tr><td>Critical location
 
</td></tr>
<tr><td>Critical location</td><td>Connections of lower stool shelf plate to lower stool and corrugated transverse bulkheads.
Connections of shedder plates to corrugated transverse bulkhead.</td></tr>
<tr><td>Critical location</td><td>The use of scallops is to be avoided on diaphragms/web at lower stool top plates.
Gusset plates are to be fitted to corrugated bulkheads.
Gusset plates are to be made out of the same material and have the same as-built thickness as corrugated bulkheads; and, the height of gusset plates is to be greater than half of breadth of the corrugation.
To reduce stress concentrations at the crossing of the shedder plates one plate is to be moved higher than the other (as shown in Figure). Alternatively, bracketed stiffener can be fitted at the crossing points underneath the shedder plating facing the ballast hold.</td></tr>
<tr><td>Building tolerances</td><td>Ensure alignment between lower stool sloping plates and corrugation faces according to IACS Recommendation No. 47.</td></tr>
<tr><td>Welding requirement</td><td>Full penetration welding is to be applied between lower stool top plates and the side plating of lower stools and corrugated bulkheads.
Partial or full penetration welding is to be applied around gusset plates. However, full penetration welding is to be applied between lower stool top plates and gusset plates.
Ensure start and stop of welding is as far away as practicable from the critical corners.</td></tr>
</table>

Design standard K – transverse or longitudinal corrugated bulkhead connection detail, oil tanker **Table 11**

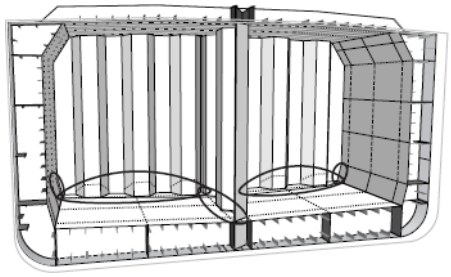
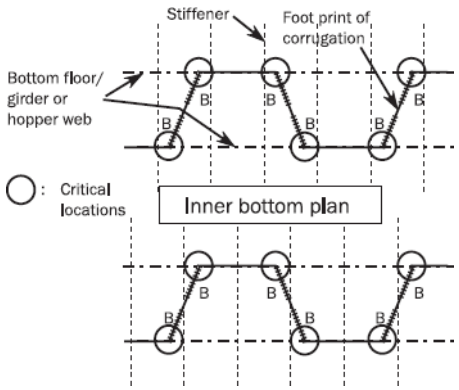
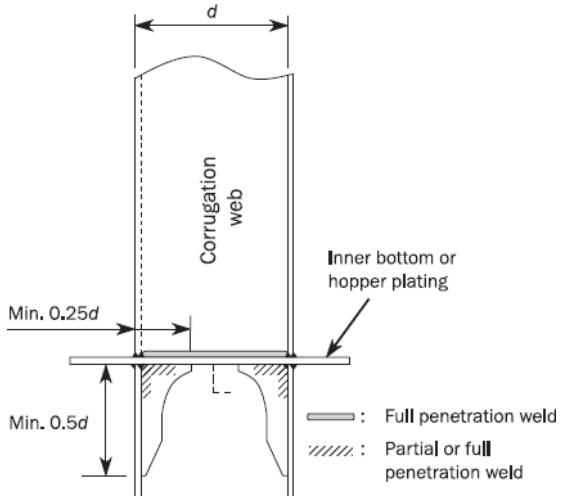
<table>
<tr><td colspan="2">Connections of transverse or longitudinal bulkhead with lower stool - oil tanker</td></tr>
<tr><td>Critical areas</td><td>Design standard K</td></tr>
<tr><td> 
Critical locations
 
</td><td> 
</td></tr>
<tr><td>Critical location</td><td colspan="2">Connections of lower stool top plate to corrugated transverse or longitudinal bulkheads.</td></tr>
<tr><td>Detail design standard</td><td colspan="2">The use of scallops is to be avoided on diaphragms/web at lower stool top plates. Supporting brackets are to be fitted in line with corrugation web as required in Ch 6, Sec 4, [2.6.2]. Scallop is not permitted in the supporting bracket.</td></tr>
<tr><td>Building tolerances</td><td colspan="2">Ensure alignment between lower stool side plates and corrugation faces according to IACS Recommendation No. 47.</td></tr>
<tr><td>Welding requirement</td><td colspan="2">Full or partial penetration welding is to be applied between lower stool top plates and the side plating of lower stools.
Full penetration welding is to be applied between lower stool top plates and vertical corrugated bulkheads.
Full or partial penetration welding is to be applied between lower stool top plates and supporting brackets.
Ensure start and stop of welding is as far away as practicable from the critical corners.
Connection ‘J’, as shown in the figure, of in line supporting bracket to stool top plate and side plate of lower stool is to be full or partial penetration welding, on minimum 300 mm from the corner.</td></tr>
</table>

Design standard L – transverse bulkhead connection detail, bulk carrier (Ballast hold)

Table 12

<table>
<tr><td colspan="2">Connections of transverse bulkhead with sloped plate of upper stool</td></tr>
<tr><td>Critical areas</td><td>Design standard L</td></tr>
<tr><td> 
</td><td rowspan="2"> 
</td></tr>
<tr><td>Critical locations</td></tr>
<tr><td> 
</td><td></td></tr>
<tr><td>Critical location</td><td colspan="2">Connections of corrugated transverse bulkhead to the topside tank sloping plating and upper stool.</td></tr>
<tr><td>Detail design standard</td><td colspan="2">The use of scallops is to be avoided on diaphragms/web at upper stool bottom plates.
Gusset plates are to be fitted between the face plates of corrugated bulkheads in way of heavy ballast hold.
In way of heavy ballast hold, a deep transverse web or well-stiffened backing stiffener is to be provided in the topside tank in line with the face plate of the bulkhead corrugations to ensure that the loads are effectively dissipated.
Gusset plates are to have a thickness and material properties not less than those required for corrugation flanges.</td></tr>
<tr><td>Building tolerances</td><td colspan="2">Ensure alignment between the face plates of corrugated bulkheads with the stool side plates as well as the watertight bulkheads and deep transverse web (or well- stiffened backing stiffener) in the topside tanks according to IACS Recommendation No. 47.</td></tr>
<tr><td>Welding requirement</td><td colspan="2">Partial or full penetration welding is to be applied between upper stool bottom plates and corrugation.
● Fillet welding having minimum weld factor of 0.44 is to be applied between upper stool bottom plates and upper stool side plating.
● Fillet welding having minimum weld factor of 0.44 is to be applied between upper stool bottom plates and diaphragms/web rings.
Ensure start and stop of welding is as far away as practicable from the critical corners in all holds.</td></tr>
</table>

Design standard M – connection details for vertically corrugated bulkheads in cargo tanks and heavy ballast hold **Table 13**

<table>
<tr><td colspan="2">Connections of vertically corrugated bulkhead to inner bottom/hopper plating without stool</td></tr>
<tr><td>Critical areas</td><td>Design standard M</td></tr>
<tr><td rowspan="3"> 
Critical locations
 
</td><td>Detail of in line bracket:
 

Note1: Brackets are to be arranged below inner bottom and hopper tank plating in line with corrugation webs.
Note2: Where gusset plate with shedder plate according to Ch 6, Sec 4, [2.6.4] item b, is provided, in line bracket may be omitted on the side of gusset plate.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Critical location</td><td>-</td></tr>
<tr><td>Material and scantling requirement</td><td>Inner bottom and hopper tank plating in way of corrugations is to be in accordance to Ch 6, Sec 4, [2.6.4].
Floors/girders and hopper web that support corrugation flange is to be in accordance to Ch 6, Sec 4, [2.6.4].
Supporting bracket aligned with corrugation web is to be in accordance with Ch 8, Sec 2, [5.2] and Ch 6, Sec 4, [2.6.4].</td></tr>
<tr><td>Detail design standard</td><td>Supporting brackets are to be fitted in line with corrugation web as required in Ch 6, Sec 4, [2.6.2]. Scallop is not permitted in the supporting bracket.</td></tr>
<tr><td>Building tolerances</td><td>Median line of corrugation is to be in line with the median line of the supporting members with an allowable tolerance of $t_{as\text{-}built}$ /3 or 5 mm, whichever is less, where $t_{as\text{-}built}$ is the inner bottom thickness.</td></tr>
<tr><td>Welding requirement</td><td>For the connection of vertically corrugated bulkheads to the inner bottom/hopper plating, full penetration welding is to be provided in according to Ch 12, Sec 3, [2.4].
For the connection of supporting structures to inner bottom/hopper plating, partial or full penetration welding is to be provided in accordance with Ch 12, Sec 3, [2.4].
Partial or full penetration welding is also to be applied for the connection of in line brackets below corrugation web in accordance with Ch 12, Sec 3, [2.4] on minimum 300 mm from the corner.</td></tr>
</table>

7 BULKHEAD CONNECTION TO INNER BOTTOM

7.1 Design standard M

7.1.1

The connection of vertically corrugated bulkhead to inner bottom/hopper plating of cargo tanks and heavy ballast hold are to be designed according to the design standard M, as shown in Table 13.

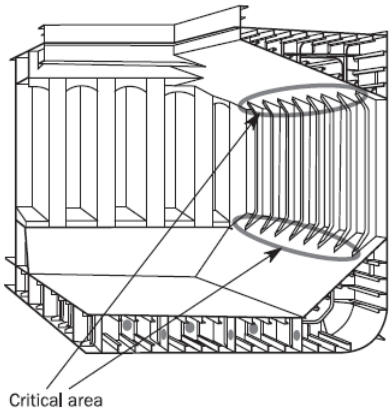
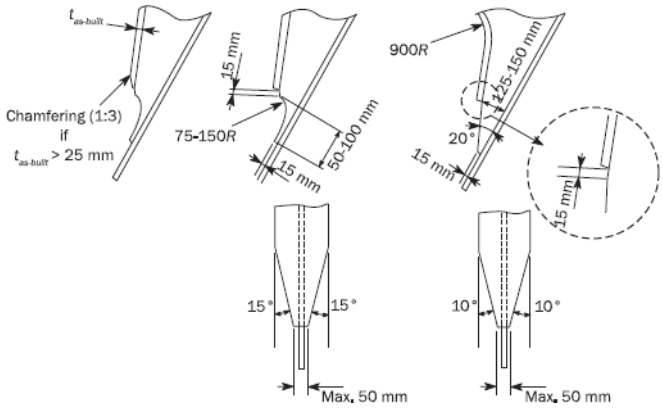
8 LOWER AND UPPER TOE OF HOLD FRAME

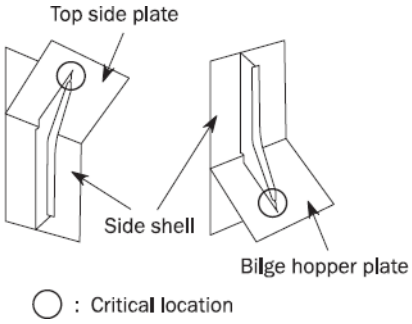
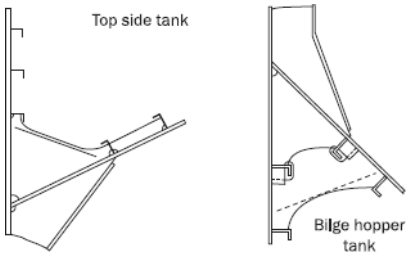
8.1 Design standard N

8.1.1

The welded connections of lower and upper bracket toes of hold frame of bulk carriers are to be designed according to design standard N, as shown in Table 14

Design standard N – lower and upper toe detail of hold frame - bulk carrier Table 14

<table>
<tr><td colspan="2">Lower and upper hold frame connections</td></tr>
<tr><td>Critical areas</td><td>Design standard N</td></tr>
<tr><td> 
</td><td rowspan="2"> 

Examples of the soft and extended toes at the end of hold frames.</td></tr>
<tr><td>Critical locations</td></tr>
<tr><td> 
</td><td> 

Connection of lower and upper end bracket of hold frame.</td></tr>
</table>

Minimum requirement	As a minimum the detail design standard N is to be applied. Tapered extended toes are more effective and are to be considered for high tensile steel side shell frame.
Critical location	Toe connection of side shell frame lower and upper brackets to the hopper and topside sloping plates, including face plate terminations.

Lower and upper hold frame connections	
Detail design standard	Alternative geometries than stipulated above are permissible subject to demonstration of satisfactory fatigue performance. However, the maximum angles shown on the figures for thickness chamfering and face width tapering are not to be exceeded. Bracket toe height and the distance between the face plate termination and start of the toe radius (or toe taper) are to be kept to a minimum. The face plates of hold frames at lower or upper brackets are to be tapered and chamfered as shown. While chamfering may be dispensed with if the thickness of the face plates is less than 25 mm, it is nevertheless a recommended practice, with a larger gradient if necessary. Frames are to be built-up symmetrical sections with integral upper and lower brackets and are to be arranged with soft or elongated toes as shown. The side frame flange is to be curved (not knuckled) at the connection with the end brackets. Where the frame upper brackets are not positioned directly below a ring web, supporting brackets are to be provided. In the design ensure that if a topside tank stiffener is positioned above the end of frame upper bracket, the stiffener cut-out is avoided or closed with a full collar. Increasing the size of supporting brackets will reduce stress concentrations in the critical area. Where the frame lower brackets are not positioned directly above a ring web, supporting brackets are to be provided. In the design ensure that if a hopper tank stiffener is positioned below the end of the frame lower bracket, the stiffener cut-out is avoided or closed with a full collar. Increasing the size of supporting brackets will reduce stress concentrations in the critical area.
Building tolerances	Ensure alignment between side shell frame lower and upper bracket and transverse ring webs or supporting brackets according to IACS Recommendation No. 47. Maximum misalignment is to be not greater than $t_{as\text{-}built}$ /3 where $t_{as\text{-}built}$ is the thinner as-built thickness of the webs to be aligned and misalignment is the overhang of the as-built thinner thickness.
Welding requirement	Welding is to comply with Ch 12, Sec 3, [3]. In way of the wrap around weld at the face plate termination, care should be taken to ensure no over- run onto the radius part and the toe is free from notches and undercut.

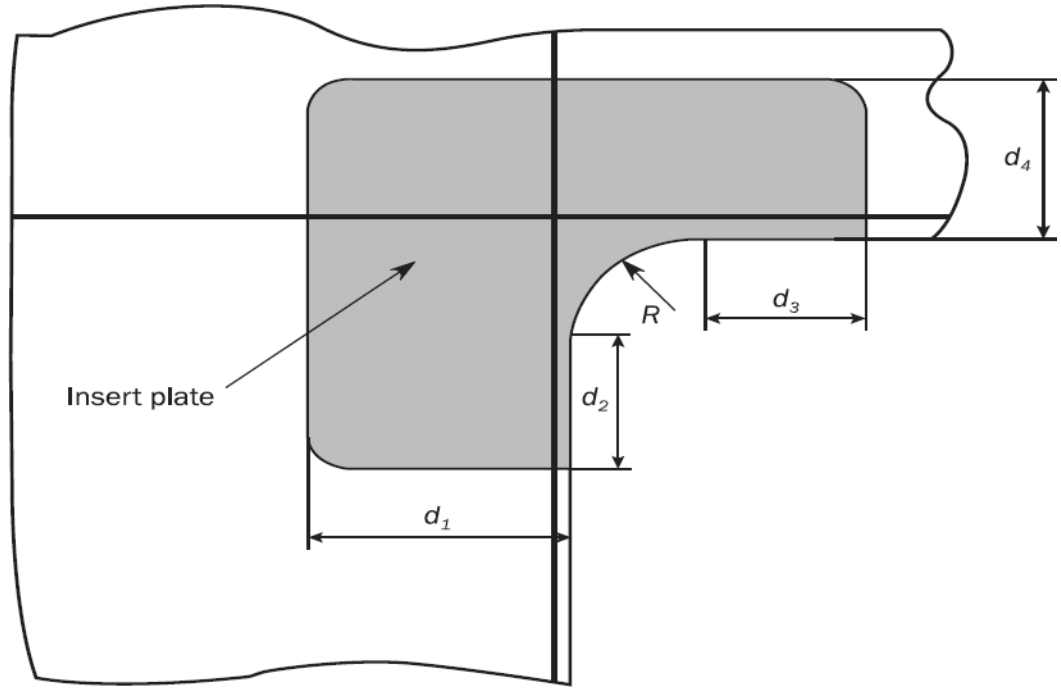
9 HATCH CORNER

9.1 Design standard O

9.1.1

Hatch corners in the cargo hold region, located on the strength deck of bulk carriers are required to be designed according to design standard O, as shown in Table 15.

Design standard O – hatch corner of bulk carriers **Table 15**

Hatch corner (bulk carriers)		
Design standard O		
		
	without insert plate	with insert plate
Critical location	Hatch corner curve	Curved Radius Transition insert plate to deck plating
Detail design standard	Shape of hatch corner as required by Pt 2, Ch 1, Sec 2	Radius and insert plate dimensions and thickness as required by Pt 2, Ch 1, Sec 2. Insert plate has to be tapered for smooth thickness transition to deck plating, the transition taper length has to be not less than 3 times the offset.
Post-treatment	Grinding of cut edge within the radius	Grinding of cut edge within the radius

Chapter 10 OTHER STRUCTURES

Section 1 FORE PART

SYMBOLS

For symbols not defined in this section, refer to Ch1, Sec 4.

α_p : Correction factor for the panel aspect ratio to be taken as:

$$\alpha_p = 1.2 - \frac{b}{2.1a}$$ but not to be taken as greater than 1.0.

f_{bdg} : Bending moment factor taken as:

$$f_{bdg} = 8(1 + \frac{n_s}{2})$$

n_s : End fixation factor taken as:

n_s = 0 for both ends with low end fixity (simply supported).

n_s = 1 for one end fixed and one end simply supported.

n_s = 2 for continuous members or members with bracketed fitted at both ends

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to the following structures of the fore part as defined in Ch 1, Sec 1, [2.4.2]:

- Fore peak structures.
- Stem.

In addition, the requirements of this section apply to structure subjected to impact loads:

- Flat bottom forward, according to [3.2].
- Bow area, according to [3.3].

2 STRUCTURAL ARRANGEMENT

2.1 Floors and bottom girders

2.1.1 Floors

In case of transverse framing, solid floors are to be fitted at each web frame location.

In case of longitudinal framing, the spacing of solid floors is not to be greater than 3.5 m or four transverse frame spaces, whichever is smaller.

The minimum depth of the floor at the centreline is not to be less than the required depth of the double bottom of the foremost cargo hold. See Ch 2, Sec 3, [2.3].

2.1.2 Bottom girders

A supporting structure is to be provided at the centreline either by extending the centreline girder to the stem or by providing a deep girder or centreline bulkhead.

Where a centreline girder is fitted, the minimum depth and thickness is not to be less than that required for the depth of the double bottom in the neighbouring cargo hold region, and the upper edge is to be stiffened.

In case of transverse framing, the spacing of bottom girders is not to exceed 2.5 m.

In case of longitudinal framing, the spacing of bottom girders is not to exceed 3.5 m.

2.1.3 Alternative design verification

This spacing, defined in [2.1.1] and [2.1.2] may be increased, if the designer performs a verification of the bottom structure by means of grillage analysis or FE analysis and provides their full documentation. The acceptance criteria to be applied are defined in Ch 6, Sec 6, [3]. A FE analysis is to be performed under consideration of the requirements provided in Ch 7.

2.2 Wash bulkheads

2.2.1

Where a centreline wash bulkhead is fitted, the lowest strake is to have thickness not less than required for a centreline girder.

Where a longitudinal wash bulkhead supports bottom transverses, the details and arrangements of openings in the bulkhead are to be configured to avoid areas of high stresses in way of the connection of the wash bulkhead with bottom transverses.

2.3 Side shell supporting structure

2.3.1 Web frames

The spacing of web frames, S, in m as defined in Ch 1, Sec 4, Table 5, is to be taken as:

$S = 2.6 + 0.005\,L$, but not to be taken greater than 3.5 m.

Perforated flats are to be fitted to limit the effective span of web frames to not greater than 10 m.

2.3.2 Stringers

The transverse framing forward of the collision bulkhead stringers are to be spaced approximately 3.5 m apart. Stringers are to have an effective span not greater than 10 m, and are to be adequately supported by web frame structures.

2.3.3 Alternative design verification

The spacing of web frames and stringers may be increased, if the designer performs a verification of the side shell supporting structure by means of beam analysis or FE analysis and provides their full documentation.

The acceptance criteria to be applied are defined in Ch 6, Sec 6, [3]. A FE analysis is to be performed under consideration of the requirements provided in Ch 7.

2.4 Tripping brackets

2.4.1

For side shell and tank walls, located forward of the collision bulkhead and vertically framed, tripping brackets spaced not more than 2.6 m are to be fitted, according to Figure 1, between primary supporting members, decks and/or platforms.

The as-built thickness of the tripping brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.

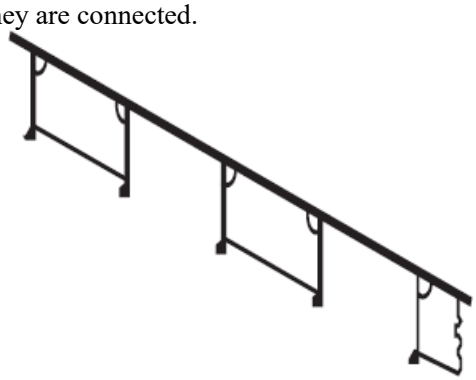


Figure 1 Tripping brackets

2.5 Bulbous bow

2.5.1 General

Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

2.5.2 Diaphragm plates

At the forward end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced about 1m apart in conjunction with a deep centreline web.

In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

2.5.3 Special bulbous bow designs

In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is

generally to be fitted.
In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames is to be fitted.

2.5.4 Strengthening for anchor and chain cable contact

The shell plating is to be increased in thickness at the forward end of the bulb and also in areas likely to be subjected to contact with anchors and chain cables during anchor handling. The increased plate thickness is to be the same as that required for plated stems given in [4.1.1].

3 STRUCTURE SUBJECTED TO IMPACT LOADS

3.1 General

3.1.1 Application

The requirements of this sub-section cover the strengthening requirements for local impact loads that may occur in the forward structure. The impact loads to be applied in [3.2] and [3.3] are described in Ch 4, Sec 5, [3].

3.1.2 General scantling requirements

The requirements of [3.2] and [3.3] are to be applied in addition to applicable scantling requirements in Ch 6. Local scantling increases due to impact loads are to be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

3.2 Bottom slamming

3.2.1 Application

Where the minimum draughts forward, $T_{F\text{-}e}$ or $T_{F\text{-}f}$, as specified in Ch 4, Sec 5, [3.2.1], are less than 0.045 L, the bottom forward is to be additionally strengthened to resist bottom slamming pressures.
The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information, as required in Ch 1, Sec 5.
The load calculation point of the primary supporting members is specified in Ch 3, Sec 7, [4].

3.2.2 Extent of strengthening

The strengthening is to extend forward of 0.3 L from the FP over the flat of bottom and adjacent plating with attached stiffeners up to a height of 500 mm above the baseline, see Figure 2.

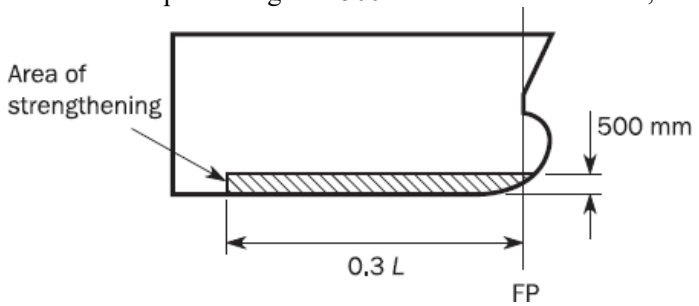


Figure 2 Extent of strengthening against bottom slamming

Outside the region strengthened to resist bottom slamming the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

3.2.3 Design to resist bottom slamming loads

The design of end connections of stiffeners in the bottom slamming region is to provide end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with Ch 3, Sec 6, [3.2]. Where it is not practical to comply with this requirement, the net plastic section modulus, *Zpl-alt*, in cm3, for alternative end fixity arrangements is not to be less than:

$$Z_{pl-alt} = \frac{16 Z_{pl}}{f_{bdg}}$$

where:

Z_{pl}: Net plastic section modulus, in cm3, as required by [3.2.5].
Scantlings and arrangements of primary supporting members, including bulkheads in way of stiffeners, are to comply with [3.2.7].

3.2.4 Shell plating

The net thickness of the hull envelope plating, t, in mm, except for the transversely stiffened bilge plating within the cylindrical part of the ship, is not to be less than :

$$t = \frac{0.0158\alpha_p b}{C_d}\sqrt{\frac{P_{SL}}{C_a R_{eH}}}$$

where:
C_d :Plate capacity correction coefficient taken as:
C_d = 1.3.
C_a : Permissible bending stress coefficient taken as:
C_a = 1.0 for acceptance criteria set AC-I.
The transversely stiffened bilge plating within the cylindrical part of the ship is to comply with the requirement given in Pt 1, Ch 6, Sec 4, [2.2].

3.2.5 Shell stiffeners

The shell stiffeners within the strengthening area defined in [3.2.2] are to comply with the following criteria:

a) The net plastic section modulus, Z_{pl}, in cm^3, is not to be less than:

$$Z_{pl-alt} = \frac{P_{SL} s l_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:
C_s : Permissible bending stress coefficient taken as:
C_s = 0.9 for acceptance criteria set AC-I.

b) The net web thickness, t_w, in mm, is not to be less than:

$$t_w = \frac{P_{SL} s l_{shr}}{2 d_{shr} C_t \tau_{eH}}$$

where:
C_t : Permissible shear stress coefficient taken as:
C_t = 1.0 for acceptance criteria set AC-I.

c) he slenderness ratio is to comply with Ch 8, Sec 2.

3.2.6 Bottom slamming load area for primary supporting members

The scantlings of primary supporting members according to [3.2.7] are based on the application of the slamming pressure defined in Ch 4, Sec 5, [3.2] to an idealised slamming load area of hull envelope plating, A_{SL} , in m^2, given by:

$$A_{SL} = \frac{1.1 \cdot L \cdot B \cdot C_b}{1000}$$

3.2.7 Primary supporting members

The size and number of openings in web plating of the floors and girders is to be minimised considering the required shear area as given in a):

a) Net shear area
The net shear area, $A_{shr\text{-}n50}$, in cm^2, of each primary supporting member web at any position along its span is not to be less than:

$$A_{shr-n50} = 10\frac{Q_{SL}}{C_t \tau_{eH}}$$

where:
Q_{SL} :The greatest shear force due to slamming for the position being considered, in kN, based on the application of a patch load, *FSL* to the most onerous location, as determined in accordance with b) or c).

C_t : Permissible shear stress coefficient taken as:
$C_t = 0.9$ for acceptance criteria set AC-I.

b) Simplified calculation of slamming shear force
For simple arrangements of primary supporting members, where the grillage effect may be ignored, the shear force, Q_{SL}, in kN, is given by:
$Q_{SL}=f_{pt}f_{dist}F_{SL}$
where:
f_{pt} : Correction factor for the proportion of patch load acting on a single primary supporting member, taken as

$$f_{pt} = 0.5(f_{SL}^3 - 2f_{SL}^2 + 2)$$

f_{SL} : Patch load modification factor taken as:

$$f_{SL} = 0.5\frac{b_{SL}}{S}$$

f_{dist} : Factor for the greatest shear force distribution along the span, according to Figure 3.
F_{SL} : Patch load, in kN, taken as:
$F_{SL}=P_{SL}l_{SL}b_{SL}$
l_{SL} : Extent of slamming load area along the span, in m, taken as:

$l_{SL} = \sqrt{A_{SL}}$ but not to be greater than $0.5l_{shr}$.

b_{SL} : Breadth of impact area supported by primary supporting member, in m, taken as:

$b_{SL} = \sqrt{A_{SL}}$ but not to be greater than S.

A_{SL} : Surface defined in [3.2.6].

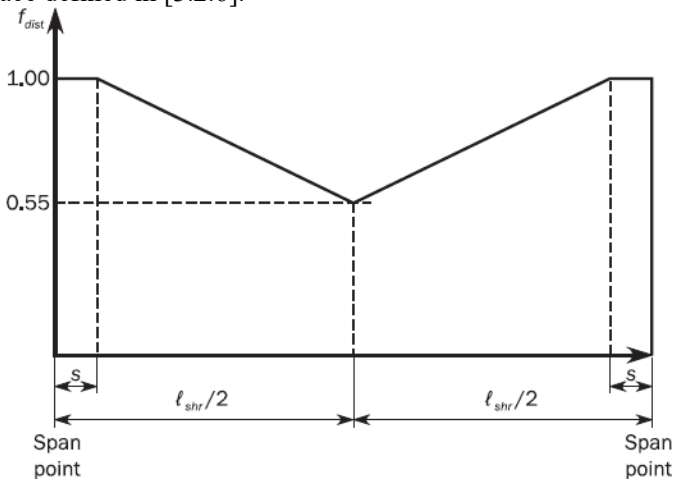


Figure 3 Distribution of f_{dist} along the span of simple primary supporting members

c) Direct calculation method for slamming shear force
For complex arrangements of primary supporting members, the greatest shear force, Q_{SL}, at any location along the span of each primary supporting member is to be derived by direct calculation in accordance with Table 1.

d) Web thickness of primary supporting member
The net web thickness, t_w, in mm, of primary supporting members adjacent to the shell is not to be less than:

$$t_w = \frac{s_W}{70}\sqrt{\frac{R_{eH}}{235}}$$

where:
s_W : Plate breadth, in mm, taken as the spacing between the web stiffening.

3.3 Bow impact

3.3.1 Application

The side structure in the ship forward area is to be strengthened against bow impact pressures. The strengthening is to extend forward of 0.1 L from the FP and vertically above the minimum design

ballast draught, T_{BAL}, defined in Ch 1, Sec 4, [3.1.5] and forecastle deck if any. See Figure 4.

Direct calculation methods for derivation of Q_{SL} **Table 1**

Type of analysis	Model extent	Assumed end fixity of floors
Beam theory	Overall span of member between effective bending supports.	Fixed at ends
Double bottom grillage	Longitudinal extent to be one cargo tank length. Transverse extent to be between inner hopper knuckle and centreline.	Floors and girders to be fixed at boundaries of the model.
Note1: The envelope of greatest shear force along each primary supporting member is to be derived by applying the load patch on a square area as defined in [3.2.6], to a number of locations along the span. Note2: A more extensive model in length and breadth can be considered.		

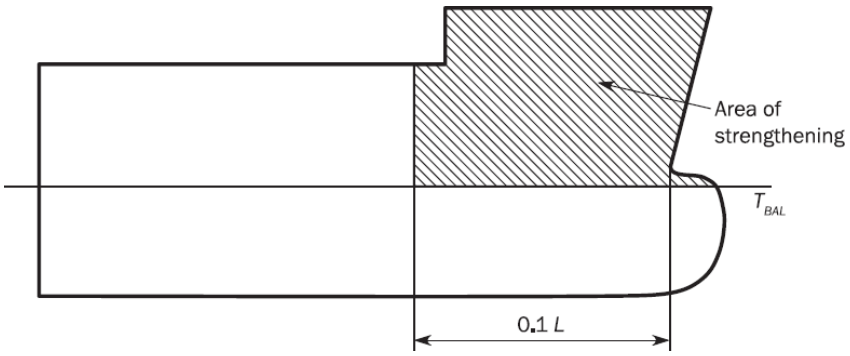


Figure 4 Extent of strengthening against bow impact

Outside the strengthening area the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

3.3.2 Design to resist bow impact loads

a) In1 the bow impact strengthening area, longitudinal framing is to be carried as far forward as practicable.
The design of end connections of stiffeners in the bow impact region are to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with Ch 3, Sec 6, [3.2]. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{pl\text{-}alt}$ in cm^3, for alternative end fixity arrangements is not to be less than:

$$Z_{pl-alt} = \frac{16 Z_{pl}}{f_{bdg}}$$

where:
Z_{pl} : Effective net plastic section modulus, in cm^3, required by [3.3.4].

b) Scantlings and arrangements of primary supporting members, including decks and bulkheads, in way of the stiffeners, are to comply with [3.3.6]. In areas of the greatest bow impact load, the web stiffeners arranged perpendicular to the hull envelope plating and the double sided lug connections are to be provided.
The main stiffening direction of decks and bulkheads supporting shell framing is to be arranged parallel to the span direction of the supported shell frames, to protect against buckling.

3.3.3 Side shell plating

The net thickness of the side shell plating, t, in mm is not to be less than:

$$t = 0.0158\alpha_p b\sqrt{\frac{P_{FB}}{C_a R_{eH}}}$$

where:

C_a : Permissible bending stress coefficient taken as:

C_a = 1.0 for acceptance criteria set AC-I.

3.3.4 Side shell stiffeners

The side shell stiffeners within the strengthening area defined in [3.3.1] are to comply with the following criteria:

a) The effective net plastic section modulus, Z_{pl}, in cm^3 in association with the effective plating to which it is attached, is not to be less than:

$$Z_{pl} = \frac{P_{FB} s l_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

C_s : Permissible bending stress coefficient taken as:

C_s = 0.9 for acceptance criteria set AC-I.

b) The net web thickness, t_w, in mm, is not to be less than:

$$t_w = \frac{P_{FB} s l_{shr}}{2 d_{shr} C_t \tau_{eH}}$$

where:

d_{shr}: Effective web depth of stiffener, in mm, as defined in Ch 3, Sec 7, [1.4.3].

C_t : Permissible shear stress coefficient taken as:

C_t = 1.0 for acceptance criteria set AC-I.

c) The slenderness ratio is to comply with Ch 8, Sec 2.

3.3.5 Bow impact load area for primary supporting members

The scantlings of primary supporting members according to [3.3.6] are based on the application of the bow impact pressure, as defined in Ch 4, Sec 5, [3.3.1], to an idealised bow impact load area of hull envelope plating, A_{BI}, in m^2, is given by:

$$A_{BI} = \frac{1.1 L B C_b}{1000}$$

3.3.6 Primary supporting members

a) The section modulus of the primary supporting member is to apply along the bending span clear of end brackets and cross sectional areas of the primary supporting member are to be applied at the ends/supports and may be gradually reduced along the span and clear of the ends/supports following the distribution of f_{dist} indicated in Figure 3.

b) Primary supporting members in the bow impact strengthening area are to be configured to provide effective continuity of strength and the avoidance of hard spots.

c) End brackets of primary supporting members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross section.

d) Tripping arrangements are to comply with Ch 8, Sec 2, [5.1.1]. In addition, tripping brackets are to be fitted at the toes of end brackets and at locations where the primary supporting member flange is knuckled or curved.

e) The net section modulus of each primary supporting member, Z_{n50}, in cm^3, is not to be less than:

$$Z_{n50} = 1000\frac{f_{bdg-pt} P_{FB} b_{BI} f_{BI} l_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

f_{bdg-pt} : Correction factor for the bending moment at the ends and considering the patch load taken as:

$$f_{bdg-pt} = 3f_{BI}^3 - 8f_{BI}^2 + 6f_{BI}$$

f_{BI} : Patch load modification factor taken as:

$$f_{BI} = \frac{l_{BI}}{l_{bdg}}$$

l_{BI} : Extent of bow impact load area, in m, along the span:

$l_{BI} = \sqrt{A_{BI}}$ but not to be taken as greater than l_{bdg}

b_{BI} : Breadth of impact load area, in m, supported by the primary supporting member, to be taken as the spacing between primary supporting members, S, as defined in Ch 1, Sec 4, Table 5, but not to be taken as greater than l_{BI}.

A_{BI} : Bow impact load area, in m^2, as defined in [3.3.5].

f_{bdg} : Bending moment factor taken as:

f_{bdg} = 12 for primary supporting members with end fixed continuous flange or where brackets at both ends are fitted in accordance with Ch3, Sec 6, [4.4].

C_s : Permissible bending stress coefficient taken as:

C_s = 0.8 for acceptance criteria set AC-I.

f) The net shear area of the web, $A_{shr-n50}$, in cm^2, of each primary supporting member at the support/toe of end brackets is not to be less than:

$$A_{shr-n50} = \frac{5f_{PL}P_{FB}b_{BI}l_{shr}}{C_t\tau_{eH}}$$

where:

f_{PL} : Patch load modification factor taken as:

$$f_{PL} = \frac{l_{BI}}{l_{shr}}$$

l_{BI} : Extent of bow impact load area, in m, along the span taken as,

$l_{BI} = \sqrt{A_{BI}}$ but not greater than l_{shr}

C_t : Permissible shear stress coefficient taken as:

C_t = 0.75 for acceptance criteria set AC-I.

g) The net web thickness of each primary supporting member, t_w, in mm including decks/bulkheads directly welded to the side shell is not to be less than:

$$t_w = \frac{P_{FB}b_{BI}}{\sin\varphi_w\sigma_{cr}}$$

where:

φ_w : Angle, in deg, between the primary supporting member web and the shell plate, see Figure 5.

σ_{crb} : Critical buckling stress in compression of the web of the primary supporting member or deck/bulkhead panel in way of the applied load given by Ch 8, Sec 5, [2.2.3], in N/mm^2. In the calculation, both σ_x and σ_y given in Ch 8, Sec 5, [2.2.3] are to be considered and UP-B is to be applied.

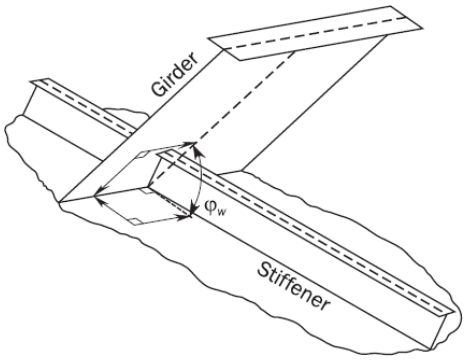


Figure 5 Angle between shell primary member and shell plate

4 ADDITIONAL SCANTLING REQUIREMENTS

4.1 Plate stem

4.1.1

The net thickness, t_{Stm} in mm, from keel line above to T_{SC} + 0.6 m is not to be less than:

$t_{Stm} = (0.6 + 0.4S_B)(0.08L + 2.7)\sqrt{k}$ but need not be greater than $22\sqrt{k} - 1$

where:

S_B: Spacing, in m, between horizontal stringers (partial or not), breasthooks, or equivalent horizontal stiffening members.

Starting from 0.6 m above the summer load waterline up to T_{SC} + C_w, the net thickness may gradually be reduced to $0.8t_{Stm}$.

4.1.2 Breasthooks and diaphragm plating

The net thickness of breasthooks/diaphragm plates in way of bow impact strengthening area defined in [3.3.1], t_w in mm, is not to be less than:

$$t_w = \frac{s}{70}\sqrt{\frac{R_{eH}}{235}}$$

where:

s : Spacing of stiffeners on the web, as defined in Ch 1, Sec 4, Table 5, in mm. Where no stiffeners are fitted, *s* is to be taken as the depth of the web.

4.2 Thruster tunnel

4.2.1

The net thickness of the tunnel plating, t_{tun}, in mm, is not to be less than the net required thickness for the shell plating in the vicinity of the bow thruster.

In addition, t_{tun} is not to be taken less than:

$t_{tun} = 0.008\, d_{tun} + 1.8$

where:

d_{tun} : Inside diameter of the tunnel, in mm, but not to be taken less than 970 mm.

Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

Section 2 MACHINERY SPACE

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to the scantlings and arrangement of structures located in the machinery space. It is the shipyard responsibility to design the ship in accordance with the machinery manufacturer's requirements.

2 MACHINERY SPACE ARRANGEMENT

2.1 Structural arrangement

2.1.1

Where openings in decks/bulkheads are provided in the machinery space, the arrangements are to support the deck, side, and bottom structure.

2.1.2

All parts of the machinery, shafting, etc, are to be supported to distribute the loads into the ship's structure. The adjacent structure is to be suitably stiffened.

2.1.3

Primary supporting members are to be positioned giving consideration to the provision of through stiffeners and in line pillar supports to achieve an efficient structural design.

2.1.4

The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces. Web frames are to be connected at the top and bottom to members of suitable stiffness, and supported by deck transverses.

2.1.5

End connections of side longitudinals at transverse bulkheads are to provide fixity, lateral support, and when not continuous are to be provided with soft-toe brackets. Brackets lapped onto the longitudinals are not to be fitted.

2.1.6

Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

2.1.7

Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

2.1.8

The foundations for main propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are to maintain the required alignment and rigidity under all anticipated conditions of loading. Consideration is to be given to the submittal of the following plans to the machinery manufacturer for review:

a) Foundations for main propulsion units.
b) Foundations for reduction gears.
c) Foundations for thrust bearings.
d) Structure supporting a), b) and c).

2.2 Double bottom

2.2.1 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in Ch 2, Sec 3, [2.3.1]. This depth may need to be considerably increased in relation to the type and depth of main machinery seatings.

The above height is to be increased by the shipyard where the machinery space is very large and where there is a considerable variation in draught between light ballast and full load conditions.

Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be provided by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located in way of floors. Lesser double bottom height may be accepted in local areas provided that the overall strength of the double bottom structure is not thereby impaired.

2.2.2 Centreline girder

The double bottom is to be arranged with a centreline girder. In way of any openings for manholes on the centreline girder, permitted only where absolutely necessary for double bottom access and maintenance, local strengthening is to be arranged.

2.2.3 Side bottom girders

In the machinery space, the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to provide adequate rigidity of the structure. The side bottom girders in longitudinal stiffened double bottom, are to be a continuation of any bottom longitudinals in the areas adjacent to the machinery space and are generally to have a spacing not greater than 3 times that of longitudinals and in no case greater than 3 m.

2.2.4 Girders in way of machinery seatings

Additional side bottom girders are to be fitted in way of machinery seating.

2.2.5 Floors in longitudinally stiffened double bottom

Where the double bottom is longitudinally stiffened, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.

2.2.6 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely stiffened, floors are to be arranged at every frame.

2.2.7 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.

Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.

Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2.8 Inner bottom plating

Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19 mm. Hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and the arrangements of hold-down bolts are also to consider the manufacturer’s recommendations.

2.2.9 Heavy equipment

Where heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders is to be suitably increased.

3 MACHINERY FOUNDATIONS

3.1 General

3.1.1

Main engines and thrust bearings are to be effectively secured to the hull structure by foundations of strength that is sufficient to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

3.1.2

In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integral with the double bottom structure. Consideration is to be given to substantially increase the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case and the thrust bearing, see Type 1 of Figure 1.

3.1.3

For main machinery supported on foundations of Type 2, as shown in Figure 2, the forces from the engine into the adjacent structure are to be distributed as uniformly as possible. Longitudinal members supporting the foundation are to be aligned with girders in the double bottom, and transverse stiffening is to be arranged in line with the floors, see Type 2 of Figure 2.

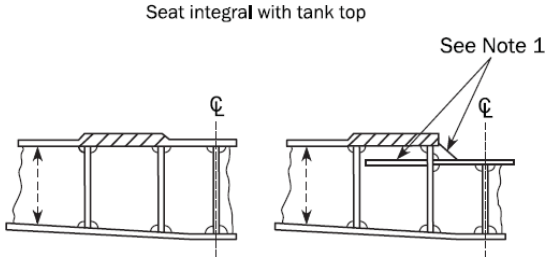


Figure1 Machinery foundations Type 1

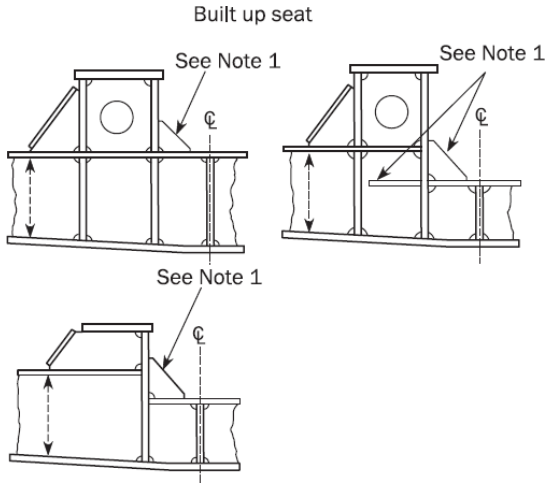


Figure 2 Machinery foundations Type 2

Note1: Brackets are to be as large as possible. Brackets may be omitted to avoid interference with the girders of the engine foundation, in accordance with recommendations of the engine manufacturer.

3.2 Foundations for internal combustion engines and thrust bearings

3.2.1

In determining the scantlings of foundations for internal combustion engines and thrust bearings, consideration is to be given to the general rigidity of the engine and to its design characteristics with regard to out of balance forces.

3.2.2

Generally, two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings.

3.3 Auxiliary foundations

3.3.1

Auxiliary machinery is to be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

Section 3 AFT PART

SYMBOLES
For symbols not defined in this section, refer to Ch 1, Sec 4.

1 GENERAL

1.1 Application

1.1.1
The requirements of this section apply for the scantlings and arrangement of structures located aft of the aft peak bulkhead.

2 AFT PEAK

2.1 Structural arrangement

2.1.1 Floors

Floors are to be fitted at each frame space in the aft peak and carried to a height at least above the stern tube. Where floors do not extend to flats or decks, they are to be stiffened by flanges at their upper end.
Heavy plate floors are to be fitted in way of the aft face of the horn and in line with the webs in the rudder horn. They may be required to be carried up to the first deck or flat. In this area, cut outs, scallops or other openings are to be kept to a minimum.

2.1.2 Platforms and side girders

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.
Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured by adopting wide tapering brackets.
Where the aft peak is adjacent to a machinery space whose side is longitudinally framed, the side girders in the aft peak are to be fitted with tapering brackets.
Where the depth from the peak tank top to the weather deck is greater than 2.6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

2.1.3 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted on the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.
Where either the stern overhang is very large or the maximum breadth of the space divided by watertight and wash bulkheads is greater than 20 m, additional longitudinal wash bulkheads may be required.

2.1.4 Alternative design verification

The spacing and arrangement requirements, defined in [2.1.1], [2.1.2] and [2.1.3] may be increased, if the designer performs a verification by means of grillage analysis or FE analysis and provides their full documentation. The acceptance criteria to be applied are defined in Ch 6, Sec 6, [3]. A FE analysis is to be performed under consideration of the requirements provided in Ch 7.

2.2 Stiffening of floors and girders in aft peak

2.2.1
Stiffeners on the floors and girders in aft peak ballast or fresh water tanks above propeller are to be designed in accordance with [2.2.2] and [2.2.3]. This applies for stiffeners located in an area extending longitudinally between the forward edge of the rudder and the after end of the propeller boss and transversely within the diameter of the propeller.

2.2.2
The height of stiffeners, h_{stf}, in mm, on the floors and girders are not to be less than:
$h_{stf} = 80 l_{stf}$ for flat bar stiffeners.

$H_{stf} = 70 l_{stf}$ for bulb profiles and flanged stiffeners.
where:
l_{stf} : Length of stiffener, in m, as shown in Figure 1. Length need not be taken greater than 5 m.

2.2.3
End brackets are to be provided as follows:

- Brackets are to be fitted at the lower and upper ends when $l_{stf\text{-}t}$ exceeds 4 m.
- Brackets are to be fitted at the lower end when $l_{stf\text{-}t}$ exceeds 2.5 m.

where:
$l_{stf\text{-}t}$:Total length of stiffener, in m, as shown in Figure 1.

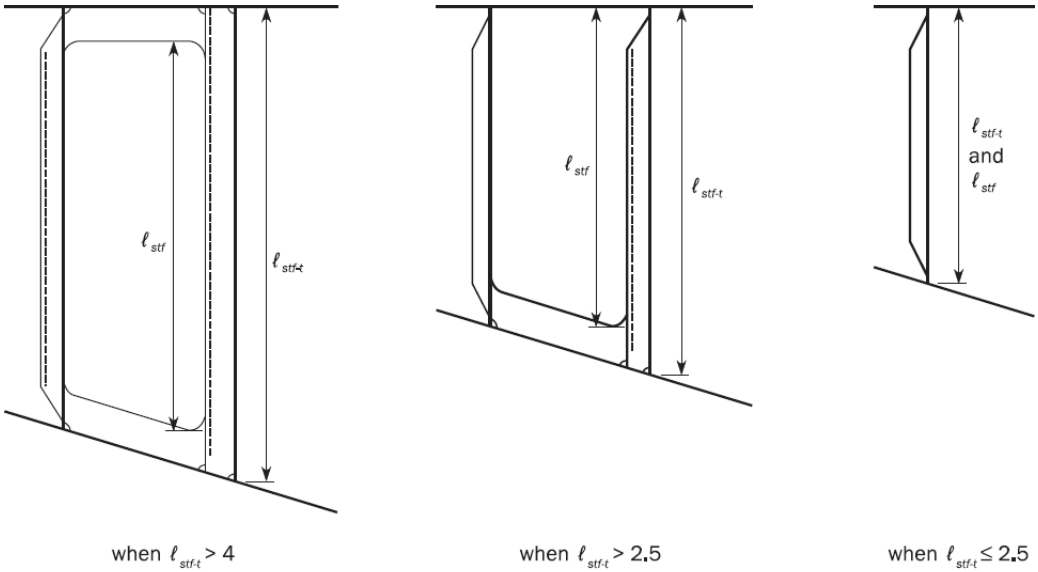


Figure 1 Stiffening of floors and girders in the aft peak tank

3 STERN FRAMES

3.1 General

3.1.1
Stern frames may be fabricated from steel plates or made of cast steel with a hollow section. For applicable material specifications and steel grades, see Ch 3, Sec 1. Stern frames of other material or construction will be specially considered.

3.1.2
Cast steel and fabricated stern frames are to be strengthened by adequately spaced horizontal plates with gross thickness not less than 80% of required thickness for stern frames, t_1, as defined in Table 1 or Table 2. Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

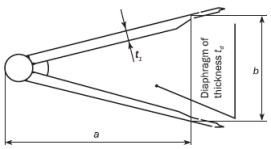
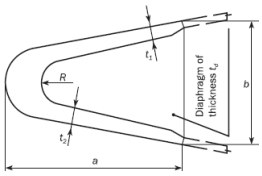
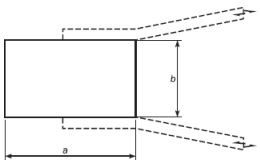
3.1.3
In the upper part of the propeller aperture, where the hull form is full and centreline supports are provided, the thickness of stern frames may be reduced to 80% of the applicable requirement in [3.2.1].

3.2 Propeller posts

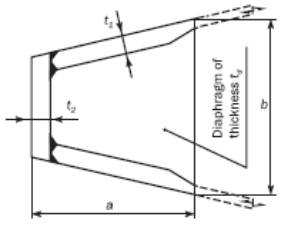
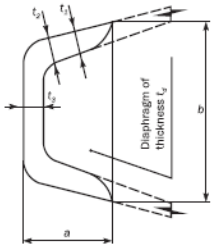
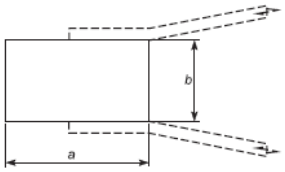
3.2.1 Gross scantlings of propeller posts

The gross scantlings of propeller posts are not to be less than those obtained from the formulae in Table 1 for single screw ships and Table 2 for twin screw ships.
Scantlings and proportions of the propeller post which differ from Table 1 and Table 2 may be considered acceptable provided that the section modulus of the propeller post section about its longitudinal axis is not less than that calculated with the propeller post scantlings in Table 1 or Table 2, as applicable.

Single screw ships - Gross scantlings of propeller posts **Table 1**

Gross scantlings of propeller posts, in mm	Fabricated propeller post	Cast propeller post	Bar propeller post, cast or forged, having rectangular section
			
a	$50\ L_1^{1/2}$	$33\ L_1^{1/2}$	$10\sqrt{7.2L-256}$
b	$35\ L_1^{1/2}$	$23\ L_1^{1/2}$	$10\sqrt{4.6L-164}$
t_1	$2.5\ L_1^{1/2}$	$3.2\ L_1^{1/2}$	-
t_2	-	$4.4\ L_1^{1/2}$	-
t_d	$1.3\ L_1^{1/2}$	$2.0\ L_1^{1/2}$	-
R	-	50mm	-

Twin screw ships - Gross scantlings of propeller posts **Table 2**

Gross scantlings of propeller posts, in mm	Fabricated propeller post	Cast propeller post	Bar propeller post, cast or forged, having rectangular section
			
a	$25\ L_1^{1/2}$	$12.5\ L_1^{1/2}$	$2.4L+6$
b	$25\ L_1^{1/2}$	$25\ L_1^{1/2}$	$0.8L+2$
t_1	$2.5\ L_1^{1/2}$	$2.5\ L_1^{1/2}$	-
t_2	$3.2\ L_1^{1/2}$	$3.2\ L_1^{1/2}$	-
t_3	-	$4.4\ L_1^{1/2}$	-
t_d	$1.3\ L_1^{1/2}$	$2.0\ L_1^{1/2}$	-

3.2.2 Propeller shaft bossing

In single screw ships, the thickness of the propeller shaft bossing, included in the propeller post, is not to be less than 60% of the dimension b required in [3.2.1] for bar propeller posts with a rectangular section.

3.3 Connections

3.3.1 Connections with hull structure

Stern frames are to be effectively attached to the aft structure and the required scantling for the lower part of the propeller post is to be extended from the aft end of the propeller post, at the centerline of the propeller shaft, to a length not less than $1500 + 6L_2$ mm, in order to provide an effective connection with the keel. However, the stern frame need not extend beyond the aft peak bulkhead.

3.3.2 Connection with keel plate

The thickness of the lower part of the stern frames is to be gradually tapered to that of the solid bar keel or keel plate.

Where a keel plate is fitted, the lower part of the stern frame is to be designed to ensure an effective connection with the keel.

3.3.3 Connection with transom floors

Rudder posts and propeller posts are to be connected with transom floors having height not less than that of the double bottom height and a net thickness not less than that obtained, in mm, from the following formula:

$t = 9 + 0.023\ L_1$

3.3.4 Connection with centre girder

Where the stern frame is made of cast steel, the lower part of the stern frame is to be fitted, as far as practicable, with a longitudinal web for connection with the centre girder.

4 SPECIAL SCANTLING REQUIREMENTS FOR SHELL STRUCTURE

4.1 Shell plating

4.1.1 Shell plating connected with stern frame

The net thickness of shell plating connected with the stern frame is not to be less than that obtained, in mm, from the following formula:

$t = 0.094\ (L_2 - 43) + 0.009\ b$

In way of the boss and heel plate, the net thickness, t, of shell plating, in mm, is not to be less than:

$t = 0.105\ (L_2 - 47) + 0.011\ b$

where:

b : Breadth of plate panel, in mm, as defined in Ch 3, Sec 7, [2.2.2].

4.1.2 Heavy shell plates

Heavy shell plates are to be fitted locally in way of the heavy plate floors as required by [2.1.1]. The net thickness of heavy shell plates is not to be less than the value given in [4.1.1]. Outboard of the heavy floors, the heavy shell plates may be reduced in thickness in as gradual a manner as practicable. Where the horn plating is radiused into the shell plating, the radius at the shell connection, r in mm, is not to be less than:

$r = 150 + 0.8L_2$

4.1.3 Thruster tunnel plating

The net thickness of the tunnel plating, t_{tun} in mm, is to comply with the requirements in Ch 10, Sec 1, [4.2.1].

Section 4 TANKS SUBJECT TO SLOSHING

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

α_p : Correction factor for the panel aspect ratio to be taken as:

$$\alpha_p = 1.2 - \frac{b}{2.1a}$$ but not to be taken as greater than 1.0.

a : Length of plate panel, in mm, as defined in Ch 3, Sec 7, [2.1.1].

b : Breadth of plate panel, in mm, as defined in Ch 3, Sec 7, [2.1.1].

l_{bdg} : Effective bending span, as defined in Ch 3, Sec 7, [1.1.2], in m.

l_{slh} : Effective sloshing length, in m, as defined in Ch 4, Sec 6, [6.3.2].

b_{slh} : Effective sloshing breadth, in m, as defined in Ch 4, Sec 6, [6.4.2].

$I_{y\text{-}n50}$: Net horizontal hull girder moment of inertia, at the longitudinal position being considered, as defined in Ch 5, Sec 1, [1.5], in m4.

M_{sw} : Permissible hull girder hogging and sagging still water bending moment for seagoing operation at the location being considered, in kNm, as defined in Ch 4, Sec 4, [2.2.2].

z_n : Distance from the baseline to the horizontal neutral axis, as defined in Ch 5, Sec 1, in m.

z : Vertical coordinate of the load calculation point or at the reference point under consideration, in m.

σ_{hg} : Hull girder bending stress, in N/mm^2, calculated at the load calculation point defined in Ch 3, Sec 7, [2.2] or in Ch 3, Sec 7, [3.2], as the case may be:

$$\sigma_{hg} = (\frac{(z - z_n)M_{sw}}{I_{y-n50}})10^{-3}$$

1 GENERAL

1.1 Application

1.1.1

The requirements of this section cover the strengthening requirements for localised sloshing loads that may occur in tanks carrying liquid.

Sloshing loads due to the free movement of liquid in tanks are given in Ch 4, Sec 6, [6].

1.2 General requirements

1.2.1 Filling heights of cargo and ballast tanks

The scantlings of all cargo and ballast tanks are to comply with the sloshing requirements given in this section for the following cases:

- Unrestricted filling height for ballast tanks,
- Unrestricted filling height for cargo tanks with cargo density equal to ρ_L, as defined in Ch 4, Sec 6,
- All filling levels up to h_{part} for cargo tanks with cargo density equal to ρ_{part} taken as:

$$h_{part} = \frac{h_{tk} \cdot \rho_L \cdot f_{cd}}{\rho_{part}}$$

where:

h_{part} : Maximum permissible filling height, in m, associated with a partial filling of the considered cargo tank with a high liquid density equal to ρ_{part}

h_{tk} : Maximum tank height, in m.

ρ_L : Cargo density as defined in Ch 4, Sec 6.

f_{cd} : Factor defined in Ch 4, Sec 6.

ρ_{part} : Maximum permissible high liquid density as defined in Ch 4, Sec 6.

1.2.2 Cargo holds of bulk carrier intended for the carriage of ballast water

Cargo holds of bulk carrier intended for the carriage of ballast water are assumed either full or empty in seagoing condition and are not required to be assessed for sloshing pressures.

1.2.3 Structural details

Local scantling increases due to sloshing loads are to be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

1.3 Application of sloshing pressure

1.3.1 General

The structural members of the following tanks are to be assessed for the design sloshing pressures $P_{slh\text{-}lng}$ and $P_{slh\text{-}t}$ in accordance with [1.3.4] and [1.3.5].

a) Cargo and slop tanks of oil tankers.
b) Fore peak and aft peak ballast tanks.
c) Other tanks which allow free movement of liquid, e.g. ballast tanks, fuel oil bunkering tanks and fresh water tanks, etc.

Where the effective sloshing length, l_{slh} is less than 0.03 L, calculations involving $P_{slh\text{-}lng}$ are not required and where the effective sloshing breadth b_{slh} is less than 0.32 B, calculations involving $P_{slh\text{-}t}$ are not required.

1.3.2 Minimum sloshing pressure

The minimum sloshing pressure, $P_{slh\text{-}min}$, as defined in Ch 4, Sec 6, [6.2] is to apply to tanks in which the effective sloshing length, l_{slh} or breadth b_{slh}, is less than defined in [1.3.1].

1.3.3 Structural members to be assessed

The following structural members are to be assessed:

a) Plates and stiffeners forming boundaries of tanks.
b) Plates and stiffeners on wash bulkheads.
c) Web plates and web stiffeners of primary supporting members located in tanks.
d) Tripping brackets supporting primary supporting members in tanks.

1.3.4 Application of design sloshing pressure due to longitudinal liquid motion

The design sloshing pressure due to longitudinal liquid motion, $P_{slh\text{-}lng}$, as defined in Ch 4, Sec 6, [6.3.3] is to be applied to the following members as shown in Figure 1.

a) Transverse tight bulkheads.
b) Transverse wash bulkheads.
c) Stringers on transverse tight and wash bulkheads.
d) Plating and stiffeners on the longitudinal bulkheads, deck and inner hull within a distance from the transverse bulkhead taken as:
   - 0.25 l_{slh},
   - The distance between the transverse bulkhead and the first web frame if located inside the tank at the considered level,

   whichever is less.

In addition, the first web frame next to a transverse tight or wash bulkhead if the web frame is located within 0.25l_{slh} from the bulkhead, as shown in Figure 1, is to be assessed for the web frame reflected sloshing pressure, $P_{slh\text{-}wf}$, as defined in Ch 4, Sec 6, [6.3.4].

The minimum sloshing pressure, $P_{slh\text{-}min}$ as defined in Ch 4, Sec 6, [6.2] is to be applied to all other members.

1.3.5 Application of design sloshing pressure due to transverse liquid motion

The design sloshing pressure due to transverse liquid motion, $P_{slh\text{-}t}$, as defined in Ch 4, Sec 6, [6.4.3], is to be applied to the following members as shown in Figure 2.

a) Longitudinal tight bulkhead.
b) Longitudinal wash bulkhead.
c) Horizontal stringers on longitudinal tight and wash bulkheads.
d) Plating and stiffeners on the transverse tight bulkheads including stringers and deck within a distance from the longitudinal bulkhead taken as:
   - 0.25 b_{slh}
   - The distance between the longitudinal bulkhead and the first girder if located inside the tank at the considered level,

   whichever is less.

In addition, the first girder next to the longitudinal tight or wash bulkhead if the girder is located

within 0.25 b_{slh} from the longitudinal bulkhead, as shown in Figure 2, is to be assessed for the reflected sloshing pressure, $P_{slh\text{-}grd}$ as defined in Ch 4, Sec 6, [6.4.4].
The minimum sloshing pressure, $P_{slh\text{-}min}$, as defined in Ch 4, Sec 6, [6.2], is to be applied to all other members.

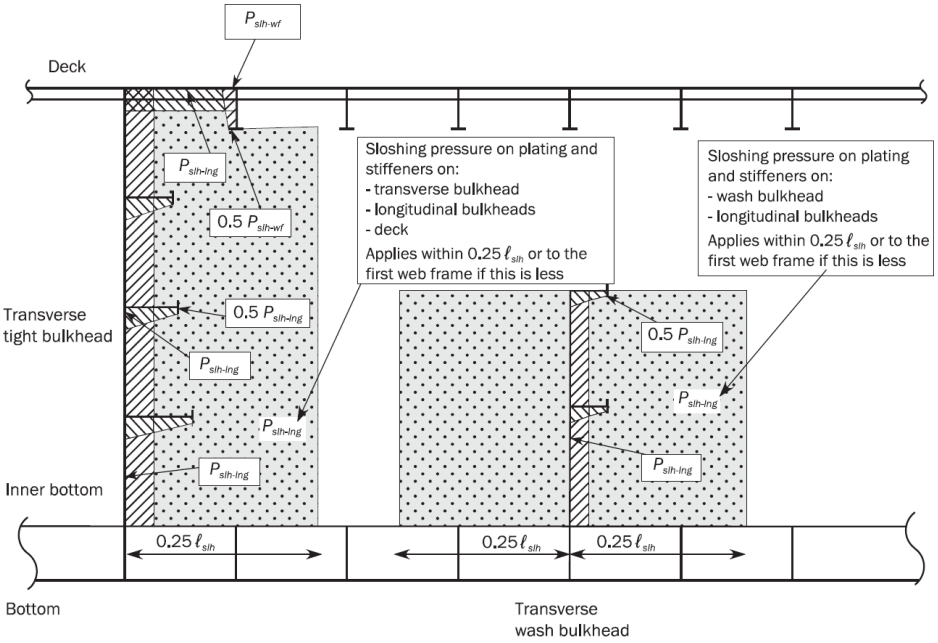


Figure 1 Application of sloshing loads due to longitudinal liquid motion

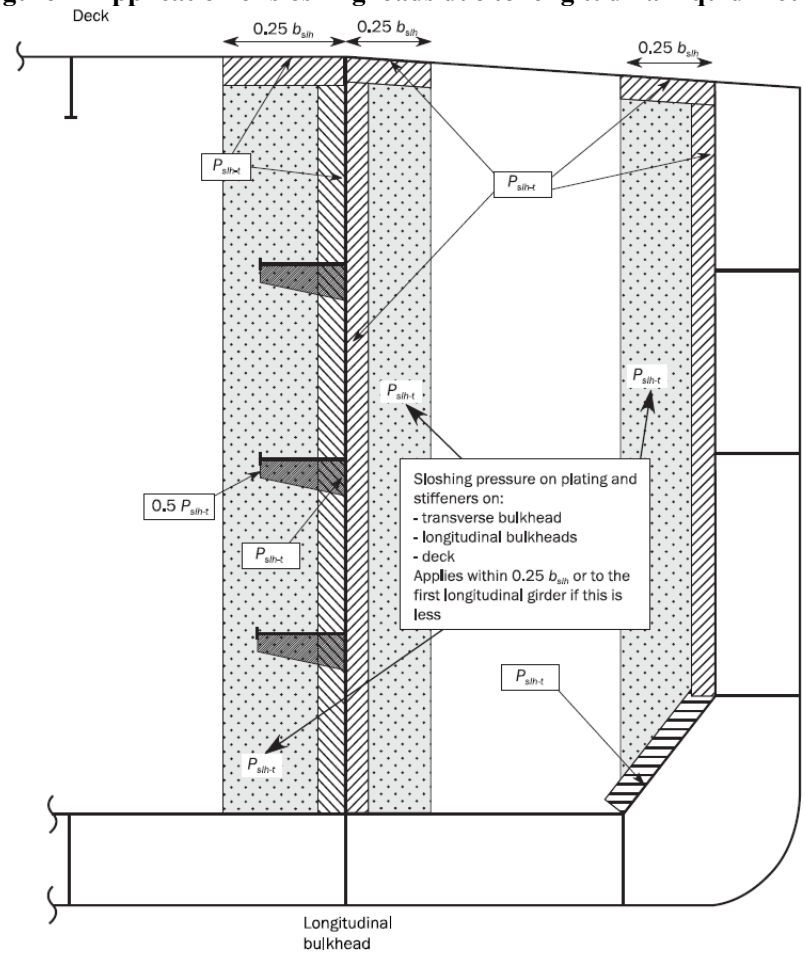


Figure 2 Application of sloshing loads due to transverse liquid motion

1.3.6 Combination of transverse and longitudinal fluid motion

The sloshing pressures due to transverse and longitudinal fluid motion are assumed to act independently. Structural members are therefore to be evaluated based on the greatest sloshing pressure due to longitudinal and transverse fluid motion.

1.3.7 Additional sloshing impact assessment

For tanks with effective sloshing breadth, b_{slh}, greater than 0.56B or effective sloshing length, l_{slh}, greater than 0.13L, an additional sloshing impact assessment is to be carried out in accordance with the individual Society's procedures

CCS 1.3.7a Where l_s>0.13L or b_s>0.56B for the tank, the structural strength assessment under level 3 sloshing loads is to be carried out in accordance with relevant requirements of Section 3 of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

2 SCANTLING REQUIREMENTS

2.1 Plating

2.1.1 Net thickness

The net thickness of plating, t in mm, subjected to sloshing pressures is not to be less than:

$$t = 0.0158\alpha_p b\sqrt{\frac{P_{slh}}{C_a R_{eH}}}$$

where:

C_a : Permissible bending stress coefficient to be taken as:

$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$ with coefficients defined in Table 1, but not to be taken greater than $C_{a\text{-}max}$.

σ_{hg} : Hull girder bending stress, in N/mm^2, corresponding to the greatest of the sagging and hogging bending moment in absolute value.

P_{slh} : The greater of $P_{slh\text{-}lng}$, $P_{slh\text{-}t}$ or $P_{slh\text{-}min}$ as specified in [1.3].

Definition β_a, α_a and $C_{a\text{-}max}$ **Table 1**

Acceptance criteria set	Structural member		β_a	α_a	$C_{a\text{-}max}$
AC-S	Longitudinal strength members in the cargo hold region including but not limited to: ● Deck. ● Longitudinal plane bulkhead. ● Horizontal corrugated longitudinal bulkhead. ● Longitudinal girders and stringers.	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely or vertically stiffened plating	0.9	1.0	0.8
	Other strength members including: ● Vertical corrugated longitudinal bulkhead. ● Transverse plane bulkhead. ● Transverse corrugated bulkhead. ● Transverse stringers and web frames. ● Plating of tank boundaries and primary supporting members outside the cargo hold region.		0.8	0	0.8

2.2 Stiffeners

2.2.1 Net section modulus

The net section modulus, Z in cm^3, of stiffeners subjected to sloshing pressures is not to be less than:

$$Z = \frac{P_{slh} s l_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

f_{bdg} : Bending moment factor:

f_{bdg} = 12 for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners.

f_{bdg} = 8 for stiffeners with one or both ends not fixed against rotation. This is generally to be

applied to discontinuous stiffeners.

C_s : Permissible bending stress coefficient to be taken as:

- For members subject to hull girder stress: coefficient to be taken as defined in Table 2.
- $C_s = C_{s\text{-}max}$ for other cases.

P_{slh} : The greater of $P_{slh\text{-}ing}$, $P_{slh\text{-}t}$ or $P_{slh\text{-}min}$ as specified in [1.3].

$C_{s\text{-}max}$: Coefficient as defined in Table 3.

Permissible bending stress coefficient C_s **Table 2**

Sign of hull girder bending stress, σ_{hg} (1)	Lateral pressure acting on (2)	Stiffener boundary condition (3)	f_{bdg}	Coefficient C_s
Tension (positive)	Stiffener side	F - F	12	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		F - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		S - S	8	$C_s = C_{s\text{-}max}$
	Plate side	F - F	12	$C_s = C_{s\text{-}max}$
		F - S	8	$C_s = C_{s\text{-}max}$
		S - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression (negative)	Stiffener side	F - F	12	$C_s = C_{s\text{-}max}$
		F - S	8	$C_s = C_{s\text{-}max}$
		S - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
	Plate side	F - F	12	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		F - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
		S - S	8	$C_s = C_{s\text{-}max}$

(1) σ_{hg} is to be considered for the hogging and sagging situations.
(2) For primary supporting members located inside the considered tank and for wash bulkheads, the sloshing pressure is to be applied both on stiffener and plate sides.
(3) F - F stands for both ends of the stiffener fixed against rotation
(4) F - S stands for one end of the stiffener fixed and the other not fixed against rotation
(5) S - S stands for both ends of the stiffener not fixed against rotation

Definition β_s ,α_s and $C_{s\text{-}max}$ **Table 3**

Acceptance criteria set	Structural member		β_s	α_s	$C_{s\text{-}max}$
AC-S	Longitudinal strength members in the cargo hold region including but not limited to: ● Deck stiffeners. ● Stiffeners on longitudinal bulkheads. ● Stiffeners on longitudinal girders and stringers.	Longitudinal stiffeners	0.85	1.0	0.75
		Transverse or vertical stiffeners	0.7	0	0.7
	Other strength members including: ● Stiffeners on transverse bulkheads. ● Stiffeners on transverse stringers and web frames. ● Stiffeners on tank boundaries and primary supporting members outside the cargo hold region.		0.75	0	0.75

2.3 Primary supporting members

2.3.1 Web plating

The web plating net thickness of primary supporting members, t in mm, is not to be less than:

$$t = 0.0158\alpha_p b\sqrt{\frac{P_{slh}}{C_a R_{eH}}}$$

where:

P_{slh} : The greater of $P_{slh\text{-}Ing}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ and $P_{slh\text{-}min}$ as specified in [1.3]. The pressure is to be calculated at the load application point, defined in Ch 3, Sec 7, [4.1], taking into account the distribution over the height of the member, as shown in Figure 1 and Figure 2.

C_a : Permissible plate bending stress coefficient, as given in [2.1.1].

2.3.2 Stiffeners on web plating

The net section modulus, Z in cm3, of each individual stiffener on the web plating of primary supporting members subjected to sloshing pressures is not to be less than:

$$Z = \frac{P_{slh} s l_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

P_{slh} : The greater of $P_{slh\text{-}Ing}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ and $P_{slh\text{-}min}$ as specified in [1.3]. The pressure is to be calculated at the load application point, defined in Ch 3, Sec 7, [3.2], taking into account the distribution over the height of the member, as shown in Figure 1 and Figure 2.

C_s : Permissible bending stress coefficient as given in [2.2.1].

f_{bdg} : Bending moment factor as given in [2.2.1].

2.3.3 Tripping brackets supporting primary supporting members

The net section modulus, Z in cm^3 in way of the base within the effective length, d, of tripping brackets and net shear area, A_{shr} in cm^2, after deduction of cut-outs and slots, of tripping brackets supporting primary supporting members is not to be less than:

$$Z = \frac{1000 P_{slh} s_{trip} h^2}{2 C_s R_{eH}}$$

$$A = 10\frac{P_{slh} s_{trip} h}{C_t \tau_{eH}}$$

where:

P_{slh} : The greater of $P_{slh\text{-}Ing}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ and $P_{slh\text{-}min}$ as specified in [1.3]. The average pressure may be calculated at mid point of the tripping bracket taking into account the distribution as shown Figure 1 and Figure 2.

s_{trip} : Mean spacing, between tripping brackets or other primary supporting members or bulkheads, in m.

h : Height of tripping bracket, see Figure 3, in m.
C_s : Permissible bending stress coefficient for tripping brackets to be taken as 0.75.
C_t : Permissible shear stress coefficient for tripping brackets to be taken as 0.75.
The effective breadth of the attached plate to be used for calculating the section modulus of the tripping bracket is to be taken as h/3.

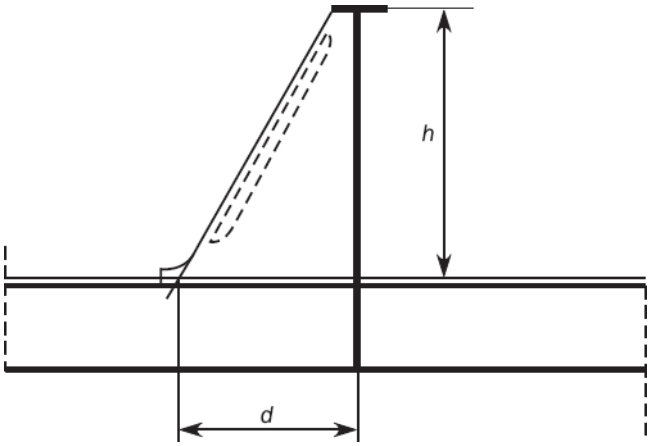


Figure 3 Effective length of tripping bracket

Chapter 11 SUPERSTRUCTURE, DECKHOUSES AND HULL OUTFITTING

Section 1 SUPERSTRUCTURES AND DECKHOUSES

SYMBOLS

For symbols not defined in this section, refer to Ch 1, Sec 4.

P : Pressure applied on the considered superstructure side or deck, in kN/m^2

$P = P_D$ for exposed decks,

$P = P_{dl}$ for unexposed deck,

$P = P_{SI}$ for superstructure side.

P_D : Lateral pressure for exposed decks, in kN/m^2, as defined in Ch 4, Sec 5, [2] and in Ch 4, Sec 5, [4.2].

P_{dl} : Lateral pressure for unexposed decks, in kN/m^2, as defined in Ch 4, Sec 6, [5].

P_{SI} : Lateral pressure for superstructure side, in kN/m^2, as defined in Ch 4, Sec 5, [4.3].

P_{FB}: Lateral pressure for side shell plating, in kN/m^2, affected by bow impact requirements according to Ch 4, Sec 5, [3.3.1].

P_A : External pressure for end bulkheads of superstructure and deckhouse walls, in kN/m^2 according to Ch 4, Sec 5, [4.4.1].

l_{bdg} : Effective bending span, in m, as defined in Ch 3, Sec 7.

l_{shr} : Effective shear span, in m, as defined in Ch 3, Sec 7.

c : Coefficient taken as:

$c = 0.75$ for beams, girders and transverses which are simply supported in one or both ends.

$c = 0.55$ in other cases.

m_a : Coefficient taken as:

$$m_a = 0.204 \frac{s}{1000 l_{bdg}} \left[4 - \left(\frac{s}{1000 l_{bdg}} \right)^2 \right] \text{ with } \frac{s}{1000 l_{bdg}} \leq 1$$

1 GENERAL

1.1 Application

1.1.1

The requirements of this section are applicable to superstructures and deckhouses made of steel. The scantling requirements are listed in Table 1.

Applicable requirements **Table 1**

Item	Superstructure	Deckhouse
Exposed decks	[3.1.1]	[3.2]
Unexposed decks	[3.2.2] to [3.2.5]	[3.2]
Side walls	[3.1.1]	[3.3]
End bulkheads (fore and aft)	[3.3]	[3.3]

1.1.2

For the application of this section, a superstructure is considered being located aft or forward 0.4L amidships or having a length of less than 0.15 L.

1.1.3

For the application of this section, the length of a deckhouse located within 0.4 L amidships is considered not exceeding 0.2 L.

1.2 Gross scantlings

1.2.1

With reference to Ch 3, Sec 2, [1.1.3], all scantlings and dimensions referred to in [3] are gross, unless otherwise specified.

2 STRUCTURAL ARRANGEMENT

2.1 Structural continuity

2.1.1 Bulkheads and sides of deckhouses

The aft, front and side bulkheads are to be effectively supported by under deck structures such as bulkheads, girders and pillars.

Sides and main longitudinal and transverse bulkheads are to be in line in the various tiers of deckhouses. Where such arrangement in line is not possible, other effective support is to be provided.

Arrangements are to be made to minimize the effect of discontinuities in erections. All openings cut in the sides are to be framed and have well-rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings.

2.1.2 Deckhouse corners

At the corners where the deckhouse is attached to the strength deck, attention is to be given to the arrangements to transmit load into the under deck supporting structure.

2.2 End connections

2.2.1 Deck stiffeners

Transverse beams are to be connected to side frames by brackets according to Ch 3, Sec 6, [3.2.1], [3.2.2] and [3.2.3]. Beams crossing longitudinal walls and girders may be attached to the stiffeners of longitudinal walls and the webs of girders respectively by welding without brackets.

2.2.2 Longitudinal and transverse deck girders

Face plates are to be stiffened by tripping brackets according to Ch 3, Sec 6, [4.3].

2.2.3 End connections of superstructure frames

Vertical frames are to be welded to the main frames below, or to the deck under provision of a sufficient supporting structure.

2.3 Local reinforcement on bulkheads

2.3.1

Local reinforcement is to be provided in way of large openings and areas supporting life saving appliances or high loads from other equipment, fittings, etc.

3 SCANTLINGS

3.1 Superstructures sides and decks

3.1.1 Exposed sides and exposed decks

When the side of superstructure is part of the side shell, the net scantlings of exposed sides and exposed decks plating, stiffeners and primary supporting members are to comply with the applicable requirements of Ch 6, Sec 3, Ch 6, Sec 4, Ch 6, Sec 5 and Ch 6, Sec 6, respectively, with the pressure P_D , P_{dl} and P_{SI} defined in this Section. The net scantling approach defined in Ch 3, Sec 2 and the corrosion additions defined in Ch 3, Sec 3, are to be considered.

When the side of superstructure is not part of the side shell, the exposed sides and exposed deck plating inclusive their supporting structure are to comply with the requirements given in [3.3], [3.2.1] and [3.2.3] to [3.2.5], respectively.

3.2 Deckhouses decks

3.2.1 Exposed deck plating

The gross thickness of the deckhouses exposed deck plating, $t_{gr\text{-}exp}$, in mm, is not to be less than

$$t_{gr-\exp} = 7.5\sqrt{\frac{ks}{s_{std}}}$$, on first tier

$t_{gr-\exp} = 7.0\sqrt{\frac{ks}{s_{std}}}$, on second tier.

$t_{gr-\exp} = 6.5\sqrt{\frac{ks}{s_{std}}}$, on third tier and above.

where:

s_{std} *:* Standard reference spacing of stiffeners or beams, in mm, taken as:

$s_{std} = 470 + 1.67\,L_1$

Where deck is protected by sheathing, the gross thickness of the deck plating may be reduced by 1.5 mm, without being less than 5 mm.

Where sheathing other than wood is used, attention is to be paid that the sheathing does not affect the steel. The sheathing is to be effectively fitted to the deck.

3.2.2 Unexposed deck plating

The gross thickness of the deckhouses unexposed deck plating, $t_{gr\text{-}unexp}$, in mm, is not to be less than the greater value of:

$t_{gr\text{-}unexp}=0.9t_{gr\text{-}exp}$, at the tier considered, and

$t_{gr\text{-}unexp} = (5.8\frac{s}{1000}+1)\sqrt{k}$, but not less than 5.5 mm.

3.2.3 Beams and stiffeners

The gross section modulus Z_{gr}, in cm^3, and the gross shear area $A_{gr\text{-}sh}$, in cm^2, of deckhouses deck transverse beams and of stiffeners are not to be less than:

$$Z_{gr} = ckP\frac{s}{1000}{l_{bdg}}^2$$

$$A_{gr-sh} = 0.05(1-0.817m_a)kP\frac{s}{1000}l_{shr}$$

3.2.4 Girders and transverses

The gross section modulus Z_{gr}, in cm^3, and the gross shear area $A_{gr\text{-}sh}$, in cm^2, of deckhouses deck girders and transverses are not to be less than:

$$Z_{gr} = ckPS{l_{bdg}}^2$$

$$A_{gr-sh} = 0.05kPSl_{shr}$$

The girder depth is not to be less than l/25. The web depth of girders scalloped for continuous deck beams is to be at least 1.5 times the depth of the deck beams.

3.2.5 Alternative grillage analysis for girders and transverses

Where arrangements of deck girders and transverses are such that these members act as a grillage structure, additional analysis may be carried out with a structural model based on the gross scantling.

The resulting stresses are not to exceed the following permissible bending, shear and equivalent stresses, in N/mm^2, taken as:

σ_b=150/k

τ=100/k

σ_{eqv}=180/k

3.3 Deckhouses walls and end bulkheads of superstructures

3.3.1 Application

The requirements in [3.3] apply to end bulkhead of superstructure and deckhouse walls forming the only protection for openings and for accommodations.

Special consideration may be given to the bulkhead scantlings of deckhouses which do not protect openings in the freeboard deck, superstructure deck or in the top of a lowest tier deckhouse. Special consideration may also be given to the bulkhead scantlings of deckhouses which do not

protect machinery casings, provided they do not contain accommodation or do not protect equipment essential to the operation of the ship.

CCS 3.3.1a The bulkheads scantling of deckhouses which do not protect openings in the freeboard deck, superstructure deck or in the top of a lowest tier deckhouse are to comply with the requirements of [3.3.2] and [3.3.3]. The bulkheads scantlings of deckhouses which do not protect machinery casings are also to comply with the requirements of [3.3.2] and [3.3.3].

3.3.2 Plate thickness

The gross thickness of the plating t_{gr}, in mm, is not to be less than the greater of:

$$t_{gr} = 0.9\frac{s}{1000}\sqrt{kP_A} + 1.5$$

$t_{gr} = (5.0 + \frac{L_2}{100})\sqrt{k}$, for the lowest tier.

$t_{gr} = (4.0 + \frac{L_2}{100})\sqrt{k}$, for the upper tiers, without being less than 5.0 mm.

3.3.3 Stiffeners

The gross section modulus Z_{gr}, in cm^3, of the stiffeners is not to be less than:

$$Z_{gr} = 0.35kP_A\frac{s}{1000}l^2$$

This requirement assumes the webs of lowest tier stiffeners to be efficiently welded to the decks. Scantlings for other types of end connections are to be specially considered.

The section modulus of deckhouse side stiffeners needs not to be greater than that of side frames on the deck situated directly below, taking account of spacing *s* and span *l*.

Section 2 BULWARK AND GUARD RAILS

1 GENERAL REQUIREMENTS

1.1 Application

1.1.1

Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks, at the boundary of first tier of deckhouses and at the ends of superstructures.

1.2 Minimum height

1.2.1

Bulwarks, or guard rails, are to be a minimum of 1.0 m in height, measured above sheathing, and are to be constructed as required in [2.2] and [3.2]. Where this height would interfere with the normal operation of the ship, a lesser height may be accepted, on the basis of justifying information to be submitted.

2 BULWARKS

2.1 General

2.1.1

Plate bulwarks are to be stiffened at the upper edge by a suitable rail and supported either by stays or plate brackets spaced not more than 2.0 m apart.

The free edge of the stay or the plate bracket is to be stiffened.

2.1.2

Within 0.6 *L* amidships, bulwarks are to be arranged to ensure that they are free from hull girder stresses.

2.1.3

Bulwarks are to be adequately strengthened and increased in thickness in way of mooring pipes.

Cut-outs in bulwarks for gangways or other openings are to be kept clear of breaks of superstructures.

2.1.4

Bulwark plating and stays are to be adequately strengthened in way of eye plates used for shrouds or other tackles in use for cargo gear operation, as well as in way of hawser holes or fairleads provided for mooring or towing.

2.1.5

Openings in bulwarks are to be arranged so that the protection of the crew is to be at least equivalent to that provided by the horizontal courses in [3.1.2].

For this purpose, vertical rails or bars spaced approximately 230 mm apart may be accepted in lieu of rails or bars arranged horizontally.

2.1.6

In the case of ships intended for the carriage of timber deck cargoes, the specific provisions of the freeboard regulations are to be complied with.

2.1.7

Where mooring fittings subject the bulwark to large forces, the stays are to be adequately strengthened.

2.2 Construction of bulwarks

2.2.1 Plating

The gross thickness of bulwark plating, at the boundaries of exposed freeboard and superstructure decks, is not to be less than that given in Table 1.

2.2.2 Stays

The gross section modulus of stays, $Z_{stay\text{-}gr}$, in cm^3, is not to be less than:

$$Z_{stay-gr} = 77 h_{blwk}{}^2 s_{stay}$$

where:

h_{blwk} : Height of bulwark from the top of the deck plating to the top of the rail, in m.

s_{stay} : Spacing of the stays, in m.

In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck. Where the bulwark plating is connected to the sheer strake, a width of attached plating, not exceeding 600 mm, may also be included.

Thickness of bulwark plates **Table 1**

Height of bulwark	Gross thickness
1.8 m or more	Thickness required for a superstructure side in the same position, obtained from Ch11, Sec 1 [3.2.1], but not to be less than 6.5 mm
1.0 m	6.5 mm
Intermediate height	To be determined by linear interpolation

2.2.3

Where bulwarks are cut completely, stays or plate brackets of increased strength are to be fitted at the ends of openings.

Bulwark stays are to be supported by, or are to be in line with, suitable under deck stiffening. The stiffening is to be connected by double continuous fillet welds in way of bulwark stay connections.

2.2.4

At the ends of superstructures and for the distance over which their side plating is tapered into the bulwark, the latter is to have the same thickness as the side plating. Where openings are cut in the bulwark at these positions, adequate compensation is to be provided either by increasing the thickness of the plating or by other suitable means.

3 GUARD RAILS

3.1 General

3.1.1

Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

3.1.2

In Type B-100 and Type A ships, open rails on the weather parts of the freeboard deck for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with ICLL are to be fitted.

3.2 Construction of guard rails

3.2.1

Stanchions of guard rails are to comply with the following requirements:

a) Fixed, removable or hinged stanchions are to be fitted approximately 1.5 m apart.
b) At least every third stanchion is to be supported by a bracket or stay.
c) Removable or hinged stanchions are to be capable of being locked in the upright position.
d) In the case of ships with rounded sheer strake, the stanchions are to be placed on the flat of the deck.
e) In the case of ships with welded sheer strake, the stanchions are not to be attached to the sheer strake, upstand or a continuous gutter bar.

3.2.2

The size of openings, below the lowest course of rails and the deck or upstand, is to be a maximum of 230 mm. The distance between other courses is not to be greater than 380 mm.

3.2.3
Wire ropes may be accepted, in lieu of guard rails, only in special circumstances and then only in limited lengths. In such cases, they are to be made taut by means of turnbuckles.

3.2.4
Chains may be accepted, in lieu of guard rails, only where they are fitted between two fixed stanchions and/or bulwarks. if the opening is wide, the chains are to be fitted with vertical courses to prevent the horizontal courses from spreading apart.

Section 3 EQUIPMENT

SYMBOLS
DELETED

1 GENERAL

1.1 Application

1.1.1
Anchoring equipment shall be considered by individual Society.

CCS 1.1.1a Anchoring equipment is to comply with the requirements of PART TWO, Ch 3, Sec 2 of CCS Rules for Classification of Sea-going Steel Ships.

Section 4 SUPPORTING STRUCTURE FOR DECK EQUIPMENT AND FITTINGS

SYMBOLS
DELETED

1 GENERAL

1.1 Application

1.1.1
The supporting structure and foundations for deck equipment and fittings shall be considered by individual Society in addition to the requirements in this section.

CCS 1.1.1a In addition to the requirements of this section, the supporting structure and foundations for deck equipment and fittings are to comply with the requirements of PART TWO, Ch 3, Sec 6 of CCS Rules for Classification of Sea-going Steel Ships. The corrosion addition shall comply with the requirements of Ch 3, Sec 3 of this part.

1.1.2
Where deck equipment is subject to multiple load cases, such as operational loads and green sea load, the loads are be applied independently for the evaluation of strength of foundations and support structure.

1.2 Documents to be submitted

1.2.1
The documents to be submitted are indicated in Ch 1, Sec 3.

2 ANCHORING WINDLASS AND CHAIN STOPPER

2.1 General

2.1.1
The windlass is to be efficiently bedded and secured to the deck.

2.1.2
The builder and the windlass manufacturer are to ensured that the foundation is suitable for the safe operation and maintenance of the windlass equipment.

2.1.3
The supporting structure is to be dimensioned to ensure that for each of the load scenarios specified in [2.1.5] and [2.1.6], the stresses do not exceed the permissible values given in [2.1.12] to [2.1.15].

CCS 2.1.3a For the strength check of supporting structure and foundation, a three-dimensional FE model may be applied in the analysis. The principles for extent, element types and boundary conditions of a three- dimensional model are as follows:

(1) Extent and boundary conditions: The structural model is a local three-dimensional one (hereinafter referred to as local model), centred on the centroid of a plane rectangle (a×b) for effects of the foundation and extending outwards for a distance respectively at least one time the length and width corresponding to the rectangle (3a ×3b). This extension reaches vertically from the foundation plane to the first platform (deck) under main deck or at least D/4 (D being moulded depth). Where there is no primary support member of the structure at the boundary taken in the above way, the model is to further extend until the boundary is at such support member. Free or fixed support may be taken into account for boundary conditions. Where the boundary conditions or the extent of the model is sensitive to calculation results of the centre area, the extent taken for the local model is to be suitably extended again, provided that calculation results of the centre area will not be affected.

(2) Idealization of local model: The principles for element selection, properties and model meshing etc. are as given in Section 1 of Chapter 7.

CCS 2.1.3b In accordance with the design load of 2.1.3, the allowable equivalent stress of plate

element $[\sigma_e] = 1.00R_{eH.}$
where:
R_{eH} *– yield stress of material, in* N/mm^2.

2.1.4
These requirements are to be assessed based on net scantlings.

2.1.5
The following load cases are to be examined for the anchoring operation, as appropriate:

a) Windlass where chain stoppers are fitted but not attached to the windlass is provided: 45% of BS.
b) Windlass where no chain stopper is fitted or the chain stopper is attached to the windlass: 80% of BS.
c) Chain stopper: 80% of BS.

where:
BS : Minimum breaking strength of the chain cable.

2.1.6
The following forces are to be applied in the independent load cases that are to be examined for the design loads due to green sea over the forward 0.25 *L*, see Figure 1:
$P_x = 200\ A_x$, in kN, acting normal to the shaft axis.
$P_y = 150\ A_y\ f$, in kN, acting parallel to the shaft axis (inboard and outboard directions to be examined separately).
where:
A_x : Projected frontal area, in m^2.
A_y : Projected side area, in m^2.
f : Coefficient taken as:
$f = 1 + B_w/H$, but not to be taken greater than 2.5.
B_w : Breadth of windlass measured parallel to the shaft axis, in m, see Figure 1.
H : Overall height of windlass, in m, see Figure 1.

2.1.7
Forces resulting from green sea design loads in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by a number of bolt groups, *N*, each containing one or more bolts. See Figure 2.

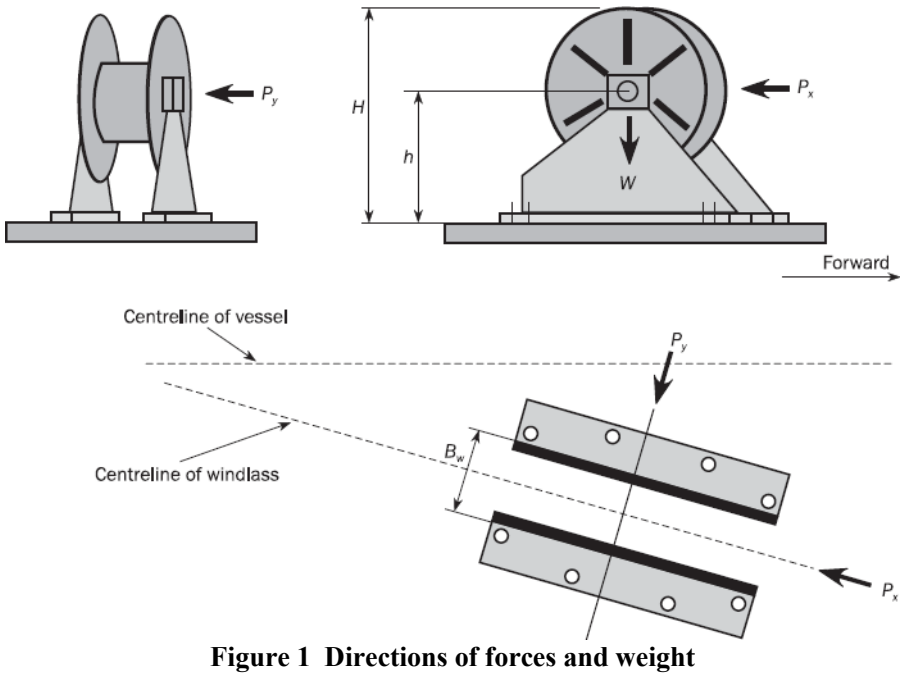


Figure 1 Directions of forces and weight

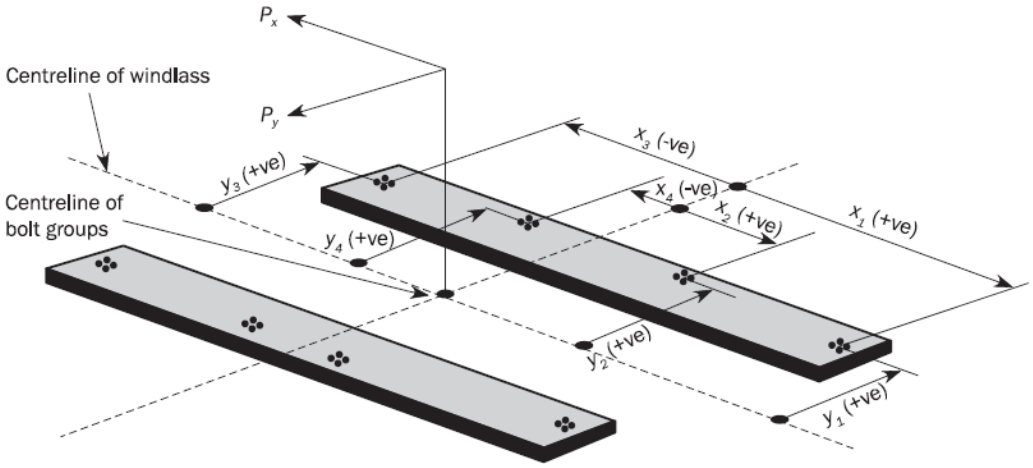


Figure 2 Bolting arrangements and sign conventions

2.1.8

The axial forces, *Rxi* and *Ryi*, in bolt group (or bolt) *i*, positive in tension, are given by:

$$R_{xi} = P_x h x_i A_i / I_x$$

$$R_{yi} = P_y h y_i A_i / I_y$$

$$R_i = R_{xi} + R_{yi} - R_{si}$$

where:

P_x : Force acting normal to the shaft axis, in kN.

P_y : Force acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in bolt group *i*, in kN.

h : Shaft centre height above the windlass mounting, in cm, see Figure 1.

x_i, y : x and y coordinates of bolt group *i* from the centroid of all *N* bolt groups, in cm. Positive in the direction opposite to that of the applied force.

A_i : Cross sectional area of all bolts in group *i*, in cm^2.

I_x : Inertia in x direction for *N* bolt groups, in cm^4, taken as:

$$I_x = \Sigma A_i x_i^2$$

I_y : Inertia in y direction for *N* bolt groups, in cm^4, taken as:

$$I_y = \Sigma A_i y_i^2$$

R_{si} : Static reaction at bolt group *i*, due to the weight of windlass, in kN.

2.1.9

The shear forces, F_{xi} and F_{yi}, applied to the bolt group *i*, and the resultant combined force F_i, are given by:

$$F_{xi} = (P_x - C_1 mg) / N$$

$$F_{yi} = (P_y - C_1 mg) / N$$

$$F_i = \sqrt{F_{xi}^{\ 2} + F_{yi}^{\ 2}}$$

where:

C_1 : Coefficient of friction, taken equal to 0.5.

m : Mass of windlass, in t.

g : Acceleration due to gravity, taken equal to 9.81 m/s^2.

N : Number of bolt groups.

2.1.10

The resultant forces from the application of the loads specified in [2.1.5] and [2.1.6] are to be considered in the design of the supporting structure.

2.1.11

Where a separate foundation is provided for the windlass brake, the distribution of resultant forces is to be calculated on the assumption that the brake is applied for load cases (a) and (b) defined in

[2.1.5].

2.1.12
The stresses resulting from anchoring design loads induced in the supporting structure are not to be greater than the following permissible values:

- Normal stress, 1.00 R_{eH}
- Shear stress, 0.6 R_{eH}

2.1.13
The tensile axial stresses resulting from green sea design loads in the individual bolts in each bolt group *i* are not to exceed 50% of the bolt proof strength. The load is to be applied in the direction of the chain cable. Where fitted bolts are designed to support shear forces in one or both directions, the von Mises equivalent stresses are not to exceed 50% of the bolt proof strength.

2.1.14
The horizontal forces resulting from the green sea design loads, F_{xi} and F_{yi} may be supported by shear chocks. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculation.

2.1.15
The stresses resulting from green sea design loads induced in the supporting structure are not to be greater than the following permissible values:

- Normal stress, 1.00 R_{eH}.
- Shear stress, 0.6 R_{eH}.

3 CRANES, DERRICKS, LIFTING MASTS AND LIFE SAVING APPLIANCES

3.1 General

3.1.1
Supporting structure of life saving appliances and supporting structures of cranes, derricks and lifting masts with a Safe Working Load greater than 30kN, or a maximum overturning moment to the supporting structure greater than 100kNm, are to comply with these requirements.

3.1.2
These requirements apply to the connection to the deck and the supporting structure of cranes, derricks and lifting masts. Where the crane, derrick or lifting mast is to be certified by the Society, additional requirements may be applied by the Society.

CCS 4.1.2a In addition to the requirements of 4.1.2, the applicable requirements of Section 10, Chapter 3 of CCS Rules for Lifting Appliances of Ships and Offshore Installations are also to be complied with.

3.1.3
These requirements do not cover the following items:

a) Supports of lifting appliances for personnel or passengers, except foundation for life saving appliances.
b) The structure of the lifting appliance pedestals or post above the area of the deck connection.
c) Holding down bolts and their arrangement, which are considered part of the lifting appliance. The term ‘lifting appliance’ is defined as a crane, derrick or lifting mast.

3.1.4 SWL Definition
The Safe Working Load (SWL) is defined as the maximum load which the lifting appliance is certified to lift at any specified outreach.

3.1.5 Self weight
The self weight is the calculated gross self weight of the lifting appliance, including the weight of

any lifting gear.

3.1.6 Overturning moment

The overturning moment is the maximum bending moment, calculated at the connection of the lifting appliance to the ship structure, due to the lifting appliance operating at Safe Working Load, taking into account outreach and self weight.

3.1.7

The crane pedestal and derrick mast are as defined in Figure 3.

3.1.8

Deck plating and under deck structure is to provide adequate support for derrick masts and crane pedestals against the loads and maximum overturning moment. Where the deck is penetrated, the deck plating is to be suitably strengthened.

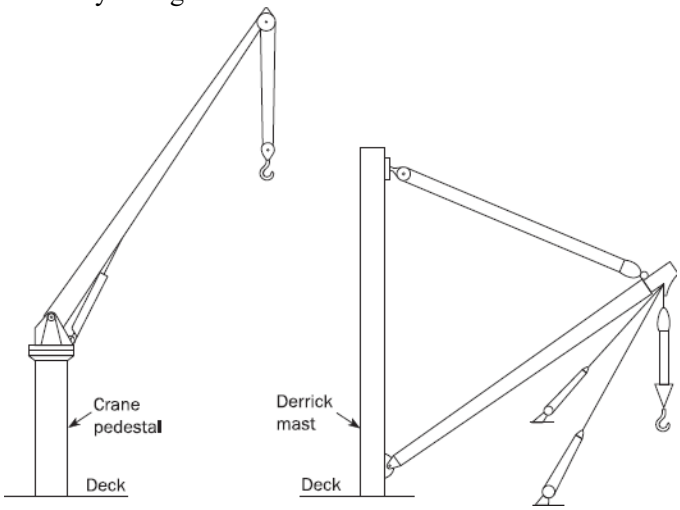


Figure 3 Crane pedestal and derrick mast

3.1.9

Structural continuity of the deck structure is to be maintained.

Under deck members are to be provided to support the crane pedestal and to comply with:

a) Where the pedestal is directly connected to the deck, without above deck brackets, adequate under deck structure directly in line with the crane pedestal is to be provided. Where the crane pedestal is attached to the deck without bracketing or where the crane pedestal is not continuous through the deck, welding to the deck of the crane pedestal and its under deck support structure is to be made by suitable full penetration welding. The design of the weld connection is to be adequate for the calculated stress in the welded connection, in accordance with [3.1.15].

b) Where the pedestal is directly connected to the deck with brackets, under deck support structure is to be fitted to ensure a satisfactory transmission of the load, and to avoid structural hard spots. Above deck brackets may be fitted inside or outside of the pedestal and are to be aligned with deck girders and webs. The design is to avoid stress concentrations caused by an abrupt change of section. Brackets and other direct load carrying structure and under deck support structure are to be welded to the deck by suitable full penetration welding. The design of the connection is to be adequate for the calculated stress, in accordance with [3.1.15].

3.1.10

Deck plating are to be of a material strength compatible with the crane pedestal. Where necessary, a thicker insert plate is to be fitted. In no case are doublers to be used where structures are subject to tension.

3.1.11

The supporting structure is to be dimensioned to ensure that for the load cases specified in [3.1.13] and [3.1.14], the stresses do not exceed those given in [3.1.15].

The capability of the supporting structure to resist buckling failure is to be assured.

CCS 4.1.11a In accordance with the design load of 4.1.11, a three-dimensional FE model may be applied in the analysis for the supporting structure in accordance with [CCS 2.1.3a]. The allowable equivalent stress, $[\sigma_e] = 0.8R_{eH}$, where: R_{eH} – yield stress of material, in N/mm^2.

3.1.12
These requirements are to be assessed based on gross scantlings.

3.1.13
For lifting appliances which are limited to use in harbour, design load is to be taken equal to 1.3 times SWL added to the lifting appliances self weight.

3.1.14
For life saving appliances, design load is to be taken as 2.2 times SWL.

3.1.15
The stresses induced in the supporting structure are not to exceed the following permissible values:

- Normal stress, 0.67 R_{eH}
- Shear stress, 0.39 R_{eH}

4 MISCELLANEOUS DECK FITTINGS

4.1 Support and attachment

4.1.1
The following requirements are to be considered in the design of the support and attachment of miscellaneous fittings which impose relatively small loads on the ship's structure. The arrangement of such details and their approval is considered on a case-by-case basis by the Society.

CCS 6.1.1a The strength assessment is carried out to the supporting structure of other deck equipment in accordance with the strength analysis method and criteria of this Section based on the design load submitted by the manufacturer.
CCS 6.1.1b For the connection structures of hull outfitting equipment to the deck, it is to be noted that:

(1) For the supporting structures of pipelines, open type sections (e.g. T, L, I, X etc.) are used and the corresponding supporting structures are strengthened by using web plates, collar plates and backing brackets. Ring support is used for large pipelines.
(2) Where pipelines pass through the deck, seamless casing pipes or those with welds ground are used to assist pipelines passing through the deck.
(3) Local transition is to be avoided in way of the backing strengthening under the deck. Transition is to made from the structure to the stiffener or frame.
(4) Stress concentration or high stress areas are to be avoided for cut-outs such as manholes/hatches. The watertight manhole covers are to be such that their strength is equivalent to the local strength of the associated deck. The edge of cut-outs is to be ground smooth.

4.1.2
Support positions are to be arranged so that the attachment to the ship structure is clear of deck openings and stress concentrations, such as the toes of end brackets. Design of supports is to be such that the attachment to the deck minimises the creation of hard points.

Section 5 SMALL HATCHWAYS

SYMBOLS
For symbols not defined in this section, refer to Ch 1, Sec 4.

1 GENERAL

1.1 Application

1.1.1
The requirements in [1.2] to [1.6] apply to small hatchways at weather deck in positions 1 and 2 as defined in Ch 1, Sec 4, [3.2]. The requirements in [2] apply to small hatchways fitted on the exposed fore deck over the forward 0.25 *L*.
Hatchways of bulk carriers not covered by the definition of small hatchways in [1.4.1] are to comply with applicable requirements in Pt 2, Ch 1.

1.2 Materials

1.2.1
Materials used for the construction of steel hatch covers are to comply with the applicable requirements of the Society.

CCS 1.2.1a Materials used for the construction of small steel hatch covers are to comply with the applicable requirements of Chapter 3, PART ONE of CCS Rules for Materials and Welding.

1.2.2
The use of materials other than steel is considered by the Society on a case-by-case basis.

CCS 1.2.2a Small *hatch covers constructed of materials other than steel are to provide a strength equivalent to that of small steel hatch covers.*

1.3 Height of hatch coamings

1.3.1
The height above the deck of hatch coamings is not to be less than:

- 600 mm in position 1.
- 450 mm in position 2.

1.3.2
The height, given in [1.3.1], of hatch coamings closed by steel covers provided with gaskets and securing devices may be reduced or the coamings may be omitted entirely, on condition that the Flag Administration is satisfied that the safety of the ship is not thereby impaired in any sea conditions.
In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case-by-case basis.

CCS 1.3.2a Subject to the agreement of the flag Administration, the height of hatch coamings may be appropriately reduced provided that the safety of the ship is not thereby impaired and that effective measures are taken. In this case, the scantlings of the hatch covers are to comply with the requirements of 2.2. The arrangement of sealing gasket and securing devices is to comply with the relevant requirements of this Section, taking into account the strength and arrangement of pressure head, stoppers and securing devices as well as factors such as the effectiveness of drainage and sealing materials.

1.4 Small hatchways

1.4.1
Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weathertight or watertight, as applicable. Their opening is generally equal to or less than 2.5 m^2.
Hatch covers on exposed decks are to be weathertight.

Hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

1.4.2
Securing arrangements and stiffening of hatch cover edges are to be such that weathertightness can be maintained in any sea condition. At least one securing device is to be fitted at each side. Circular hole hinges are considered equivalent to securing devices.

1.4.3
Hatchways of special design are considered by the Society on a case-by-case basis.

CCS 1.4.3a The design of special securing arrangement and the rigidity of edge of hatch covers is to take into account the strength and arrangement of pressure head, stoppers and securing arrangement as well as factors such as the effectiveness of drainage measures and sealing materials.

1.4.4
The gross thickness of covers is to be not less than 8 mm. This thickness is to be increased or an efficient stiffening is to be fitted where the greatest horizontal dimension of the cover exceeds 0.6 m.

1.4.5
The gross thickness of coaming plate is not to be less than the lesser of the following values:

- The gross thickness for the deck in way of hatch coaming, assuming as spacing of stiffeners the lesser of the values of the height of the coaming and the distance between its stiffeners.
- 10 mm.

Coamings are to be strengthened where their height exceeds 0.8 m or their greatest horizontal dimension exceeds 1.2 m, unless their shape ensures an adequate rigidity.

1.5 Cargo tank access hatchways

1.5.1
Requirements given in [1.2] to [1.4] have to be considered as minimum requirements for cargo tank hatchways.
The requirements of [1.5.4] do not apply to dished covers or covers of other specially approved design.

1.5.2
Covers for access hatches, tank cleaning and other openings for cargo tanks and adjacent spaces are to be manufactured from the following material:

a) Normal strength steel in accordance with Ch 3, Sec 1.
b) Non-ferrous material may be considered, such as bronze or brass. Aluminium alloy is not to be used for covers of any opening to cargo tanks and spaces adjacent thereto.
c) Synthetic materials may be considered, taking into account their fire resistance and their physical and chemical properties in relation to the intended operating conditions. Details of the properties of the material, the design of the cover, and the method of manufacture are to be submitted for approval.

The hatch cover packing material is to be compatible with the cargoes that are intended to be carried and is to be effectively held in place.

1.5.3
The height of the hatch coaming above the upper surface of the freeboard deck is not to be less than 600 mm. Lower heights may be permitted by the Flag Administration. In addition, the top of the hatch coaming is not to be lower than the highest point of the tank over which it is fitted and is to be of sufficient height for the purpose of damage stability.
The gross thickness of the coaming plate is not to be less than 10 mm. Where the coaming height, as fitted, exceeds 600 mm, the thickness may be required to be increased or edge stiffening fitted. The scantlings of coaming plates of tank access coamings that enclose an area of 1.2 m^2 or more, and/or those that are not configured with a well rounded shape, may be subject to additional

requirements.

CCS 1.5.3a For the coaming plates of tank access small hatchways that enclose an area of 1.2 m^2 or more, and/or those that are not configured with a well rounded shape, stiffeners are to be fitted on the hatch coaming. The thickness of hatch coaming and the stiffeners on the coaming plate are to comply with the requirements of 6.3.1 and 6.3.2, Section 5, Chapter 1 of PART 9-2.

1.5.4
The gross thickness of unstiffened plate covers with an area less than 1.2 m^2 is not to be less than 12.5 mm. The gross thickness of covers of a larger area will need to be increased or the cover will require stiffening.
Flat and unstiffened covers on circular hatchways are to be secured by fastenings with a spacing of not more than 600 mm.
On rectangular hatchways, the spacing of fastenings is generally not to be greater than 450 mm and the distance between hatch corners and adjacent fastenings is not to be greater than 230 mm.
Where the cover is hinged, adequate stiffening of the coaming and cover in way of the hinge is to be provided. In general, hinges are not to be considered securing devices for the cover and are to be designed so as to prevent the gasket from being over-tightened.

1.6 Gaskets
1.6.1
The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness.

1.6.2
Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

2 SMALL HATCHWAYS FITTED ON THE EXPOSED FORE DECK
2.1 General
2.1.1
These requirements apply to small hatchways (generally openings 2.5 m^2 or less) on the exposed deck within 0.25 *L* from the FP and located at a height less than 0.1 *L* or 22 m, whichever is less, from the summer load water line at the location of the hatch.

2.1.2
Hatchways designed for emergency escape need not comply with the requirements [2.3.1] items (a) and (b), [2.4.3] and [2.5.1].

2.1.3
Securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g. one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover.

2.2 Strength
2.2.1
For small rectangular steel hatch covers, the gross plate thickness, stiffener arrangement and scantlings are to be not less than those obtained, in mm, from Table 1 and Figure 2. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in [2.4.1] and shown in Figure 2. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, see Figure 1.

Gross scantlings for small steel hatch covers on the fore deck **Table 1**

Nominal size, in mm	Cover plate thickness, in mm	Primary stiffeners	Secondary stiffeners
		Flat bar size, in mm ; number of stiffeners	
630 × 630	8	-	-
630 × 630	8	100 × 8 ; 1	-
830 × 630	8	100 × 8 ; 1	-
830 × 630	8	100 × 10 ; 1	-
1030 × 1030	8	120 × 12 ; 1	80 × 8 ; 2
1330 × 1330	8	150 × 12 ; 2	100 × 10 ; 2

2.2.2
The upper edge of the hatchway coaming is to be suitably reinforced by a horizontal member, normally not more than 190 mm from the upper edge of the coaming.

2.2.3
For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to provide strength and stiffness equivalent to the requirements for small rectangular hatches.

2.2.4
For small hatch covers constructed of materials other than normal strength steel, the required scantlings are to provide equivalent strength and stiffness.

2.3 Primary securing devices
2.3.1
The primary securing devices are to be fitted such that the hatch cover can be secured in place and be made weathertight by means of a closing mechanism employing any one of the following methods:

a) Butterfly nuts tightening onto forks (clamps),
b) Quick acting cleats, or
c) A central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

2.4 Requirement to primary securing
2.4.1
The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Figure 2 and of sufficient capacity to withstand the bearing force.

2.4.2
The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

2.4.3
For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimise the risk of butterfly nuts being dislodged while in use; by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is to be not less than 16 mm. An example arrangement is shown in Figure 1.

2.4.4
For small hatch covers located on the exposed deck forward of the foremost cargo hatch, the hinges are to be fitted such that the predominant direction of green seas will cause the cover to

close, which means that the hinges are normally to be located on the fore edge.

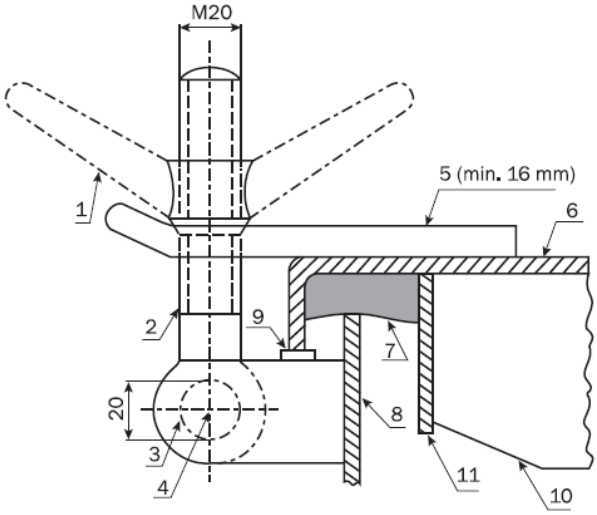
2.4.5

On small hatches located between the main hatches, for example between No. 1 and No. 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

2.5 Secondary securing devices

2.5.1

Small hatches on the fore deck are to be fitted with an independent secondary securing device, e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.



1. Butterfly nut
2. Bolt
3. Pin
4. Centre of pin
5. Fork (clamp) plate
6. Hatch cover
7. Gasket
8. Hatch coaming
9. Bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10. Stiffener
11. Inner edge stiffener

(Note: Dimensions in millimetres)

Figure 1: Example or primary securing device

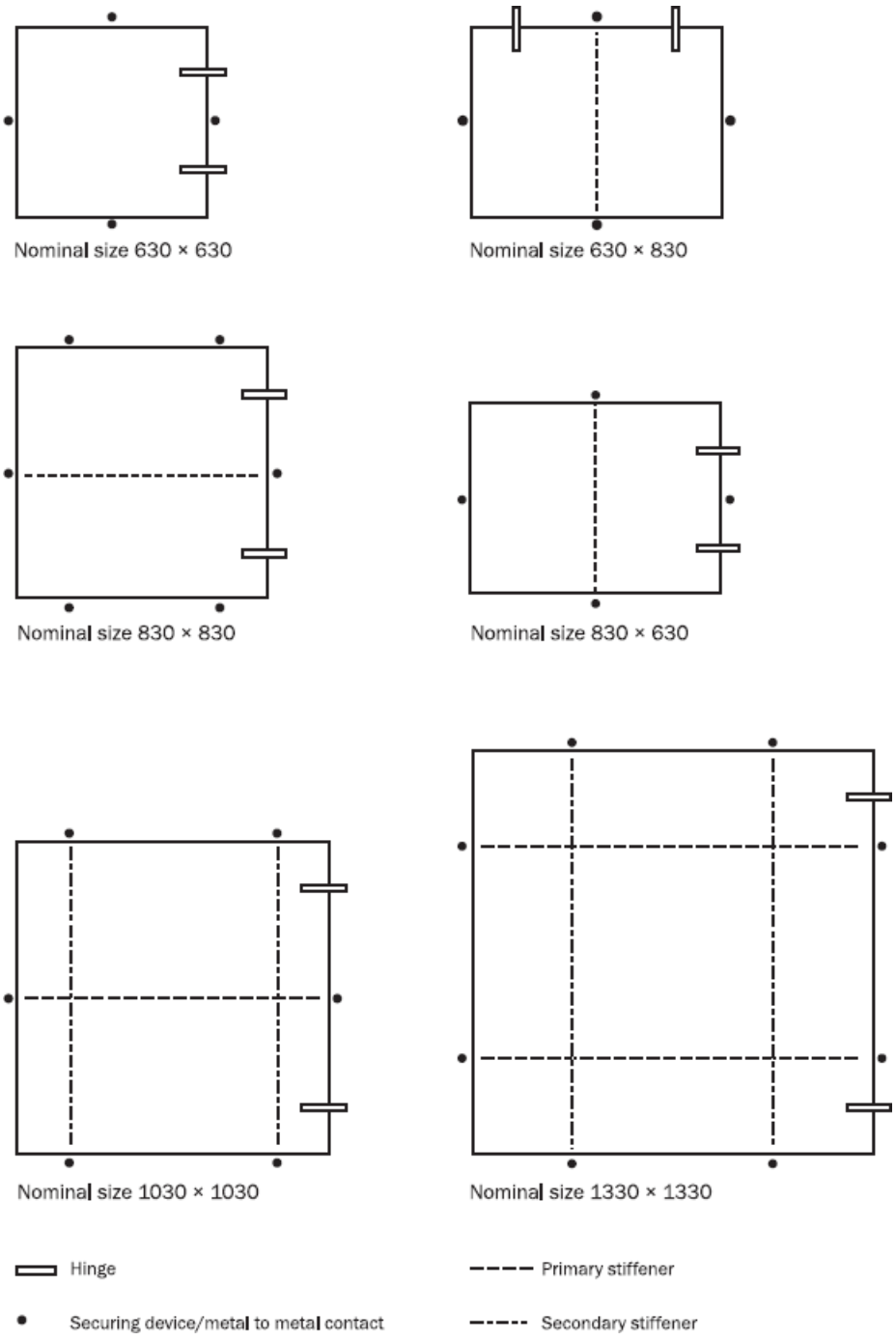


Figure 2: Arrangement of stiffeners

Chapter 12 CONSTRUCTION

Section 1 CONSTRUCTION AND FABRICATION

1 GENERAL

1.1 Workmanship

1.1.1

All workmanship is to be of commercial marine quality and acceptable to the surveyor. Welding is to be in accordance with the requirements of Ch 12, Sec 2. Any defect is to be rectified to the satisfaction of the surveyor before the material is covered with paint, cement or any other composition.

1.2 Fabrication standard

1.2.1

Structural fabrication is to be carried out in accordance with IACS Recommendation No. 47 or with a recognised fabrication standard which has been accepted by the Society prior to the commencement of fabrication /construction.

CCS 1.2.1a Where other standards are used by the shipyard, documents are to be provided by the shipyard to demonstrate that such standards are equivalent to IACS Recommendation No. 47.

1.2.2

The fabrication standard to be used during fabrication/construction is to be made available to the attending representative of the Society prior to the commencement of the fabrication/construction.

1.2.3

The fabrication standard is to include information, to establish the range and the tolerance limits, for the items specified as follows:

a) Cut edges: the slope of the cut edge and the roughness of the cut edges.
b) Flanged stiffeners and brackets and built-up sections: the breadth of flange and depth of web, angle between flange and web, and straightness in plane of flange or at the top of face plate.
c) Pillars: the straightness between decks and cylindrical structure diameter.
d) Brackets and flat bar stiffeners: the distortion at the free edge line of tripping brackets and flat bar stiffeners.
e) Sub-assembly stiffeners: details of sniped end of face plates and webs.
f) Plate assembly: for flat and curved blocks, the dimensions (length and breadth), distortion and squareness, and the deviation of interior members from the plate.
g) Cubic assembly: in addition to the criteria for plate assembly, twisting deviation between upper and lower plates, for flat and curved cubic blocks.
h) Special assembly: the distance between upper and lower gudgeons, distance between aft edge of propeller boss and aft peak bulkhead, twist of stern frame assembly, breadth and length of top plate of main engine bed. Where boring out of the propeller boss and stern frame, skeg or solepiece are to be carried out after completing the major part of the welding of the aft part of the ship. Where block boring is used, the shaft alignment is to be carried out using a method and sequence submitted to and recognised by the Society. The fit-up and alignment of the rudder, pintles and axles are to be carried out after completing the major parts of the welding of the aft part of the ship. The contacts between the conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.
i) Butt joints in plating: alignment of butt joint in plating.
j) Cruciform joints: alignment measured on the median line and measured on the heel line of cruciform joints.
k) Alignment of interior members: alignments of flange of T profiles, alignment of panel stiffeners, gaps in T joints and lap joints, and distance between scallop and cut-outs for

continuous stiffeners in assembly and in erection joints.

l) Keel and bottom sighting: deflections for whole length of the ship, and for the distance between two adjacent bulkheads, cocking-up of fore body and of aft body, and rise of floor amidships.
m) Dimensions: length between perpendiculars, moulded breadth and depth at midship, and length between aft edge of propeller boss and main engine.
n) Fairness of plating between frames: deflections between frames of shell, tank top, bulkhead, upper deck, superstructure deck, deckhouse deck and wall plating.
o) Fairness of plating in way of frames: deflections of shell, tank top, bulkhead, strength deck plating and other structures measured in way of frames.

CCS 1.2.3a Where block boring is used, the shaft alignment is to comply with the relevant requirements of Section 5, Chapter 12, PART THREE MACHINERY of CCS Rules for Classification of Sea-going Steel Ships

2 CUT-OUTS, PLATE EDGES

2.1 General

2.1.1

The free edges (cut surfaces) of cut-outs, hatch corners, etc are to be properly prepared and are to be free from notches. As a general rule, cutting draglines, etc are to be smoothly ground. All edges are to be broken or in cases of highly stressed parts, be rounded off.

Free edges on flame or machine cut plates or flanges are not to be sharp cornered and are to be finished off as specified above. This also applies to cutting drag lines, etc, in particular to the upper edge of sheer strake and analogously to weld joints, changes in sectional areas or similar discontinuities.

2.1.2

Corners in hatch opening are to be machine cut.

3 COLD FORMING

3.1 Special structural members

3.1.1

For highly stressed components of the hull girder where notch toughness is of particular concern (e.g. items required to be Class III in Ch 3, Sec 1, Table 3, such as radius gunwales (bent sheer plates) and bilge strakes), the inside bending radius, in cold formed plating, is not to be less than 10 times the as-built plate thickness for carbon-manganese steels (see Ch 3, Sec 1). The allowable inside bending radius may be reduced provided the requirements stated in [3.3] are complied with.

3.2 Corrugated bulkheads and hopper knuckles

3.2.1

For corrugated bulkheads and hopper knuckles, the inside bending radius, in cold formed plating, is not to be less than 4.5 times the as-built plate thickness for carbon-manganese steels (see Ch 3, Sec 1). The allowable inside bending radius may be reduced provided the requirements stated in [3.3] are complied with.

3.3 Low bending radius

3.3.1

When the inside bending radius is reduced below 10 times or 4.5 times the as-built plate thickness according to [3.1] and [3.2] respectively, supporting data is to be provided. The bending radius is in no case to be less than 2 times the as-built plate thickness. As a minimum, the following additional requirements are to be complied with:

a) or all bent plates:
   - 100% visual inspection of the bent area is to be carried out.
   - Random checks by magnetic particle testing are to be carried out.
b) In addition to a), for bent plates at boundaries to tanks or ballast holds:
   - The steel is to be of Grade D/DH or higher.

- The material is impact tested in the strain-aged condition and satisfies the requirements stated herein. The deformation is to be equal to the maximum deformation to be applied during production, calculated by the formula $t_{as\text{-}built}/(2r_{bdg} + t_{as\text{-}built})$, where $t_{as\text{-}built}$ is the as-built thickness of the plate material and r_{bdg} is the bending radius. One sample is to be plastically strained at the calculated deformation or 5%, whichever is greater and then artificially aged at 250°C for one hour then subject to Charpy V-notch testing. The average impact energy after strain ageing is to meet the impact requirements specified for the grade of steel used.

4 HOT FORMING

4.1 Temperature requirements

4.1.1

Steel is not to be formed between the upper and lower critical temperatures. If the forming temperature exceeds 650°C for as-rolled, controlled rolled, thermo-mechanical controlled rolled or normalised steels, or is not at least 28°C lower than the tempering temperature for quenched and tempered steels, mechanical tests are to be made to assure that these temperatures have not adversely affected both the tensile and impact properties of the steel. Where curve forming or fairing, by line or spot heating, is carried out in accordance with [4.2.1] these mechanical tests are not required.

4.1.2

After further heating, other than specified in [4.1.1], of Thermo-Mechanically Controlled Steels (TMCP plates) for forming and stress relieving, it is to be demonstrated that the mechanical properties meet the requirements specified by a procedure test using representative material.

4.2 Line or spot heating

4.2.1

Curve forming or fairing, by linear or spot heating, is to be carried out using approved procedures in order to ensure that the properties of the material are not adversely affected. Heating temperature on the surface is to be controlled so as not to exceed the maximum allowable limit applicable to the plate grade.

5 ASSEMBLY AND ALIGNMENT

5.1 General

5.1.1

The use of excessive force is to be avoided during the assembly of individual structural components or during the erection of sections. Major distortions of individual structural components are to be corrected before further assembly.
After completion of welding, straightening and aligning are to be carried out in such a manner that the material properties are not influenced significantly. In case of doubt, the Society may require a procedure test or a working test to be carried out.

5.1.2

Structural members are to be aligned following the provisions of IACS Recommendation No. 47, Tables 7 or according to the requirements of a recognised fabrication standard that has been accepted by the Society. In the case of critical components, control drillings are to be made where necessary, which are then to be welded up again on completion.

Section 2 FABRICATION BY WELDING

1 GENERAL

1.1 Application

1.1.1

The requirements of this section apply to the preparation, execution and inspection of welded connections in hull structures.

1.2 Limits of application to welding procedures

1.2.1 Weld type, size and materials

The requirements of this section for weld type, size and materials are based on the following considerations:

- Joint type.
- Criticality of the joint.
- Magnitude, type and direction of the stresses in the joint.
- Material properties of the parent and weld material.
- Weld gap size.

1.2.2 Preparation, execution and inspection

The requirements of this section are to be complemented by the general requirements relevant to fabrication by welding and qualification of welding procedures given by the Society when deemed appropriate by the Society.

CCS 1.2.2a Welding procedures are also to comply with the applicable requirements of Section 1, Chapter 5, PART THREE of CCS Rules for Materials and Welding.

2 WELDING PROCEDURES, WELDING CONSUMABLES AND WELDERS

2.1 General

2.1.1

All welding is to be carried out by approved welders, in accordance with approved welding procedures, using approved welding consumables, in compliance with the Rules of the Society.
Personnel manning automatic welding machines and equipment are to be competent, sufficiently trained and certified by the Society as specified in Society Rules or Guidelines for welding.

CCS 2.1.1a The approval of welding consumables, welding procedures and qualification tests of welders are to comply with the requirements of Chapters 2,3 and 4 of PART THREE of CCS Rules for Materials and Welding.
CCS 2.1.1b The qualification tests of automatic submerged arc welding operators are to comply with the requirements of Section 3, Chapter 3 of CCS Guidelines for Inspection of Hull Welds.

3 WELD JOINTS

3.1 General

3.1.1

Welding of connections is to be executed according to the approved plans.

3.1.2

The quality standard adopted by the shipyard is to be submitted to the Society and it applies to all welded connections unless otherwise specified on a case-by-case basis.

CCS 3.1.2a The quality standard adopted by the shipyard is to be in accordance with paragraph 1.2.1, Section 1 of this Chapter. In special cases, equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

3.1.3

Consideration is to be given to the assembly sequence and the effect of the overall shrinkage of plate panels, assemblies, etc, resulting from the welding processes employed. Welding is to

proceed systematically, with each welded joint being completed in correct sequence, without undue interruption. When practicable, welding is to commence at the centre of a joint and proceed outwards, or at the centre of assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions.

3.1.4
Completed welded joints are to be to the satisfaction of the attending surveyor. Edge preparations and root gaps are to be in accordance with the approved welding procedure. The gap between the members being joined should not exceed the maximum values given in IACS Recommendation No. 47 or as specified in recognised fabrication standard approved by the Society. Where the gap between members being joined exceeds the specified values, corrective measures are to be taken in accordance with an approved welding procedure specification.

3.1.5
Where small fillets are used to attach heavy plates or sections, welding is to be based on approved welding procedure specifications. Special precautions, such as the use of preheating, low-hydrogen electrodes or low- hydrogen welding processes, are accepted.

3.1.6
When heavy structural members are attached to relatively light plating, the weld size and sequence may require modification.

3.1.7
Where quality control systems are in place which ensure that the grade of welding consumable used is higher than the minimum required for the particular strength steel being welded, the welding consumables that are used may have a weld deposit material yield strength that is greater than the minimum specified in Ch 12, Sec 3, [2.5.2] and the size of the weld may be determined based on the yield strength of the higher grade welding consumable.

3.1.8
In general, butt joints are to be welded from both sides. Before welding is carried out on the second side, unsound metal is to be removed at the root by a suitable method. Butt welding from one side will only be permitted for specific applications with an approved welding procedure specification.

3.1.9 Arrangements at junctions of welds
Welds are to be made flush in way of the faying surface where stiffening members, attached by continuous fillet welds, cross the completely finished butt or seam welds. Similarly, butt welds in webs of stiffening members are to be completed and made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden changes of section. Where these conditions can not be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of the size, and in a position, that a satisfactory return weld can be made.

3.1.10 Leak stoppers
Where structural members pass through the boundary of a tank, leakage into adjacent space could be hazardous or undesirable, and full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively, a small scallop of suitable shape may be cut in a member close to the boundary outside of the compartment, and carefully welded all around.

4 NON-DESTRUCTIVE EXAMINATION (NDE)
4.1 General
4.1.1
The NDE plan to be submitted for approval has to contain the necessary data relevant to the locations and number of examinations, welding procedures applied, method of NDE applied, etc. Visual inspection of finished welds is to be carried out by the shipyard to ensure that all welding

has been satisfactory completed. In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld. Above inspections are to be carried out as per the requirements of the Society.

CCS 4.1.1a NDE is to be carried out in accordance with the applicable requirements of Section 3, Chapter 5,PART THREE of CCS Rules for Materials and Welding.

4.1.2

NDE of welding is to be carried out at the positions indicated by the NDE plan in order to ensure that the welds are free from cracks and unacceptable internal defects with regards to the requirements of the Society. NDE is to be carried out by qualified personnel certified by recognised bodies in compliance with recognised standards.

CCS 4.1.2a The acceptance standards of NDE of welds are to comply with the applicable requirements of Chapter 7 of CCS Guidelines for Inspection of Hull Welds.

Section 3 DESIGN OF WELD JOINTS

SYMBOLS

A_{weld} : Effective fillet weld area, in cm^2.
f : Root face, in mm.
f_{weld} : Weld factor.
f_{yd} : Correction factor taking into account the yield strength of the weld deposit as defined in [2.5.2].
l_{dep} : Total length of deposit of weld metal, in mm.
l_{leg} : Leg length of continuous, lapped or intermittent fillet weld, in mm.
l_{weld} : Length of the welded connection in mm.
R_{eH_weld} : Minimum yield stress of weld deposit, in N/mm^2.
$t_{as\text{-}built}$: As-built thickness of the member being joined, in mm.
t_{gap} : Allowance for fillet weld gap, is to be taken equal to 2.0 mm.
t_{throat} : Throat thickness of fillet weld in mm, as defined in [2.5.3].

1 GENERAL

1.1 Application

1.1.1
The requirements of this section apply to the design of welded connections in hull structures and are based on the considerations mentioned in Ch 12, Sec 2, [1.2.1].

1.1.2
Plans and/or specifications showing weld sizes and weld details are to be submitted for approval.

1.1.3
The leg length of welds is to comply with the minimum leg length given in Table 1.

1.2 Alternatives

1.2.1
The requirements given in this section are considered minimum for electric-arc welding in hull construction, but alternative methods, arrangements and details will be specially considered for approval.

CCS 1.2.1a The requirements given in this Section are considered minimum for electric-arc welding in hull construction, but alternative methods, arrangements and details are to be approved in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

2 TEE OR CROSS JOINT

2.1 Application

2.1.1
The connection of primary supporting members, stiffener webs to plating as well as the plating abutting on another plating, are to be made by fillet or penetration welding, as shown on Figure 1.

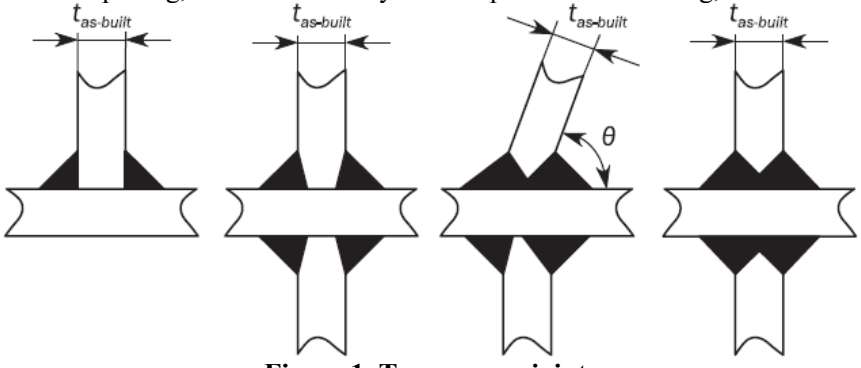


Figure 1 Tee or cross joints

$t_{as\text{-}built}$: As-built thickness of the member being attached, mm.

θ : Connecting angle, in deg.

2.1.2
Where the connection is highly stressed or otherwise considered critical, a partial or full penetration weld is to be achieved by bevelling the edge of the abutting plate.

2.2 Continuous fillet welds
2.2.1
Continuous welding is to be adopted in the following locations:

a) Connection of the web to the face plate for all members.
b) All fillet welds where higher strength steel is used.
c) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
d) Boundaries of tanks and watertight compartments.
e) All structures inside tanks and cargo holds.
f) Stiffeners and primary supporting members at tank boundaries.
g) All structures in the aft peak and stiffeners and primary supporting members of the aft peak bulkhead.
h) All structures in the fore peak.
i) Welding in way of all end connections of stiffeners and primary supporting members, including end brackets, lugs, scallops, and at orthogonal connections with other members.
j) All lap welds in the main hull.
k) Primary supporting members and stiffener members to bottom shell in the 0.3 L forward region.
l) Flat bar longitudinals to plating.
m) The attachment of minor fittings to higher strength steel plating and other connections or attachments.
n) Pillars to heads and heels.
o) Hatch coaming stay webs to deck plating, see [2.4.5].

2.3 Intermittent fillet welds
2.3.1
Where continuous welding is not required, intermittent welding may be applied.

2.3.2
Where beams, stiffeners, frames, etc, are intermittently welded and pass through slotted girders, shelves or stringers, there is to be a pair of matched intermittent welds on each side of every intersection. In addition, the beams, stiffeners and frames are to be efficiently attached to the girders, shelves and stringers.
Where intermittent welding or one side continuous welding is permitted, double continuous welds are to be applied for one-tenth of their shear span at each end, in accordance with [2.5.2] and [2.5.3].

2.3.3 Deckhouses
One side continuous fillet welding is acceptable in the dry spaces of deckhouses.

2.3.4 Size for one side continuous weld
The size for one side continuous weld is to be of fillet required by [2.5.2] for intermittent welding, where f_3 factor is to be taken as 2.0.

2.4 Partial or full penetration welds
2.4.1 High stress area definition
For the application of this section, high stress area means an area where fine mesh finite element analysis is to be carried out and the fine mesh yield utilisation factor in elements adjacent to the weld is more than 90% of the fine mesh permissible utilisation factor, as defined in Ch 7, Sec 3, [6.2].

2.4.2 Partial or full penetration welding

In areas with high tensile stresses or areas considered critical, full or partial penetration welds are to be used. In case of full penetration welding, the root face is to be removed, e.g. by gouging before welding of the back side.

For partial penetration welds the root face, f, is, to be taken between 3 mm and $t_{as\text{-}built}$ /3.

The groove angle made to ensure welding bead penetrating up to the root of the groove, α, is usually from 40° to 60°.

The welding bead of the full/partial penetration welds is to cover root of the groove. Examples of partial penetration welds are given on Figure 2.

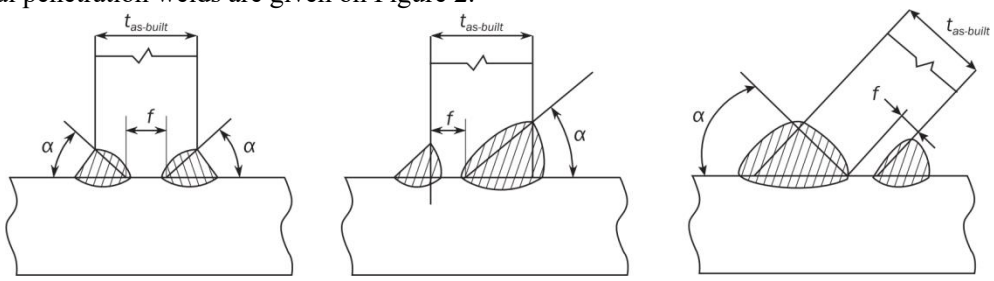


Figure 2 Partial penetration welds

2.4.3 One side partial penetration weld

For partial penetration welds with one side bevelling the fillet weld at the opposite side of the bevel is to satisfy the requirements given in [2.5.2].

2.4.4 Extent of full or partial penetration welding

The extent of full or partial penetration welding in each particular location listed in [2.4.5] and [2.4.6] is to be approved by the Society. However, the minimum extent of full/partial penetration welding from the reference point (i.e. intersection point of structural members, end of bracket toe, etc.) is not to be taken less than 300 mm, unless otherwise specifically stated.

2.4.5 Locations required for full penetration welding

Full penetration welds are to be used in the following locations and elsewhere as required by the rules, see Figure 3:

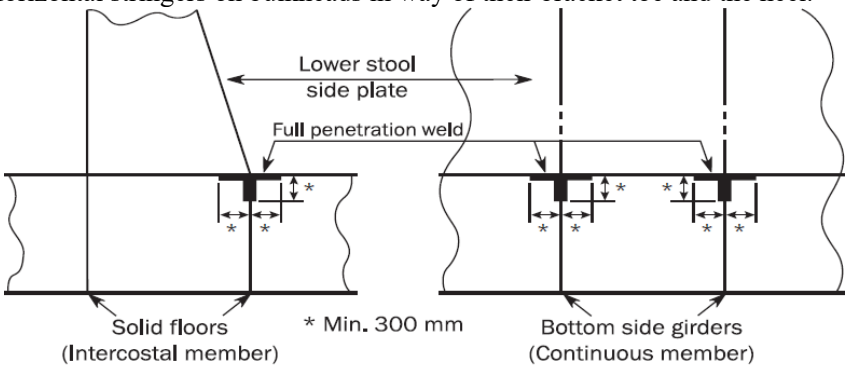
a) Floors to hopper/inner bottom plating in way of radiused hopper knuckle.
b) Radiused hatch coaming plate at corners to deck.
c) Connection of vertical corrugated bulkhead to the lower hopper plate and to the inner bottom plate within the cargo hold region, when the vertical corrugated bulkhead is arranged without a lower stool.
d) Connection of structural elements in the double bottom in line with corrugated bulkhead flanges to the inner bottom plate, when the vertical corrugated bulkhead is arranged without a lower stool.
e) Connection of vertical corrugated bulkhead to the lower hopper plate, and connection of structural elements in the lower hopper area in line with corrugated bulkhead flanges to the lower hopper plate, where connections are clear of lower stools.
f) Connection of vertical corrugated bulkhead to top plating of lower stool.
g) Corrugated bulkhead lower stool side plating to lower stool top plate.
h) Corrugated bulkhead lower stool side plating to inner bottom.
i) Connection of structural elements in double bottom to the inner bottom plate in holds intended for the carriage of liquid at sea with a distance of 150300 mm from the side plating of the lower stool, see Figure3.
j) Edge reinforcement or pipe penetration both to strength deck, sheer strake and bottom plating within 0.6 L amidships, when the dimensions of the opening exceeds 300 mm.
k) Abutting plate panels with as-built thickness less than or equal to 12 mm, forming outer shell boundaries below the scantling draught, including but not limited to: sea chests, rudder trunks, and portions of transom. For as-built thickness greater than 12mm, partial penetration in accordance with [2.4.2].
l) Crane pedestals and associated bracketing and support structure.

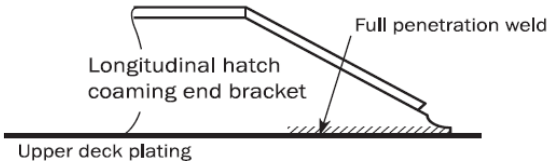
m) For toe connections of longitudinal hatch coaming end bracket to the deck plating, full penetration weld for a distance of 0.15 H_c from toe of side coaming termination bracket is required, where H_c is the hatch coaming height.
n) Rudder horns and shaft brackets to shell structure.
o) Thick flanges of long transverse web frames to side web frames. Thick flanges of long longitudinal girder to bulkhead web frames.

2.4.6 Locations required for partial penetration welding

Partial penetration welding as defined in [2.4.2], is to be used in the following locations (see examples in Figure
3):

a) Connection of hopper sloping plate to longitudinal bulkhead (inner hull) or horizontal girder in double side space.
b) End connection of longitudinal/transverse bulkhead primary supporting member including buttress structure to the double bottom and both end connections of backing bracket, where it is fitted.
c) Corrugated bulkhead lower stool supporting floors to inner bottom.
d) Corrugated bulkhead gusset and shedder plates.
e) Lower 15% of the length of built-up corrugation of vertical corrugated bulkheads
f) Structural elements in double bottom below bulkhead primary supporting members and stool plates, except in way of [2.4.5] i).
g) Lower hopper plate to inner bottom.
h) Horizontal stringers on bulkheads in way of their bracket toe and the heel.





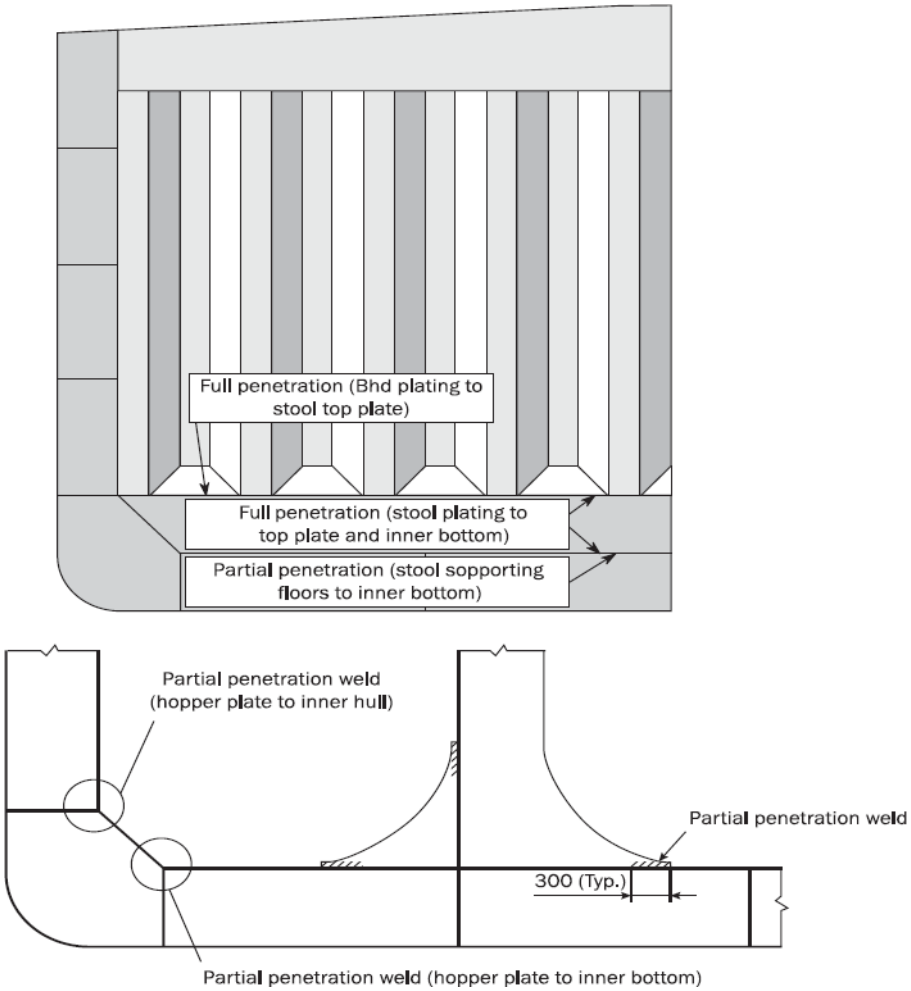


Figure 3 High stress areas welding (examples)

2.4.7 Fine mesh finite element analysis

In high stress area, at least partial penetration welds as defined in [2.4.2] are to be used. The minimum extent of full or partial penetration welding in that case is to be the greater of the following:

- 150 mm in either direction from the element with the highest yield utilisation factor.
- The extent covering all elements that exceed the above mentioned yield utilisation factor criteria.

2.4.8 Shedder plates

In case where shedder plates are fitted at the lower end of corrugated bulkhead, the shedder plates are to be welded to the corrugation and the top plate of the transverse lower stool by one side penetration welds.

2.5 Weld size criteria

2.5.1

The required weld sizes are to be rounded to the nearest half millimetre.

2.5.2

The leg length, *lleg* in mm, of continuous, lapped or intermittent fillet welds is not to be taken less than the greater of the following values:

$l_{leg} = f_1 f_2 t_{as\text{-}built}$

$l_{leg} = f_{yd} f_{weld} f_1 f_2 t_{as\text{-}built} + t_{gap}$

l_{leg} as given in Table 1

where

f_1: Coefficient depending on welding type:

f_1 = 0.30 for double continuous welding.
f_1= 0.38 for intermittent welding.

f_2 : Coefficient depending on the edge preparation:
f_2 = 1.0 for welds without bevelling.
f_2 = 0.70 for welds with one/both side bevelling and $f = t_{as\text{-}built}$ /3.

f_{yd}: Coefficient not to be taken less than the following:

$$f_{yd} = (\frac{1}{k})^{0.5}(\frac{235}{R_{eH_weld}})^{0.75}$$

f_{yd} = 0.71.

R_{eH_weld} : Specified minimum yield stress for the weld deposit in N/mm^2, not to be less than:
: R_{eH_weld} = 305 N/mm^2 for welding of normal strength steel with R_{eH} = 235N/mm^2.
: R_{eH_weld} = 375 N/mm^2 for welding of higher strength steels with R_{eH} from 265 to 355 N/mm^2.
: R_{eH_weld} = 400 N/mm^2 for welding of higher strength steel with R_{eH} = 390N/mm^2.

f_{weld} : Weld factor dependent on the type of the structural member, see Table 2, Table 3 and Table 4.

k : Material factor of the abutting member.

f_3 : Correction factor for the type of weld:
f_3=1.0 for double continuous weld.
$f_3 = s_{ctr}/l_{weld}$ for intermittent or chain welding.

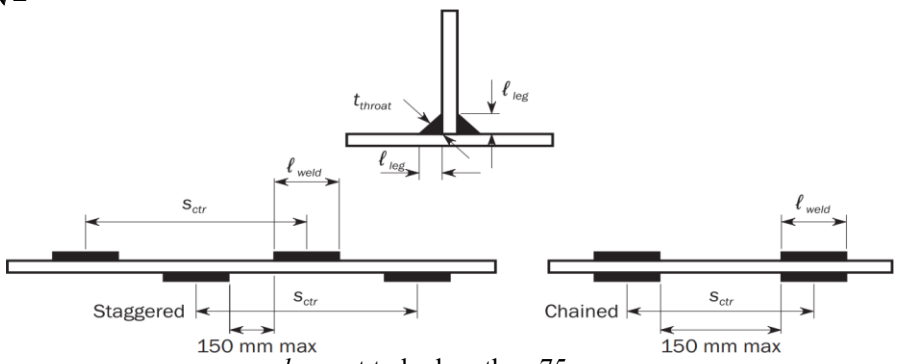
s_{ctr} : Distance between successive fillet welds, in mm.

Leg length for intermittent welding is not to exceed the greater of 6.5mm or 0.62 * $t_{as\text{-}built}$.

2.5.3

The throat size t_{throat}, in mm, as shown in Figure 4, is not to be less than:

$$t_{throat} = \frac{l_{leg}}{\sqrt{2}}$$



l_{weld} not to be less than 75mm

Figure 4 Weld scantlings definitions

2.5.4

For primary supporting members connections not listed in Table 2, and Table 3 the weld factors from Table 4 are to be used.

Minimum leg size **Table 1**

Area	Type of space		Minimum length, in mm
Cargo hold region	Cargo tanks and holds	Within 3m below top of tank(2)	6.5 (1)
		Elsewhere	6.0 (1)
	Water ballast tanks	Within 3m below top of tank(2)	6.5 (1)
		Elsewhere	6.0 (1)

Area	Type of space		Minimum length, in mm
	Dry spaces and voids		5.0
	Other tanks		6.0 (1)
Other areas	Water ballast tanks	Within 3m below top of tank(2)	6.0 (1)
		Elsewhere	5.5 (1)
	Fuel oil, diesel oil , fresh water and other tanks		4.5
	Dry spaces and voids		4.0
	Superstructures and deckhouses		3.5

(1) If the as-built thickness of the element is less than 12 mm, the minimum leg length may be reduced by 0.5 mm.
(2) Only applicable to cargo tanks and ballast tanks with weather deck as the tank top. The 3m distance is measured vertically from and parallel to the top of the tank.

Weld factors for different structural members **Table 2**

Hull area	Connection				f_{weld}
	Of		To		
General, unless otherwise specified in the table	Watertight plate		Boundary plating		0.48
	Oil-tight plate		Boundary plating		0.51
	Brackets at ends of members				0.48
	Ordinary stiffener and collar plates		Deep tank bulkheads		0.24
			Web of primary supporting members and collar plates		0.38
	Web of stiffener		Plating (except deep tank bulkhead)		0.20
			Face plates of built-up stiffeners	At ends (15% of span)	0.38
				Elsewhere	0.20
Bottom and double bottom	Ordinary stiffener		Bottom and inner bottom plating		0.24
	Centre girder		Shell plates		0.38
			Inner bottom plate		0.38
	Side girder including intercostal plates		Bottom and inner bottom plating		0.24
	Floor		Shell plates and inner bottom plates	At ends, on a length equal to two frame spaces	0.38
			Centre girder and side girders in way of hopper tanks		0.38
			Elsewhere		0.24
	Bracket on centre girder		Centre girder, inner bottom, floors and shell plates		0.38
	Web stiffener		Floor and girder		0.20
Side and inner side in double side structure	Web of primary supporting members		Side plating		0.30
			Inner side plating and web of primary supporting members	in way of deck transverse and end connections	0.43
				in way of cross tie	0.36
				elsewhere	0.30
Deck	Strength deck	$t_{as_built} \geqslant 13$	Side shell plating within 0.6L midship		PPW [3]
			Elsewhere		0.48
		$t_{as_built} < 13$	Side shell plating		0.48
	Other deck		Side shell plating		0.38
			Stiffeners		0.20
	Hatch coamings		Deck plating	Longitudinal hatch coaming at corners of hatchways on a length of 15% of the hatch coaming height	FPW [4] [1]
				Longitudinal hatch coaming on a length starting from 15% of the hatch coaming height from the corners of hatchways up to 15% of the hatch length	0.48
				Elsewhere	0.38
	Web stiffeners		Coaming webs		0.20 [2]
Bulkheads [5]	Non-watertight bulkhead structure		Boundaries	Swash bulkheads	0.24
	Stiffener		Bulkhead plating	At ends (25% of span), where no end brackets are fitted	0.48

Hull area	Connection		f_{weld}
	Of	To	
Aft peak	Internal members	Boundaries and each other: below waterline	0.38
		Above waterline	0.20
Fore peak	Internal members	Boundaries and each other	0.20
Machinery space	Centre girder	Keel and inner bottom	0.48
	Floor	Centre girder and engine foundation girder	0.48
	Engine foundation girders	Top plate of main engine bed and inner bottom plate, where applicable	PPW (3)
	Floors and girders	Inner bottom and shell plate	0.38
Superstructure and deckhouse	External bulkhead (first and second tier erections)	Deck, external bulkhead	0.48
	External bulkheads and internal bulkheads	Elsewhere	0.20

(1) f_{weld} =0.43 for hatch coaming other than in cargo holds.
(2) Continuous welding.
(3) PPW: Partial penetration welding in accordance with [2.4.2]. When one side partial penetration weld is adopted, f_{weld} = 0.48 is to be used for the fillet.
(4) FPW: Full penetration welding in accordance with [2.4.2].
(5) Bulkheads of superstructure and deckhouse are to be considered in the row corresponding to "Superstructure and deckhouse".

Weld factors for miscellaneous fittings and equipment **Table 3**

Item		Connection to	f_{weld}
Hatch cover	Primary supporting members	At ends (10% of span) of PSM	0.48(1)
		Elsewhere	0.24
	Stiffeners	At ends	0.38 (2)
		Elsewhere	0.20
Mast, derrick post, crane pedestal, etc.		Deck / Underdeck reinforced structure	0.43
Deck machinery seat		Deck	0.24
Mooring equipment seat		Deck	0.43
Ring for access hole type cover		Anywhere	0.43
Stiffening of side shell doors and weathertight doors		Anywhere	0.24
Frames of shell and weathertight doors		Anywhere	0.43
Coaming of ventilator and air pipe		Deck	0.43
Ventilators, etc., fittings		Anywhere	0.24
Scupper and discharge		Deck	0.55
Bulwark stay		Deck	0.24
Bulwark plating		Deck	0.43
Guard rail, stanchion		Deck	0.43
Cleats and fittings		Hatch coaming and hatch cover	0.24 (3)

(1) For bulk carrier hatch covers f_{weld} = 0.38.
(2) For bulk carrier hatch covers f_{weld} = 0.24 at ends of stiffeners.
(3) Minimum weld factor. Where $t_{as\text{-}built}$>11.5mm l_{leg} need not exceed 0.62$t_{as\text{-}built}$. Penetration welding may be required depending on design.

Weld factors for primary supporting members **Table4**

Hull structural member	Connection			f_{weld}
	Of	To		
Primary supporting member	Web plate	Shell plating, deck plating, inner bottom plating, bulkhead	Within end 15% of shear span and extending to end of member	0.48
			Elsewhere	0.38
		Face plate	In tanks/holds Members located within 0.125L from fore peak	0.38
			Elsewhere if cross section area of face plate exceeds 65 cm^2	0.38
			Elsewhere	0.24
	End connections		In way of boundaries of ballast and cargo tanks	0.48
			Elsewhere	0.38

2.5.5

Where the as-built web thickness of the abutting longitudinal stiffener is greater than 15 mm and exceeds the thickness of the attached plating, the welding is to be double continuous and the leg length of the weld is not to be less than the largest of the following:

a) $0.30t_{as\text{-}built}$, where $t_{as\text{-}built}$ is the as-built thickness of the attached plating without being taken greater than 30 mm.

b) $0.27t_{as\text{-}built} + 1$, where $t_{as\text{-}built}$ is the as-built thickness of the abutting member. The leg size resulting of this formula needs not to be taken greater than 8.0 mm.

c) Leg length given in the Table 1.

2.5.6

Where the minimum weld size is determined by the requirements of second formula shown in [2.5.2], the weld connections to shell, decks or bulkheads are to take account of the material lost in the cut out, where stiffeners pass through the member. In cases where the width of the cut-out exceeds 15 % of the stiffener spacing, the size of weld leg length is to be multiplied by:

$$\frac{0.85s}{l_w}$$

where:

s : Stiffener spacing in mm, as shown in Figure 5.

l_w : Length of web plating between notches, in mm, as shown in Figure 5.

2.5.7 Shear area of primary supporting member end connections

Welding of the end connections, inclusive 10% of shear span, of primary supporting members is to be such that the weld area is to be equivalent to the gross cross sectional area of the member. The weld leg length in mm, l_{leg}, is to be taken as:

$$l_{leg} = 1.41 f_{yd} \frac{h_w t_{gr-req}}{l_{weld}}$$

where:

h_w : Web height of primary supporting members, in mm.

t_{gr_req} : Required gross thickness of the web in way of the end connection, including 10% of shear span, based on the highest average usage factor for yield from cargo hold FE analysis or the shear area requirement for PSM outside cargo hold region, in mm.

l_{weld} : Length of the welded connection in mm, as shown in Figure 6.

l_{dep} : Total length of deposit of weld metal, in mm, see Figure 6 taken as:

$l_{dep} = 2\ l_{weld}$

The size of weld is not to be less than the value calculated in accordance with [2.5.2].

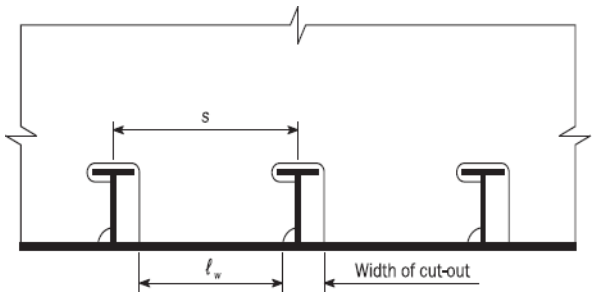


Figure 5 Effective material in web cut-outs for stiffeners

2.5.8 Longitudinals

Welding of longitudinals to plating is to be doubled continuous at the ends of the longitudinals at the extent of 15 % of shear span as defined in Ch 3, Sec 7, [1.1.3].

In way of primary supporting members, the length of the double continuous weld is to be equal to the depth of the longitudinal or the end bracket, whichever is greater.

2.5.9 Deck longitudinals

For deck longitudinals, a matched pair of welds is required at the intersection of longitudinals with primary supporting members.

2.5.10 Longitudinal continuity provided by brackets

Where a longitudinal strength member is to cut at a primary supporting structure and the continuity of strength is provided by brackets, the weld area A_{weld} is not to be less than the gross cross sectional area of the member. The weld area, A_{weld} in cm^2, is to be determined by the following formula:

$$A_{weld} = \frac{f_{yd} t_{throat} l_{dep}}{100}$$

2.5.11 Unbracketed stiffeners

Where intermittent welding is permitted, unbracketed stiffeners of shell, watertight and oil-tight bulkheads, and deckhouse fronts are to have double continuous welds for one-tenth of their length at each end. Unbracketed stiffeners of non-tight structural bulkheads, deckhouse sides and aft ends are to have a pair of matched intermittent welds at each end.

2.5.12 Reduced weld size

Where an approved automatic deep penetration procedure is used and quality control facilitates are working to a gap between members of 1 mm and less, the weld factors given in Table 2 may be reduced by 15% but not more than fillet weld leg size of 1.5 mm. Reductions of up to 20%, but not more than the fillet weld leg size of 1.5 mm, will be accepted provided that the shipyard is able to consistently meet the following requirements:

a) The welding is performed to a suitable process selection confirmed by welding procedure tests covering both minimum and maximum root gaps.
b) The penetration at the root is at least the same amount as the reduction into the members being attached.
c) Demonstrate that an established quality control system is in place.

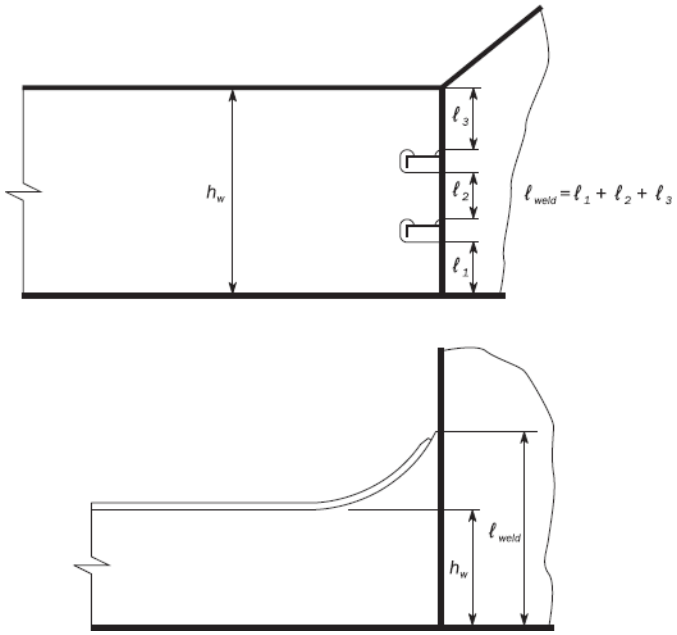


Figure 6 Shear area of primary supporting member

Note1: The length l_{weld} is the length of the welded connection. The total length of the weld deposit l_{dep} if welded with double continuous fillet welds is twice the length of the welded connection l_{weld}.

2.5.13 Reduced weld size justification

Where any of the methods for reduction of the weld size are adopted, the specific requirements giving justification for the reduction are to be indicated on the drawings. The drawings are to document the weld design and dimensioning requirements for the reduced weld length and the required weld leg length given by [2.5.2] without the leg length reduction. Also, notes are to be added to the drawings to describe the difference in the two leg lengths and the requirements for their application.

3 BUTT JOINT

3.1 General

3.1.1

Joints in the plate components of stiffened panel structures are generally to be joined by butt welds, see Figure 7.

3.2 Thickness difference

3.2.1 Taper

In the case of welding of plates with difference in as-built thickness greater than 4 mm, the thicker plate is normally to be tapered. The taper has to have a length of not less than 3 times the difference in as- built thickness. If the width of groove is not less than 3 times the difference the transition taper is to be avoided.

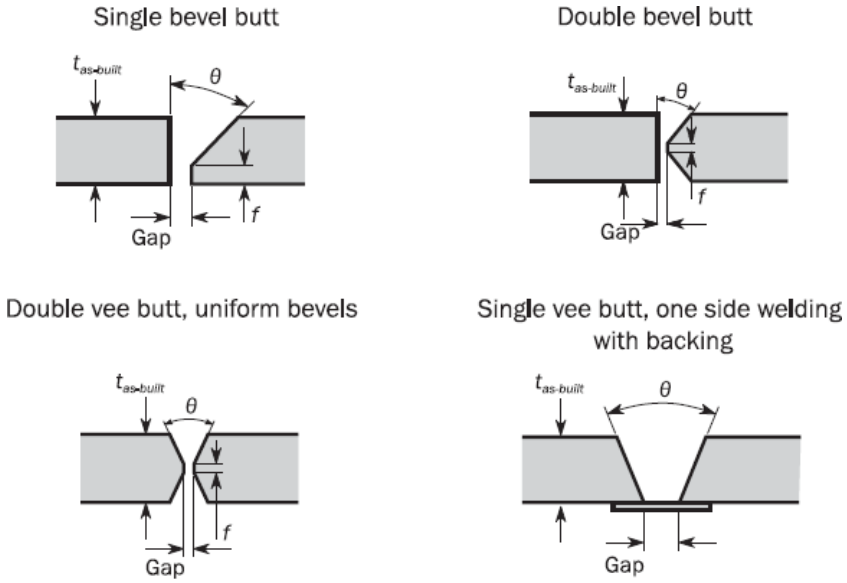


Figure 7 Typical butt welds

4 OTHER TYPES OF JOINTS

4.1 Lapped joints

4.1.1 Areas

Lap joint welds may be adopted in very specific cases subject to the approval of the Society. Lap joint welds may be adopted for the following:

- Peripheral connections of doublers.
- Internal structural elements subject to very low stresses.

4.1.2 Overlap width

Where overlaps are adopted, the width of the overlap is not to be less than three times, but not greater than four times the as-built thickness of the plates being joined, see Figure 8. Where the as-built thickness of the thinner plate being joined has a thickness of 25 mm or more, the overlap will be subject to special consideration.

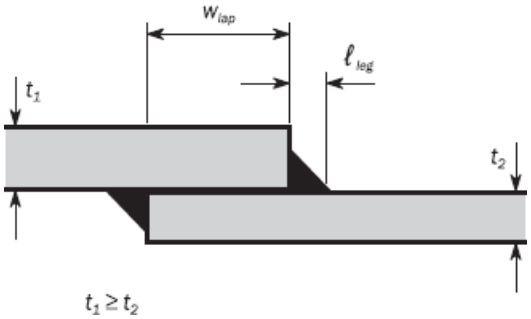


Figure 8 Fillet weld in lapped joint

4.1.3 Overlaps for lugs

The overlaps for lugs and collars in way of cut-outs for the passage of stiffeners through webs and bulkhead plating are not to be less than three times the thickness of the lug but need not be greater than 50 mm.

4.1.4 Lapped end connections

Lapped end connections are to have continuous welds on each edge with leg length, l_{leg} in mm, as shown on Figure 8 such that the sum of the two leg lengths is not less than 1.5 times the as-built thickness of the thinner plate.

4.1.5 Overlapped seams

Overlapped seams are to have continuous welds on both edges, of the sizes required by [2.5.2] for the boundaries of tank/hold or watertight bulkheads. Seams for plates with as-built thickness of

12.5 mm or less, which are clear of tanks/holds, may have one edge with intermittent welds in accordance with [2.5.2] for watertight bulkhead boundaries.

4.2 Slot welds

4.2.1

Slot welds may be adopted in very specific cases subject to the approval of the Society. However, slot welds of doublers on the outer shell and strength deck are not permitted within 0.6 *L* amidships.

CCS 4.2.1a Slot welds are not adopted in general. Where internal access for welding from the back side is not practicable, e.g. where direct application of fillet welding is not practicable for the connection of plating to internal webs, slot welds may be adopted. However, slot welds of doublers on the outer shell and strength deck are not permitted within 0.6 L amidships.

4.2.2

Slots are to be well-rounded and have a minimum slot length, l_{slot} of 75 mm and width, w_{slot} of twice the as- built plate thickness. Where used in the body of doublers and similar locations, such welds are in general to be spaced a distance, s_{slot} of $2l_{slo}$ to $3l_{slo}$ but not greater than 250 mm, see Figure 9. The size of the fillet welds is to be determined from second formula shown in [2.5.2] using $t_{as\text{-}built}$ of the thinner plate and a weld factor of 0.48.

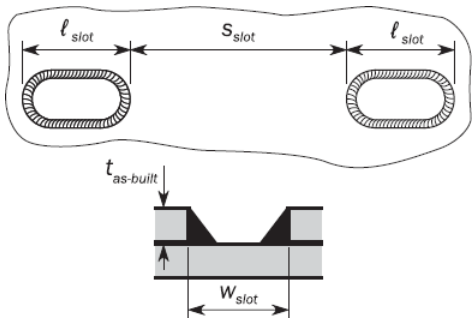


Figure 9 Slot welds

4.2.3 Closing plates

For the connection of plating to internal webs, where access for welding is not practicable, the closing plating may be attached by slot welds to face plates fitted to the webs.

4.2.4

Slots are to be well-rounded and have a minimum slot length, l_{slot} of 90 mm and a minimum width, w_{slot} of twice the as-built plate thickness. Slots cut in plating are to have smooth, clean and square edges and are in general to be spaced a distance, s_{slot} not greater than 140 mm. Slots are not to be filled with welding.

4.3 Stud and lifting lug welds

4.3.1

Where permanent or temporary studs or lifting lugs are to be attached by welding to main structural parts in areas subject to high stress, the proposed locations are to be submitted for approval.

5 CONNECTION DETAILS

5.1 Bilge keels

5.1.1

The ground bar is to be connected to the shell with a continuous fillet weld, and the bilge keel to the ground bar with a continuous fillet weld in accordance with Table 5.

Connections of bilge keels **Table 5**

Structural items being joined	Leg length of weld, in mm	
	At ends(1)	Elsewhere
Ground bar to the shell	0.62 t_{1as_built}	0.48 t_{1as_built}
Bilge keel web to ground bar	0.48 t_{2as_built}	0.30 t_{2as_built}

$t_{1as\text{-}built}$: As-built thickness of ground bar, in mm.
$t_{2as\text{-}built}$: As-built thickness of web of bilge keel, in mm.
(1): Zone "*b*" in Fig. 19 and Fig. 20 in Pt 1 Ch 3 Sec 6 for definition of "ends".

5.1.2
Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating as shown in Figure 10. In general, shell butts are to be flush in way of the ground bar and ground bar butts are to be flush in way of the bilge keel. Direct connection between ground bar butt welds and shell plating is not permitted. This may be obtained by use of removable backing.

5.1.3
The ground bar is to be continuously fillet welded with a leg length as given in Table 4. At the ends of the ground bar, the leg length is to be increased as given in Table 4, without exceeding the as-built thickness of the ground bar as shown in Figure 10. The welded transition at the ends of the ground bar to the plating connection should be formed with the weld flank angle of 45 deg or less.

5.1.4
In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width of the butt weld and is to be a minimum of 25 mm. Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

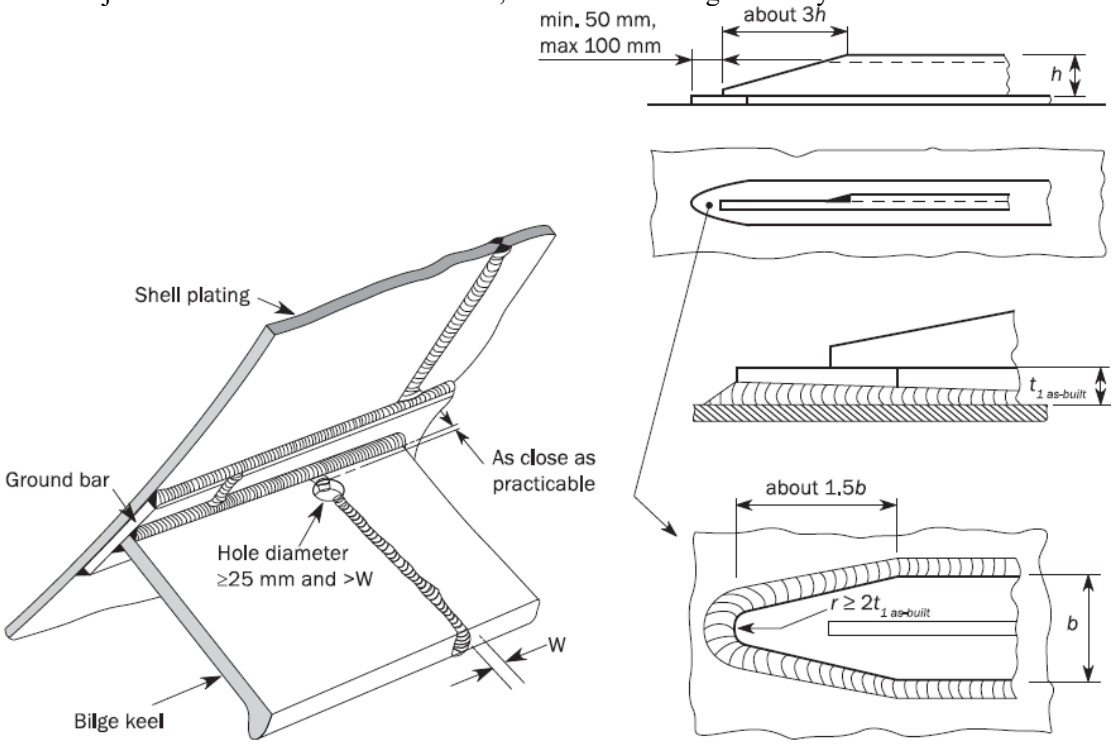


Figure 10 Bilge keel

5.2 Bulk carrier side frames
5.2.1

The following requirements are applicable to side frames, end brackets and tripping brackets of single side skin bulk carriers.

5.2.2
For zones 'a' and 'b' as shown in Figure 11, double continuous fillet welding should be used with leg lengths of $0.62t_{as\text{-}built}$ and $0.57t_{as\text{-}built}$ respectively where $t_{as\text{-}built}$ is the as-built thickness of the thinner of two connected members, in mm.

5.2.3
Double continuous welding is to be adopted for the connections of tripping brackets with side shell frames and plating. The leg length, l_{leg} in mm, for these connections should be taken as:

- $0.5t_{as\text{-}built} + 1.0$ if $t_{as\text{-}built} < 10$
- $0.4\ t_{as\text{-}built} + 1.0$ if $10 \leqslant t_{as\text{-}built} < 20$
- $0.3\ t_{as\text{-}built} + 1.0$ if $t_{as\text{-}built} \geqslant 20$

In these formulas $t_{as\text{-}built}$ is as-built thickness of the abutting plate.

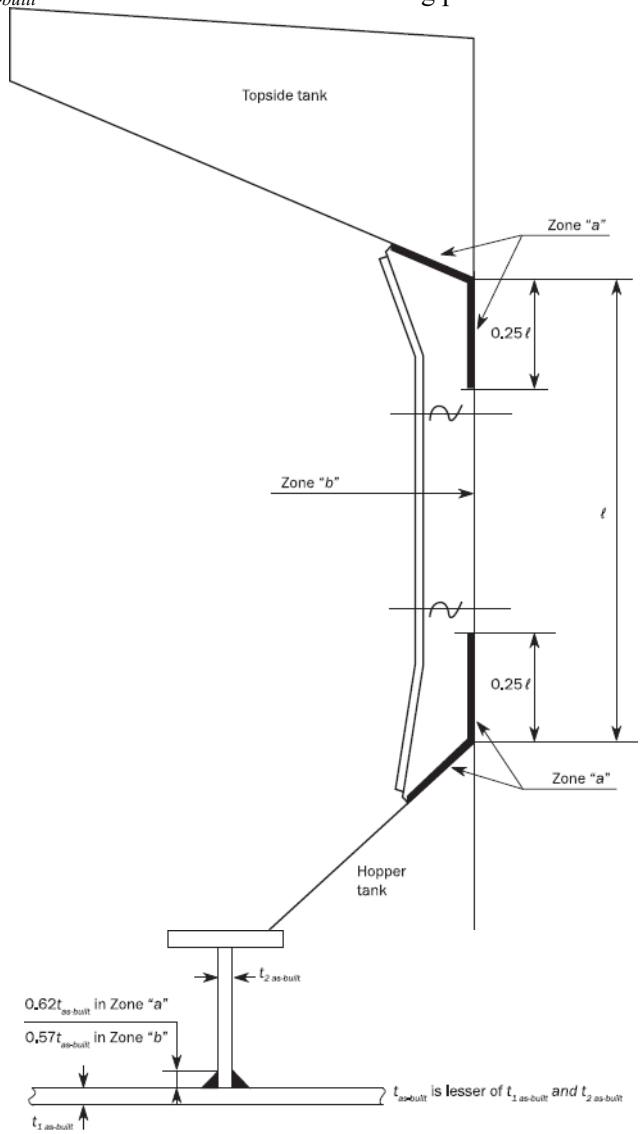


Figure 11 Bulk carrier side frames

5.3 End connections of pillars and cross ties
5.3.1
The end connections of pillars and cross ties are to have an effective fillet weld area, in cm^2, (weld throat multiplied by weld length) not less than:

$$A_{weld} = f_3(\frac{235}{R_{eH_weld}})^{0.75} F$$

where:

F : Design load, for the structure under consideration, in kN.

f_3 : Coefficient equal to:

f_3 = 0.05 when pillar or cross tie is in compression only.

f_3= 0.14 when pillar or cross tie is in tension.

5.4 Abutting plates with small angles

5.4.1

Where the angle θ between the abutting plate and the connected plate is less than 75 deg as shown in Figure 12, the size of fillet welds l_θ, in mm, for the side of larger angle is to be increased in accordance with:

$$l_\theta = \frac{l_{leg}}{\sqrt{2}\sin\frac{\theta}{2}}$$

where:

l_{leg} : Leg length of fillet weld, in mm, as defined in [2.5.2].

θ : Connecting angle, in deg, as shown in Figure 12.

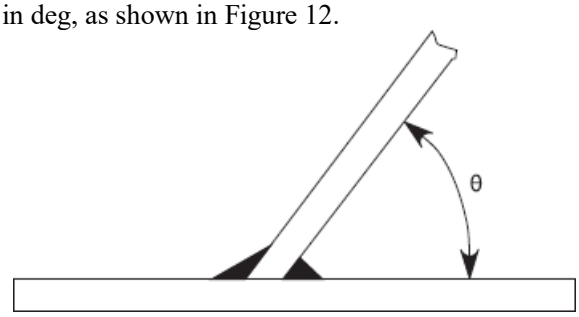


Figure 12 Connecting angle

5.4.2

Connections of main strength members where θ is less than 45 deg, see Figure 12, may be applied only in dry spaces and voids.

Chapter 13 SHIP IN OPERATION - RENEWAL CRITERIA

Section 1 PRINCIPLES AND SURVEY REQUIREMENTS

1 PRINCIPLES

1.1 Application

1.1.1

The purpose of this chapter is to provide criteria for the allowable thickness diminution of ships'hull structures.

1.1.2

The criteria apply only to ships in operation that are classed in accordance with these Rules.

1.1.3

Thickness measurement is to be used to assess ships' hull structures against the specified renewal criteria.

1.1.4

The hull survey requirements are those given, as applicable, in the Rules and/or documents of the individual Society which incorporate:

- UR Z10.2 for single side skin bulk carriers.
- UR Z10.4 for double hull oil tankers.
- UR Z10.5 for double side skin bulk carriers.

1.2 Corrosion allowance concept

1.2.1 Corrosion allowance

Corrosion allowance is comprised of two aspects: local and global corrosion, as defined in Ch 3, Sec 2, [1.1.2].

1.2.2 Assessment

Assessment against both local and global corrosion renewal criteria is required during the operational life of ships.

Assessment against the newbuilding requirements which incorporate corrosion additions, given in Ch 3, Sec 3, and which consider all relevant loads and limit states, e.g. yielding, buckling, and fatigue is not required during the operational life of ships, provided that the measured thickness of any structural members remain greater than the renewal thickness specified in Ch 13, Sec 2, [2].

1.2.3 Steel renewal

Steel renewal is required if either the local or global corrosion allowance is exceeded.

1.3 Requirements for documentation

1.3.1 Plans

The plans to be supplied onboard the ship, as required in Ch 1, Sec 3, are to include, for each structural element, both the as-built and renewal thickness as defined in Ch 13, Sec 2. Any thickness for voluntary addition is also to be clearly indicated on the plans.

For the list of plans and information to be supplied onboard the ship, reference is made to the Rules and/or documents of the individual Society which incorporate IACS UR Z10.2, Z10.4 or Z10.5 as applicable.

1.3.2 Hull girder sectional properties

The Midship section plan to be supplied onboard the ship is to include the minimum required hull girder sectional properties, as defined in Ch5, Sec 1, for the representative transverse sections of all cargo holds.

2 HULL SURVEY REQUIREMENTS

2.1 General

2.1.1 Minimum hull survey requirements

The minimum hull survey requirements including thickness measurements for the maintenance of class are given in the Rules and/or documents of the individual Society which incorporate IACS UR Z10.2, Z10.4 and Z10.5.

Section 2 ACCEPTANCE CRITERIA

SYMBOLS

$t_{as\text{-}built}$: As built thickness, in mm.

t_c : Corrosion addition in mm, as defined in Ch 3, Sec 2.

t_{res} : Reserve thickness, taken equal to 0.5 mm.

t_{vol_add} : Thickness for voluntary addition, in mm.

1 GENERAL

1.1 Application

1.1.1

This section gives requirements for the application of the acceptance criteria.

1.2 Definition

1.2.1 Deck zone

The deck zone includes all the following items contributing to the hull girder strength:

- For bulk carriers: elements above or crossed by the 0.9 *D* level line above the baseline such as:
  - Strength deck plating.
  - Deck stringer.
  - Sheer strake.
  - Side shell plating.
  - Inner hull and other longitudinal bulkhead plating, if any.
  - Topside tank sloped plating, including horizontal and vertical strakes.
  - Longitudinal stiffeners, girders and stringers connected to the above mentioned plating.
- For oil tankers: elements above or crossed by the 0.9D level line above the baseline such as:
  - Strength deck plating.
  - Deck stringer.
  - Sheer strake.
  - Inner hull and other plane longitudinal bulkheads upper most strake.
  - Topside tank sloped plating, including horizontal and vertical strakes.
  - Longitudinal upper stool.
  - Longitudinal stiffeners, girders and stringers connected to the above mentioned plating.

1.2.2 Bottom zone

The bottom zone includes the following items contributing to the hull girder strength:

- For bulk carriers: elements up to the upper level of the hopper sloping plating or up to and including the inner bottom plating if there is no hopper tank:
  - Keel plate.
  - Bottom plating.
  - Bilge plating.
  - Bottom girders.
  - Inner bottom plating.
  - Hopper tank sloping plating, and horizontal plating, if any.
  - Side shell plating.
  - Plane longitudinal bulkheads lower strake.
  - Longitudinal stiffeners connected to the above mentioned plating.
- For oil tankers:
  - Keel plate.
  - Bottom plating.
  - Bilge plating.
  - Plane longitudinal bulkheads lower strake.
  - Bottom girders.

- Inner bottom plating.
- Hopper tank sloping plating, and horizontal plating, if any.
- Side shell plating.
- Longitudinal lower stool.
- Longitudinal stiffeners connected to the above mentioned plating.

1.2.3 Neutral axis zone

The neutral axis zone includes the following items between the deck zone and the bottom zone, as for example:

- Side shell plating.
- Inner hull plating and longitudinal bulkheads, if any.
- Topside tank sloped plating.

For the longitudinal strength members forming the web of the hull girder which are inclined to the vertical, the area of the member to be included in the zone area is to be based on the projected area onto the vertical plane.

2 RENEWAL CRITERIA

2.1 Local corrosion

2.1.1 Renewal thickness of local structural elements

Local structural elements include local supporting members and primary supporting members.

Steel renewal is required if the measured thickness, *tm* in mm, is less than the renewal thickness, t_{ren} defined as:

$$t_{ren} = t_{as-built} - t_c - t_{vol_add}$$

2.1.2 Renewed area

Areas which need to be renewed based on the renewal criteria in [2.1.1] are, in general, to be repaired with inserted material which is to have the same or greater grade and yield stress as the original, and to have a thickness, t_{repair} in mm, not less than:

$$t_{repair} = t_{as-built} - t_{vol_add}$$

2.1.3 Alternative solutions

Alternative solutions may be adopted in accordance with the requirements of the Rules and/or documents of the individual Society which incorporate IACS UR Z10.2, Z10.4 and Z10.5, where the measured thickness, t_m is such as:

$$t_{ren} \leqslant t_m < t_{ren} + t_{res}$$

2.2 Global corrosion

2.2.1 Application

The ship's longitudinal strength is to be evaluated by using the thickness of structural members measured, renewed and reinforced, as appropriate, during special surveys, for ships over 10 years of age.

2.2.2 Renewal criteria

The hull girder strength criteria are given as detailed below.

a) Deck and bottom zones:
The current hull girder section modulus at deck and at bottom determined with the thickness measurements are not to be less than 90% of the section modulus calculated according to Ch 5, Sec 1 with the gross offered thickness.
Alternatively, the current sectional areas of the bottom zone and of the deck zone which are the sum of the measured item areas of the considered zones are not to be less than 90% of the sectional area of the corresponding zones determined with the gross offered thickness.

b) Neutral axis zone:
The current sectional area of the neutral axis zone, which is the sum of the measured plating areas of this zone, is not to be less than the sectional area of the neutral axis zone calculated with the gross offered thickness minus 0.5 t_c.

If the actual reduction of the gross offered thickness of all items, of a given transverse section, which contribute to the hull girder strength is less than 10% for the deck and bottom zones and $0.5t_c$ for the neutral axis zone, the hull girder strength criteria of this transverse section is satisfied and the calculations of the different zone areas with measured thicknesses need not be carried out.

The gross offered thickness is defined in Ch 3, Sec 2.

CCS Appendix A WAVE LOAD DIRECT CALCULATION METHOD BASED ON EQUIVALENT DESIGN WAVE METHOD

Symbols:

t : *Time, in s.*

V : *Ship speed under consideration, in m/s.*

x,y,z : *Coordinate X, Y and Z of the considered point in reference coordinate system as defined in [1.2], in m.*

x_G,y_G,z_G :*Coordinate X, Y and Z of ship gravity center corresponding to the considered loading condition in reference coordinate system as defined in [1.2], in m.*

L : *Rule length, in m.*

ω_e: *Encounter frequency.*

η_i (i=1,6)*: Ship motions displacements relative to the ship gravity center in six degrees of freedom as surge, sway, heavy, roll, pitch and yaw.*

θ *: Roll amplitude, in rad.*

φ *: Pitch amplitude, in rad.*

a_X, a_Y, a_Z *: Acceleration of any point.*

f_S *: Coefficient for symbol. For vertical bending moment, hogging is positive and sagging is negative. For horizontal bending moment, tension on the starboard side is positive and compression on the starboard side is negative.*

f_{ps} *: Coefficient for strength assessments which is dependent on the applicable design load scenario specified in Section 7, Chapter 4 of PART 9-1 and to be taken as :*

f_{ps} *= 1.0 for extreme design load scenario and fatigue assessment.*

f_{ps} *= 0.9 for fatigue assessment.*

f_{ps} *= 0.8 for the ballast water exchange design load scenario.*

f_{ps} *= 0.8 for the accidental flooded design load scenario at sea.*

f_{ps} *= 0.4 for the harbour/sheltered water design load scenario.*

f_β *: Heading correction factor, to be taken as :*

- *For strength assessment*

  f_β *= 0.8 for BSR and BSP load cases for the extreme sea loads design load scenario.*

  f_β *=1.0 for HSM, HSA, FSM, OST and OSA load cases for the extreme sea loads design load scenario.*

  f_β *=1.0 for ballast water exchange at sea, harbour/sheltered water and accidental flooded design load scenarios.*

- *For fatigue assessment*

  f_β *=1.0.*

f_m *: Distribution factor for vertical wave bending moment along the ship's length, see Figure 3-1.*

f_{nl} *: Coefficient considering nonlinear effects applied to vertical wave bending moment. For strength assessment, in hogging condition, it is taken as* $f_{nl\text{-}vh}$*; in sagging condition, it is taken as* $f_{nl\text{-}vs}$*. For fatigue assessment,* f_{nl} *is taken as 1.0.*

$f_{nl\text{-}vh}$ *: Taken as* $\dfrac{0.19C_B}{0.15C_B + 0.0385}$

$f_{nl\text{-}vs}$*: Taken as* $\dfrac{0.11C_B + 0.077}{0.15C_B + 0.0385}$

M_{WV} *: Vertical wave bending moment in given loading and given equivalent design wave, in kNm.*

Q_{WV} *: Vertical wave shear force in given loading and given equivalent design wave, in kN.*

M_{WH} *: Horizontal wave bending moment in given loading and given equivalent design wave, in kNm.*

M_{WT} *: Wave torsional moment in given loading and given equivalent design wave, in kNm.*

P_{ex} *: Total sea pressure in given loading and given equivalent design wave, in kN/m*^{2}*.*

P_{es} *: Hydrostatic pressure in given loading and given equivalent design wave, in kN/m*^{2}*.*

P_{ed} *: Hydrodynamic pressure in given loading and given equivalent design wave, in kN/m*^{2}*.*

P_{in} *: Total internal pressure in given loading and given equivalent design wave, in kN/m*^{2}*.*

1 GENERAL PROVISIONS

1.1 Application

This Appendix is applicable to the wave load direct calculation of oil tankers and bulk carriers with unrestricted worldwide navigation and may also be used as a reference for the wave load direct calculation of oil tankers and bulk carriers of other service areas.

1.2 Reference coordinate system

The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand coordinate system (see Figure 1-1) :

Origin : at the intersection among the longitudinal plane of symmetry of ship, the aft end of L and the baseline;

X axis : longitudinal axis, positive forwards;

Y axis : transverse axis, positive towards portside;

Z axis : vertical axis, positive upwards.

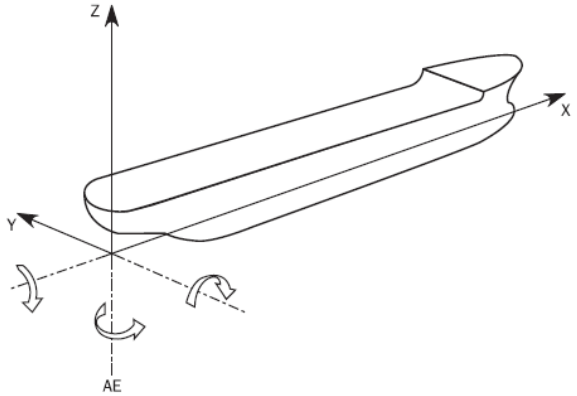


Figure 1-1 Reference Coordinate System

2 PRINCIPLE OF EQUIVALENT DESIGN WAVE METHOD

2.1 Wave load direct calculation method

Wave load direct calculation method is based on the three-dimensional linear potential flow theory.

Once the fluid velocity potential at the junction of fluid and hull together with its partial derivative in relation to the space coordinate are obtained, the interacting forces between fluid and hull can be obtained, then hull motion responses and section loads will be obtained, based on the Bernoulli's equation.

The solution for velocity potential is mainly to solve a boundary integral equation for meeting definite conditions, i.e. the fluid domain condition, the free surface condition, the body surface condition, the bottom condition and the remote radiation condition. Current solving methods mainly include free surface Green function method in frequency domain or time domain and the simple Green function method.

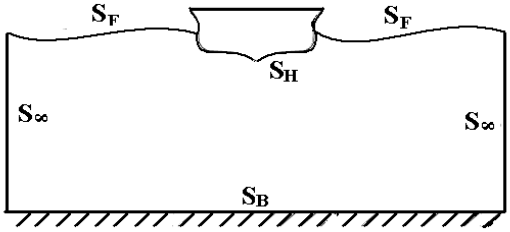


Figure 2-1 Boundary Condition for the Solution of Velocity Potential

Based on the Bernoulli's equation, the diffraction pressure response function and hydrodynamic coefficient will be obtained and then the ship's motions, accelerations and radiation pressure response function together with the response function of section loads will be obtained when the velocity potential is obtained.

2.2 Long term and short term prediction of linear wave loads

2.2.1 Short term prediction of linear wave loads

The short-term wave may be regarded as stationary random Gaussian process with average value of zero. Based on the random process theory, the response wave loads (output) subject to the wave

(input) will also be stationary random Gaussian process with average value of zero. The relationship between input wave spectrum S_ζ and output response spectrum S_w is expressed by the following formula:

$$S_W(\omega, H_{1/3}, T_Z, V, \beta+\theta) = H^2(\omega, V, \beta+\theta) S_\zeta(\omega, H_{1/3}, T_Z, \theta)$$

where:

ω is wave frequency, $H_{1/3}$ is significant wave height, T_Z is average zero-crossing period, V is ship speed, β is course and θ is heading angle.

For a stationary random Gaussian process with average value of zero, under the narrow spectrum assumption, the amplitude complies with Rayleigh distribution and the corresponding probability density is:

$$f_0(x) = \frac{2x}{E[(H_{1/3}, T_Z), V, \beta]} \exp[-\frac{x^2}{E[H_{1/3}, T_Z], V, \beta}]$$

where:

E is two times wave load variance, expressed as follows:

$$E[(H_{1/3}, T_Z), V, \beta] = 2\int_{-\pi/2}^{+\pi/2} \int_0^\infty S_W(\omega, H_{1/3}, T_Z, V, \beta+\theta) \mathrm{d}\omega \mathrm{d}\theta$$

The distribution function, 1/3 significant value and 1/10 significant value of loads are obtained in accordance with load response function and wave parameters.

2.2.2 Long term prediction of linear wave loads

Where it is assumed that short term conditions consisting of various different sea states and navigation conditions are independent from each other, the long term probability distribution will be the weighted combination of short term probability distribution, i.e. the exceedance probability of the wave load amplitude X greater than certain fixed value x is :

$$Q(x) = p\{X \geq x\} = \sum_i \sum_j \sum_k p_i(H_{1/3}, T_Z), p_i(H_{1/3}, T_Z), p_j(\beta), p_k(V) \exp\left\{\frac{-x^2}{E[(H_{1/3}, T_Z]_i, \beta_j, V_K}\right\}$$

The probability of occurrence of heading angle is assumed to be uniformly distributed between 0 and 2π. The probability of occurrence of sea state depends on the wave statistics of the navigation area of ship and at present the unrestricted service area is taken as the sea state of North Atlantic. After the navigation area of ship and probability level are determined, the maximum value of corresponding wave load characteristic may be obtained according to the above formula. Such value means the maximum wave load likely to occur once on average during the service period with number of cycles n.

2.3 Equivalent design wave method

2.3.1 General principle

For the structural strength assessment of ships and offshore engineering, the combination of load components is a complicated issue. The actual irregular wave is transformed to an equivalent regular wave by the equivalent design wave method, assuming that the maximum value of combined loads occurs when one of the variable loads reaches the maximum value during the service period and corresponding transient values are used for other variable loads. The method is also referred to as dynamic load method. The selected wave load components which have a deciding effect on structural strength generally include ship motion and acceleration, wave bending moment, torsional moment and shear force, sea pressure etc.

2.3.2 Determination of relevant parameters

The main steps of determination of parameters of equivalent design wave are as follows, see Figure 2-2 :

a) selection of target loads to carry out hydrodynamic analysis and calculate the response function of target loads under different headings and frequencies;

b) determination of predominant load and its probability level, carrying out spectrum analysis to solve the long-term distribution value of predominant load under the probability level;

c) determination of heading, frequency and phase of equivalent design wave in accordance with long-term statistics and response function, calculation of design wave height;

d) calculation of relevant load components of equivalent design wave in accordance with its heading, frequency, phase and wave height;
e) application of relevant loads of the equivalent design wave for structural analysis.

3 WAVE LOAD CALCULATION AND APPLICATION BASED ON EQUIVALENT DESIGN WAVE METHOD

3.1 Basic assumption and provision

3.1.1 General

This part specifies the basic assumption, basic calculation steps, calculation model requirements and calculation software requirements. Relevant calculation is to comply with the provisions of sub-sections.

3.1.2 Relevant assumption

The wave load calculation based on equivalent design wave method is based on the following assumptions:

a) based on the three-dimensional linear potential flow theory;
b) based on the wave environment of North Atlantic, and the wave scatter diagram and short-term and long-term prediction of wave loads are based on IACS Rec.34;
c) the two parameter P-M spectrum recommended by IACS Rec.34 is used as the wave spectrum;
d) the heading step is 30 deg. and the probability of occurrence of all headings are equal;
e) the calculation frequency is 0.2 rad/s to 1.2 rad/s and the frequency interval is 0.05 rad/s;
f) cos2is used as the energy transfer function of wave;
g) the strength assessment is based on 10-8 probability level and the speed is taken as 5 knots;
h) the fatigue assessment is based on 10-2 probability level and the speed is taken as 75% of the service speed.

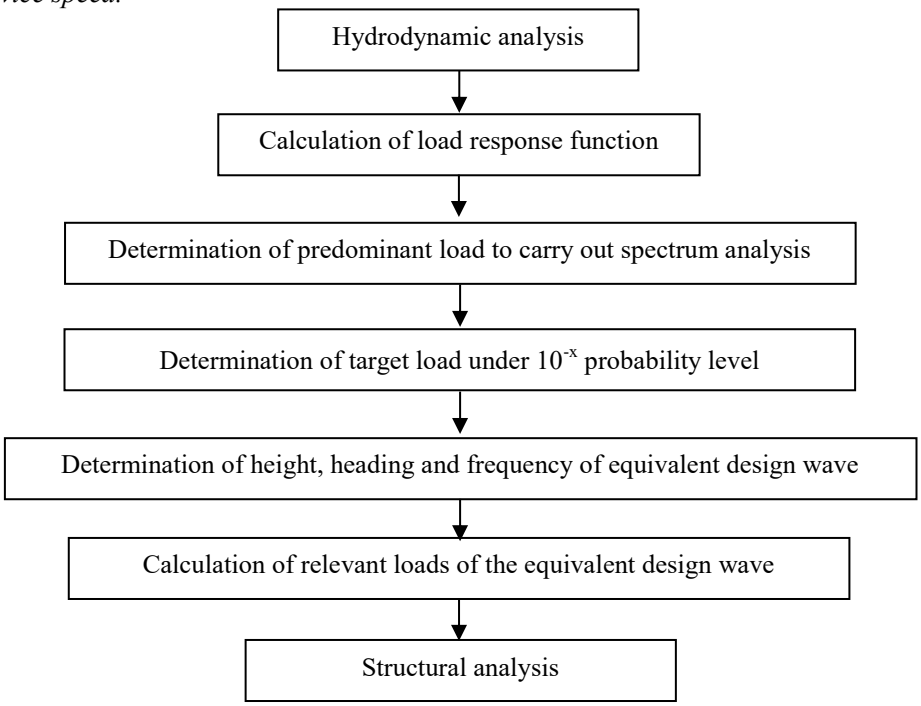


Figure 2-2 Flow Chart of Wave Load Calculation by Equivalent Design Wave Method

3.1.3 Calculation steps

The main steps of calculation of wave loads based on equivalent design wave method are as follows :

a) selection of loading pattern, establishment of hydrodynamic model and mass distribution model;
b) calculation of wave load response function of each heading;
c) selection of wave environment for long-term prediction of target wave load, in order to obtain the limit value and phase of relevant target load;

d) determination of parameters such as wave height, heading, frequency and phase of equivalent design wave;

e) calculation of hull girder loads, acceleration in way of ship's center of gravity and distribution of sea pressure of relevant equivalent design wave, calculation of internal pressure in accordance with position of compartment and loaded cargo.

3.1.4 Requirements for calculation model

The calculation model of wave loads based on equivalent design wave method is to comply with the following requirements :

a) the mass model is to be fine enough in order to ensure that the error between mass of model and that of real ship is not greater than 0.1% and the error between position of center of gravity of model and that of real ship is not greater than 0.1%L;

b) the model of wetted surface is to simulate the shape of real ship in so far as practicable, the error between displacement of model and that of real ship is not greater than 0.1% and the error between position of center of buoyancy of model and that of real ship is not greater than 0.1%L;

c) the number of meshes of the wetted surface model is to be sufficient and the mesh length is generally not to be greater than0.01L.

3.1.5 Requirements for calculation software

The calculation software of wave loads based on equivalent design wave method is to be based on the three-dimensional linear potential flow theory and approved by CCS.

3.2 Loading conditions

3.2.1 General requirements

For the loading conditions for structural strength assessment, see relevant provisions of Section 8, Chapter 4 of PART 9-1.

For the loading conditions for fatigue strength assessment, see relevant provisions of Section 8, Chapter 4 of PART 9-1. Unless there is more accurate data, the time scale factor of corresponding loading condition is given in Section 1, Chapter 9 of PART 9-1.

3.2.2 Loading conditions to be considered in the strength assessment

Loading conditions to be considered in the strength assessment prescriptive method

(1) The following loading conditions are to be considered for oil tankers:
- *a) homogeneous full load (departure);*
- *b) normal ballast condition (arrival);*
- *c) emergency ballast condition (arrival);*
- *d) other potential critical loading conditions in the loading manual.*

(2) The following loading conditions are to be considered for bulk carriers :
- *a) homogeneous heavy cargo full load (departure);*
- *b) homogeneous light cargo full load (departure);*
- *c) alternate heavy cargo full load (departure);*
- *d) alternate light cargo full load (departure);*
- *e) heavy ballast condition (arrival);*
- *f) normal ballast condition (arrival);*
- *g) other potential critical full load in the loading manual.*

Loading conditions to be considered in FE method

(1) The following loading conditions are to be considered for oil tankers fitted with one longitudinal bulkhead:
- *a) optional loading condition of 0.9 T_{SC};*
- *b) partial loading condition of 0.60 T_{SC};*
- *c) emergency ballast condition of T_{BAL-EM}.*

(2) The following loading conditions are to be considered for oil tankers fitted with two longitudinal bulkheads:
- *a) optional loading condition of 0.9 T_{SC};*
- *b) partial loading condition of 0.65 T_{SC};*
- *c) partial loading condition of 0.60 T_{SC};*

d) emergency ballast condition of T_{BAL-EM}.

(3) The following loading conditions are to be considered for bulk carriers:

a) homogeneous light cargo, homogeneous heavy cargo, alternate heavy cargo, alternate light cargo of T_{SC};

b) partial loading condition of $0.67T_{SC}$;

c) partial loading condition of $0.75T_{SC}$;

d) partial loading condition of $0.83T_{SC}$;

e) heavy ballast condition of T_{BAL-H}.

3.2.3 Loading conditions to be considered in the fatigue assessment

Loading conditions to be considered for bulk carriers include:

a) homogeneous light cargo full load (departure);

b) homogeneous heavy cargo full load (departure);

c) heavy ballast condition (arrival);

d) normal ballast condition (arrival).

The following loading conditions are to be considered for oil tankers:

a) homogeneous full load (departure);

b) normal ballast condition (arrival).

3.3 Equivalent design wave

3.3.1 Introduction

The equivalent design wave to be calculated is to represent the dynamic load cases corresponding to the most critical condition of relevant structures, mainly including the minimum and maximum of vertical bending moment of head sea and following sea amidships, the minimum and maximum of L/4 torsional moment, the minimum and maximum of pressure at waterline, the minimum and maximum of roll, the minimum and maximum of vertical acceleration of head sea and oblique sea, etc.

- *HSM load cases :*
  HSM-1 and HSM-2: Head sea EDWs that minimise and maximise the vertical wave bending moment amidships respectively.
- *HSA load cases:*
  HSA-1 and HSA-2: Head sea EDWs that maximise and minimise the head sea vertical acceleration at FP respectively.
- *FSM load cases :*
  FSM-1 and FSM-2: Following sea EDWs that minimise and maximise the vertical wave bending moment amidships respectively.
- *BSR load cases :*
  BSR-1P and BSR-2P: Beam sea EDWs that minimise and maximise the roll motion downward and upward on the port side respectively with waves from the port side.
  BSR-1S and BSR-2S: Beam Sea EDWs that maximise and minimise the roll motion downward and upward on the starboard side respectively with waves from the starboard side.
- *BSP load cases :*
  BSP-1P and BSP-2P: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the port side respectively.
  BSP-1S and BSP-2S: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the starboard side respectively.
- *OST load cases :*
  OST-1P and OST-2P: Oblique sea EDWs that minimise and maximise the torsional moment at 0.25Lfrom the AE with waves from the port side respectively.
  OST-1S and OST-2S: Oblique sea EDWs that maximise and minimise the torsional moment at 0.25Lfrom the AE with waves from the starboard side respectively.
- *OSA load cases :*
  OSA-1P and OSA-2P: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the port side respectively.
  OSA-1S and OSA-2S: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the starboard side respectively.

3.3.2 Application of equivalent design wave

The equivalent design waves to be considered for strength assessment include 7 categories, i.e. HSM, HAS, FSM, BSR, BSP, OST and OSA.

The equivalent design waves to be considered for fatigue assessment include 5 categories, i.e. HSM, FSM, BSR, BSP and OST.

3.4 Load calculation

3.4.1 Motion and acceleration

The roll angle θ and pitch angle φ of hull are calculated in accordance with the following formulae:

$\theta = f_{ps}\mathrm{Re}(\eta_4)$, $\varphi = f_{ps}\mathrm{Re}(\eta_5)$

The acceleration response function of any point of hull is determined from the following formulae :

$a_X = -g\sin(\varphi) + a_{surge} + (z-z_G)\cdot a_{pitch} - (y-y_G)\cdot a_{yaw}$

$a_Y = g\sin(\theta) + a_{sway} + (x-x_G)\cdot a_{yaw} - (z-z_G)\cdot a_{roll}$

$a_z = a_{heave} + (y-y_G)\cdot a_{roll} - (x-x_G)\cdot a_{pitch}$

Where,η_i (i=1,6) denotes ship motions displacements relative to the ship gravity center in six degrees of freedom, where η_{Re} is real part, η_{Im} is imaginary part,

$a_{surge} = f_{ps}\mathrm{Re}(\ddot{\eta}_1)$, $a_{sway} = f_{ps}\mathrm{Re}(\ddot{\eta}_2)$, $a_{heave} = f_{ps}\mathrm{Re}(\ddot{\eta}_3)$, $a_{roll} = f_{ps}\mathrm{Re}(\ddot{\eta}_4)$, $a_{pitch} = f_{ps}\mathrm{Re}(\ddot{\eta}_5)$,

$a_{yaw} = f_{ps}\mathrm{Re}(\ddot{\eta}_6)$

The relationship between speed $\dot{\eta}_i$ of six degrees of freedom and motion is as follows:

$$\dot{\eta}_i = i\omega_e \cdot (\eta_{i,\mathrm{Re}} + i\eta_{i,\mathrm{Im}}) = -\omega_e\eta_{i,\mathrm{Im}} + i\omega_e\eta_{i,\mathrm{Re}}, \quad \mathrm{Re}(\eta_i) = -\omega_e\dot{\eta}_{i,\mathrm{Im}}$$

The relationship between acceleration $\ddot{\eta}_1$ of six degrees of freedom and motion is as follows:

$$\ddot{\eta}_i = -\omega_e^2 \cdot (\eta_{i,\mathrm{Re}} + i\eta_{i,\mathrm{Im}}) = -\omega_e^2\eta_{i,\mathrm{Re}} - \omega_e^2\eta_{i,\mathrm{Im}}, \quad \mathrm{Re}(\eta_i) = -\omega_e^2\ddot{\eta}_{i,\mathrm{Re}}$$

where : ω_e is encounter frequency.

3.4.2 Hull girder loads

3.4.2.1 Hull girder still water loads

The hull girder vertical still water bending moment and vertical shear force are to taken as the permissible still water bending moment and permissible still water shear force.

3.4.2.2 Hull girder vertical wave bending moment

The hull girder vertical wave bending moment under equivalent design wave specified by each loading condition is calculated in accordance with the following formula :

$M_{WV} = f_S f_{ps} f_\beta f_m f_{nl} M_{WV,MID,MAX}$

where:

$M_{WV,MID,MAX}$ *is taken as the maximum of vertical wave bending moment between 0.4L and 0.6L in corresponding condition.*

f_m *: Distribution factor of vertical wave bending moment along ship length, as shown in Figure 3-1.*

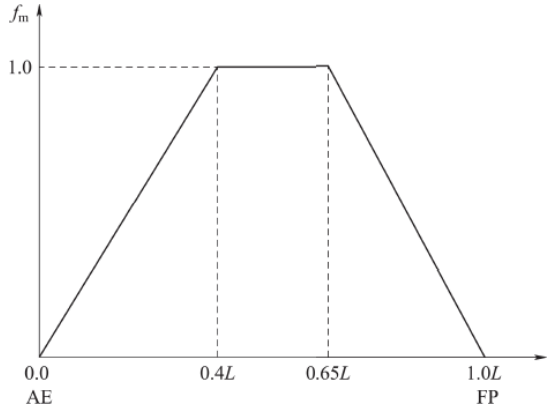


Figure 3-1 Distribution Factor f_m along the Ship's Length

The envelope of hull girder vertical wave bending moment is to be taken as the envelope of wave bending moment of all conditions.

3.4.2.3 Calculation of hull girder vertical wave shear force

For a given loading condition, the wave shear force at any section under any equivalent design wave is to be taken as:

$$Q_{WV} = f_{ps} f_{\beta} f_q f_{lp} Q_{WV,MAX}$$

where:

f_q *: distribution factor of vertical wave shear force, to be taken as* $f_{q\text{-}pos}$ *if it is greater than or equal to zero, see Figure 3-2 and* $f_{q\text{-}neg}$ *if it is less than zero, see Figure 3-3;*

f_{lp}*: coefficient for symbol of vertical wave shear force,* f_{lp} *=1.0 for hogging and* $x/L<0.5$*, or sagging and* $x/L\geqslant 0.5$*, otherwise* f_{lp} *=-1.0;*

$Q_{WV,MAX}$*: to be taken as* $MAX\left[\frac{MAX\left|Q_{WV,CAL,A,i}\right|}{0.92}, \frac{MAX\left|Q_{WV,CAL,F,i}\right|}{1.0}\right]$*, where* $Q_{WV,CAL,A,i}$ *is calculation value of wave shear force of each section when* $x/L<0.5$ *and* $Q_{WV,CAL,F,i}$ *is calculation value of wave shear force of each section when* $x/L\geqslant 0.5$*.*

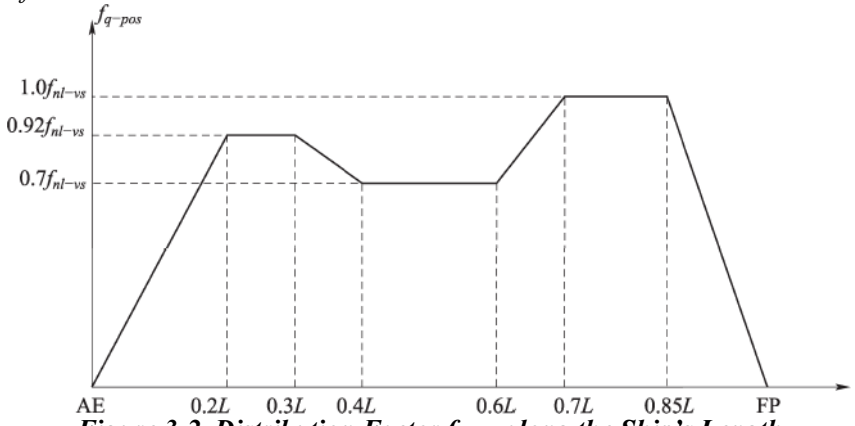


Figure 3-2 Distribution Factor $f_{q\text{-}pos}$ along the Ship's Length

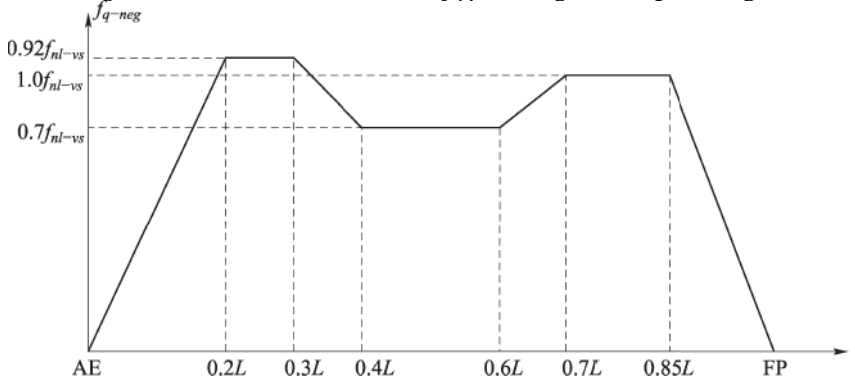


Figure 3-3 Distribution Factor $f_{q\text{-}neg}$ along the Ship's Length

3.4.2.4 Hull girder horizontal wave bending moment

The hull girder horizontal wave bending moment under equivalent design wave specified by each loading condition is calculated in accordance with the following formula :

$$M_{WH} = f_S f_{ps} f_b f_m f_{nlh} M_{WH,MID,MAX}$$

where:

f_{nlh}*: Coefficient considering nonlinear effect to be taken as:*

$f_{nlh} = 0.9$ *for strength assessment*

$f_{nlh} = 1.0$ *for fatigue assessment*

$M_{WH,MID,MAX}$ *is the maximum of horizontal wave bending moment between 0.4L and 0.6Lunder the equivalent design wave.*

3.4.2.5 Hull girder wave torsional moment

The hull girder torsional moment is considered for only OST and OSA cases for each loading condition and is to be taken as the fitted value of 20 calculation points uniformly distributed along the ship's length. The value between any two calculation points is obtained by linear interpolation, taking into account the correction of f_β.

$M_{WT}=f_{ps}f\ M_{WT,\ CAL}$

3.4.3 Sea pressure

3.4.3.1 Hydrostatic pressure

The hydrostatic pressure is calculated in accordance with the following formula, but not to be less than zero :

$P_{es}=\rho g(T_{LC}-z)$

3.4.3.2 Hydrodynamic pressure

The wave dynamic pressure of any point of section under equivalent design wave specified by each loading condition is to be taken as the linear fitted value of pressure of three points of bottom centre line point, bilge calculation point and water line point, but is not to be less than -$\rho g(T_{LC}-z)$ below the water line and not less than zero above the water line, i.e. :

$P_{ed}=f_{ps}f_{nl-p}[P_{ctr}+\frac{y}{y_{bilge}}(P_{bilge}-P_{ctr})]$, *between bottom centre line point and bilge calculation point;*

$P_{ed}=f_{ps}f_{nl-p}[P_{bilge}+\frac{z-z_{bilge}}{T_{LC}-z_{bilge}}(P_{WL}-P_{bilge})]$, *between bilge calculation point an water line point;*

$P_{ed}=f_{ps}f_{nl-p}\ [P_{WL}-10(z-T_{LC})]$, *above the water line, for strength assessment.*

$P_{ed}=f_{ps}f_{nl-p}[P_{WL}-5(z-T_{LC})]$, *above the water line, for fatigue assessment.*

Where,

y_{bilge} *and* z_{bilge} *: the coordinate Y and Z of the bilge calculation point as referring to the figure 3-4.*

f_{nl-p} *:Coefficient considering nonlinear effects applied to hydrodynamic pressure. For strength assessment, see the definition in Part 9-1, Ch 4, Sec 5. For fatigue assessment, it is taken as 1.0.*

The pressure of three points of bottom centerline point, bilge calculation point and water line point is to be taken as the fitted value of 20 calculation points uniformly distributed along the ship's length. The interpolation function between any two section is to be taken as the cubic function determined by four calculation points nearby.

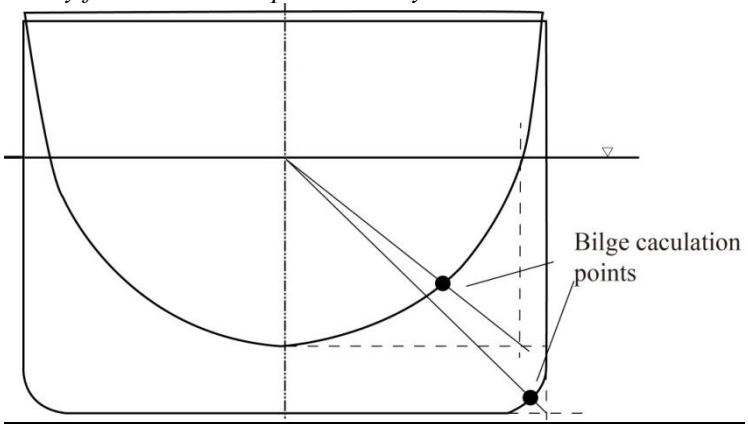


Figure 3-4 Bilge Calculation Points

3.4.3.3 Total sea pressure

The total sea pressure is calculated in accordance with the following formula, but not to be less than zero:

$P_{ex}=P_{es}+P_{ed}$

3.4.4 Pressure in tanks

3.4.4.1 Liquid pressure in tanks

The static liquid pressure in tanks P_{ls} is calculated in accordance with 1.2, Section 6, Chapter 4 of PART 9-1.
The dynamic liquid pressure in tanks P_{ld} is calculated in accordance with 1.3, Section 6, Chapter 4 of PART 9-1, where the acceleration of center of gravity of compartment a_X, a_Y and a_Z are taken as the results calculated in accordance with 3.4.1 of this Appendix.

3.4.4.2 Dry bulk cargo pressure in tanks
The calculation formulae of dry bulk cargo static pressure P_{bs}, dynamic pressure P_{bd}, static shear load $P_{bs\text{-}s}$ and dynamic shear loads $P_{bs\text{-}d}$, $P_{bs\text{-}dx}$, $P_{bs\text{-}dy}$ are given in 2, Section 6, Chapter 4 of PART 9-1, where the acceleration of center of gravity of compartment a_X, a_Y and a_Z are taken as the results calculated in accordance with 3.4.1 of this Appendix.

3.4.4.3 Total internal pressure
The total internal pressure P_{in} is to be taken as the sum of static and dynamic pressure of liquids or dry bulk cargoes in tanks, but not to be less than zero.

3.5 Application of relevant loads
3.5.1 Correspondence between relevant loads and PART 9-1

Corresponding load pa rameters between Appendix A and Part 1 Table1

Name of load	*Symbol of the Rules*	*Paragraph of definition in PART 9-1*	*Symbol of this Appendix*	*Paragraph of this Appendix*
Roll angle	θ	*Symbols, Section 3, Chapter 4*	θ	*3.4.1*
Pitch angle	φ	*Symbols, Section 3, Chapter 4*	φ	*3.4.1*
Acceleration at any point	$a_X\ a_Y\ a_Z$	*Table 4, Section 4, Chapter 1*	$a_X\ a_Y\ a_Z$	*3.4.1*
Vertical wave bending moment	$M_{wv\text{-}LC}$	*3.5.2, Section 4, Chapter 4*	M_{wv}	*3.4.2.2*
Vertical wave shear force	$Q_{wv\text{-}LC}$	*3.5.3, Section 4, Chapter 4*	Q_{wv}	*3.4.2.3*
Horizontal wave bending moment	$M_{wh\text{-}LC}$	*3.5.4, Section 4, Chapter 4*	M_{WH}	*3.4.2.4*
Wave torsional moment	$M_{wt\text{-}LC}$	*3.5.5, Section 4, Chapter 4*	M_{WT}	*3.4.2.5*
Total sea pressure	P_{ex}	*Table 4, Section 4, Chapter 1*	P_{ex}	*3.4.3.3*
Hydrostatic pressure	P_S	*1.2.1, Section 5, Chapter 4*	P_S	*3.4.3.1*
Hydrodynamic pressure	P_W	*1.3 and 1.4, Section 5, Chapter 4*	P_W	*3.4.3.2*
Total internal pressure	P_{in}	*Table 4, Section 4, Chapter 1*	P_{in}	*3.4.4.3*
Static liquid pressure	P_{ls}	*1.2, Section 6, Chapter 4*	P_{ls}	*3.4.4.1*
Dynamic liquid pressure	P_{ld}	*1.3, Section 6, Chapter 4*	P_{ld}	*3.4.4.1*
Dry bulk cargo static pressure	P_{bs}	*2.4.2, Section 6, Chapter 4*	P_{bs}	*3.4.4.2*
Dry bulk cargo dynamic pressure	P_{bd}	*2.4.3, Section 6, Chapter 4*	P_{bd}	*3.4.4.2*

3.5.2 Application of relevant loads in prescriptive methods

3.5.2.1 Hull girder strength

The still water bending moment and shear force for hull girder strength assessment are to use relevant permissible values.

The envelope of vertical wave bending moment and shear force for hull girder strength assessment is taken as the value calculated in accordance with 3.4.2.2 and 3.4.2.3 of this Appendix.

3.5.2.2 Yielding and buckling strength

The design load sets for assessment of yielding and buckling strength are given in Table 1, Section 2, Chapter 6 of PART 9-1, and relevant loads are given in this Appendix.

3.5.2.3 Fatigue strength of longitudinals

The assessment of fatigue strength of longitudinals is given in Section 4, Chapter 9 of PART 9-1, and relevant loads are given in this Appendix.

3.5.3 Application of relevant loads in FE methods

3.5.3.1 Strength assessment

Loading conditions and dynamic load cases for FE strength assessment are given in 1 to 4, Section 8, Chapter 4 of PART 9-1, and relevant loads are given in this Appendix.

3.5.3.2 Fatigue assessment

Loading conditions and dynamic load cases for FE fatigue assessment are given in 5, Section 8, Chapter 4 of PART 9-1, and relevant loads are given in this Appendix.

CCS Appendix B SUPPLEMENTARY REQUIREMENTS FOR DIRECT CALCULATION LOAD CONDITIONS

1 GENERAL

1.1 General requirements

1.1.1

Direct calculation of load conditions for special structural arrangement in compliance with the requirements of 2.5.1 of Section 8, Chapter 4 of PART 9-1 is to be carried out according to the requirements of this Appendix.

1.1.2

This Appendix specifies the general principles for determining the direct calculation load conditions for the above mentioned special structural arrangement and direct calculation conditions for specific structural arrangement.

1.1.3

The structural FE model and boundary conditions, calculation and applying of loads, loads adjustment, calculation criteria included in this Appendix are to comply with the requirements for direct calculation in Chapter 7 of PART 9-1.

1.2 Application

1.2.1

This Appendix is applicable to double or single hull bulk carriers and oil tankers with one or two longitudinal bulkhead in compliance with the requirements of PART 9-1.

1.2.2

The direct calculation load conditions as specified in this Appendix are only applicable to structural strength assessment.

1.3 Symbols and definitions

1.3.1

The parameters and symbols used in this Appendix are those defined in Chapter 4 of PART 9-1.

2 GENERAL PRINCIPLES

2.1 General requirements

2.1.1

The types and density of dry bulk cargo, density of cargo oil, density of ballast water and fuel oil are to comply with the requirements of Chapter 4 of PART 9-1.

2.1.2

Typical loading patterns (departure, arrival, harbour, partially filled ballast tanks) are to comply with the requirements of Section 8, Chapter 4 of PART 9-1.

2.1.3

The loading condition and draught are to comply with the requirements of Section 8, Chapter 4 of PART 9-1 and the worst loading pattern is to be selected as the case to be checked according to the actual situation specified in the loading manual.

2.2 Principles for selection of loading condition

2.2.1

Oil tankers are to comply with the requirements for design loading condition as specified in Section 8, Chapter 4 of PART 9-1, including:

(1) heavy ballast condition where all ballast tanks may be full, partially full or empty, 100% filling of fore peak water ballast tanks;

(2) other seagoing conditions in loading manual where these differ significantly from the ballast conditions;

(3) any specified non-uniform distribution of loading.

2.2.2

Bulk carriers are to comply with the requirements for design loading condition as specified in Section 8, Chapter 4 of PART 9-1, including:

(1) homogeneous light and heavy cargo loading conditions
(2) alternate loading conditions;
(3) multiport loading conditions, where applicable;
(4) alt-block loading conditions, where applicable;
(5) load case where heavy ballast conditions of designated heavy ballast hold or normal ballast condition in case of no heavy ballast hold, including ballasting of fore peak tank.

2.2.3 Special structural arrangement loading conditions

(1) Loading pattern

In general, cargo tanks and dry bulk cargo holds in cargo tank/hold region are to comply with the requirements for typical structural arrangement as specified in PART 9-1. Where the arrangement of cargo hold or double hull mid hold (ballast tank or fuel oil tank) is inconsistent with the typical structure as specified in PART 9-1, the loading pattern is to be defined according to the requirements of Section4,Chapter 8 of PART 9-1 and the actual location of cargo hold or double hull mid hold.

(2) Draught

Draught of oil tanker in loading conditions is to comply with the requirements of Section 8, Chapter 4 of PART 9-1. For tankers with two oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.15 L or tankers with one centreline oil-tight longitudinal bulkhead, where the cargo tank length is less than 0.11L. The load case draught is to be taken the draught as required by the Rules or the actual draught in loading manual. Generally, the draught which imposes more severe effect to the structural strength is to be selected.

Draught of bulk carriers in loading conditions is to comply with the requirements of Section 8, Chapter 4 of PART 9-1.

(3) Target location for hull girder shear force adjustment

The cargo hold region selected for direct calculation model is to be arranged with 3 cargo holds and 4 transverse bulkheads. The shear force is to be adjusted at target bulkhead in alternate loading conditions included in load cases in case of special structural arrangement.

3 TYPICAL ADDITIONAL LOADING CONDITIONS

3.1 Oil tankers

3.1.1

There are in general various forms of arrangement for the slop tank in the aftmost region of cargo tank in oil tankers. In addition to the general arrangement as given in Section 8, Chapter 4 of PART 9-1, typical arrangements for slop tank of oil tankers are shown in Figure 3.1.1(1) and Figure 3.1.1(2).

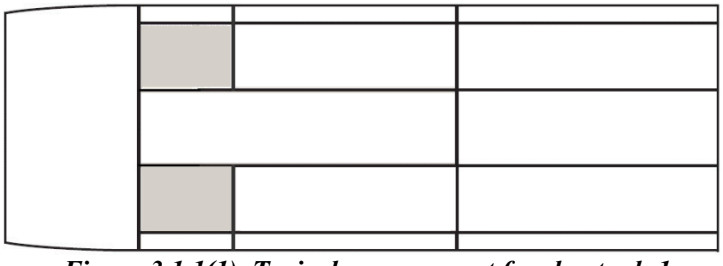


Figure 3.1.1(1) Typical arrangement for slop tank-1

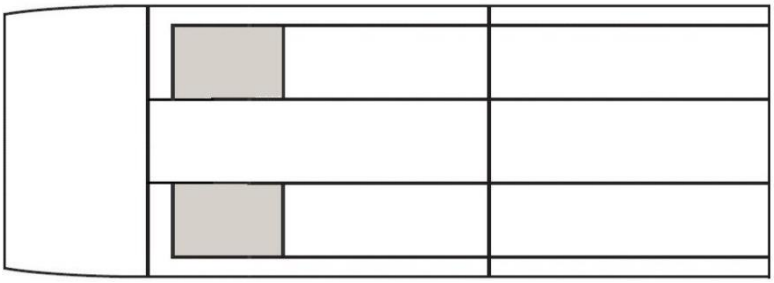
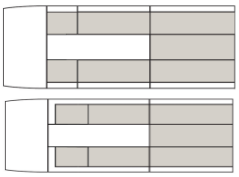
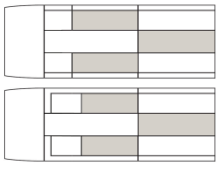


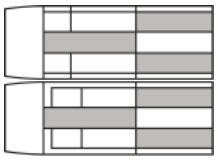
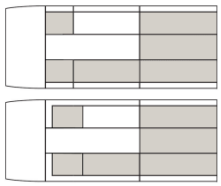
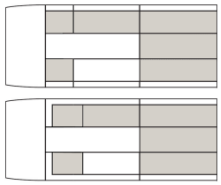
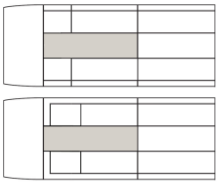
Figure 3.1.1(2) Typical arrangement for slop tank-2

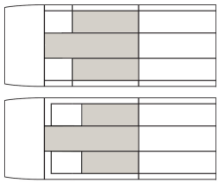
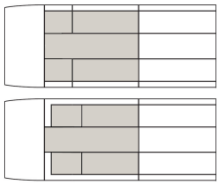
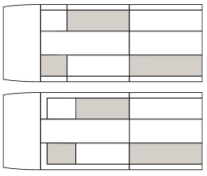
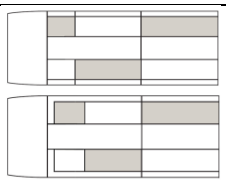
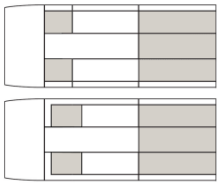
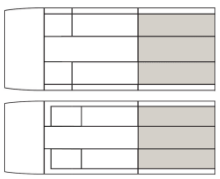
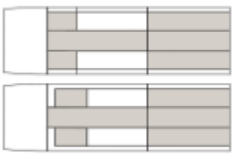
3.1.2

The load cases for the above mentioned arrangement for slop tank are shown in Table 3.1.2.

Load Cases ***Table 3.1.2***

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	% of perm. SWBM	% of perm. SWSF	Aftmost cargo hold
Seagoing Conditions					
A1[4]		$0.9T_{SC}$	100% (sagging)	100%	all LC[2]
			100% (hogging)	100%	all LC[2]
A2[4]		$0.9T_{SC}$	100% (sagging)	100%	all LC[2]
			100% (hogging)	100%	all LC[2]
A3-1[1][3]		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2 FSM-2
				100%	Group 2 LC[9] except HSM-2, FSM-2
			100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	Group 1 LC[8] except HSM-1, FSM-1
A3-2[1][4]		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2 FSM-2
				100%	Group 2 LC[9] except HSM-2, FSM-2
			100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	Group 1 LC[8] except HSM-1, FSM-1
A4[3]		$0.6T_{SC}$	100% (sagging)	100%	all LC[1]

No.	*Loading pattern*	*Still water loads*			*Dynamic load cases*
		Draught	*% of perm. SWBM*	*% of perm. SWSF*	*Aftmost cargo hold*
A5-1[3]		$0.65T_{SC}$	*100% (sagging)*	*100% Max SFLC*	*HSM-1 FSM-1*
				100%	*Group 1 LC*[8] *except HSM-1, FSM-1*
			100% (hogging)	*100% Max SFLC*	*HSM-2 FSM-2*
				100%	*Group 2 LC*[9] *except HSM-2, FSM-2*
A5-2[4]		$0.65T_{SC}$	*100% (sagging)*	*100% Max SFLC*	*HSM-1 FSM-1*
				100%	*Group 1 LC*[8] *except HSM-1, FSM-1*
			100% (hogging)	*100% Max SFLC*	*HSM-2 FSM-2*
				100%	*Group 2 LC*[9] *except HSM-2, FSM-2*
A6[4]		$0.6T_{SC}$	*100% (hogging)*	*100%*	*all LC* [1]
A7a[4]		T_{LC}	*100% (hogging)*	*100%*	*all LC* [1]
A7b[4]		T_{LC}	*100% (hogging)*	*100%*	*all LC* [1]
Harbour and testing conditions					
A10[4]		$0.25T_{SC}$	*100% (sagging)*	*100%*	*N/A*

No.	*Loading pattern*	*Still water loads*			*Dynamic load cases*
		Draught	*% of perm. SWBM*	*% of perm. SWSF*	*Aftmost cargo hold*
A11-1[3]		$0.6T_{SC}$	*100% (sagging)*	*100%*[5] *Max SFLC*	*N/A*
				100%[6] *Max SFLC*	*N/A*
A11-2[4]		$0.6T_{SC}$	*100% (sagging)*	*100%*[5] *Max SFLC*	*N/A*
				100%[6] *Max SFLC*	*N/A*
A12a[5]		$0.33T_{SC}$	*N/A*	*N/A*	*N/A*
A12b[5]		$0.33T_{SC}$	*N/A*	*N/A*	*N/A*
A13-1[3]		$0.65T_{SC}$	*100% (hogging)*	*100%*[5] *Max SFLC*	*N/A*
				100%[6] *Max SFLC*	*N/A*
A13-2[4]		$0.33T_{SC}$	*100% (hogging)*	*100%*[5] *Max SFLC*	*N/A*
				100%[6] *Max SFLC*	*N/A*
A14[4]		T_{SC}	*100% (hogging)*	*100%*	*N/A*

Notes:

(1) 100% filling of fuel and water ballast tanks in engine room, with tank boundaries at the forward engine room bulkhead.

(2) "All LC" means: all the dynamic load cases as defined in Ch 4, Sec 2 for both sagging and hogging and both P and S.

(3) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward slop tank bulkhead.

(4) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward

machinery space bulkhead.

(5) The shear force and bending moment that results from the application of local loads are to be used for non-hull girder adjustment conditions.

(6) The shear force is to be adjusted to target value at forward machinery bulkhead.

(7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.

(8) Group1 LC means: all Head sea LC in sagging, all Following sea LC in sagging, all Beam Sea LC and all Oblique Sea load cases.

(9) Group2 LC means: all Head sea LC in hogging, all Following sea LC in hogging, all Beam Sea LC and all Oblique Sea load cases.

3.1.3

In addition to the above mentioned typical tank arrangement, the general principles for determining the target location of shear force adjustment are as follows in cases there are other special arrangement for cargo tank, slop tank and ballast tank in the aftmost region of oil tanker.

(1) in general, the forward machinery bulkhead is to be taken as the reference location;

(2) where alternate loading condition is taken for slop tank an adjacent cargo tank, forward bulkhead of slop tank is to be taken as the reference location.

3.2 Bulk carriers

3.2.1

Special arrangement for the double hull tanks (fuel oil tank, ballast tank, empty tank) of bulk carriers are shown in Figure 3.2.1.

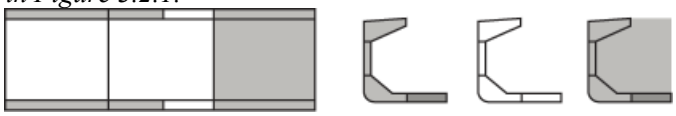
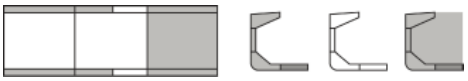


Figure 3.2.1 Special arrangement for bulk carriers

3.2.2

For special arrangement as shown in Figure 3.2.1, load cases are to be supplemented according to Table 3.2.2 for heavy ballast condition in addition to the load cases as required in Section 8 of Chapter 4.

Additional load cases in heavy ballast conditions ***Table 3.2.2***

No.	*Description*	*Loading pattern Aft Mid Fore*	*Draught*	*% of perm. SWBM*	*% of perm. SWSF*	*Dynamic load case*
Seagoing conditions						
1	*Deepest Ballast (4.2.1 of Section 8, Chapter 4 of PART 9-1)*		*THB*	*100% (hogging)*	*100%(1)*	*FSM-2 BSR-1P, BSR-1S OST-2P, OST-2S*
				100% (sagging)	*100%(1)*	*BSP-1P, BSP-1S BSR-1P, BSR-1S, OST-1P, OST-1S*

Note:

(1) The shear force is to be adjusted to target value at watertight transverse bulkhead of double hull ballast tank of the mid-hold.

*CCS Appendix C ASSESSMENT OF ULTIMATE STRENGTH OF HULL **GIRDERS USING NON-LINEAR FEM***

1 GENERAL

1.1 Application

1.1.1

The non-linear finite element method for assessment of the ultimate strength of hull girders, as provided in this Appendix, is applicable to the assessment of the ultimate strength of intact hull girders and damaged hull girders after collision/grounding.

1.1.2

For the hull girder FE models in this Appendix, the relevant non-linear effects given in paragraph 3.1.1, Appendix 2, Chapter 5 of PART 9-1 of the Rules are to be taken into account.

2 SINGLE SPAN FE MODEL

2.1 Application

2.1.1

The longitudinal extent of the single span FE model is one span of transverse web frames, its transverse extent is the entire breadth of the ship and its vertical extent is the entire moulded depth.

2.1.2

The FE model is to cover all longitudinal continuous members and the stiffeners having an influence on local buckling.

2.1.3

The FE model is to take into account manholes and lightening holes in hull structures.

2.1.4

The FE model is to use net scantlings, i.e. the as-built scantlings deducted by half the corrosion addition. For corrosion addition, see Section 3, Chapter 3 of PART 9-1 of the Rules.

2.1.5

For the stress-strain curve of hull structural materials, a bilinear model is to be used taking into account the strain-hardening effects.

2.2 Finite element types and meshing

2.2.1

4-nodes shell elements are to be used for plates, stiffeners and primary supporting members, and beam elements may also be used for stiffener flanges and for web stiffeners of primary supporting members.

2.2.2

The mesh size of the FE model is to be such that local buckling deformations and stress redistribution after localized plastic collapse of structural members (including plating, stiffeners, primary supporting members, etc.) is sufficiently presented. Meshes are to be square as far as possible.

2.3 Initial geometric imperfections

2.3.1

For all longitudinal members of the FE model, the initial geometric imperfections, which may lead to the most critical failure of hull girders, are to be considered.

2.3.2

For the mode of initial geometric imperfections, the overall deformations of stiffened plates between web frames, local deformation of plating and sideways initial deformations of stiffeners

are to be considered.

2.3.3
For the amplitude of initial geometric imperfections, deformations from welding or assembly are to be taken into account.

2.4 Boundary conditions and loading
2.4.1
An independent point is to be established at the intersection of neutral axis of cross sections of fore and aft ends of the model respectively.

2.4.2
The two independent points are to be related to the nodes on fore end and aft end of the model respectively, and simply supported restraints are to be applied to the independent points.

2.4.3
An equal hogging/sagging bending moment (or rotation angle) is to be applied to the two independent points and the bending moment (or rotation angle) is to be increased gradually.

2.4.4
When the bending moment-curvature curve reaches its extreme value point and the hogging or sagging failure of the model is evident, the bending moment at this point is the ultimate load-carrying capacity of hull girders.

2.5 Damages due to collision and grounding
2.5.1
For assumptions regarding damage extents, see paragraph 2.2, Section 3, Chapter 5 of PART 9-1.

2.6 Checking criteria
2.6.1
When single span FE model is used to check the ultimate strength and residual strength of hull girders, the partial safety factors of the checking criteria need to be specially considered.

3 CARGO HOLD FE MODEL
3.1 General
3.1.1
The longitudinal extent of a cargo hold FE model is the length of one cargo compartment, its transverse extent is the entire breadth of the ship and its vertical extent is the entire moulded depth, taking into account the effects of lateral loads (including both internal and external loads).

3.1.2
The cargo hold FE model is to cover all transverse members other than transverse bulkheads, upper and lower stools.

3.1.3
Other requirements for the cargo hold FE model are given in paragraphs 2.1.3 to 2.1.6.

3.2 Finite element types and meshing
3.2.1
The requirements for meshing of the cargo hold FE model are given in paragraph 2.2.

3.3 Initial geometric imperfections
3.3.1
The requirements for initial geometric imperfections of the cargo hold FE model are given in paragraph 2.3.

3.4 Lateral loads

3.4.1
The lateral loads in both full load and ballast conditions are to be considered. For bulk carriers, the lateral loads in alternate loading conditions are also to be considered, if applicable.

3.5 Boundary conditions and loading
3.5.1
The boundary conditions for the cargo hold FE model are given in paragraphs 2.4.1and 2.4.2.

3.5.2
The lateral loads specified in paragraph 3.4.1 are to be applied to the FE model.

3.5.3
An equal hogging/sagging bending moment (or rotation angle)is to be applied to the two independent points and the bending moment (or rotation angle) is to be increased gradually.

3.5.4
When the bending moment-curvature curve reaches its extreme value point and the hogging or sagging failure of the model is evident, the bending moment at this point is the ultimate load-carrying capacity of hull girders.

3.6 Damages due to collision and grounding
3.6.1
For assumptions regarding vertical and transverse damage extents, see paragraph 2.2, Section 3, Chapter 5 of PART 9-1, and special consideration is to be given to the longitudinal damage extent.

3.7 Checking criteria
3.7.1
When the cargo hold FE model is used to check the ultimate strength and residual strength of hull girders, the partial safety factors of the checking criteria need to be specially considered.

CCS Appendix D RECOMMENDATION FOR ASSESSING DESIGN INSTANCES BASED ON APPLICATION OF ALTERNATIVE METHODS IN THE HULL STRUCTURAL DESIGN OF CSR SHIPS

1 GENERAL

1.1

This Appendix is applied to this PART of CCS Rules for Classification of Sea-going Steel Ship and gives recommendations for assessing alternative (novel) design instance and alternative (novel) design method (technology).

2 SCOPE

2.1

The scope of this Appendix is to provide guidance for the assessment of alternative (novel) design instances and designs in compliance with requirements of this PART of CCS Rules for Classification of Sea-going Steel Ship, based on the application of alternative (novel) design method (technology) or alternative design and calculation methods within the context of Goal Based Standards and this PART of CCS Rules for Classification of Sea-going Steel Ship.

3 DEFINITIONS

3.1 Alternative (novel) design instance

An alternative or a novel design instance is defined via CCS Rules for Classification of Sea-going Steel Ship, Part 9-1 Ch 1 Sec 3 [6.2.1] i.e. ship design of unusual form, proportions, speed and structural arrangements outside those specified in Part 9-1 Ch 1, Sec 2, [3.2].
Design instances covered by additional class notations or additional class requirements (e.g. strengthening for operation in ice) are not considered alternative or novel design instances.
For ships not complying with CCS Rules for Classification of Sea-going Steel Ship, Part 9-1 Ch1 Sec 2 [3.2], Part 9-1 Ch1 Sec 2 [CCS 3.2.1a] and CCS Appendix A of Part 9-1 are to be applied.

3.2 Alternative (novel) design method (technology)

An alternative design method or alternative design technology is a method or technology applied in the design process that has no/limited documented track record for application in this field. This means that there is no documentation that can be arranged by the designers to prove with confidence that the outcome or result of the method (or technology) e.g. scantlings of hull structural elements or fatigue assessment of structural details, will be equivalent to a design based on the requirements of this Part of CCS Rules for Classification of Sea-going Steel Ship.

4 APPLICATION

4.1

The scantlings determined by the prescriptive requirements are not to be reduced by any form of alternative calculations such as FE analysis, unless explicitly stated. (CCS Rules for Classification of Sea-going Steel Ship, Part 9-1 Ch 1 Sec 2 [5.5.4])

4.2

Where indicated in specific sections of the Rules, alternative calculation methods to those shown in the Rules may be accepted provided it is demonstrated that the scantling and arrangements are of at least equivalent strength to those derived using the Rules.

5 EQUIVALENCE PRINCIPLE

5.1

For the application of alternative methods in the design, the main principle is to get sufficient evidence, and verify such evidence, that the resulting alternative design instance is equivalent (i.e. has at least the same structural safety level) to a design instance compliant to this Part.

6 ASSESSMENT OF ALTERNATIVE(NOVEL) DESIGN INSTANCES

6.1 General

The handling of alternative(novel) design instances should follow as far as practicable the

procedures given in CCS Circular No.498 " The Notice on the approval of IMO MSC.1/Circ.1455"[(1)].
Deviations from this PART of CCS Rules for Classification of Sea-going Steel Ship and/or other requirements that are proven to be in compliance with IMO Goal Based Standards may have impact on the compliance of the design with SOLAS Reg II-1/3-10. Therefore, a flag Administration need to consider the statutory approval of an alternative (novel) design instance in this case.

6.2 Role of the Classification Society

CCS reviews the delivered documentation; states further requirements for documentation if necessary, can request verification of achieved results and eventually grants approval.
This means that CCS is to assess whether the design has been sufficiently examined and whether any risks have been reduced acceptably and to evaluate the adequacy of the delivered information and the assumptions made. CCS is to make the final decision for applying CCS Circular No.498 to approve equivalency to this Part of CCS Rules for Classification of Sea-going Steel Ship of the alternative (novel) design instance, and the final responsibility of class approval for the design instance rests with CCS.
The task and role of CCS is to verify that - based on submitted information from the designer / shipyard - the design instance is in compliance with this Part of CCS Rules for Classification of Sea-going Steel Ship or its structural safety level is at least equivalent to that ensured by the requirements given in this Part of CCS Rules for Classification of Sea-going Steel Ship.

7 DESCRIPTION OF ALTERNATIVE DESIGN AND CALCULATION METHODS USED IN THE HULL STRUCTURAL DESIGN

7.1 General

Alternative design and calculation methods may be applied to the extent specified in this Part of CCS Rules for Classification of Sea-going Steel Ship for:
(1) Improvement of the design process
(2) Optimization of the hull structure (weight of the structure, improvements in fabrication, etc.)
This Part allows explicitly the application of alternative design and calculation methods in the following paragraphs:

Procedure for alternative design or calculation methods ***Table 1***

Rule reference	*Details*	*Alternative design / calculation method*	*Detail procedure in this Part*
Pt 9-1, Ch 5, Appendix 2	*Hull girder ultimate capacity*	*Direct non-linear finite element analysis*	*Yes, Part 9-1, CCS Appendix C*
Pt 9-1, Ch 6, Sec 6, [2.2.2]	*Primary supporting members within cargo region for bulk carrier less than 150 m*	*FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-1, Ch 9, Sec 1, [4.5]	*Fatigue design standards for alternative design*	*FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-1, Ch 9, Sec 4, [5.3]	*Stress concentration factors for alternative design*	*FEA (Finite Element Analysis)*	*Yes, detail FEA procedure in [5.3.1]*
Pt 9-1, Ch 9, Sec 6, [2.2]	*Equivalent design of stiffener-frame connections*	*FEA (Finite Element Analysis)*	*Yes, detail FEA procedure in [2.2]*

[1] *Note (1): CCS Circular No.498 is the transformation of the International Maritime Organization "the Guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments" (refer to IMO MSC.1/Circ.1455).*

Rule reference	*Details*	*Alternative design / calculation method*	*Detail procedure in this Part*
Pt 9-1, Ch 10, Sec 1, [2.3.3]	*The spacing of web frames and stringers iwo side shell*	*FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-1, Ch 10, Sec 3, [2.1.4]	*The spacing and arrangement requirements*	*FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-1, Ch 11, Sec 1, [3.2.5]	*Arrangements of deck girders and transverses*	*Grillage or FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-2, Ch 1, Sec 4, [4.1.2]	*Primary supporting members in cargo hold structures, subjected to lateral pressure for ships having a length L less than 150 m*	*Grillage or FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*
Pt 9-2, Ch 2, Sec 3, [1.5.4]	*Deck transverses fitted above the upper deck*	*FEA (Finite Element Analysis)*	*Yes, FEA procedure of this Rules can be applied.*

The application of alternative design and calculation methods should result in a design instance compliant with this Part of CCS Rules for Classification of Sea-going Steel Ship.
CCS should assess the resulting design instance with respect to compliance with the rules. Assessment of the alternative design and calculation method used for the design is not necessary.
The requirements in Section 6 and Section 8 of this Appendix should be followed only in case the application of alternative design method results in alternative (novel) design instance.

8 DUCUMENTATION

8.1

Documentation provided with an application for alternative (novel) design method (technology) used in the hull structural design as equivalency should identify the detail of the methods that have been undertaken, the equivalent safety level and the sufficient supporting information to validate assessments as well as the resulting scantlings, materials, etc.

8.2

In case of a ship where alternative methods are applied and an equivalency for the alternative (novel) design instance is considered by CCS, this should be noted in the relevant structural drawings and/or appropriate approval documents as required by CCS's procedures. The documentation on the application of alternative methods should be included in the Ship Construction Files (SCF) in accordance with the requirement in CCS Rules for Classification of Sea-going Steel Ships Part 1, Chapter 4, Appendix 1, Annex 2, [3.1.1], (3)[(2)].

[2] *Note (2): The requirement is incorporation of IACS Unified Requirement (UR) Z23.*

Chapter 1 BULK CARRIERS

Section 1 GENERAL ARRANGEMENT DESIGN

1 FORECASTLE

1.1 General

1.1.1

An enclosed forecastle is to be fitted on the freeboard deck.

The aft bulkhead of the enclosed forecastle is to be fitted in way or aft of the forward bulkhead of the foremost hold, as shown in Figure 1.However, if this requirement hinders hatch cover operation, the aft bulkhead of forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7% of ship length for freeboard as specified in Pt 1, Ch 1, Sec 4, [3.1.2] abaft the fore side of stem.

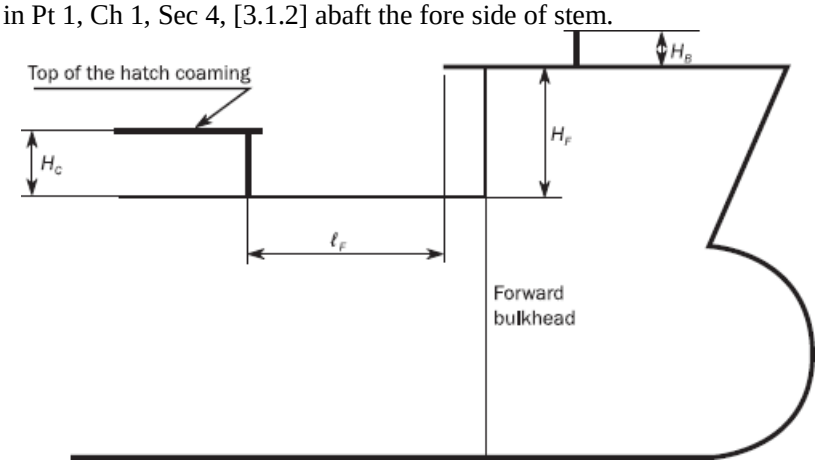


Figure 1 Forecastle arrangement

1.1.2

The forecastle height, *HF* above the main deck is not to be less than the greater of the following values:

- The standard height of a superstructure as specified in Pt 1, Ch 1, Sec 4, [3.3].
- H_C + 0.5 m, where H_C is the height of the forward transverse hatch coaming of the foremost cargo hold, i.e. cargo hold No. 1.

1.1.3

All points of the aft edge of the forecastle deck are to be located at a distance less than or equal to l_F, taken as:

$$l_F = 5\sqrt{H_F - H_C}$$

from the hatch coaming plate.

1.1.4

A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centreline is not less than H_B / tan 20 ° forward of the aft edge of the forecastle deck, where H_B is the height of the breakwater above the forecastle, see Figure 1.

2 ACCESS ARRANGEMENTS

2.1 Special arrangements for bulk carriers

2.1.1

Where a duct keel or pipe tunnel is fitted, provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other.

The aft access may lead from the engine room to the duct keel. Where an aft access is provided from the engine room to the duct keel, the access opening to the duct keel is to be provided with

watertight hatch cover, cover plate or door.
Ventilation may be aided by the use of mechanical means as required.

2.1.2
Where a watertight door is fitted for access to the duct keel, the scantlings of the watertight door are to comply with the requirements of the individual Society.

Section 2 STRUCTURAL DESIGN PRINCIPLES

SYMBOLS
For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

1 APPLICATION
1.1
1.1.1
This section applies to structures in all parts of bulk carriers, in addition to requirements given in Pt 1, Ch 3, Sec 6.

2 CORROSION PROTECTION
2.1 General
2.1.1 Void double side skin spaces
Void double side skin spaces are to have a corrosion protective system fitted in accordance with [2.2].

2.1.2 Cargo holds and ballast holds
Cargo holds and ballast holds are to have a corrosion protective system fitted in accordance with [2.3].

2.2 Protection of void double side skin spaces
2.2.1
Void double side skin spaces in the cargo area for ships having a freeboard length L_{LL} of not less than 150 m are to have an efficient corrosion prevention system, such as hard protective coatings or equivalent.

2.3 Protection of cargo hold spaces
2.3.1 Coating
It is the responsibility of the builder and of the owner to choose coatings suitable for the intended cargoes, in particular for the compatibility with the cargo.

2.3.2 Application
All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of cargo holds (side and transverse bulkheads), excluding the inner bottom area and part of the hopper tank sloping plate and lower stool sloping plate, are to have an efficient protective coating, of an epoxy type or equivalent, applied in accordance with the manufacturer's recommendation.
The side and transverse bulkhead areas to be coated are specified in [2.3.3] and [2.3.4] respectively.

2.3.3 Side areas to be coated
The areas to be coated are the internal surfaces of:

- The inner side plating.
- The internal surfaces of the topside tank sloping plates.
- The internal surfaces of the hopper tank sloping plates for a distance of 300 mm below the frame end bracket for holds of single side skin construction, or below the hopper tank upper end for holds of double side skin construction.

These areas are shown in Figure 1.

2.3.4 Transverse bulkhead areas to be coated
The areas of transverse bulkheads to be coated are all the areas located above an horizontal level located at a distance of 300 mm below the frame end bracket for holds of single side skin construction or below the hopper tank upper end for holds of double side skin construction.

3 STRUCTURAL DETAIL PRINCIPLES
3.1 Double bottom structure

3.1.1 Application

In addition to the requirements provided in Pt 1, Ch 2, Sec 3, [2], the requirements of this sub-article are applicable to the following ships:

- All bulk carriers with freeboard length L_{LL} less than 150 m,
- Bulk carriers having a freeboard length L_{LL} of 150 m or above, with one or more cargo holds arranged for carriage of water ballast.

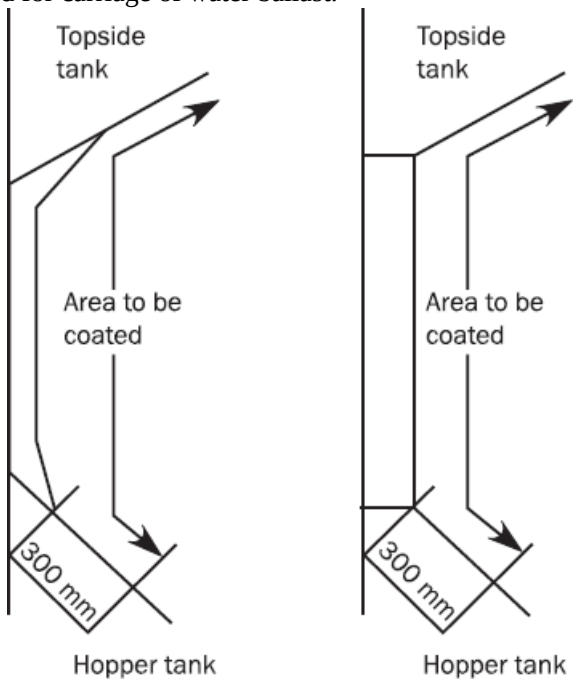


Figure 1 Side areas to be coated

3.1.2 Double bottom height

Height of double bottom in cargo area, d_{DB}, in m, measured from keel line at mid-length of each cargo hold is not to be less than:

$$d_{DB} = 32B + 190\sqrt{T_{SC}}$$

A lower double bottom height may be accepted, provided all of the following requirements are satisfied:

- The spacing of adjacent girders is not to be greater than 4.6 m or 5 times the spacing of bottom or inner bottom stiffeners, whichever is the smaller.
- The spacing of floors is not to be greater than 3.5 m or 4 times the side frame spacing, whichever is the smaller. Where side frames are not transverse, the nominal frame spacing as specified by the designer is to be used.

3.1.3 Girder spacing

The spacing of adjacent girders is generally not to be greater than 4.6 m or 5 times the spacing of bottom or inner bottom stiffeners, whichever is the smaller.

3.1.4 Floor spacing

The spacing of floors is generally not to be greater than 3.5 m or 4 times the side frame spacing, whichever is the smaller. Where side frames are not transverse, the nominal frame spacing as specified by the designer is to be used.

3.2 Single side structure

3.2.1 Application

This article applies to the single side structure with transverse framing of single side bulk carrier.
If single side structure is supported by transverse or longitudinal primary supporting members, the requirements in Pt 1, Ch 3, Sec 6, [8] apply to these primary supporting members as regarded to ones in double side skin.

3.2.2 General arrangement

Side frames are to be arranged at every frame space.

If air pipes are passing through the cargo hold, they are to be protected by appropriate measures to avoid a mechanical damage.

3.2.3 Side frames

Frames are to be built-up symmetrical sections with integral upper and lower brackets and are to be arranged with soft toes.

The side frame flange is to be curved (not knuckled) at the connection with the end brackets. The radius of curvature is not to be less than *r*, in mm, given by:

$$r = \frac{0.4 b_f^2}{t_f + t_C}$$

where:

t_c : Corrosion addition, in mm, specified in Pt 1, Ch 3, Sec 3.

b_f, t_f : Flange width and net thickness of the curved flange, in mm. The end of the flange is to be sniped.

In ships less than 190 m in length, mild steel frames may be asymmetric and fitted with separate brackets. The face plate or flange of the bracket is to be sniped at both ends. Brackets are to be arranged with soft toes.

The dimensions of side frames are defined in Figure 2.

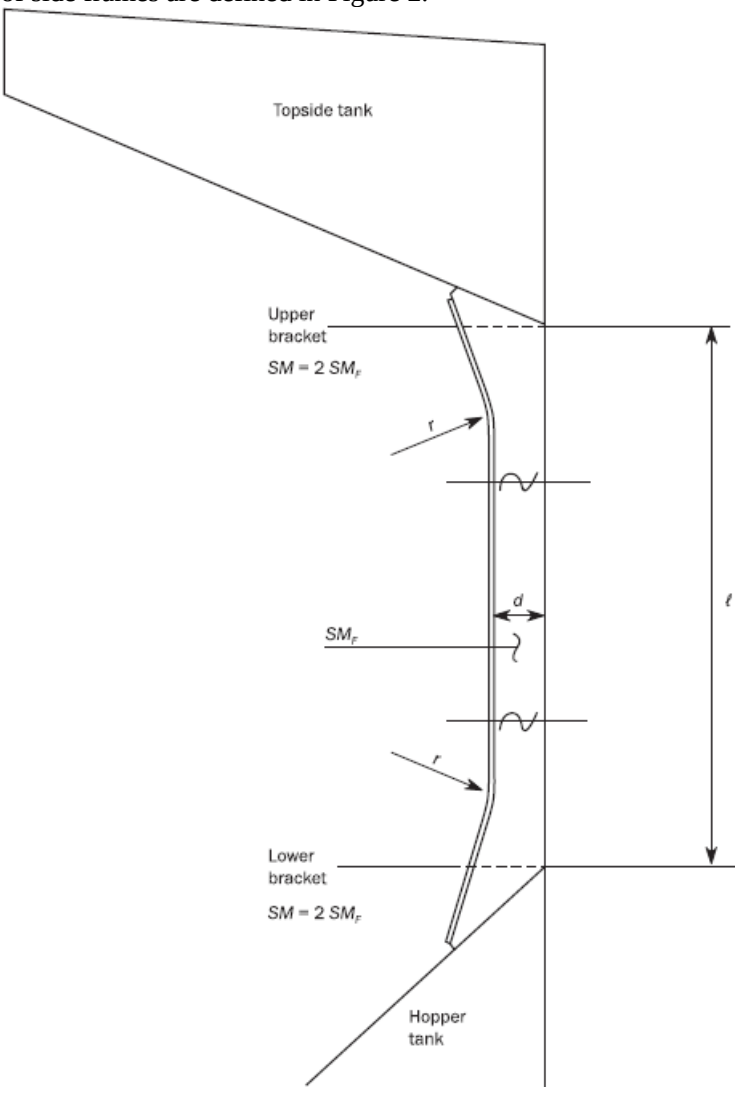


Figure 2 Dimensions of side frames

3.2.4 Upper and lower brackets

The face plates or flange of the brackets is to be sniped at both ends. Brackets are to be arranged with soft toes. The as-built thickness of the brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.
The dimensions (in particular the height and length) of the lower brackets and upper brackets are not to be less than those shown in Figure 3.

3.2.5 Tripping brackets

In way of the foremost hold and in the holds of BC-A ships, side frames of asymmetrical section are to be fitted with tripping brackets at every two frames, as shown in Figure 4.
The as-built thickness of the tripping brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.
Double continuous welding is to be adopted for the connections of tripping brackets with side shell frames and plating.

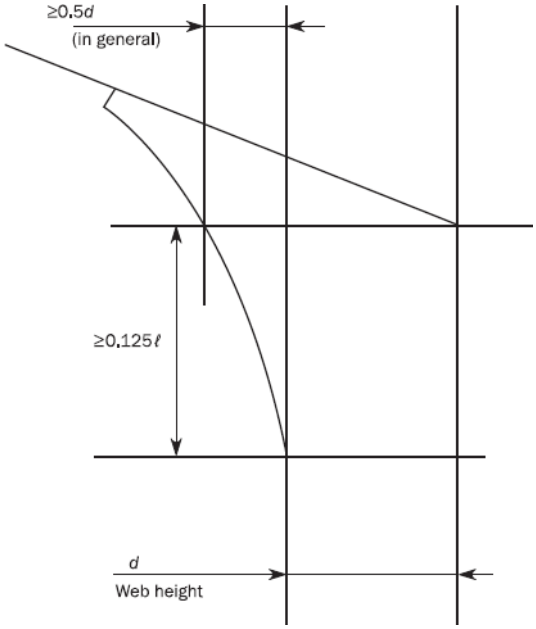


Figure 3 Dimensions of lower and upper bracket

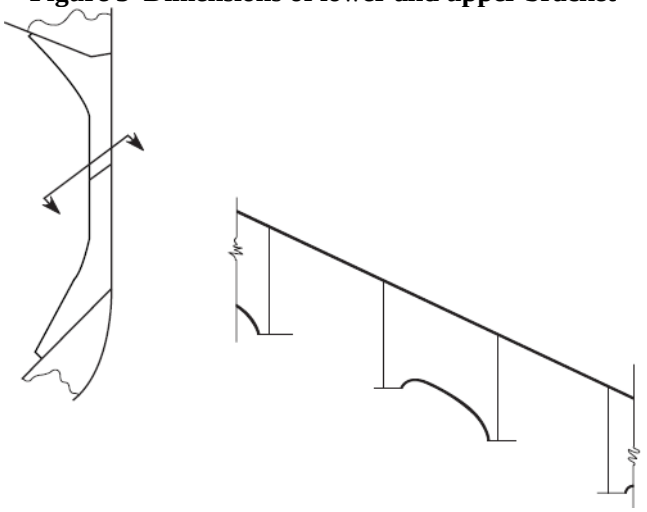


Figure 4 Tripping brackets to be fitted in way of foremost hold

3.2.6 Support structure

Structural continuity with the lower and upper end connections of side frames is to be ensured within hopper and topside tanks by connecting brackets as shown in Figure 5.

3.3 Deck structures

3.3.1 Web frame spacing in topside tanks

For bulk carriers with freeboard length L_{LL} less than 150 m, the spacing of web frames in topside

tanks is generally not to be greater than 6 frame spaces.

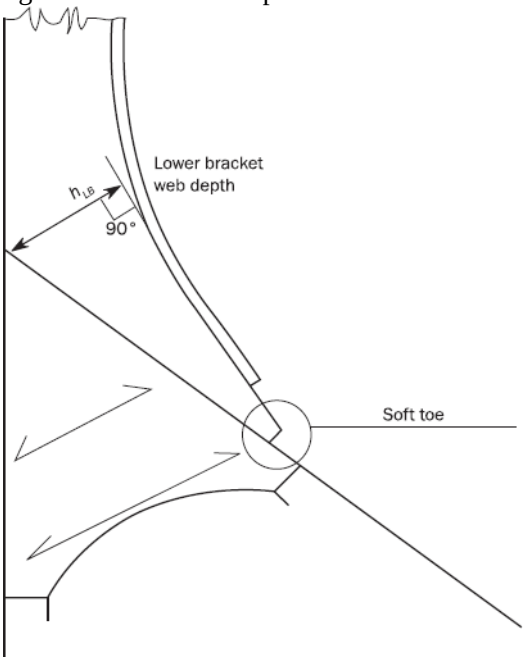


Figure 5 Example of support structure for lower end

3.3.2 Cross deck between hatches of bulk carriers

Inside the line of openings, where a transversely framed structure is adopted for the cross deck structures, hatch end beams and cross deck beams are to be adequately supported by girders and extended outward to the second longitudinal from the hatch side girders towards the deck side. Where the extension of girders outward is impracticable, intercostal stiffeners are to be fitted between the hatch side girder and the second longitudinal and checks of the structure are to be performed in compliance with the requirements in Pt 1, Ch 7 or by means deemed appropriate by the Society.

The transverse primary members supporting the cross deck are to be supported by side or topside tank primary supporting members.

Smooth connection of the strength deck at side with the transversely framed cross deck is to be ensured by a plate of intermediate thickness.

CCS 3.3.2a The structural strength is to be checked in compliance with the requirements in Chapter 7 of PART9-1.

3.3.3 Topside tank structures

The topside tank sloping plates are to be longitudinally framed.

Topside tank structures, where fitted, are to extend as far as possible within the machinery space and are to be adequately tapered.

Where a double side primary supporting member is fitted outside the plane of the topside tank web frame, special attention is to be paid to structural continuity.

3.3.4 Openings in strength deck - Corner of hatchways

a) Within the cargo hold region

For cargo hatchways located within the cargo hold region, insert plates, the thicknesses of which are to be determined according to the formula given after, are to be fitted in way of corners where the plating cut-out has a circular profile.

The radius of circular corners is not to be less than 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming.

Corner radius, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case-by-case basis.

For hatchways located within the cargo hold region, insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile

and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction.
- Twice the transverse dimension, in the fore and aft direction.

Where insert plates are required, their net thickness is to be obtained, in mm, from the following formula:

$t_{INS} = (0.8+0.4l/b)t_{off}$

without being taken less than t_{off} or greater than 1.6 t_{off}.

where:

l : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction, see Pt 1, Ch 3, Sec 6, Figure 15.

b: Width, in m, of the hatchway considered, measured in the transverse direction, see Pt 1, Ch 3, Sec 6, Figure 15.

t_{off} : Offered net thickness, in mm, of the deck at the side of the hatchways.

For the extreme corners of end hatchways, insert plates are required. The net thickness of these insert plates is to be 60% greater than the net offered thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than permissible values.

Where insert plates are required, the arrangement is shown in Pt 1, Ch 9, Sec 6, Table 15, in which d_1, d_2, d_3 and d_4 are to be greater than the stiffener spacing.

For ships having a freeboard length L_{LL} of 150 m or above, the corner radius, the thickness and the extent of insert plate may be determined by the results of a direct strength assessment according to Pt 1, Ch 7, including buckling check and fatigue strength assessment of hatch corners according to Pt 1, Ch 8 and Pt 1, Ch 9 respectively. For such type of ships it is recommended to arrange circular hatch corners.

b) Outside the cargo hold region
For hatchways located outside the cargo hold region, a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case-by-case basis.

CCS 3.3.4a Where two or more hatchways are arranged athwartships, the corner radius is not to be less than 5% of the total width of these hatchways.

3.3.5 Protection against wire rope

Wire rope grooving in way of cargo holds openings is to be prevented by fitting suitable protection such as half- round bar on the hatch side girders (i.e. upper portion of topside tank plates) or hatch end beams in cargo hold and upper portion of hatch coamings.

3.3.6 Protection of cargo hatch opening corners against mechanical damage

Specific measures are to be arranged to prevent the hatch opening corners from mechanical damage incurred by coming into direct contact with the vertical grab wire under normal operations.

Section 3 HULL LOCAL SCANTLINGS

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

C_{XG}, C_{YS}, $C_{YR,}$ C_{YG}, C_{ZP}, C_{ZR} : Load combination factors, as defined in Pt 1, Ch 4, Sec 2.

d_{shr} : Effective shear depth of the stiffener as defined in Pt 1, Ch 3, Sec 7, [1.4.3].

F_R : Resultant force, in kN, as defined in Pt 1, Ch 4, Sec 6, Table 7.

$F_{sc\text{-}ib\text{-}s}$: Static load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.3.1].

$F_{sc\text{-}ib}$: Total load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.2.1].

$F_{sc\text{-}hs\text{-}s}$: Static load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.3.2].

$F_{sc\text{-}hs}$: Total load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.2.2].

l : Distance, in m, as defined in Pt 1, Ch 4, Sec 6.

l_p : Distance, in m, as defined in Pt 1, Ch 4, Sec 6.

l_{bdg} :Effective bending span, in m, as defined in Ch 3, Sec 7, [1.1.2].

l_{SF} : Side frame span l , in m, as defined in Ch 1, Sec 2, Figure 2, not to be taken less than 0.25 D.

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2] and calculated at the load calculation point defined in Pt 1, Ch 3, Sec 7, [3.2].

P_R : Resultant pressure, in kN/m^2, as defined in Pt 1, Ch 4, Sec 6, Table 7.

s_{cw} : Plate width, in mm, taken as the width of the corrugation flange $b_{f\text{-}cg}$ or the web $b_{w\text{-}cg}$, whichever is greater,see Pt 1, Ch 3, Sec 6, Figure 21.

s_{cg} : Half pitch, in mm, of the corrugation flange as defined in Pt 1, Ch 3, Sec 6, Figure 21.

1 CARGO HOLD SIDE FRAMES OF SINGLE SIDE BULK CARRIERS

1.1 Strength criteria

1.1.1 Net section modulus and net shear sectional area

The net section modulus Z, in cm^3, and the net shear sectional area A_{shr}, in cm^2, in the mid-span area of side frames subjected to lateral pressure are not to be taken less than:

$$Z = 1.125\alpha_m \frac{Psl_{SF}^2}{f_{bdg}C_s R_{eH}}$$

$$A_{shr} = 5.0\alpha_S \frac{Psl_{SF}}{C_t \tau_{eH}} \left(\frac{l_{SF} - 2l_B}{l_{SF}}\right) 10^{-3}$$

where:

α_m : Coefficient taken as:

α_m = 0.42 for BC-A ships.

α_m = 0.36 for other ships.

f_{bdg} : Bending coefficient taken as 10.

C_s : Permissible bending stress coefficient for the design load set being considered taken as:

C_s = 0.75 for acceptance criteria set AC-S.

C_s = 0.90 for acceptance criteria set AC-SD.

α_S : Coefficient taken as:

α_S = 1.1 for side frames of empty holds in alternate condition of BC-A ships.

α_S = 1.0 for other side frames.

l_B : Lower bracket length, in m, as defined in Figure 1.

P : Design pressures, in kN/m^2, for design load sets as defined in Pt 1, Ch 6, Sec 2, Table 1,

C_t : Permissible shear stress coefficient for the design load set being considered, taken as:

C_t = 0.75 for acceptance criteria set AC-S.

C_t = 0.90 for acceptance criteria set AC-SD.

1.1.2 Side frames in ballast holds

In addition to [1.1.1], for side frames in cargo holds designed to carry ballast water in heavy ballast condition, the net section modulus Z, in cm^3, and the net web thickness, t_w, in mm, all along the span are to be in accordance with Pt1, Ch 6, Sec 5 where the span of the side frame is l as defined in Pt 1, Ch 3, Sec 7, [1.1] with consideration to brackets at ends.

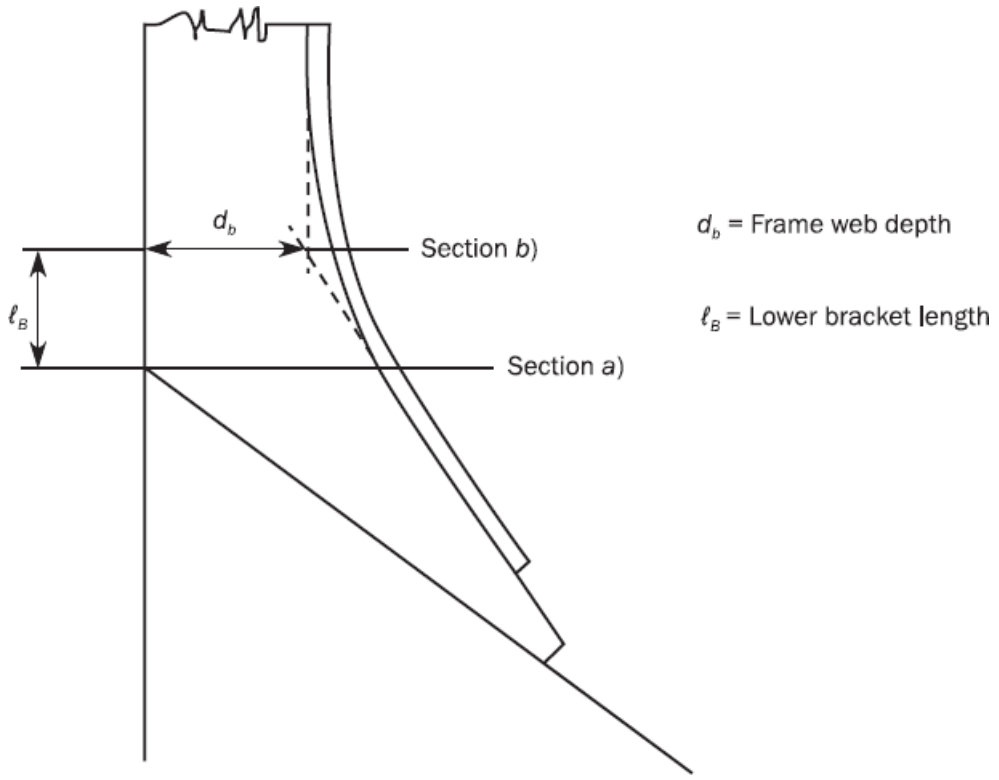


Figure 1 Side frame lower bracket length

1.1.3 Additional strength requirements

The net moment of inertia *I*, in cm^4, of the three side frames located immediately abaft the collision bulkhead is not to be taken less than:

$$I = 0.18\frac{Pl_{SF}^4}{n}$$

where:

n : Frame number of considered side frame counted from the collision bulkhead to the frame in question, taken equal to 1, 2 or 3.

As an alternative, supporting structures, such as horizontal stringers, are to be fitted between the collision bulkhead and a side frame which is in line with transverse webs fitted in both the topside tank and hopper tank, maintaining the continuity of the forepeak stringers within the foremost hold.

1.2 Lower bracket of side frame

1.2.1

At the level of the lower bracket as shown in Ch 1, Sec 2, Figure 2, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is not to be taken less than twice the required net section modulus *Z*, in cm^3,for the frame mid-span area obtained from [1.1.1].

1.2.2

For holds intended to carry ballast water in heavy ballast condition, the net section modulus *Z*, in cm^3, at the level of the lower bracket is not to be taken less than twice the greater of the required net section moduli given in [1.1.1] and [1.1.2].

1.2.3

The net thickness t_{LB}, in mm, of the lower bracket is not to be taken less than:

$t_{LB} = t_w + 1.5$

where t_w is the net thickness of the side frame web, in mm.

1.2.4

The net thickness t_{LB} of the lower bracket is to comply with the following formula:

- For symmetrically flanged frames:

$$\frac{h_{LB}}{t_{LB}} \le 87\sqrt{k}$$

- For asymmetrically flanged frames:

$$\frac{h_{LB}}{t_{LB}} \le 73\sqrt{k}$$

The web depth h_{LB} of lower bracket is to be measured from the intersection between the hopper tank sloping plating and the side shell plate, perpendicularly to the face plate of the lower bracket as shown in Ch 1, Sec 2, Figure 5.

For the three side frames located immediately abaft the collision bulkhead, where the frames are strengthened in accordance with [1.1.3] and the offered t_{LB} is greater than 1.73 t_w, the t_{LB} applied in [1.2.4] may be taken as t'_{LB} given by:

$t'_{LB}=（t^2_{LB}t_W）^{1/3}$

where t_w is the net thickness of the side frame web, in mm, corresponding to A_{shr} determined in accordance to [1.1.1]

1.3 Upper bracket of side frame

1.3.1

At the level of the upper bracket as shown in Ch 1, Sec 2, Figure 2 the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is not to be taken less than twice the net section modulus *Z* required for the frame mid-span area obtained from [1.1.1].

1.3.2

For holds intended to carry ballast water in heavy ballast condition, the net section modulus Z, in cm^3, at the level of the upper bracket is not to be taken less than twice the greater of the required net sections modulus obtained from [1.1.1] and [1.1.2].

The net thickness t_{UB} of the upper bracket, in mm, is not to be less than the net thickness of the side frame web.

1.4 Provided support at upper and lower connections of side frames

1.4.1 Net section modulus

The net section modulus of the:

- Side shell and hopper tank longitudinals supporting the lower connecting brackets.
- Side shell and topside tank longitudinals supporting the upper connecting brackets.

is to comply with the following formula:

$$\sum_n Z_{pli} d_i \ge \alpha_T \frac{P l_{SF}^2 l_1^2}{16 R_{eH}}$$

where:

n : Number of the longitudinal stiffeners on the side shell and hopper/topside tank supporting the lower/upper end connecting bracket of the side frame, as applicable.

$Z_{pl\,i}$: Net plastic section modulus, in cm^3, of the *i*-th longitudinal stiffener on the side shell or hopper /topside tank supporting the lower/upper end connecting bracket of the side frame, as applicable.

d_i : Distance, in m, of the above *i*-th longitudinal stiffener from the intersection point of the side shell and hopper/topside tank.

l_1 : Spacing, in m, of transverse supporting webs in hopper/topside tank, as applicable.

R_{eH} *:* Lowest value of specified yield stress, in N/mm^2, among the materials of the longitudinal stiffeners of side shell and hopper/topside tanks that support the lower/upper end connecting bracket of the side frame.

α_T : Coefficient taken as:

α_T =150 for the longitudinal stiffeners supporting the lower connecting brackets.

α_T = 75 for the longitudinal stiffeners supporting the upper connecting brackets.

1.4.2 Net connection area of brackets

The net connection area of the lower or upper connecting bracket to the supporting longitudinal stiffener is to comply with the following formula:

$$\sum_i A_i d_i R_{eH,bkt-i} \geq 0.02\alpha_T P s l_{SF}^2 10^{-3}$$

where:

A_i : The offered net connection area of the bracket connecting with the *i*-th longitudinal stiffener, in cm^2.

A_i , α_T : As defined in [1.4.1].

$R_{eH,\,bkt-i}$: The specified minimum yield stress of the bracket connecting with the *i*-th longitudinal stiffener, in N/mm^2.

s : The space of the side frame, in mm.

2 STRUCTURE LOADED BY STEEL COILS ON WOODEN DUNNAGE

2.1 General

2.1.1

The net thickness of inner bottom plating, hopper side plating and inner hull plating for ships intended to carry steel coils is to comply with [2.3.1] and [2.4.1] up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

The net section modulus and the net shear sectional area of longitudinal stiffeners on inner bottom, hopper tank top and inner hull for ships intended to carry steel coils are to comply with [2.3.2] and [2.4.2] up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

Standard terminology and means for securing of steel coils is described in Figure 2.

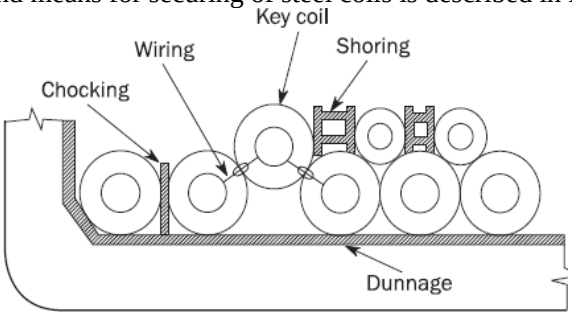


Figure 2 Inner bottom loaded by steel coils

2.2 Load application

2.2.1 Design load sets

The static and dynamic load components are to be determined in accordance with Pt 1, Ch 4, Sec 7, Table 1. Radius of gyration, k_r, and metacentric height, *GM*, are to be in accordance with Pt 1, Ch 4, Sec 3, Table 2 for the considered loading condition specified in the design load set. The design load sets for steel coil loading is given in Table 1.

Design load sets **Table 1**

Item	Design load set	Load component	Draught	Design load	Loading condition
Inner bottom, hopper sloping plate and inner hull	BC-9	$F_{sc\text{-}ib\text{-}s}$ or $F_{sc\text{-}hs\text{-}s}$	T_{SC}	S	Steel Coil condition
Inner bottom, hopper sloping plate and inner hull	BC-10	$F_{sc\text{-}ib}$ or $F_{sc\text{-}hs}$	T_{SC}	S+D	Steel Coil condition

2.3 Inner bottom

2.3.1 Inner bottom plating

The net thickness *t*, in mm, of plating of longitudinally framed inner bottom is not to be taken less than:

$$t = K_1\sqrt{\frac{F_{sc-ib-s}\times 10^3}{C_a R_{eH}}}$$ for design load set BC-9

$t = K_1\sqrt{\frac{F_{sc-ib}\times 10^3}{C_a R_{eH}}}$ for design load set BC-10

where:

K_1 : Coefficient taken as:

$$K_1 = \sqrt{\frac{1.7\frac{s}{1000}lK_2 - 0.73(\frac{s}{1000})^2 K_2^2 - (l-l_{lp})^2}{2l_{lp}(2\frac{s}{1000}+2lK_2)}}$$

K_2 : Coefficient taken as:

$$K_2 = -\frac{s}{1000l} + \sqrt{(\frac{s}{1000l})^2 + 1.37(\frac{1000l}{s})^2(1-\frac{l_{lp}}{l})^2 + 2.33}$$

C_a : Permissible bending stress coefficient, as defined in Pt 1, Ch 6, Sec 4, [1.1.1].

2.3.2 Stiffeners of inner bottom plating

The net section modulus *Z*, in cm^3, and the net web thickness, t_w, in mm, of single span stiffeners located on inner bottom plating are not to be taken less than:

$Z = K_3\frac{F_{sc-ib-s}}{8C_s R_{eH}}10^3$ and $t_w = \frac{0.5F_{sc-ib-s}}{d_{shr}C_t\tau_{eH}}\times 10^3$ for design load set BC-9.

$Z = K_3\frac{F_{sc-ib}}{8C_s R_{eH}}10^3$ and $t_w = \frac{0.5F_{sc-ib}}{d_{shr}C_t\tau_{eH}}\times 10^3$ for design load set BC-10

where:

K_3 *:* Coefficient as defined in Table 2.

$K_3 = 2l_{bdg}/3$, when $n_2 > 10$.

C_s *:* Permissible bending stress coefficient, as defined in Pt 1, Ch 6, Sec 5, [1.1.2].

C_t*:* Permissible shear stress coefficient for the design load set being considered, to be taken as:

$C_t = 0.85$ for acceptance criteria set AC-S.

$C_t = 1.00$ for acceptance criteria set AC-SD.

n_2*:* Number of load points per EPP of the inner bottom, see Pt 1, Ch 4, Sec 6, [4.1.3].

Coefficient K_3 **Table 2**

n_2	1	2	3	4	5
K_3	l_{bdg}	$l_{bdg}-\frac{l_{lp}^2}{l_{bdg}}$	$l_{bdg}-\frac{2l_{lp}^2}{3l_{bdg}}$	$l_{bdg}-\frac{5l_{lp}^2}{9l_{bdg}}$	$l_{bdg}-\frac{l_{lp}^2}{2l_{bdg}}$

n_2	6	7	8	9	10
K_3	$l_{bdg}-\frac{7l_{lp}^2}{15l_{bdg}}$	$l_{bdg}-\frac{4l_{lp}^2}{9l_{bdg}}$	$l_{bdg}-\frac{3l_{lp}^2}{7l_{bdg}}$	$l_{bdg}-\frac{5l_{lp}^2}{12l_{bdg}}$	$l_{bdg}-\frac{11l_{lp}^2}{27l_{bdg}}$

2.4 Hopper tank and inner hull

2.4.1 Hopper sloping plating and inner hull plating

The net thickness *t*, in mm, of plating of longitudinally framed bilge hopper sloping plate and inner hull is not to be taken less than:

$t = K_1\sqrt{\frac{F_{sc-hs-s}}{C_a R_{eH}}10^3}$ applicable for design load set BC-9.

$t = K_1\sqrt{\frac{F_{sc-hs}}{C_a R_{eH}}10^3}$ applicable for design load set BC-10.

where:

K_1 *:* Coefficient as defined in [2.3.1].

C_a : As defined in [2.3.1].

2.4.2 Stiffeners of hopper sloping plating and inner hull plating

The net section modulus Z, in cm^3, and the net web thickness, t_w, in mm, of single span ordinary stiffeners located on bilge hopper sloping plate and inner hull plate are not to be taken less than:

$Z = K_3 \frac{F_{sc-hb-s}}{8C_s R_{eH}} 10^3$ and $t_w = \frac{0.5F_{sc-hb-s}}{d_{shr} C_t \tau_{eH}} \times 10^3$, applicable for design load set BC-9.

$Z = K_3 \frac{F_{sc-hb}}{8C_s R_{eH}} 10^3$ and $t_w = \frac{0.5F_{sc-hb}}{d_{shr} C_t \tau_{eH}} \times 10^3$, applicable for design load set BC-10.

where:

K_3 : Coefficient as defined in Table 2.

$K_3 = 2l_{bdg}/3$, when $n_2 > 10$.

C_s, C_t : As defined in [2.3.2].

3 TRANSVERSE VERTICALLY CORRUGATED WATERTIGHT BULKHEADS SEPARATING CARGO HOLDS IN FLOODED CONDITION

3.1 Net thickness of corrugation

3.1.1 Cold formed corrugation

The net plate thickness t, in mm, of transverse vertically corrugated watertight bulkheads separating cargo holds is not to be taken less than:

$$t = 14.9 \cdot 10^{-3} s_{CW} \sqrt{\frac{1.05P_R}{R_{eH}}}$$

The net thicknesses is also to comply with the requirements given in Pt 1, Ch 6, Sec 4, [1.2.1].

3.1.2 Built-up corrugation

Where the thicknesses of the flange and web of built-up corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds are different, the net plate thicknesses are not to be taken less than that obtained from the following formula.

The net thickness t_N, in mm, of the narrower plating is not to be taken less than:

$$t_N = 14.9 \cdot 10^{-3} s_N \sqrt{\frac{1.05P_R}{R_{eH}}}$$

s_N : Plate width, in mm, of the narrower plating.

The net thickness t_W, in mm, of the wider plating is not to be taken less than the greater of the following formulae:

$$t_W = 14.9 \cdot 10^{-3} s_{CW} \sqrt{\frac{1.05P_R}{R_{eH}}}$$

$$t_W = \sqrt{\frac{4.62 s_{CW}^2 P_R}{R_{eH} 10^4} - t_{NO}^2}$$

where:

t_{NO} : Net offered thickness of the narrower plating, in mm, not to be taken greater than:

$$t_{NO} = 14.9 \cdot 10^{-3} s_{CW} \sqrt{\frac{1.05P_R}{R_{eH}}}$$

The net thicknesses is also to comply with the requirements given in Pt 1, Ch 6, Sec 4, [1.2.2].

3.1.3 Lower part of corrugation

The net thickness of the lower part of corrugations is to be maintained for a distance of not less than $0.15l_C$ measured from the top of the lower stool, or from the inner bottom where no lower stool is fitted. The span of the corrugations l_C, in m, is to be taken as given in Pt 1, Ch 3, Sec 6, [10.4.5].

3.1.4 Middle part of corrugation

The net thickness of the middle part of corrugations is to be maintained for a distance not greater than 0.3 l_C from the bottom of the upper stool, or from the deck if no upper stool is fitted. The net thickness is also to com- ply with the requirements in [3.2.1] and Pt 1, Ch 6, Sec 4, [1.2].

3.2 Bending, shear and buckling check

3.2.1 Bending capacity and shear capacity

The bending capacity and the shear capacity of the corrugations of transverse watertight corrugated bulkheads separating cargo holds are to comply with the following formulae:

$$0.5W_{LE} + W_M \geq \frac{M}{0.95R_{eH}}10^3$$

where:

M : Bending moment in a corrugation, in kNm, taken as:

$$M = \frac{F_R l_C}{8}$$

F_R : Resultant force, in kN, given in Pt 1, Ch 4, Sec 6, [3.1.7].

l_C : Span of the corrugations, in m, as given in Pt 1, Ch 3, Sec 6, [10.4.5].

W_{LE} : Net section modulus, in cm3, of one half pitch corrugation, to be calculated at the lower end of the corrugations according to [3.3], not to be taken greater than:

$$W_{LE,M} = W_G + \frac{Qh_G 10^3 - 0.5h_G^2 s_C p_R}{R_{eH}}$$

W_G : Net section modulus, in cm^3, of one half pitch corrugation, to be calculated in way of the upper end of shedder or gusset plates, as applicable, according to [3.3].

Q : Shear force, in kN, at the lower end of a corrugation, to be taken as:
$Q = 0.8\ F_R$

h_G : Height, in m, of shedders or gusset plates, as applicable as shown in Figure 4 to Figure 6.

P_R : Resultant pressure, in kN/m^2, to be calculated in way of the middle of the shedders or gusset plates, as applicable, according to Pt 1, Ch 4, Sec 6, [3.1.7].

W_M : Net section modulus, in cm3, of one half pitch corrugation, to be calculated at the mid-span of corrugations according to [3.3] without being taken greater than 1.15 W_{LE}.

τ : Shear stress, in N/mm^2, in the corrugation to be taken as:

$$\tau = 10\frac{Q}{A_{shr}}$$

A_{shr} : Net shear area, in cm^2, of one half pitch corrugation. The calculated net shear area is to consider possible reduced shear efficiency due to non-straight angles between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by $\sin\phi$.

ϕ : Angle between the web and the flange, see Pt 1, Ch 3, Sec 6, Figure 21.

The net section modulus of the corrugations in the upper part of the bulkhead, as defined in Figure 3, is not to be taken less than 75% of that of the middle part complying with this requirement and Pt 1, Ch 6, Sec 4, [1.2], corrected for different minimum yield stresses.

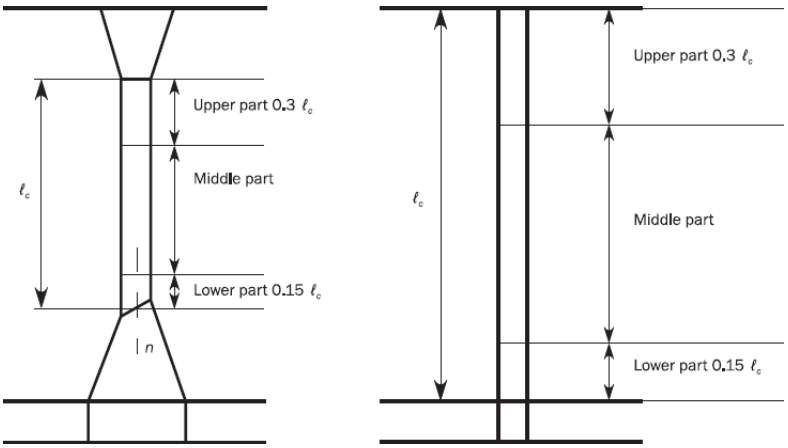


Figure 3 Parts of corrugation

3.2.2 Shear buckling check of the bulkhead corrugation webs

The shear stress τ , calculated according to [3.2.1], is to comply with the following formula:

$\tau \leq \tau_C$

where:

τ_C : Critical shear buckling stress, in N/mm^2, to be taken as:

$$\tau \leqslant \tau_C \text{ for } \tau_E \leq \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{eH}}{\sqrt{3}}(1-\frac{R_{eH}}{4\sqrt{3}\tau_E}) \text{ for } \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

τ_E : Euler shear buckling stress, in N/mm^2, to be taken as:

$$\tau_E = 0.9k_t E(\frac{t_w}{b_{w-cg}})^2$$

k_t : Coefficient, to be taken equal to 6.34.

t_w : Net thickness, in mm, of the corrugation webs.

$b_{w\text{-}cg}$: Width, in mm, of the corrugation webs as shown in Pt 1, Ch 3, Sec 6, Figure 21.

3.3 Net section modulus of the corrugations

3.3.1 Effective flange width

The net section modulus of the corrugations is to be calculated with the compression flange having an effective flange width b_{eff} not larger than the following formula:

$b_{eff} = C_E b_{f\text{-}cg}$

where:

C_E : Coefficient to be taken equal to:

$$C_E = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \quad \text{for } \beta > 1.25$$

C_E=1.0 for $\beta \leq 1.25$

β : Coefficient to be taken equal to:

$$\beta = \frac{b_{f-cg}}{t_f}\sqrt{\frac{R_{eH}}{E}}$$

$b_{f\text{-}cg}$: Width, in mm, of the corrugation flange as shown in Pt 1, Ch 3, Sec 6, Figure 21.

t_f : Net flange thickness, in mm.

3.3.2 Webs not supported by local brackets

Unless welded to a sloping stool top plate as defined in [3.3.5], if the corrugation webs are not supported by local brackets below the stool top plate (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

3.3.3 Effective shedder plates

Provided that effective shedder plates are fitted as shown in Figure 4, when calculating the section modulus at the lower end of the corrugations (Sections '1' in Figure 4), the net area, in cm^2, of flange plates may be increased by I_{SH} to be taken as:

$I_{SH} = 2.5 \cdot 10^{-3} b_{f-cg} \sqrt{t_f t_{SH}}$ without being taken greater than $2.5 b_{f\text{-}cg}\, t_f\, 10^{-3}$

where:

$b_{f\text{-}cg}$: Width, in mm, of the corrugation flange as shown in Pt 1, Ch 3, Sec 6, Figure 21.

t_{SH} : Net shedder plate thickness, in mm.

t_f : Net flange thickness, in mm.

Effective shedder plates are those which:

- are not knuckled,
- are welded to the corrugations and the lower stool top plate according to Pt 1, Ch 12,
- are fitted with a minimum slope of 45°, their lower edge being in line with the lower stool side plating,
- have net thickness not less than 75% of the net required for the corrugation flanges,
- have material properties not less than those required for the flanges.

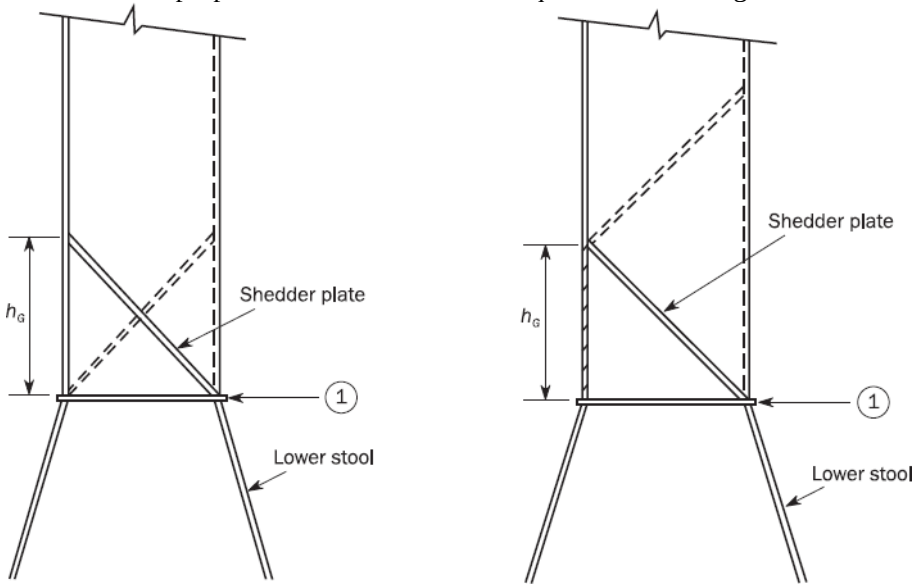


Figure 4 Symmetrical and unsymmetrical shedder plates

3.3.4 Effective gusset plates

Provided that effective gusset plates are fitted, when calculating the section modulus at the lower end of the corrugations (Sections '1' in Figure 5 and Figure 6), the net area, in cm^2, of flange plates may be increased by I_G to be taken as:

$I_G = 7\, h_G\, t_f$

h_G : Height, in m, of gusset plates as shown in Figure 5 and Figure 6 but not to be taken greater than:

$$\frac{10 S_{GU}}{7}$$

S_{GU} : Width, in m, of gusset plates.

t_f : Net flange thickness, in mm.

Effective gusset plates are those which:

- are in combination with shedder plates having thickness, material properties and welded connections as requested for shedder plates in [3.3.3],
- have a height not less than half of the flange width,
- are fitted in line with the lower stool side plating,
- are welded to the lower stool top plate, corrugations and shedder plates according to Pt1, Ch12, Sec 3, [2.4.6],
- have net thickness and material properties not less than those net required for the flanges.

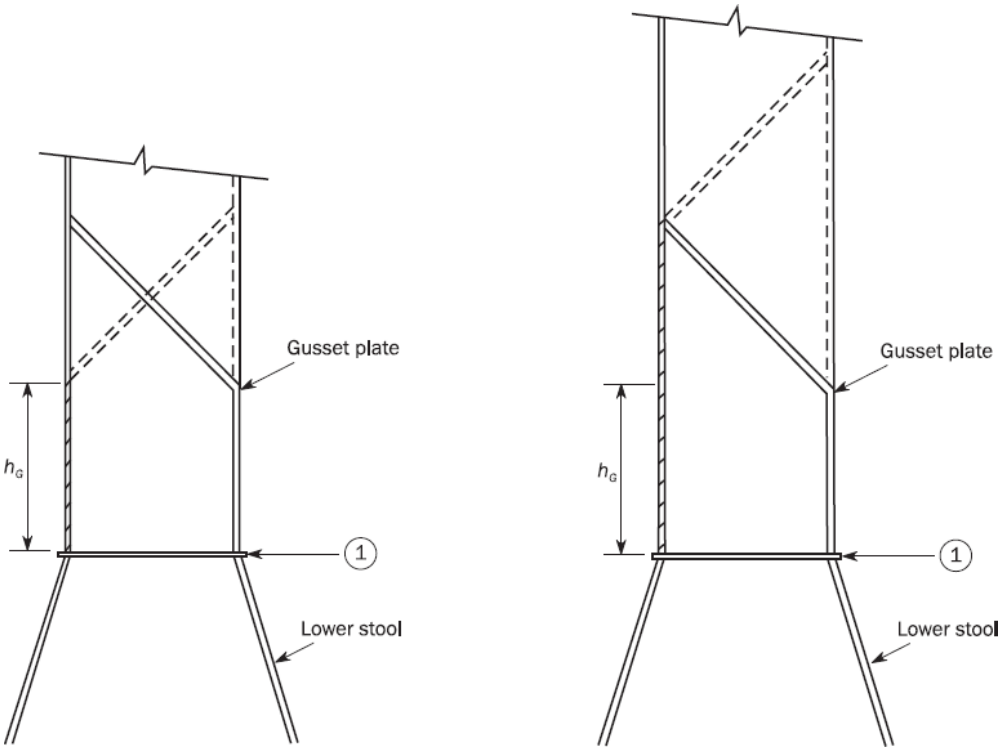


Figure 5 Symmetrical and unsymmetrical gusset / shedder plates

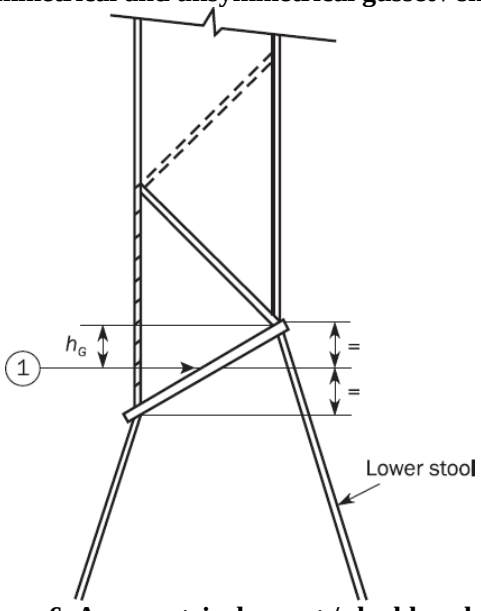


Figure 6 Asymmetrical gusset / shedder plates

3.3.5 Sloping stool top plate

Where the corrugation webs are welded to a sloping stool top plate which has an angle not less than 45 º with the horizontal plane, the section modulus at the lower end of the corrugations may be calculated considering the corrugation webs fully effective. For angles less than 45 º, the effectiveness of the web may be obtained by linear interpolation between 30% efficient for 0 º and 100% efficient for 45 º.

Where effective gusset plates are fitted, when calculating the net section modulus of corrugations, the net area of flange plates may be increased as specified in [3.3.4] above. No credit may be given to shedder plates only.

4 ALLOWABLE HOLD LOADING FOR BC-A & BC-B SHIPS IN FLOODED CONDITIONS

4.1 Evaluation of double bottom capacity and allowable hold loading

4.1.1 Shear capacity of the double bottom

The shear capacity of the double bottom is to be calculated as the sum of the shear strength at each end of:

- Floors connected to hopper tanks, less one half of the shear strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted as shown in Figure 7. The shear strength of floors is to be calculated according to [4.1.2].
- Double bottom girders connected to stools, or transverse bulkheads if no stool is fitted. The shear strength of girders is to be calculated according to [4.1.3].

The floors and girders to be considered when calculating the shear capacity of the double bottom are those inside the hold boundaries formed by the hopper tanks and stools or transverse bulkheads if no stool is fitted. Where both ends of girders or floors are not directly connected to the hold boundaries, their strength is to be evaluated for the connected end only.

The hopper tank side girders and the floors directly below the connection of the stools or transverse bulkheads if no stool is fitted to the inner bottom may not be included.

For special double bottom designs, the shear capacity of the double bottom is to be calculated by means of direct calculations carried out in accordance with requirements specified in Pt 1, Ch 7, as applicable.

4.1.2 Floor shear strength

The floor shear strength, in kN, is to be taken as given in the following formulae:

- In way of the floor panel adjacent to the hopper tank:

$$S_{f1} = A_f \frac{\tau_A}{\eta_1} 10^{-3}$$

- In way of the openings in the outermost bay (i.e., that bay which is closer to the hopper tank):

$$S_{f1} = A_{f,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

where:

A_f : Net sectional area, in mm^2, of the floor panel adjacent to the hopper tank.

$A_{f,h}$: Net sectional area, in mm^2, of the floor panels in way of the openings in the outermost bay (i.e., the bay which is closer to the hopper tank).

τ_A : Allowable shear stress, in N/mm^2, to be taken as the lesser of:

$$\tau_A = 0.645 \frac{R_{eH}^{0.6}}{(s/t)^{0.8}} \text{ and } \tau_A = \frac{R_{eH}}{\sqrt{3}}$$

For floors adjacent to the stools or transverse bulkheads, τ_A is taken as:

$$\frac{R_{eH}}{\sqrt{3}}$$

t : Floor web net thickness, in mm.

s : Spacing, in m, of stiffening members of the panel considered.

η_1 : Coefficient to be taken equal to 1.1.

η_2 : Coefficient to be taken equal to 1.2. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the openings in the outermost bay, to be examined by the Society on a case-by-case basis.

CCS 4.1.2a Where appropriate reinforcements are fitted in way of the openings in the outermost bay, e.g. circular flat bars attached to the inner edge of an opening or stiffeners fitted around an opening, η_2 may be taken as 1.1.

4.1.3 Girder shear strength

The girder shear strength, in kN, is to be taken as given in the following formulae:

- In way of the girder panel adjacent to the stool or transverse bulkhead, if no stool is fitted:

$$S_{g1} = A_g \frac{\tau_A}{\eta_1} 10^{-3}$$

- In way of the largest opening in the outermost bay (i.e., that bay which is closer to the stool) or transverse bulk-head, if no stool is fitted:

$$S_{g2} = A_{g,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

A_g : Net sectional area, in mm^2, of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted).

$A_{g,h}$: Net sectional area, in mm^2, of the girder panel in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool) or transverse bulkhead, if no stool is fitted.

τ_A : Allowable shear stress, in N/mm^2, as defined in [4.1.2] where t is the girder web net thickness.

η_1 : Coefficient to be taken equal to 1.1.

η_2 : Coefficient to be taken equal to 1.15. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the largest opening in the outermost bay, to be examined by the Society on a case-by- case basis.

CCS 4.1.3a Where appropriate reinforcements are fitted in way of the openings in the outermost bay, e.g. circular flat bars attached to the inner edge of an opening or stiffeners fitted around an opening, η2 may be taken as 1.1.

4.1.4 Allowable hold loading

The allowable hold loading, in *t*, is to be taken as:

$$W = \rho_C V \frac{1}{F}$$

where:

ρ_C : Density of the dry bulk cargo, in t/m^3, as defined Pt 1, Ch 4, Sec 6, [2.3.3].

V : Volume, in m^3, occupied by the cargo up to the level h_B.

F : Coefficient to be taken as:

F = 1.1 in general.

F = 1.05 for steel mill products.

h_B : Level of cargo, in m, to be taken as:

$$h_B = \frac{P}{\rho_C g}$$

P : Pressure, in kN/m^2, to be taken as:

- For dry bulk cargoes, the lesser of:

$$P = \frac{Z + \rho g(z_F - 0.1D_1 - h_F)}{1 + \frac{\rho}{\rho_C}(perm - 1)}$$

$$P = Z + \rho g(z_F - 0.1D_1 - h_F perm)$$

- For steel mill products:

$$P = \frac{Z + \rho g(z_F - 0.1D_1 - h_F)}{1 - \frac{\rho}{\rho_{st}}}$$

D_1 : Distance, in m, from the baseline to the freeboard deck at side amidships.

h_F : Inner bottom flooded height, in m, measured vertically with the ship in the upright position, from the inner bottom to the flooded level z_F.

z_F : Flooded level, in m, as defined in Pt 1, Ch 4, Sec 6, [3.2.3].

perm : Permeability of cargo, which need not be taken greater than 0.3.

ρ_{ST} : Density of steel, in t/m^3, to be taken as 7.85.

Z : Pressure, in kN/m^2, to be taken as the lesser of:

$$Z = \frac{C_H}{A_{DB,H}}$$

$$Z = \frac{C_E}{A_{DB,E}}$$

C_H : Shear capacity of the double bottom, in kN, to be calculated according to [4.1.1], considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} as defined in [4.1.2] and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} as defined in [4.1.3].

$A_{DB,H}$: Area, in m^2, taken as:

$$A_{DB,H} = \sum_{i=1}^{n} S_i B_{DB,i}$$

C_E : Shear capacity of the double bottom, in kN, to be calculated according to [4.1.1], considering, for each floor, the shear strength S_{f1} as defined in [4.1.2] and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} as defined in [4.1.3].

$A_{DB,E}$: Area, in m^2, taken as:

$$A_{DB,E} = \sum_{i=1}^{n} S_i (B_{DB} - s)$$

n : Number of floors between stools or transverse bulkheads, if no stool is fitted.

S_i : Space of i-th floor, in m.

$B_{DB,i}$: Length, in m, to be taken equal to:

$B_{DB,i} = B_{DB-s}$ for floors for which $S_{f1} < S_{f2}$.

$B_{DB,i} = B_{DB,h}$ for floors for which $S_{f1} \geqslant S_{f2}$.

B_{DB} : Breadth, in m, of double bottom between the hopper tanks as shown in Figure 8.

$B_{DB,h}$: Distance, in m, between the two openings considered as shown in Figure 8.

s : Spacing, in m, of inner bottom longitudinal ordinary stiffeners adjacent to the hopper tanks.

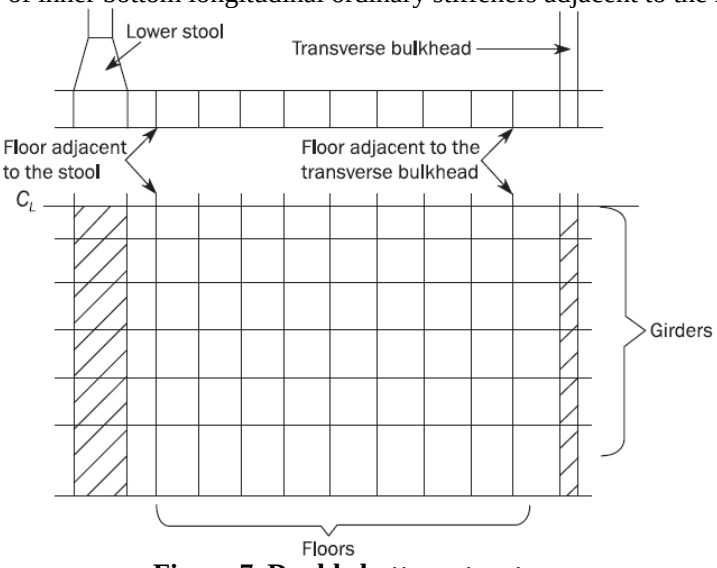


Figure 7 Double bottom structure

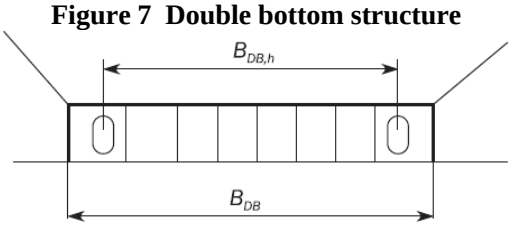


Figure 8 Dimensions B_{DB} and $B_{DB,h}$

Section 4 HULL LOCAL SCANTLINGS FOR BULK CARRIERS *L*<150M

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

$C_{t\text{-}pr}$: Permissible shear stress coefficient for primary supporting members taken equal to:

$C_{t\text{-}pr}$ = 0.70 for AC-S.

$C_{t\text{-}pr}$ = 0.85 for AC-SD.

l_{DB} : Length of the double bottom within hold under consideration, in m. Where stools are provided at transverse bulkheads, l_{DB} may be taken as the distance between the toes.

B_{DB} : Distance between the toes of hopper tanks at centre of B_{DB} within hold under consideration, in m.

x_c : *X* coordinate, in m, of the centre of double bottom structure under consideration with respect to the reference coordinate system, as defined in Pt 1, Ch 1, Sec 4, [3.6].

x, *y*, *z* : *X*, *Y* and *Z* coordinates, in m, of the evaluation point with respect to the reference coordinate system, as defined in Pt 1, Ch 1, Sec 4, [3.6].

ϕ : Depth of the openings in parallel to web depth of primary support members, in m.

α : The greater of *a* or S_1, in m.

1 GENERAL

1.1 Application

1.1.1

Unless otherwise defined, the requirements of this section define the strength criteria applicable to bulk carriers with freeboard length L_{LL} of less than 150 m.

2 STRUTS CONNECTING STIFFENERS

2.1 Scantling requirements

2.1.1 Net sectional area and moment of inertia

The net sectional area A_{SR}, in cm^2, and the net moment of inertia I_{SR} about the main axes, in cm^4, of struts connecting stiffeners are not to be less than the values obtained from the following formulae:

$$A_{SR} = \frac{P_{SR} s l}{20000}$$

$$I_{SR} = \frac{0.75 s l (P_{SR1} + P_{SR2}) A_{ASR} l_{SR}^2}{47200 A_{ASR} - s l (P_{SR1} + P_{SR2})}$$

where:

P_{SR} : Pressure to be taken as the greater of the following values, in kN/m^2:

P_{SR}=0.5(P_{SR1}+ P_{SR2}）

P_{SR}= P_{SR3}

P_{SR1} : External pressure in way of the strut, in kN/m^2, acting on one side, outside the compartment in which the strut is located.

P_{SR2} : External pressure in way of the strut, in kN/m^2, acting on the opposite side, outside the compartment in which the strut is located.

P_{SR3}: Internal pressure at mid-span of the strut, in kN/m2, in the compartment in which the strut is located.

s : Spacing, in mm, of stiffeners, measured at mid-span along the chord.

l : Span, in m, of stiffeners connected by the strut defined in Pt 1, Ch 3, Sec 7, [1.1.5].

l_{SR} : Length of the strut, in m.

A_{ASR} : Actual net sectional area of the strut, in cm^2.

3 TRANSVERSE CORRUGATED BULKHEADS OF BALLAST HOLDS

3.1 Plate thickness

3.1.1

The net thickness of web and flange plating is not to be less than the values obtained in Pt 1, Ch 6, Sec 3, [1.1.1] and Pt 1, Ch 6, Sec 4, [1.2].

3.2 Net section modulus

3.2.1

The net section modulus Z, in cm^3, of corrugated bulkhead of ballast holds, subjected to lateral pressure are not to be less than the values obtained from the following formula:

$$Z = K \frac{P s_{cg} l^2}{f_{bdg} C_s R_Y}$$

where:

K : Coefficient given in Table 1 and Table 2, according to the type of end connection. When $d_H <$ 2.5 d_0, both section modulus per half pitch of corrugated bulkhead and section modulus of lower stool at inner bottom are to be calculated.

P : Design pressure for the design load set as defined in Pt 1, Ch 6, Sec 2, Table 1 and calculated at the load calculation point defined in Pt 1, Ch 3, Sec 7, [3.2], in kN/m^2.

s_{cg} : Half pitch length, in mm, of the corrugation, as defined in Pt 1, Ch 3, Sec 6, Figure 21.

l : Length, in m, between the supports, as indicated in Figure 1.

C_s : Coefficient defined in Pt 1, Ch 6, Sec 5, [1.1.2].

f_{bdg}: Coefficient defined in Pt 1, Ch 6, Sec 5, [1.1.2].

The effective width of the corrugation flange in compression is to be considered according to Ch 1, Sec 3, [3.3.1] when the net section modulus of corrugated bulkhead is calculated.

Values of K, in case $d_H \geqslant 2.5\ d_0$ **Table 1**

Upper end support	
Welded directly to deck	Welded to stool efficiently supported by ship structure
1.00	0.83

Values of K, in case $d_H < 2.5\ d_0$ **Table 2**

Section modulus of	Upper end support	
	Connected to deck	Connected to stool
Corrugated bulkhead	0.71	0.65
Stool at bottom	1.25	1.13

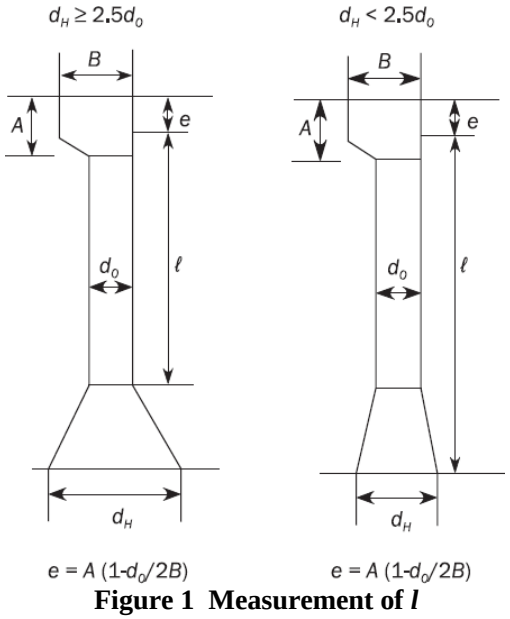


Figure 1 Measurement of *l*

4 PRIMARY SUPPORTING MEMBERS

4.1 Application

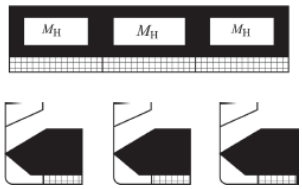
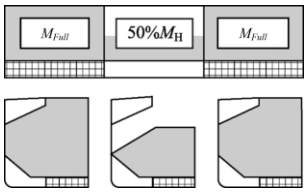
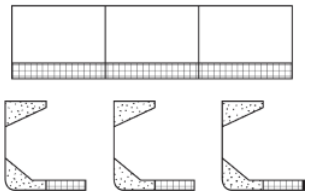
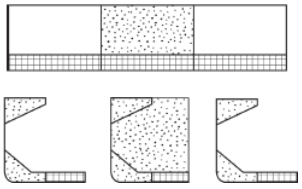
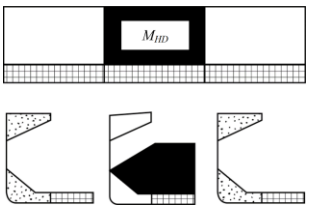
4.1.1

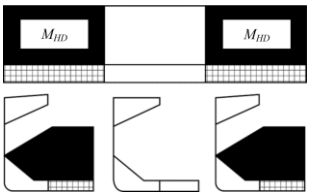
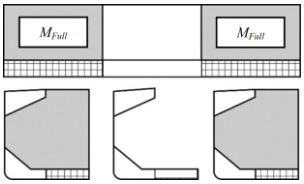
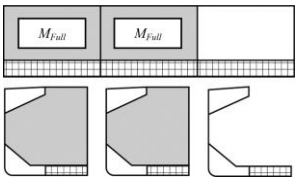
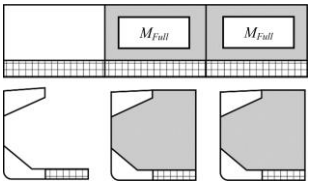
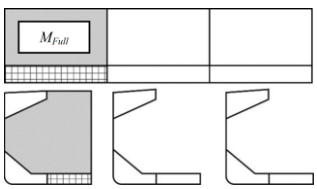
The requirements of this section apply to the strength check of primary supporting members in cargo hold structures, subjected to lateral pressure for ships having a freeboard length L_{LL} less than 150 m.

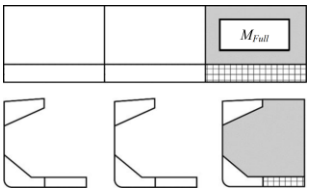
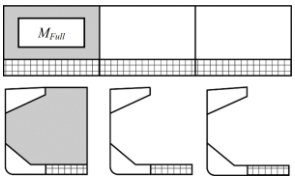
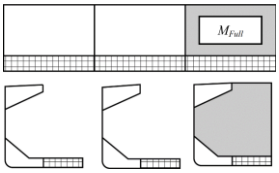
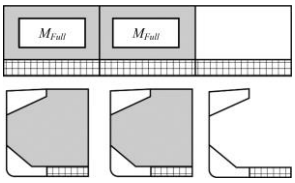
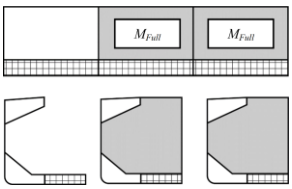
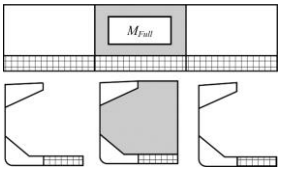
4.1.2
As an alternative to [4.1.1], the strength check may be verified by direct strength assessment deemed as appropriate by the Society.

CCS 4.1.2a As an alternative to 4.1.1, the scantlings of primary supporting members within the midship cargo hold region may be verified by direct strength assessment according to the requirements in Chapter 7 of PART 9-1 and the load combinations as given in Table CCS 4.1.2a.

FE Load combinations Table ***CCS 4.1.2a***

No	*Description*	*Loading pattern*	*Draught*	*Permissible still water bending moment (%)*	*Permissible still Water shear force (%)*	*Dynamic load case*
Seagoing conditions						
1	*Full load*		T_{SC}	*50% sag.*	*100%*	*BSP-1P, BSP-1S OST-1P,OST-1S*
2	*Slack load*		T_{SC}	*0%*	*100%*	*BSP-1P,BSP-1S*
3	*Normal ballast*		T_{BAL-N}	*100% hog.*	*100%*	*FSM-2,BSR-1P, BSR-1S, OST-2P,OST-2S*
4	*Heavy ballast (if any)*		T_{BAL-H}	*0%*	*100% Max SFLC*	*FSM-2, HSM-2*
					100%	*BSR-1P,BSR-1S*
				100% sag.	*100% Max SFLC*	*HSM-1*
					100% Max SFLC	*HSM-1*
					100%	*BSR-1P,BSR-1S*
5	*Alternate Load loaded hold (if any)*		T_{SC}	*100% hog.*	*100% Max SFLC*	*FSM-2, HSM-2*
					100%	*OST-2P,OST-2S*
				0%	*100% Max SFLC*	*FSM-1 HSM-1*
					100% Max SFLC	*FSM-1 HSM-1*
					100%	*BSP-1P, BSP-1S OST-1P,OST-1S*

No	*Description*	*Loading pattern*	*Draught*	*Permissible still water bending moment (%)*	*Permissible still Water shear force (%)*	*Dynamic load case*
6	*Alternate Load empty hold (if any)*		T_{SC}	*100% hog.*	*100% Max SFLC*	*FSM-2 HSM-2*
					100%	*OST-2P,OST-2S*
				0%	*100% Max SFLC*	*FSM-1 HSM-1*
					100% Max SFLC	*FSM-1 HSM-1*
					100%	*BSP-1P, BSP-1S OST-1P,OST-1S*
7	*Multiport (if any)*		$0.83T_{SC}$	*100% hog.*	*100% Max SFLC*	*FSM-2 HSM-2*
					100% Max SFLC	*FSM-2 HSM-2*
					100%	*OST-2P,OST-2S*
				100% sag.	*100% Max SFLC*	*HSM-1*
					100%	*BSP-1P, BSP-1S OST-1P,OST-1S*
8	*Multiport (if any)*		$0.67T_{SC}$	*100% sag.*	*100%*	*BSP-1P,BSP-1S OST-1P,OST-1S*
9	*Multiport (if any)*		$0.67T_{SC}$	*100% sag.*	*100%*	*BSP-1P,BSP-1S OST-1P,OST-1S*
10	*Multiport (if any)*		$0.75T_{SC}$	*100% hog.*	*100%*	*FSM-2 HSM-2 BSR-1P, BSR-1S OST-2P,OST-2S*
				100% sag.	*100%*	*BSP-1P, BSP-1S BSR-1P,BSR-1S OST-1P,OST-1S*

No	*Description*	*Loading pattern*	*Draught*	*Permissible still water bending moment (%)*	*Permissible still Water shear force (%)*	*Dynamic load case*
11	*Multiport (if any)*		$0.75T_{SC}$	*100% hog.*	*100%*	*FSM-2 HSM-2 BSR-1P,BSR-1S OST-2P,OST-2S*
				100% sag.	*100%*	*BSP-1P,BSP-1S BSR-1P,BSR-1S OST-1P,OST-1S*
Harbour conditions						
12	*Harbour condition*		$0.67T_{SC}$	*100% hog.*	*100%*	*N/A*
				100% sag.	*100%*	*N/A*
13	*Harbour condition*		$0.67T_{SC}$	*100% hog.*	*100%*	*N/A*
				100% sag.	*100%*	*N/A*
14	*Harbour condition*		TH_1	*100% hog.*	*100%*	*N/A*
				100% sag.	*100%*	*N/A*
15	*Harbour condition*		TH_1	*100% hog.*	*100%*	*N/A*
				100% sag.	*100%*	*N/A*
16	*Harbour condition*		TH_2	*100% hog.*	*100% Max SFLC*	*N/A*
					100% Max SFLC	*N/A*
				100% sag	*100% Max SFLC*	*N/A*
					100% Max SFLC	*N/A*

Other loading conditions from the Loading Manual, which are not covered in the above Table are also to be considered. In these cases, actual values of draught and hull girder static loads are to be used, and dynamic load cases corresponding to the loading patterns are to be applied. For example, while the still water bending moment corresponding to the loading pattern is positive, dynamic load cases with hogging wave bending moment are to be applied.

CCS 4.1.2b The scantlings of the primary supporting members in the midship cargo region are

also to comply with the minimum thickness requirements in Section 3, Chapter 6 and the aspect ratio requirements in Section 2, Chapter 8 of PART 9-1.

4.2 Design load sets

4.2.1 Application

Design load sets as given in Table 3 are to be considered for primary supporting members on cargo hold boundaries of bulk carriers with freeboard length L_{LL} less than 150 m.

Design load sets for primary supporting members in cargo hold region Table 3

Item	Design load set	Load component	Draught	Design load	Loading condition
• Double bottom floors and girders • Stringers and transverse web frames in double side structures	WB-4 (1)	P_{in}-P_{ex}	T_{BAL-H}	S+D	Heavy ballast condition
	WB-6 (1)	P_{in}	-	S	Harbour/test condition
	BC-11	P_{in}-P_{ex}	T_{SC}	S+D	Full load condition
	BC-12	P_{in}-P_{ex}	T_{SC}	S	Harbour condition
	FD-1(2)	P_{in}	T_{SC}	S+D	Flooded condition
	FD-2(2)	P_{in}	-	S	Flooded condition
(1) Only applicable to holds assigned as ballast hold. (2) Not applicable to holds assigned as ballast hold.					

4.2.2 Loading conditions

The severest loading conditions from the loading manual or otherwise specified by the designer are to be considered for the calculation of *Pin* in design load sets BC-11 to BC-12.

For Primary supporting member in bilge hopper tanks and topside tanks, applicable design load sets in Pt 1, Ch 6, Sec 2, Table 1 are to be considered.

4.3 Centre girders and side girders

4.3.1 Net web thickness

The net thickness of girders in double bottom structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_1 \frac{|P|S|x - x_c|}{(d_0 - d_1)C_{t-pr}\tau_{eH}} \left\{ 1 - 4\left(\frac{y}{B_{DB}}\right)^2 \right\}$$

where $|x - x_c|$ is less than $0.25 l_{DB}$, $|x - x_c|$ is to be taken as $0.25\ l_{DB}$.

$$t_2 = 1.75 \sqrt[3]{\frac{H^2 a^2 C_{t-pr}\tau_{eH}}{C_1'}} t_1$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted.

S : Distance between the centres of the two spaces adjacent to the centre or side girder under consideration, in m.

d_0 : Depth of the centre or side girder under consideration, in m.

d_1 : Depth of the opening, if any, at the point under consideration, in m.

C_1 : Coefficient given in Table 4 depending on B_{DB}/l_{DB}. For intermediate values of B_{DB}/l_{DB}, C_1 is to be obtained by linear interpolation.

a : Depth of girders at the point under consideration, in m. However, where horizontal stiffeners are fitted on the girder, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration.

S_1 : Spacing, in m, of vertical stiffeners or floors.

C'_1: Coefficient given in Table 5 depending on S_1/a. For intermediate values of S_1/a, C'_1 is to be determined by linear interpolation.

H : Value obtained from the following formulae:

- Where the girder is provided with an unreinforced opening:

$$H = 1 + 0.5\frac{\phi}{\alpha}$$

- In other cases:
  H=1.0

Coefficient C_1 **Table 4**

B_{DB}/l_{DB}	0.4 and under	0.6	0.8	1.0	1.2	1.4	1.6 and over
C_1	0.5	0.71	0.83	0.88	0.95	0.98	1.00

Coefficient C'_1 **Table 5**

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C'_1	64	38	25	19	15	12	10	9	8	7

4.4 Floors

4.4.1 Net web thickness

The net thickness of floors in the double bottom structure, in mm, is not to be less than the greatest of values t_1 and t_2 specified in the following according to each location:

$$t_1 = C_2 \frac{|P|SB_{DB}}{(d_0 - d_1)C_{t-pr}\tau_{eH}}\left(\frac{2|y|}{B'_{DB}}\right)\left\{1 - 2\left(\frac{x - x_c}{l_{DB}}\right)^2\right\}$$

where $|x - x_c|$ is less than $0.25l_{DB}$, $|x - x_c|$ is to be taken as $0.25l_{DB}$, and where $|y|$ is less than $B'_{DB}/4$, $|y|$ is to be taken as $B'_{DB}/4$.

$$t_2 = 1.75\sqrt[3]{\frac{H^2a^2C_{t-pr}\tau_{eH}}{C'_2}t_1}$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted.

S : Spacing of solid floors, in m.

d_0 : Depth of the solid floor at the point under consideration in m.

d_1 : Depth of the opening, if any, at the point under consideration in m.

B'_{DB} : Distance between toes of hopper tanks at the position of the solid floor under consideration, in m.

C_2 : Coefficient given in Table 6 depending on B_{DB}/l_{DB}. For intermediate values of B_{DB}/l_{DB}, C_2 is to be obtained by linear interpolation.

a : Depth of the solid floor at the point under consideration, in m. However, where horizontal stiffeners are fitted on the floor, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or the inner bottom plating or the distance between the horizontal stiffeners under consideration.

S_1 : Spacing, in m, of vertical stiffeners or girders.

C'_2 : Coefficient given in Table 7 depending on S_1/d_0. For intermediate values of S_1/d_0, C'_2 is to be determined by linear interpolation.

H : Value obtained from the following formulae:

Where openings with reinforcement or no opening are provided on solid floors:

- Where slots without reinforcement are provided:

$$H = \sqrt{4.0\frac{d_2}{S_1} - 1.0}$$ without being taken less than 1.0.

- Where slots with reinforcement are provided:
  H = 1.0

Where openings without reinforcement are provided on solid floors:

- Where slots without reinforcement are provided:

$$H = (1+0.5\frac{\phi}{d_0})\sqrt{4.0\frac{d_2}{S_1}-1.0}$$ without being taken less than $1+0.5\frac{\phi}{d_0}$

- where slots with reinforcement are provided:

$$H = 1+0.5\frac{\phi}{d_0}$$

d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater.

Coefficient C_2 **Table 6**

B_{DB}/l_{DB}	0.4 and under	0.6	0.8	1.0	1.2	1.4	1.6 and over
C2	0.48	0.47	0.45	0.43	0.40	0.37	0.34

Coefficient C'_2 **Table 7**

S_1/d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C'_2	64	38	25	19	15	12	10	9	8	7

4.5 Stringer of double side structure

4.5.1 Net web thickness

The net thickness of stringers in double side structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_3\frac{|P|S|x-x_c|}{(d_0-d_1)C_{t-pr}\tau_{eH}}$$

where $|x - x_c|$ is under $0.25l_{DS}$, $|x - x_c|$ is to be taken as $0.25l_{DS}$.

$$t_2 = 1.75\sqrt[3]{\frac{H^2a^2C_{t-pr}\tau_{eH}}{C_3^{'}}}t_1$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], as measured vertically at the upper end of hopper tank, longitudinally at the centre of l_{DS}.

S : Breadth of part supported by stringer, in m.

d_0 : Depth of stringers, in m.

d_1 : Depth of opening, if any, at the point under consideration, in m.

l_{DS} : Length of the double side structure between the transverse bulkheads under consideration, in m.

h_{DS} : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank located midway between transverse bulkheads of hold under consideration, in m.

C_3 : Coefficient given in Table 8 depending on h_{DS}/l_{DS}. For intermediate values of h_{DS}/l_{DS}. C_3 is to be obtained by linear interpolation.

a :Depth of stringers at the point under consideration, in m. However, where horizontal stiffeners are fitted on the stringer, a is the distance from the horizontal stiffener under consideration to the side shell plating or the longitudinal bulkhead of double side structure or the distance between the horizontal stiffeners under consideration.

S_1 : Spacing, in m, of transverse stiffeners or web frames.

C'_3 : Coefficient given in Table 9 depending on S_1/a. For intermediate values of S_1/a, C'_3 is to be obtained by linear interpolation.

H : Value obtained from the following formulae:

- Where the stringer is provided with an unreinforced opening:

$$H = 1+0.5\frac{\phi}{\alpha}$$

- In other cases:

H=1.0

Coefficient C_3 **Table 8**

h_{DS}/l_{DS}	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_3	0.16	0.23	0.30	0.36	0.41	0.44	0.47	0.50	0.54

Coefficient C'_3 **Table 9**

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C'_3	64	38	25	19	15	12	10	9	8	7

4.6 Transverse web in double side structure

4.6.1 Net web thickness

The net thickness of transverse webs in double side structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_4 \frac{|P| S h_{DS}}{(d_0 - d_1) C_{t-pr} \tau_{eH}} (1 - 1.75 \frac{z - z_{BH}}{h'_{DS}})$$

where $z - z_{BH}$ is greater than $0.4h'_{DS}$, $z - z_{BH}$ is to be taken as $0.4h'_{DS}$.

$$t_2 = 1.75 \sqrt[3]{\frac{H^2 a^2 C_{t-pr} \tau_{eH}}{C'_4}} t_1$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], as measured vertically at the upper end of hopper tank, longitudinally at the centre of l_{DS}.

S : Breadth of part supported by transverses, in m.

d_0 : Depth of transverses, in m.

d_1 : Depth of opening at the point under consideration, in m.

C_4 : Coefficient given in Table 10 depending on h_{DS}/l_{DS}. For intermediate values of h_{DS}/l_{DS}, C_4 is to be obtained by linear interpolation.

z_{BH} : Z coordinate, in m, of the upper end of hopper tank with respect to the reference coordinate system defined in Pt 1, Ch 1, Sec 4, [3.6].

h_{DS} : As defined in the requirements of [4.5.1].

h'_{DS}: Height of the double side structure between the upper end of hopper tank and the lower end of topside tank at the position under consideration, in m.

l_{DS} : As defined in the requirements of [4.5.1].

a : Depth of transverses at the point under consideration, in m. However, where vertical stiffeners are fitted on the transverse, a is the distance from the vertical stiffener under consideration to the side shell or the longitudinal bulkhead of double side hull or the distance between the vertical stiffeners under consideration.

S_1 : Spacing, in m, of horizontal stiffeners or stringers.

C'_4 : Coefficient given in Table 11 depending on S_1/a. For intermediate values of S_1/a, C'_4 is to be obtained by linear interpolation.

H : Value obtained from the following formulae:

- Where the transverse is provided with an unreinforced opening:

$$H = 1 + 0.5 \frac{\phi}{\alpha}$$

- In other cases:
  $H = 1.0$.

α : The greater of a or S_1 in m.

Coefficient C_4 **Table 10**

h_{DS}/l_{DS}	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_4	0.62	0.61	0.59	0.55	0.52	0.49	0.46	0.43	0.41

Coefficient C'_4 **Table 11**

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over

C'_4	64	38	25	19	15	12	10	9	8	7

4.7 Primary supporting member in bilge hopper tanks and topside tanks

4.7.1 Boundary conditions

The requirements of this sub-article apply to primary supporting members considered as clamped at both ends. For boundary conditions deviated from the above, the yielding check is to be considered on a case-by- case basis.

CCS 4.7.1a The requirements of this paragraph apply to the primary supporting members considered as clamped at both ends. For boundary conditions deviated significantly from the above, strength check is to be performed in accordance with CCS 4.1.2a.

4.7.2 Net section modulus, net shear sectional area and web thickness

The net section modulus Z, in cm^3, the net shear sectional area A_{shr}, in cm^2, and the net web thickness t_w, in mm, subjected to lateral pressure are not to be less than the values obtained from the following formulae:

$$Z = \frac{|P| Sl_{bdg}^2}{f_{bdg} C_{s-pr} R_{eH}} 10^3$$

$$A_{shr} = \frac{5|P| Sl_{shr}}{C_{t-pr} \tau_{eH}}$$

$$t_w = 1.75 \sqrt[3]{\frac{h_w C_{t-pr} \tau_{eH}}{10^4 C_5} A_{shr}}$$

where:

P : Design pressure in kN/m^2, for the design load set being considered according to Pt 1, Ch 6, Sec 2, [2.1.3], calculated at the mid-point of span l of a web frame located midway between transverse bulkheads of holds.

S : Spacing of primary supporting members, in m.

l_{bdg} : Effective bending span, in m, of primary supporting members, measured between the supporting members as defined in Pt 1, Ch 3, Sec 7, [1.1.6].

l_{shr} : Effective shear span, in m, of primary supporting members, measured between the supporting members as defined in Pt 1, Ch 3, Sec 7, [1.1.7].

f_{bdg} : Bending moment factor:

- For continuous primary supporting members and where end connections are fitted consistent with idealisation of the primary supporting members as having as fixed ends and is not to be taken higher than:
  $f_{bdg} = 10$
- For primary supporting members with reduced end fixity, the yield check is to be considered on a case-by-case basis.

C_{s-pr} : Permissible bending stress coefficient for primary supporting members taken equal to:
$C_{s-pr} = 0.70$ for AC-S.
$C_{s-pr} = 0.85$ for AC-SD.

h_w : Web height, in mm.

C_5 : Coefficient defined in Table 12 according to s_1 and d_0. For intermediate values of s_1 / d_0, coefficient C_5 is to be obtained by linear interpolation.

s_1 : Spacing of stiffeners or tripping brackets on web plate, in m.

d_0 : Spacing of stiffeners parallel to shell plate on web plate, in m.

CCS 4.7.2a For the primary supporting members with reduced end fixity, strength check is to be performed in accordance with CCS 4.1.2a.

Coefficient C_5 **Table 12**

s_1 / d_0	0.3 and less	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0 and over
C_5	60.0	40.0	26.8	20.0	16.4	14.4	13.0	12.3	11.1	10.2

Section 5 CARGO HATCH COVERS

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

P_S : Still water pressure, in kN/m^2, as defined in [4.1].

P_W : Wave pressure, in kN/m^2, as defined in [4.1].

P_C : Pressure acting on the hatch coaming, in kN/m^2, as defined in [6.2].

F_S, F_W : Coefficients taken equal to:

F_S = 0 and F_W = 0.9 for ballast water loads on hatch covers of the ballast hold.

F_S = 1.0 and F_W = 1.0 in other cases.

b_p : Effective breadth, in mm, of the plating attached to the stiffener, as defined in [3].

A_{shr} : Net shear sectional area, in cm2, of the stiffener or primary supporting member.

f_{bc} : Boundary coefficient for stiffeners and primary supporting members, taken equal to:

f_{bc} = 8, in the case of stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end.

f_{bc} = 12, in the case of stiffeners and primary supporting members clamped at both ends.

t_c : Total corrosion addition, in mm, as defined in [1.4].

σ_a,τ_a : Allowable stresses, in N/mm2, as defined in [1.5].

1 GENERAL

1.1 Application

1.1.1

The requirements in [1] to [8] apply to steel hatch covers in positions 1 and 2 on weather decks, as defined in Pt 1, Ch 1, Sec 4, [3.2].

1.2 Materials

1.2.1 Steel

The formulae for scantlings given in [5] are applicable to steel hatch covers.

Materials used for the construction of steel hatch covers are to comply with the applicable requirements of the Society.

CCS 1.2.1a Materials used for the construction of top plating, bottom plating and primary supporting members of steel hatch covers are to comply with the material grade requirements for class I as specified in Table 7 of 2.3 in Section 1, Chapter 3 of PART 9-1.

1.2.2 Other materials

The use of materials other than steel is to be considered by the Society on a case-by-case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

CCS 1.2.2a Where other materials are used, the corrosion additions of materials are to be determined in accordance with the submitted corrosion resistance information of materials. Such information is to include testing and/or historic data demonstrating that corrosion additions meet the design life of 25 years and is subject to the agreement of CCS.

1.3 Net scantlings

1.3.1

All scantlings referred to in this section are net, i.e. they do not include any margin for corrosion.

When calculating the stresses σ and τ in [5.3] and [5.4], the net scantlings are to be used.

The gross scantlings are obtained as specified in Pt 1, Ch 3, Sec 2.

The corrosion additions are given in [1.4].

1.4 Corrosion additions

1.4.1

The total corrosion addition for both sides to be considered for the plating and internal members of hatch covers is equal to the value specified in Table 1.

The corrosion addition for hatch coamings and coaming stays is defined according to Pt 1, Ch 3, Sec 3.

Corrosion addition t_c for hatch covers **Table 1**

Corrosion addition t_c, in mm, for both sides	
Plating and stiffeners of single skin hatch cover	2.0
Top and bottom plating of double skin hatch cover	2.0
Internal structures of double skin hatch cover	1.5

1.5 Allowable stresses

1.5.1

The allowable stresses σ_a, in N/mm^2, are to be obtained from Table 2.

Allowable stresses **Table 2**

Members of	Subjected to	σ_a, in N/mm^2
Weathertight hatch cover	External pressure, as defined in [4.1.2]	0.80 R_{eH}
Weathertight hatch cover	Other loads, as defined in [4.1.3] to [4.1.6]	0.90 R_{eH} for load combination: S+D 0.72R_{eH} for load combination: S

The allowable buckling utilisation factors are given in Table 3:

Allowable buckling utilisation factors **Table 3**

Structural component	Subject to	η_{all}, Allowable buckling utilisation factor
Plates and stiffeners Web of SM	External pressure, as defined in [4.1.2]	0.80 for load combination: S+D
	Other loads, as defined in [4.1.3] to [4.1.6]	0.90 for load combination: S+D 0.72 for load combination: S

2 ARRANGEMENTS

2.1 Hatch covers

2.1.1

The stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

2.1.2

The spacing of primary supporting members parallel to the direction of stiffeners is not to be greater than 1/3 of the span of primary supporting members.

2.1.3

The breadth of the primary supporting member face plate is not to be less than 40% of their depth for laterally unsupported spans greater than 3 m. Tripping brackets attached to the face plate may be considered as a lateral support for primary supporting members.
The face plate outstand is not to exceed 15 times the gross face plate thickness.

2.1.4

Efficient retaining arrangements are to be provided to prevent translation of the hatch cover under the action of the longitudinal and transverse forces exerted by cargoes on the cover, if any. These retaining arrangements are to be located in way of the hatch coaming side brackets.

2.1.5

The width of each bearing surface for hatch covers is to be at least 65 mm.

2.2 Hatch coamings

2.2.1

Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the

clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2.2.2
Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

2.2.3
Longitudinal coamings are to be vertically extended at least to the lower edge of deck beams or hatch side girders below deck are to be fitted in line with longitudinal coamings. Extended coaming plates are to be flanged or fitted with face bars or half-round bars at the level of lower edge of the deck beams. Figure 1 gives an example.

- Where they are not part of continuous deck girders, the lower edge of longitudinal coamings including below deck structure as an extension measure above are to extend for at least two frame spaces beyond the end of the hatch openings.
- Where they are part of continuous deck girders, their scantlings are to be as required in Pt 1, Ch6, Sec 6 and Pt 1, Ch 8, Sec 3.

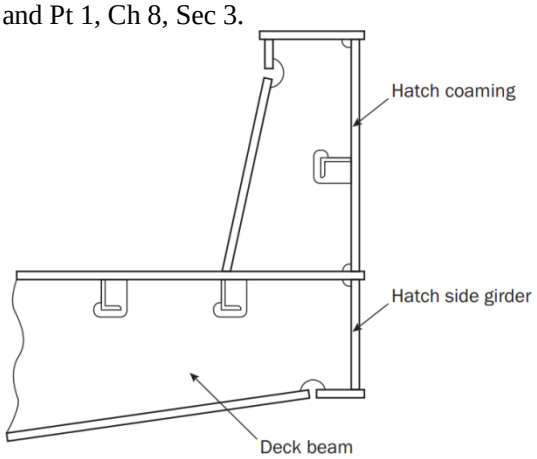


Figure 1 Example of extension to lower edge of deck beams of longitudinal coaming by fitting a hatch side girder

2.2.4
A web frame or a similar structure is to be provided below the deck in line with the transverse coaming. Transverse coamings are to extend below the deck and to be connected with the web frames.

3 WIDTH OF ATTACHED PLATING

3.1 Stiffeners

3.1.1
The width of the attached plating *bp*, in mm, to be considered for the check of stiffeners is to be taken as:

- Where the attached plating extends on both sides of the stiffener:
  $b_p = s$
- Where the attached plating extends on one side of the stiffener:
  $b_p = 0.5\ s$

4 LOAD MODEL

4.1 Lateral pressures and forces

4.1.1 General

The lateral pressures and forces to be considered as acting on hatch covers are given in [4.1.2] to [4.1.6]. When two or more panels are connected by hinges, each individual panel is to be considered separately.
In any case, the sea pressures defined in [4.1.2] are to be considered for hatch covers located on exposed decks.
Additionally, when the hatch cover is intended to carry uniform cargoes, special cargoes or

containers, the pressures and forces defined in [4.1.3] to [4.1.6] are to be considered independently from the sea pressures.

4.1.2 Sea pressures

The still water and wave lateral pressures are to be considered and are to be taken equal to:

- Still water pressure: $P_S = 0$.
- Wave pressure $P_W = P_{HC}$, as defined in Pt 1, Ch 4, Sec 5, [5.2].

4.1.3 Internal pressures due to ballast water

If applicable, the internal static and dynamic lateral pressures due to ballast water are to be considered and are defined in Pt 1, Ch 4, Sec 6, [1].

4.1.4 Pressures due to uniform cargoes

If applicable, the static and dynamic pressures due to uniform cargoes are to be considered and are defined in Pt 1, Ch 4, Sec 5, [5.3.1].

4.1.5 Pressures or forces due to special cargoes

In the case of carriage of special cargoes (e.g. pipes, etc) on the hatch covers which may temporarily retain water during navigation, the lateral pressures or forces to be applied are considered by the Society on a case- by-case basis.

CCS 4.1.5a In the case of carriage of special cargoes on the hatch covers which may temporarily retain water during navigation, lateral loads on the hatch covers shall be determined with the method specified in 4.1.4 taking into account the quality of the retained water.

4.1.6 Forces due to containers

In the case of carriage of containers on the hatch covers, the concentrated forces under the containers corners are to be determined in accordance with the applicable requirements of the Society.

CCS 4.1.6a In the case of carriage of containers on the hatch covers, the concentrated force P is to be determined by the following formula:

$P=P_S(1+a_Z)$

where:

P_S : *container stack weight, in kN;*

a_Z : *vertical acceleration, in* m/s^2*, see 3.2.4, Section 3, Chapter 4 of PART 9-1.*

4.1.7 Self weight

The effect of the hatch cover structure weight is to be included in the static loads but not in the dynamic loads.

4.2 Load point

4.2.1 Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located:

- Longitudinally, at the hatch cover mid-length.
- Transversely, on the longitudinal plane of symmetry of the ship.
- Vertically, at the top of the hatch cover.

4.2.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated at the level of the tight boundary of the cover:

- In way of the geometrical centre of gravity of the plate panel, for plating.
- At mid-span, for stiffeners and primary supporting members.

5 STRENGTH CHECK

5.1 General

5.1.1 Application

The strength check is applicable to rectangular hatch covers subjected to lateral pressure and/or concentrated loads, designed with primary supporting members arranged in one direction or as a grillage of longitudinal and transverse primary supporting members.
It is also applicable for hatch covers fitted with U-type stiffeners as shown in Figure 1. The stresses in all structural members are to be determined by a finite element analysis with the modelling requirements as described in [5.6.1].
It is to be checked that stresses of all structural members comply with the yield strength assessment requirement in [5.6.2], and the buckling strength assessment requirements as described in [5.2.3], [5.3.4], [5.4.6], [5.6.3] and [5.6.4].

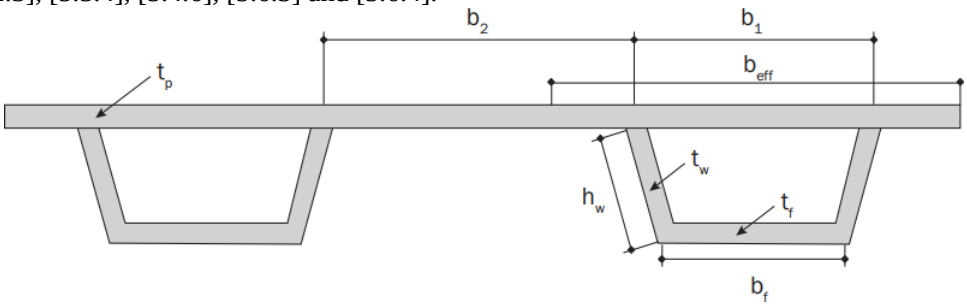


Figure 2 Example of hatch cover fitted with U type stiffener

CCS 5.1.1a When the hatch cover is arranged as a grillage of longitudinal and transverse primary supporting members, it is to be modeled as follows:

(1) The cover geometry is to be idealized as realistically as possible. Element size is to be appropriate to account for effective breadth. In way of force transfer points and cut-outs the mesh has to be refined where applicable. The ratio of element length to width is not to exceed 4.
The element height of webs of primary supporting members is not to exceed one third of the web height. Stiffeners and supporting plates against pressure loads have to be included in the idealization. Buckling stiffeners may be disregarded for the stress calculation.

(2) A right-hand coordinate system is to be used with:
the x-axis measured in the longitudinal direction, positive forward;
the y-axis measured in the transverse direction, positive to port from the centerline;
the z-axis measured in the vertical direction, positive upwards.

(3) Scantlings are to be based on net thicknesses for FE analysis.

(4) The extent of the FE model is to be determined as follows:

① For symmetry of the hatch cover girders, loads and boundary supporting conditions about only the x-axis or y-axis, it may be limited to a half of the hatch cover for check.

② For non-symmetry of hatch cover girders, loads and boundary supporting conditions about any of the axes, the whole hatch cover is to be taken for strength evaluation, see Figure CCS 5.1.1a (1).

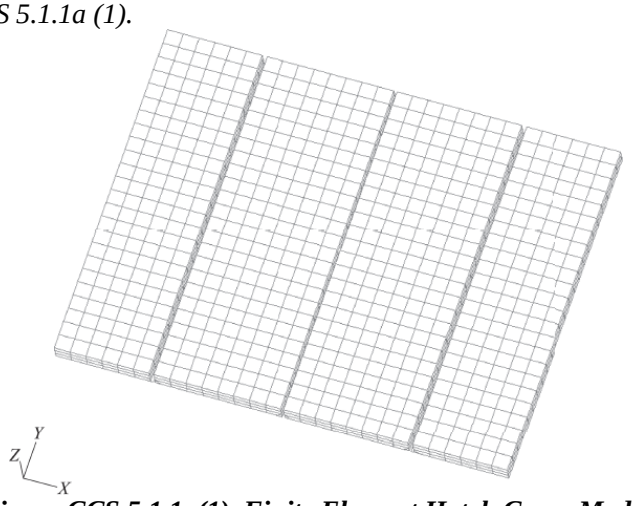


Figure CCS 5.1.1a(1) Finite Element Hatch Cover Model

(5) The model element is to comply with the following requirements:

① *All plating, including girders and stiffeners, is to be represented by the finite element model.*

② *All plating, such as top plates, bottom plates, brackets, and girder webs, face plates of primary supporting members is to modeled using plate elements, triangular elements are to be avoided where possible.*

③ *All stiffeners are to be modeled using beam, rod or plate elements.*

(6) The element mesh size is to be controlled as follows:

① *The mesh size is not to be greater than the spacing of stiffeners.*

② *The girders are to be represented by at least 3 elements in the depth.*

③ *Triangular and distorted quadrilateral elements with corner angles less than 60 degrees and greater than 120 degrees are to be avoided.*

(7) Boundary conditions are to be determined as follows:

① *For symmetry of the hatch cover girders and loads about the x-axis, the longitudinal displacement of nodes in the symmetric plane and the rotations about the y-and z-axes are to be taken as 0, respectively, i.e.* $\delta_x = \theta_y = \theta_z = 0$*, as shown in Figure CCS 5.1.1a(2).*

② *For symmetry of the hatch cover girders and loads about the y-axis, the transverse displacement of nodes in the symmetric plane and rotation about the x-and z-axes are to be taken as 0 respectively i.e.* $\delta_y = \theta_x = \theta_z = 0$*, as shown in Figure CCS 5.1.1a.*

③ *Boundary nodes in way of bearing pads on the hatch coamings are to be fixed against displacement in the z direction in general, i.e.* $\delta_y = 0$.

④ *Lifting stoppers are to be fixed against displacements in the direction determined by the stoppers.*

⑤ *Hinges in folding type hatch covers are to be represented as rigid links which tie together displacements in the z direction.*

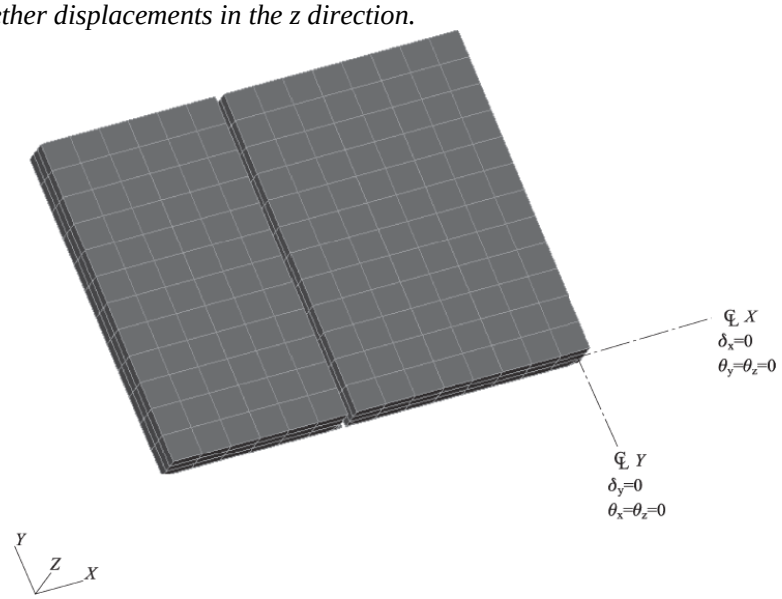


Figure CCS 5.1.1a(2) Boundary Conditions of Hatch Cover Model

5.1.2 Hatch covers supporting containers

The scantlings of hatch covers supporting containers are to comply with the applicable requirements of the Society.

CCS 5.1.2a The scantlings of hatch covers supporting containers are to comply with the requirements of 5 of this Section, taking into account the container loads in CCS 4.1.6a.

5.1.3 Hatch covers subjected to special cargoes

For hatch covers supporting special cargoes, stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and

their relative inertia. It is to be checked that stresses induced by special cargoes are in accordance with the criteria in [5.4.4].

5.2 Plating

5.2.1 Net thickness

The net thickness, in mm, of steel hatch cover top plating is not to be taken less than:

$$t = 0.0158 F_p b \sqrt{\frac{F_S P_S + F_W P_W}{0.95 R_{eH}}}$$

where:

F_p : Factor for combined membrane and bending response, equal to:

F_p = 1.5 in general.

$F_p = 1.9\ \sigma/\sigma_a$, for $\sigma \geqslant 0.8\sigma_a$ for the attached plating of primary supporting members.

σ : Normal stress, in N/mm^2, in the attached plating of primary supporting members, calculated according to [5.4.3] or determined through a grillage analysis or a finite element analysis.

5.2.2 Minimum net thickness

In addition to [5.2.1], the net thickness, in mm, of the plating forming the top of the hatch cover is not to be taken less than the greater of the following values:

$t = b/100$

$t = 6$

5.2.3 Buckling strength

The buckling strength of the hatch cover plating subjected to loading conditions as defined in [4.1] is to comply with the requirements in [5.6.3].

For hatch covers fitted with U type stiffeners, it is to comply with the requirements in [5.6.4].

5.3 Stiffeners

5.3.1

Stiffeners are to comply with the applicable slenderness and proportion requirements given in Pt 1, Ch 8, Sec 2, [3.1.1] and [3.1.2].

5.3.2 Minimum net thickness of web

The net thickness, in mm, of the stiffener web is to be taken not less than 4 mm.

5.3.3 Net section modulus and net shear sectional area

The net section modulus Z, in cm^3, and the net shear sectional area A_{shr}, in cm^2, of a stiffener subject to lateral pressure are to be taken not less than given by the following formulae:

$$Z = \frac{(F_S P_S + F_W P_W) s l_s^2}{f_{bc} \sigma_a}$$

$$A_{shr} = \frac{5(F_S P_S + F_W P_W) s l_s}{\tau_a} 10^{-3}$$

where:

l_s : Stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all stiffener spans, the stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.

5.3.4 Buckling strength

The buckling strength of the hatch cover stiffeners subjected to loading conditions as defined in [4.1] is to comply with the requirements in [5.6.3].

The buckling strength of the hatch cover fitted with U type stiffeners subjected to loading conditions as defined in [4.1] is to comply with the requirements in [5.6.4].

5.4 Primary supporting members

5.4.1 Application

Primary supporting members are to be checked with the requirements in [5.4.2] to [5.4.5].

5.4.2 Minimum net thickness of web

The web net thickness of primary supporting members, in mm, is not to be less than 6 mm.

5.4.3 Deflection limit

The net moment of inertia of a primary supporting member, when loaded by sea pressure, excluding the self- weight of the structure, is to be such that the deflection does not exceed μl_{max}.
where:

μ : Coefficient taken equal to:
μ= 0.0056 for weathertight hatch covers.

l_{max} : Greatest span, in m, of primary supporting members.

5.4.4 Buckling strength of the web panels of the primary supporting members

The web of primary supporting members subject to loading conditions as defined in [4.1] is to comply with the requirements in [5.6.3].

5.4.5 Slenderness criteria

For buckling stiffeners on webs of primary supporting members, the ratio h_w/t_w is to comply with the following formula:

$$\frac{h_w}{t_w} \le 15\sqrt{\frac{235}{R_{eH}}}$$

5.5 DELETED

5.5.1

DELETED

Figure 3 DELETED

5.6 Finite element model and buckling assessment

5.6.1 Finite element model

For the strength assessments of hatch covers subjected to loading conditions as defined in [4.1], by means of FE analysis, the hatch cover geometry shall be idealized as realistically as possible. In no case shall the element width be larger than stiffener spacing. In way of force transfer points and cutouts the mesh is to be refined where applicable. The ratio of element length to width shall not exceed 3.

The element size along the height of webs of primary supporting member is not to exceed one-third of the web height. Stiffeners, which support plates subjected to lateral pressure loads, are to be included in the FE model idealization. Stiffeners may be modelled by using beam elements, or shell/plate elements. Buckling stiffeners may be disregarded for the stress calculation.

Hatch covers fitted with U-type stiffeners as shown in Figure 1 are to be assessed by means of FE analysis. The geometry of the U-type stiffeners is to be accurately modelled using shell/plate elements. Nodal points are to be properly placed on the intersections between the webs of a U-type stiffener and the hatch cover plate, and between the webs and flange of the U-type stiffener.

5.6.2 Yield strength assessment

All hatch cover structural members are to comply with the following formula:

$\sigma_{vm} \le \sigma_a$ for shell elements in general.

$\sigma_{axial} \le \sigma_a$ for rod or beam elements in general.

where,

σ_a : Allowable stress as defined in [1.5.1], Table 2.

σ_{vm} :Von Mises stress, in N/mm², to be taken as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2}$$

σ_x : Normal stress, in N/mm^2, in *x*-direction.
σ_y : Normal stress, in N/mm^2, in *y*-direction.
σ_{xy} : Shear stress, in N/mm^2, in the *x*-*y* plane.
σ_{axial}:Axial stress in rod or beam element, in N/mm^2.
Indices *x* and *y* are coordinates of a two-dimensional Cartesian system in the plane of the considered structural element.
In case of FEM calculations using shell (or plate) elements, the stresses are to be read from the centre of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element centre may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or, the stress at the element edges shall not exceed the allowable stress. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

5.6.3 Buckling strength assessment
The plate panel of a hatch cover structure is to be modelled as stiffened panel (SP) or unstiffened panel (UP). Assessment Method A (-A) and Method B (-B) as defined in Pt 1, Ch 8, Sec 1, [3] are to be used in accordance with Table 4, Figure 3 and Figure 4. For a web panel with opening, the procedure for opening should be used for its buckling assessment.
Wherever necessary, the following corresponding buckling requirements for direct strength anaslysis in Pt 1, Ch 8, Sec 4 can be referred to:

a) Average thickness of plate panel, in Pt 1, Ch 8, Sec 4, [2.1.2].
b) Irregular plate panel, in Pt 1, Ch 8, Sec 4, [2.3].
c) Reference stress, in Pt 1, Ch 8, Sec 4, [2.4].
d) Lateral pressure, in Pt 1, Ch 8, Sec 4, [2.5].
e) Buckling criteria, in Pt 1, Ch 8, Sec 4, [2.6], but using allowable buckling utilisation factors as defined in Pt 2, Ch 1, Sec 5, Table 3.

Structural members and assessment methods Table 4

Structural elements	Assessment method[1,2]	Normal panel definition
Hatch cover top/bottom plating structures, see Figure 3		
Hatch cover top/bottom plating	SP-A	Length: between transverse girders Width: between longitudinal girders
Irregularly stiffened panels	UP-B	Plate between local stiffeners/PSM
Hatch cover webs of primary supporting members, see Figure 4		
Web of transverse/longitudinal girder (single skin type)	UP-B	Plate between local stiffeners/face plate/PSM
Web of transverse/longitudinal girder (double skin type)	SP-B[3]	Length: between PSM Width: full web depth
Web panel with opening	Procedure for opening	Plate between local stiffeners/face plate/PSM
Irregularly stiffened panels	UP-B	Plate between local stiffeners/face plate/PSM

(1) SP and UP stand for stiffened and unstiffened panel respectively.
(2) A and B stand for Method A and Method B respectively.
(3) In case that the buckling carlings/brackets are irregularly arranged in the web of transverse/longitudinal girder, UP-B method may be used.

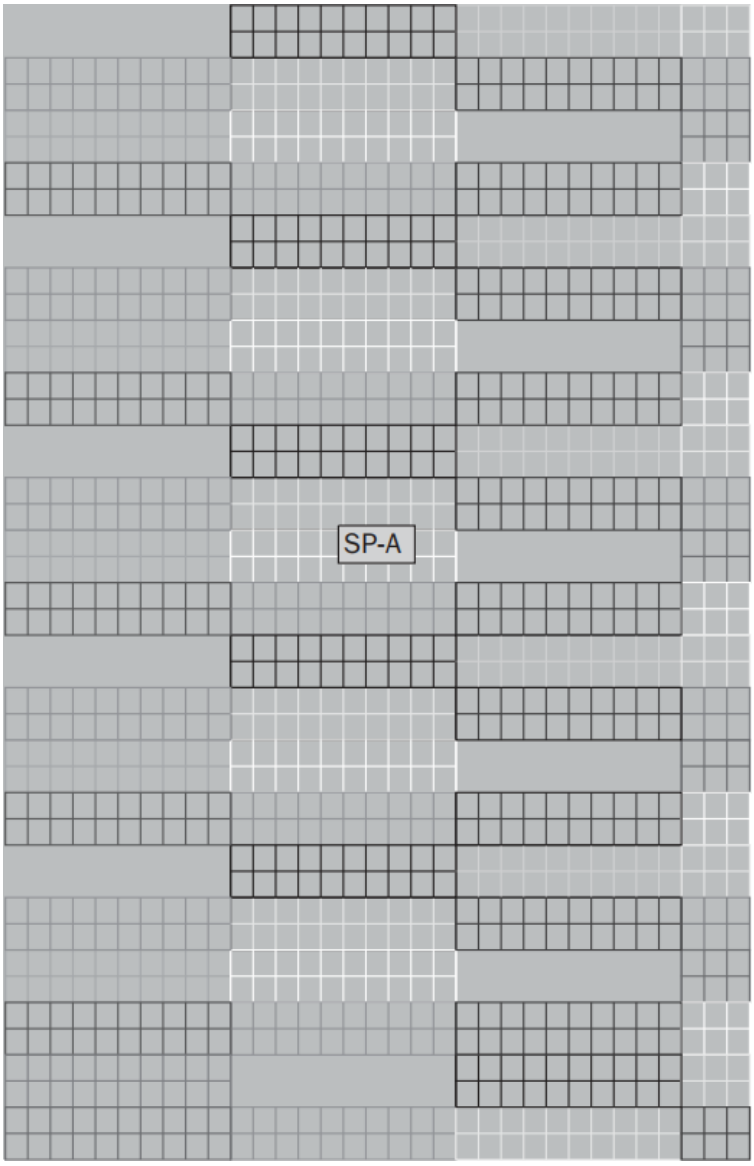


Figure 4 Hatch cover top/bottom plating structures

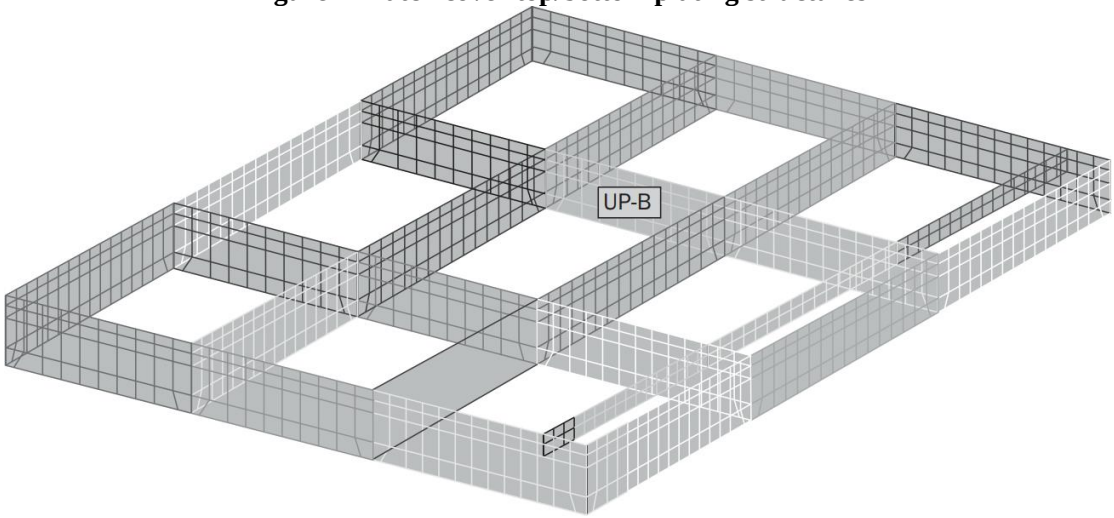


Figure 5 Hatch cover webs of primary supporting members

5.6.4 Buckling assessment of stiffened panels with U-type stiffeners

For hatch covers fitted with U-type stiffeners, local plate buckling is to be checked for each of the plate panels EPP b_1, b_2, b_f and h_w (see Figure 2) separately as follows:

- The attached plate panels EPP b_1 and b_2 are to be assessed using SP-A model, where in the calculation of buckling factors K_x as defined in Pt 1, Ch 8, Sec 5, Table 3, the correction factor F_{long} for U-type stiffeners as defined in Pt 1, Ch 8, Sec 5, Table 2 is to be used; and in the calculation of K_y as defined in Pt 1, Ch 8, Sec 5, Table 3, the F_{tran} for U-type stiffeners as defined in Pt 1, Ch 8, Sec 5, [2.2.5] is to be used.
- The face plate and web plate panels EPP b_f and h_w are to be assessed using UP-B model with F_{long}=1 and F_{tran}=1.

The overall stiffened panel capacity and ultimate capacity of stiffeners of the hatch cover fitted with U-type stiffeners are to be checked with warping stress σ_w = 0, and with bending moment of inertia including effective width of attached plating being calculated based on the following assumptions:

- The two web panels of a U-type stiffener are to be taken as perpendicular to the attached plate with thickness equal to t_w and height equal to the distance between the attached plate and the face plate of the stiffener.
- Effective width of the attached plating, b_{eff}, taken as the sum of the b_{eff} calculated for the EPP b_1 and b_2 respectively according to SP-A model.
- Effective width of the attached plating of a stiffener without the shear lag effect, b_{eff1}, taken as the sum of the b_{eff1} calculated for the EPP b_1 and b_2 respectively.

6 HATCH COAMINGS

6.1 Stiffening

6.1.1

The stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

6.1.2

Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.

6.1.3

Where the height of the coaming exceeds 900 mm, additional strengthening may be required. However, reductions may be granted for transverse coamings in protected areas.

6.1.4

When two hatches are close to each other, under deck stiffeners are to be fitted to connect the longitudinal coamings in order to maintaining the continuity of their strength.

Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length.

In some cases, the Society may require the continuity of coamings to be maintained above the deck.

6.1.5

Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

6.2 Load model

6.2.1

The wave lateral pressure, P_C in kN/m^2, to be considered as acting on the hatch coamings is defined in [6.2.2] and [6.2.3].

6.2.2

The wave lateral pressure, P_C in kN/m^2, on the No. 1 forward transverse hatch coaming is to be taken equal to:

- P_C = 220, when a forecastle is fitted in accordance with Ch 1, Sec 1, [1].
- P_C = 290, in the other cases.

6.2.3

The wave lateral pressure, P_C in kN/ m^2, on the hatch coamings other than the No. 1 forward transverse hatch coaming is to be taken equal to:
$P_C = 220$

6.2.4
For cargo holds intended for the carriage of ballast water, the liquid internal pressures applied on hatch coaming is also to be determined according to Pt 1, Ch 4, Sec 6.

6.3 Scantlings
6.3.1 Plating
The net thickness, in mm, of the hatch coaming plate is not to be taken less than the greater value given by the following formulae:

$$t = 0.016b\sqrt{\frac{p_c}{0.95R_{eH}}}$$

$t = 9.5$

6.3.2 Stiffeners
The net section modulus, Z, in cm^3, of longitudinal or transverse stiffeners fitted on hatch coamings is not to be taken less than:

$$Z = 1.21\frac{P_c s l^2}{f_{bc} c_p R_{eH}}$$

where:
f_{bc} : Coefficient taken equal to:
f_{bc} = 16 in general.
f_{bc} = 12 for the end span of stiffeners sniped at the coaming corners.
c_p : Ratio of the plastic section modulus to the elastic section modulus of the stiffeners with an attached plate breadth, in mm, equal to 40 t, where t is the plate net thickness.
c_p = 1.16 in the absence of more precise evaluation.

6.3.3 Coaming stays
At the connection with deck, the net section modulus Z, in cm^3, and the net thickness t_w, in mm, of the coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (examples shown in Figure 6 and Figure 7) are to be taken not less than:

$$Z = \frac{s_c P_c H_c^2}{1.9R_{eH}}$$

$$t_w = \frac{s_c P_c H_c}{0.5hR_{eH}}$$

where:
H_C : Stay height, in m.
s_C : Stay spacing, in mm.
h : Stay depth, in mm, at the connection with deck.

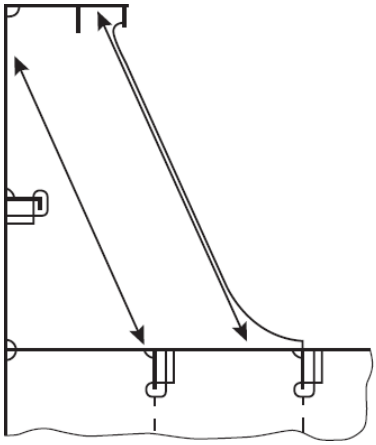


Figure 6 Coaming stay (example 1)

For calculating of offered section modulus of coaming stays, the face plate area may be taken into account only when it is welded with full penetration welds to the deck plating and provided with adequate under deck structure supporting the coaming stay in the deck structure.

For other designs of coaming stays, such as those shown in Figure 8 and Figure 9, the stress levels determined through a grillage analysis or finite element analysis, as the case may be, apply and are to be checked at the highest stressed locations. The stress levels are to comply with the following formulae:

$\sigma \leqslant 0.95\, R_{eH}$

$\tau \leqslant 0.5\, R_{eH}$

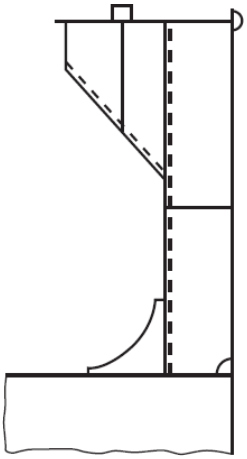


Figure 7 Coaming stay (example 2)

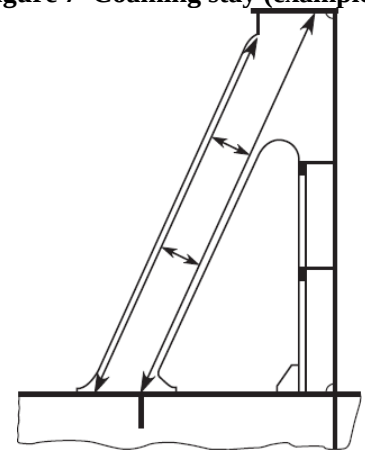


Figure 8 Coaming stay (example 3)

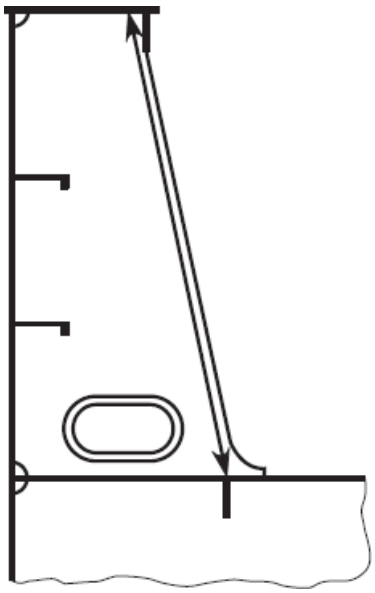


Figure 9 Coaming stay (example 4)

6.3.4 Local details

The design of local details is to comply with the requirements in this section ensuring adequate structural continuity from the hatch covers into the supporting deck structure.

Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

The normal stress σ and the shear stress γ, in N/mm^2, induced in the under deck structures by the loads transmitted by stays are to comply with the following formulae:

$\sigma \leqslant 0.95\ R_{eH}$

$\gamma \leqslant 0.5\ R_{eH}$

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the requirements of the Society.

Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld leg length is not to be less than 0.62 t_w, where t_w is the gross thickness of the stay web.

Toes of stay webs are to be connected to the deck plating with partial penetration double bevel welds extending over a distance not less than 15% of the stay width.

CCS 6.3.4a Unless otherwise stated in this Section, weld connections and materials are to be dimensioned and selected in accordance with the applicable requirements in Table 2.5.2 of Section 3, Chapter 12 and Section 1, Chapter 3 of PART 9-1.

7 WEATHERTIGHTNESS, CLOSING ARRANGEMENT, SECURING DEVICES AND STOPPERS

7.1 Weathertightness

7.1.1

Where the hatchway is exposed, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

7.1.2

In general, a minimum of two securing devices or equivalent is to be provided on each side of the hatch cover.

7.2 Gaskets

7.2.1

The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship's structure.

7.2.2
The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.
Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

7.2.3
The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship's structure or between hatch cover elements.
If necessary, suitable devices are to be fitted to limit such movements.

7.2.4
The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.
The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship's structure.
The gasket is to be effectively secured to the hatch cover.

7.2.5
Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

7.2.6
Metallic contact is required to ensure earthing connection between the hatch cover and the hull structures.

7.3 Closing arrangement, securing devices and stoppers

7.3.1 General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced along the coamings and between cover elements.
Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height according to [2.1.2] are to be considered by the Society on a case-by- case basis.

CCS 7.3.1a The closing arrangements, securing devices and stoppers of hatch cover are to comply with the requirements of this Section taking into account the effectiveness of arrangement, spacing, structure, area of securing devices and moment of inertia for edges under situation of special design.

7.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.
Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices.
At cross-joints of multi-panel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.
The location of stoppers is to be compatible with the relative movements between hatch covers and the ship's structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

7.3.3 Spacing

The spacing of the securing arrangements is not to be greater than 6 m.

7.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.
Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.
Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

7.3.5 Area of securing devices
The gross cross area of each securing device is not to be less than the value obtained, in cm^2, from the following formula:

$$A = 1.4 S_S \left(\frac{235}{R_{eH}} \right)^{\alpha}$$

where:
S_S : Spacing, in m, of securing devices.
α : Coefficient taken equal to:
α = 0.75 for R_{eH} > 235 N/mm^2.
α = 1.0 for $R_{eH} \leqslant$ 235 N/mm^2.
In the above calculations, R_{eH} may not be taken greater than 0.7 R_m.
Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area *A* is to be increased in direct proportion. The packing line pressure is to be specified.
In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area *A* of the above securing arrangements is to be determined through direct calculations.

CCS 7.3.5a The permissible stress criteria for securing devices of hatch cover is to be:
(1) For securing devices such as rods or bolts, the tensile stress is not to exceed 120/k, N/mm^2.
(2) *For other types of securing devices, the permissible stress is to be as follows:*
normal stress: σ= 120 / k N/mm^2
equivalent stress: σ_e =150 / k N/mm^2
shear stress :τ=80 / k N/mm^2.

7.3.6 Inertia of edges elements
The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.
The moment of inertia of edge elements is not to be less than the value obtained, in cm4, from the following formula:
$I=6p_L S_S^4$
where:
P_L: Packing line pressure, in N/mm, to be taken not less than 5.
S_S: Spacing, in m, of securing devices.

7.3.7 Diameter of rods or bolts
Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m2 in area.

7.3.8 Stoppers
Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.
With the exclusion of No. 1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal

forces acting on the forward end arising from a pressure of 230 kN/m^2. This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted in accordance with Ch 1, Sec 1, [1].

The equivalent stress in stoppers, their supporting structures and calculated in the throat of the stopper welds is to be equal to or less than the allowable value, equal to 0.8 R_{eH}.

7.4 Cleats

7.4.1

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

7.4.2

Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

8 DRAINAGE

8.1 Arrangement

8.1.1

Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming.

8.1.2

Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

8.1.3

Cross-joints of multi-panel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

8.1.4

If a continuous outer steel contact is arranged between the cover and the ship’s structure, drainage from the space between the steel contact and the gasket is also to be provided.

Section 6 ADDITIONAL CLASS NOTATION GRAB

SYMBOLS

M_{GR} *:* Mass of unladen grab, in t.

1 GENERAL

1.1 Application

1.1.1

The additional class notation GRAB [X] is assigned, in accordance with Pt 1, Ch 1, Sec 1, [3.2.2], to ships with holds designed for loading/unloading by grabs having a maximum mass of unladen grab, in tons up to [X] tons, in compliance with the requirements of this section.

1.1.2

It is to be noted that this additional class notation does not negate the use of heavier grabs, but the owner and operators are to be made aware of the increased risk of local damage and possible early renewal of inner bottom plating if heavier grabs are used regularly or occasionally to discharge cargo.

2 SCANTLINGS

2.1 Plating

2.1.1 General

The net thickness of plating of inner bottom and vertical sloped cargo hold; excluding bilge wells, is to be taken as the greater of the following values:

- t, as obtained according to requirements in Pt 1, Ch 6 and Pt 1, Ch 7.
- t_{GR}, as defined in [2.1.2] and [2.1.3].

2.1.2 Inner bottom plating

The net thickness t_{GR}, in mm, of the inner bottom plating is to be obtained from the following formula:

$$t_{GR} = 0.62\sqrt{bk}\left(\frac{M_{GR}}{20}\right)^{0.25}$$

2.1.3 Vertical and sloped cargo hold boundaries

The net thickness t_{GR}, in mm, as defined in this sub-section apply to the following structural elements.

- Hopper tank sloped plating.
- Transverse lower stool plating.
- Transverse plane bulkhead plating.
- Face plates of transverse corrugated bulkheads without lower stool.
- Inner hull

Up to a height of 3.0 m above, the lowest point of the inner bottom is to be obtained from the following formula:

$$t_{GR} = 0.55\sqrt{bk}\left(\frac{M_{GR}}{20}\right)^{0.25}$$

Chapter 2 OIL TANKERS

SECTION 1 GENERAL ARRANGEMENT DESIGN

1 GENERAL

1.1 General

1.1.1

This section covers the general structural arrangement requirements for oil tankers, which are based on national and international regulations.

2 SEPARATION OF CARGO TANKS

2.1 General

2.1.1

The designer's attention is to be drawn on the arrangement of the cargo pump room, cargo tanks, slop tanks and cofferdams, main cargo control stations, control stations, accommodation and service spaces as well as on the need to separate the cargo tanks from the machinery space.

3 DOUBLE HULL ARRANGEMENT

3.1 General

3.1.1

All oil tankers are to be provided with double bottom tanks and spaces, and double side tanks and spaces, in accordance with Pt 1, Ch 2, Sec 3. The double bottom and double side tanks and spaces, protect the cargo tanks or spaces, and are not to be used for the carriage of oil cargoes.

3.1.2

Cargo tanks are to be of a size and arrangement that hypothetical oil outflow from side and bottom damage, anywhere in the length of the ship, is limited.

4 ACCESS ARRANGEMENTS

4.1 Special requirements for oil tankers

4.1.1

Where a duct keel or pipe tunnel is fitted, provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. The duct keel or pipe tunnel is not to pass into machinery spaces. The aft access may lead from the pump room to the duct keel. Where an aft access is provided from the pump room to the duct keel, the access opening from the pump room to the duct keel is to be provided with an oil-tight cover plate or a watertight door.

Mechanical ventilation is to be provided and such spaces are to be sufficiently ventilated prior to entry. A notice board is to be fitted at each entrance to the pipe tunnel stating that before any attempt is made to enter, the ventilating fan must have been in operation for a sufficient period. In addition, the atmosphere in the tunnel is to be sampled by a gas monitor, and where an inert gas system is fitted in cargo tanks, an oxygen monitor is to be provided.

4.1.2

Where a watertight door is fitted in the pump room for access to the duct keel, the scantlings of the watertight door are to comply with the requirements of the individual Society and the following additional requirements:

a) The watertight door is to be capable of being manually closed from outside the main pump room entrance, in addition to bridge operation. A means of indicating whether the door is open or closed is to be provided locally and on the bridge.

b) A notice is to be affixed at each operating position to the effect that the watertight door is to be kept closed during normal operations of the ship, except when access to the pipe tunnel is required.

CCS 4.1.2a The strength of watertight doors is to be equivalent to that of the surrounding structure and to comply with the recognized standard.

4.1.3

Special consideration is to be given to any proposals to fit permanent repair/maintenance access openings with oil-tight covers in cargo tank bulkheads. Attention is drawn to the relevant national regulations concerning load line and oil outflow aspects of such arrangements.

SECTION 2 STRUCTURAL DESIGN PRINCIPLES

1 CORROSION PROTECTION

1.1 General

1.1.1 Cathodic protection systems in cargo tanks

Cathodic protection systems, if fitted in cargo tanks, are to comply with [1.2].

1.1.2 Paint containing aluminium

Paint containing aluminium, when used in cargo tanks, is to comply with [1.3].

1.2 Internal cathodic protection systems

1.2.1

When a cathodic protection system is to be fitted to steel structures in tanks used for liquid cargo with flash point below 60℃, a plan of the fitting arrangement is to be submitted for approval. The arrangements are to be considered for safety against fire and explosion. This approval also applies to adjacent tanks.

1.2.2

Permanent magnesium or magnesium alloy anodes in tanks are not acceptable, except in tanks solely intended for water ballast that are not adjacent to cargo tanks.

Impressed current systems are not to be used in cargo tanks due to the development of chlorine and hydrogen that can result in an explosion.

Aluminium anodes are accepted, however, in tanks with liquid cargo with flash point below 60℃ and in adjacent ballast tanks, aluminium anodes are to be located so a kinetic energy of not more than 275 J is developed in the event of their loosening and becoming detached.

1.2.3

Aluminium anodes are to be located in such a way that they are protected from falling objects. They are not to be located under tank hatches or Butterworth openings unless protected by adjacent structure.

1.2.4

Tanks, in which anodes are installed, are to have sufficient holes for the circulation of air to prevent gas from collecting in pockets.

1.3 Paint containing aluminium

1.3.1

The use of aluminium coatings containing greater than 10% aluminium by weight in the dry film is prohibited in cargo tanks, cargo tank deck area, pump rooms, cofferdams or any other area where cargo vapour may accumulate

1.3.2

Aluminised pipes may be permitted in ballast tanks, in inerted cargo tanks and, provided the pipes are protected from accidental impact, in hazardous areas on open deck.

SECTION 3 HULL LOCAL SCANTLING

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

S : Primary supporting member spacing as defined in Pt 1, Ch 3, Sec 7, [1.2.2], in m.

$C_{t\text{-}pr}$: Permissible shear stress coefficient for primary supporting members taken equal to:

$C_{t\text{-}pr}$ = 0.70 for AC-S.

$C_{t\text{-}pr}$ = 0.85 for AC-SD.

$C_{s\text{-}pr}$: Permissible bending stress coefficient for primary supporting members taken equal to:

$C_{s\text{-}pr}$ = 0.70 for AC-S.

$C_{s\text{-}pr}$ = 0.85 for AC-SD.

s_{cg} : Half pitch length of corrugation, in mm. See Figure 4.

l_{cg} : Length of corrugation, in m, which is defined as the distance between the lower stool and the upper stool. Where no lower or upper stool is fitted, l_{cg} is to be measured to lower or upper end as shown in Figure 4.

1 PRIMARY SUPPORTING MEMBERS IN CARGO HOLD REGION

1.1 General

1.1.1

The following requirements relate to the determination of scantlings of the primary supporting members within 0.4 L amidships and those outside 0.4 L amidships provided that the geometry and fixation of primary supporting member is similar with those amidships.

1.1.2

The section modulus and shear area criteria for primary supporting members contained in this sub-section apply to structural configurations shown in Pt 1, Ch 1, Sec 1, Figure 3 and are applicable to the following structural elements:

a) Floors and girders within the double bottom,
b) Deck transverses,
c) Side transverses within double side structure,
d) Vertical web frames on longitudinal bulkheads with or without cross ties,
e) Horizontal stringers on transverse bulkheads, except those fitted with buttresses or other intermediate supports,
f) Cross ties in wing cargo and centre cargo tanks.

1.1.3

Floors, horizontal stringers, side transverses and vertical webs adjacent to transverse bulkheads which get additional supports by horizontal stringers or buttresses are excluded from the application of this section.

1.1.4

Webs of the primary supporting members are to be stiffened in accordance with Pt 1, Ch 8, Sec 2, [4].

1.1.5

Webs of the primary supporting members are to have a depth of not less than given by the requirements of [1.5.1], [1.7.1] and [1.8.1], as applicable.

1.1.6

In any case, primary supporting members that have open slots for stiffeners are to have a depth not less than 2.5 times the depth of the slots if slots are not closed.

1.1.7

Where it is impracticable to fit a primary supporting member with the required web depth, then it is permissible to fit a member with reduced depth provided that the fitted member has equivalent moment of inertia or deflection to the required member. The required equivalent moment of

inertia is to be based on an equivalent section given by the effective width of plating at mid span with required plate thickness, web of required depth and thickness and face plate of sufficient width and thickness to satisfy the required mild steel section modulus.
The equivalent moment of inertia may be also demonstrated by an equivalent member having the same deflection as the required member.
All other rule requirements, such as minimum thicknesses, slenderness ratio, section modulus and shear area, are to be satisfied for the member of reduced depth.

1.2 Design load sets

1.2.1

The design load sets for the evaluation of primary supporting members are given in Table 1.

Design load sets for primary supporting members **Table 1**

Item	Design load set (1) (5) (6)	Load component	Draught	Design load	Loading condition
Double bottom floors and girders (3)	SEA-1	P_{ex}	$0.9T_{sc}$ (2)	S+D	Sea pressure only
	SEA-2	P_{ex}	T_{sc}	S	
	OT-4	$P_{in} - P_{ex}$	$0.6T_{sc}$	S+D	Net pressure difference between cargo pressure and sea pressure
	OT-5	$P_{in} - P_{ex}$	(4)	S	
Side transverses (3)	SEA-1	P_{ex}	$0.9T_{sc}$	S+D	Sea pressure only
	SEA-2	P_{ex}	T_{sc}	S	
	OT-1	P_{in}	T_{sc}	S+D	Cargo pressure only
	OT-2	P_{in}	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Deck transverses	SEA-1	P_{ex}	T_{sc}	S+D	Green sea pressure only or other loads on deck
	OT-1	P_{in}	T_{sc}	S+D	Cargo pressure only
	OT-2	P_{in}	$0.6\ T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Vertical web frames on longitudinal bulkheads	OT-1	P_{in}	T_{sc}	S+D	Pressure from one side only. Full cargo tank with adjacent cargo tank empty
	OT-2	P_{in}	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Horizontal stringers on transverse bulkhead	OT-1	P_{in}	T_{sc}	S+D	Pressure from one side only. Full cargo tank with adjacent forward or aft cargo tank empty.
	OT-2	P_{in}	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Cross ties in centre tanks	OT-1	$\frac{P_{in-pt}+P_{in-stb}}{2}$	T_{SC}	S+D	Full wing cargo tanks, centre tank empty.
	OT-2	$\frac{P_{in-pt}+P_{in-stb}}{2}$	$0.6T_{sc}$	S+D	
	OT-3	P_{in}	-	S	
Cross ties in wing tanks	OT-6	$\frac{P_{in}+P_{ex}}{2}$	T_{sc}	S+D	Full centre tank, wing cargo tanks

Item	Design load set (1) (5) (6)	Load component	Draught	Design load	Loading condition
	OT-7	$\frac{P_{in}+P_{ex}}{2}$	$0.6T_{sc}$	S+D	empty.
	OT-8	$\frac{P_{in}+P_{ex}}{2}$	T_{sc}	S	

where:
$P_{in\text{-}pt}$: Design pressure from port side wing cargo tank, in kN/m^2.
$P_{in\text{-}stb}$: Design pressure from starboard side wing cargo tank, in kN/m^2.
(1) The static and dynamic load components are to be determined in accordance with Pt 1, Ch 4, Sec 7, Table 1.
(2) If the loading condition where the combination of an empty cargo tank and a mean ship's draught greater than 0.9 T_{sc} is included in ship's loading manual, the maximum corresponding draught is to be considered.
(3) Draughts specified for bottom floors, girders and side transverses are based on operational limits specified in Pt 1, Ch 4, Sec 8, [2] and Pt 1, Ch 4, Sec 8, [3]. Where the optional loading conditions exceed the minimum Rule required loading conditions, the draughts will be subject to special consideration.

CCS (3) Where the optional loading conditions exceed the minimum Rule required loading conditions, the most unfavorable draught between the actual draught and the Rule required draught is to be taken if the minimum Rule required draught is exceeded.

(4) For tankers with two oil-tight longitudinal bulkheads, the draught is to be taken as 0.25 T_{sc}. For tankers with a centreline bulkhead, the draught is to be taken as 0.33 T_{sc}.
(5) When the ship's configuration cannot be described by the structural members or structural configurations identified above, then the applicable Design Load Sets to determine the scantling requirements of primary supporting member are to be selected so as to specify all applicable cases from the following:
- A full tank on one side of the member with the tank or space on the other side empty.
- A full tank on one side of the member with the external pressure minimised.
- External pressure maximised with the adjacent tank or space empty.

The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the net pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected.
(6) For a void or dry space, the pressure component from the void side is to be ignored.

1.3 Floors in double bottom

1.3.1 Structural arrangement

Plate floors are to be arranged in way of transverse bulkheads and bulkhead stools.

1.3.2 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of the floors at any position in the floor is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:
Q : Design shear force, in kN.

$$Q = f_{shr}\, PSl_{shr}$$

f_{shr} :Shear force distribution factor:

$$f_{shr} = f_{shr-i}(1-\frac{2y_i}{l_{shr}}) \text{ but not to be taken as less than 0.2}$$

$f_{shr\text{-}i}$: Shear force distribution factor at the end of the span, l_{shr}, as given in Table 2.
l_{shr} : Effective shear span, of the double bottom floor, in m, as shown in Figure 2. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in Pt 1, Ch3, Sec 7, [1.1.7]. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in Figure 2.
y_i : Distance from the considered cross section of the floor to the nearest end of the effective shear span, l_{shr} in m.
P : Design pressure given in Table 1 for the design load set being considered, calculated at mid point of effective shear span, l_{shr} of a floor located midway between transverse bulkheads or

transverse bulkhead and wash bulkhead, where fitted, in kN/m^2.

Shear force distribution factors of floors **Table 2**

Structural configuration	Centre tank (f_{shr3} in Figure 1)	Wing tank	
		At inboard end (f_{shr2} in Figure 1)	At hopper knuckle end (f_{shr1} in Figure 1)
Ships with centreline longitudinal bulkhead	-	0.40	0.60
Ships with two longitudinal bulkheads	0.5	0.50	0.65

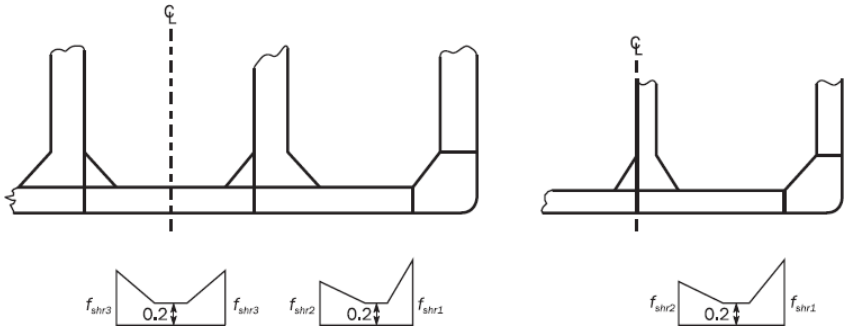
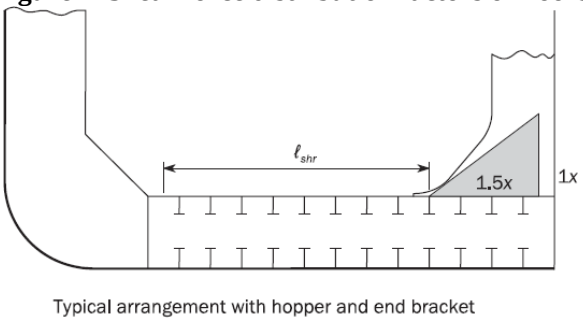
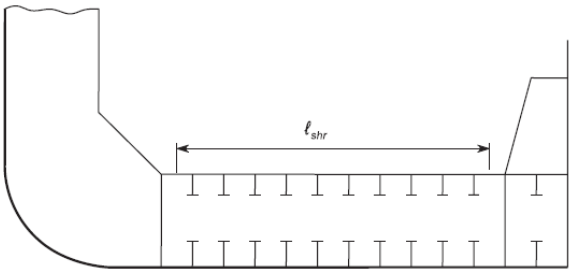


Figure 1 Shear force distribution factors of floors



Typical arrangement with hopper and end bracket



Typical arrangement with hopper and stool

Figure 2 Effective shear span of floors

1.4 Girders in double bottom

1.4.1 Structural arrangement

Continuous double bottom girders are to be arranged at the centreline or duct keel, at the hopper side and in way of longitudinal bulkheads and bulkhead stools.

1.4.2 Net shear area of centre girders

For double bottom centre girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr\text{-}n50}$ in cm^2, of the double bottom centre girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

Q : Design shear force, in kN, taken as:

$$Q = 0.21 n_1 n_2 P l^2_{shr}$$

l_{shr} : Effective shear span as defined in [1.3.2].

P : Design pressure, in kN/m^2, as defined in [1.3.2].

n_1 : Coefficient taken as:

$$n_1 = 0.00935\left(\frac{l_{shr}}{S}\right)^2 - 0.163\left(\frac{l_{shr}}{S}\right) + 1.289$$

n_2 : Coefficient taken as:

$$n_2 = 1.3 - \left(\frac{S}{12}\right)$$

S : Double bottom floor spacing, in m, as defined in Pt 1 Ch 3 Sec 7 [1.2.2].

1.4.3 Net shear area of side girders

For double bottom side girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr-n50}$ in cm^2, of the double bottom side girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

Q : Design shear force, in kN.

$$Q = 0.14 n_3 n_4 P l^2_{shr}$$

n_3 : Coefficient taken as:

$$n_3 = 1.072 - 0.0357\left(\frac{l_{shr}}{S}\right)$$

n_4 : Coefficient taken as:

$$n_4 = 1.2 - \left(\frac{S}{18}\right)$$

S : Double bottom floor spacing, in m, as defined in Pt 1 Ch 3 Sec 7 [1.2.2].

l_{shr} : Effective shear span as defined in [1.3.2].

P : Design pressure, in kN/m^2, as defined in [1.3.2].

1.5 Deck transverses

1.5.1 Web depth

The web depth of under deck transverses is not to be less than:

- 0.20 l_{bdg-dt} for deck transverses in the wing cargo tanks of ships with two longitudinal bulkheads.
- 0.13 l_{bdg-dt} for deck transverses in the centre cargo tanks of ships with two longitudinal bulkheads. The web depth of deck transverses in the centre cargo tank is not to be less than 90% of that of the deck transverses in the wing cargo tank.
- 0.10 l_{bdg-dt} for the deck transverses of ships with a centreline longitudinal bulkhead.
- The web height required in [1.1.6].

The web depth of above deck transverses is not to be less than:

- 0.10 l_{bdg-dt}
- The web height required in[1.1.6].

where:

l_{bdg-dt}: Effective bending span, in m, as defined in [1.5.2].

1.5.2 Net section modulus of deck transverses fitted below the upper deck

The net section modulus of deck transverses fitted below the upper deck, in cm^3, is not to be less than Z_{in-n50} and Z_{ex-n50} as given by the following formulae.

The net section modulus of the deck transverses fitted below the upper deck in the wing cargo tanks is also not to be less than required for the deck transverses fitted below the upper deck in the centre tanks.

$$Z_{in-n50} = \frac{850M_{in}}{C_{s-pr}R_{eH}}$$

$$Z_{ex-n50} = \frac{850M_{ex}}{C_{s-pr}R_{eH}}$$

where:

M_{in} : Design bending moment due to cargo pressure, in kNm, taken as:

- For deck transverses in wing cargo tanks of ships with two longitudinal bulkheads, and for deck transverses in cargo tanks of ships with a centreline longitudinal bulkhead: $M_{in} = 0.042\varphi_t P_{in\text{-}dt} Sl^2_{bdg\text{-}dt} + M_{st}$ but is not to be taken as less than M_0.
- For deck transverses in centre cargo tank of ships with two longitudinal bulkheads: $M_{in} = 0.042\varphi_t P_{in\text{-}dt} Sl^2_{bdg\text{-}dt} + M_{vw}$ but is not to be taken as less than M_0

M_{st} : Bending moment transferred from the side transverse, in kNm:

$M_{st} = c_{st}\beta_{st} P_{in\text{-}st}\, Sl^2_{bdg\text{-}dt}$

where a cross tie is fitted in a wing cargo tank and $l_{bdg\text{-}st\text{-}ct}$ is greater than 0.7 $l_{bdg\text{-}st}$, then $l_{bdg\text{-}st}$ in the above formula may be taken as $l_{bdg\text{-}st\text{-}ct}$.

M_{vw}: Bending moment transferred from the vertical web frame on the longitudinal bulkhead, in kNm:

$M_{st} = c_{vw}\beta_{vw} P_{in\text{-}vw}\, Sl^2_{bdg\text{-}vw}$

where $l_{bdg\text{-}vw\text{-}ct}$ is greater than 0.7 $l_{bdg\text{-}vw}$, then $l_{bdg\text{-}vw}$ in the above formula may be taken as $l_{bdg\text{-}vw\text{-}ct}$. For vertically corrugated bulkheads, M_{vw} is to be taken equal to bending moment in upper end of corrugation over the spacing between deck transverses.

M_0 : Minimum bending moment, in kNm.

$M_0 = 0.083 P_{in\text{-}dt} Sl^2_{bdg\text{-}dt}$

M_{ex} : Design bending moment due to green sea pressure, in kNm.

$M_{ex} = 0.067 P_{ex\text{-}dt} Sl^2_{bdg\text{-}dt}$

$P_{in\text{-}dt}$: Design cargo pressure given in Table 1 for the design load set being considered, calculated at mid- point of effective bending span, $l_{bdg\text{-}dt}$ of the deck transverse located at mid tank, in kN/m^2.

$P_{in\text{-}st}$: Corresponding design cargo pressure in wing cargo tank given in Table 1 for the design load set being considered, calculated at the mid-point of effective bending span, $l_{bdg\text{-}st}$ of the side transverse located at mid-tank, in kN/m^2.

$P_{in\text{-}vw}$: Corresponding design cargo pressure in the centre cargo tank of ships with two longitudinal bulkheads given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, $l_{bdg\text{-}vw}$ of the vertical web frame on the longitudinal bulkhead located at mid- tank, in kN/m^2.

$P_{ex\text{-}dt}$: Design green sea pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, $l_{bdg\text{-}dt}$ of the deck transverse located at mid tank, in kN/m^2.

φ_t : Coefficient taken as:

$$\varphi_t = 1 - 5\left(\frac{y_{toe}}{l_{bdg-dt}}\right)$$ but not taken less than 0.6.

y_{toe} : Distance from the end of effective bending span, $l_{bdg\text{-}dt}$ to the toe of the end bracket of the deck transverse, in m.

β_{st} : Coefficient taken as:

$$\beta_{st} = 0.9\left(\frac{l_{bdg-st}}{l_{bdg-dt}}\right)\left(\frac{I_{dt-n50}}{I_{st-n50}}\right)$$ but not taken less than 0.10 or greater than 0.65.

β_{vw} : Coefficient taken as:

$$\beta_{vw} = 0.9\left(\frac{l_{bdg-vw}}{l_{bdg-dt}}\right)\left(\frac{I_{dt-n50}}{I_{vw-n50}}\right)$$ but not taken less than 0.10 or greater than 0.50

$l_{bdg\text{-}dt}$: Effective bending span of the deck transverse, in m, see Pt 1, Ch 3, Sec 7, [1.1.6] and Figure 3, but is not to be taken as less than 60% of the breadth of the tank at the location being considered.

$l_{bdg\text{-}st}$: Effective bending span of the side transverse, in m, between the deck transverse and the bilge hopper, see Pt 1, Ch 3, Sec 7, [1.1.6] and Figure 3.

$l_{bdg\text{-}st\text{-}ct}$: Effective bending span of the side transverse, in m, between the deck transverse and the mid depth of the cross tie, where fitted in wing cargo tank, see Pt 1, Ch 3, Sec 7, [1.1.6].

$l_{bdg\text{-}vw}$: Effective bending span of the vertical web frame on the longitudinal bulkhead, in m, between the deck transverse and the bottom structure, see Pt 1, Ch 3, Sec 7, [1.1.6] and Figure 3.

$l_{bdg\text{-}vw\text{-}ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, in m, between the deck transverse and the mid depth of the cross tie, see Pt 1, Ch 3, Sec 7, [1.1.6].

$I_{dt\text{-}n50}$: Net moment of inertia of the deck transverse at mid-span with an effective breadth of attached plating specified in Pt 1, Ch 3, Sec 7, [1.3.2], in cm^4.

$I_{st\text{-}n50}$: Net moment of inertia of the side transverse at mid-span with an effective breadth of attached plating specified in Pt 1, Ch 3, Sec 7, [1.3.2], in cm^4.

$I_{vw\text{-}n50}$: Net moment of inertia of the longitudinal bulkhead vertical web frame at mid-span with an effective breadth of attached plating specified in Pt 1, Ch 3, Sec 7, [1.3.2], in cm^4.

c_{st} : Coefficient given in Table 3.

c_{vw} : Coefficient given in Table 3.

Values of c_{st} and c_{vw} for deck transverses **Table 3**

Structural configuration			c_{st}	c_{vw}
Ships with centreline longitudinal bulkhead			0.056	-
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M_{vw} based on $l_{bdg\text{-}vw\text{-}ct}$	-	0.044
		M_{st} based on $l_{bdg\text{-}st}$ or M_{vw} based on $l_{bdg\text{-}vw}$	0.044	0.016
	Cross ties in wing cargo tanks	M_{st} based on $l_{bdg\text{-}st\text{-}ct}$ or M_{vw} based on $l_{bdg\text{-}vw\text{-}ct}$	0.044	0.044
		M_{st} based on $l_{bdg\text{-}st}$ or M_{vw} based on $l_{bdg\text{-}vw}$	0.041	0.015

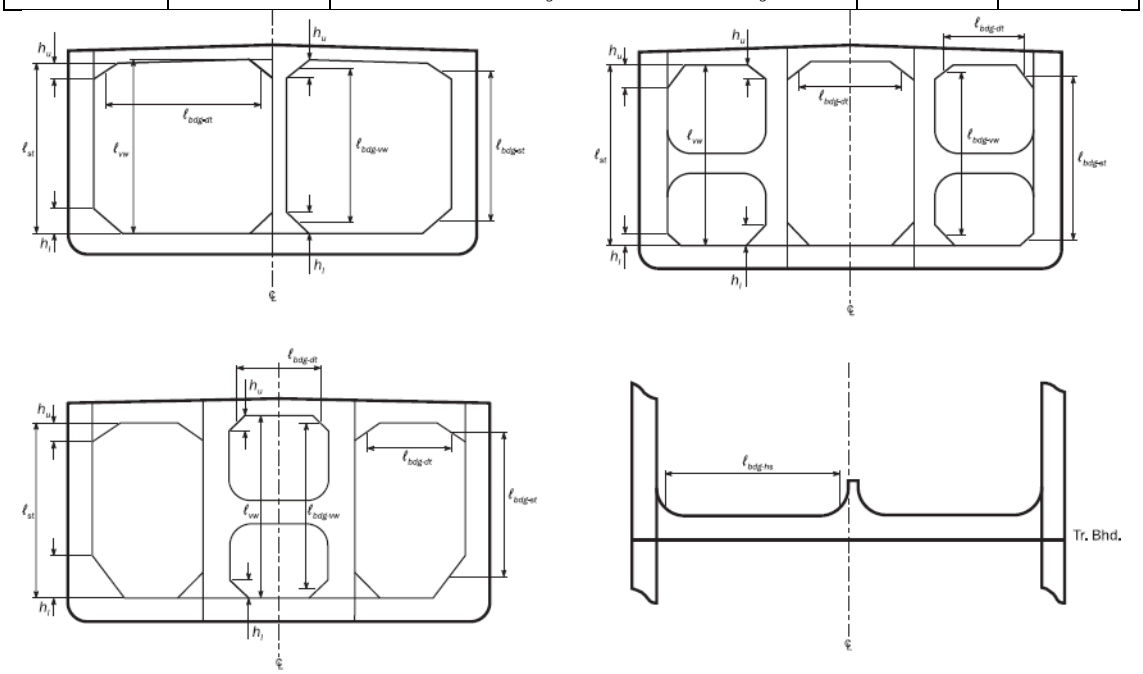


Figure 3 Definition of spans of deck, side transverses, vertical web frames on longitudinal bulkheads and horizontal stringers on transverse bulkheads

1.5.3 Net shear area of deck transverses fitted below the upper deck

The net shear area of deck transverses fitted below the upper deck, in cm^2, is not to be less than $A_{shr\text{-}in\text{-}n50}$ and $A_{shr\text{-}ex\text{-}n50}$ as given by:

$$A_{shr-in-n50} = \frac{8.5Q_{in}}{C_{t-pr}\tau_{eH}}$$

$$A_{shr-ex-n50} = \frac{8.5Q_{ex}}{C_{t-pr}\tau_{eH}}$$

where:

Q_{in} : Design shear force due to cargo pressure, in kN.

$Q_{in} = 0.65P_{in\text{-}dt}Sl_{shr} + c_1Db_{ctr}S\rho_L g$

Q_{ex} : Design shear force due to green sea pressure, in kN.

$Q_{ex}=0.65P_{ex\text{-}dt}Sl_{shr}$

$P_{in\text{-}dt}$: Design pressure in kN/m^2, defined in [1.5.2].

$P_{ex\text{-}dt}$: Design pressure in kN/m^2, defined in [1.5.2].

$l_{bdg\text{-}dt}$: Effective span, in m, defined in [1.5.2].

l_{shr} : Effective shear span, of the deck transverse, in m, see Pt 1, Ch 3, Sec 7, [1.1.7].

c_1 : Coefficient taken as:

- c_1 = 0.04 in way of wing cargo tanks of ships with two longitudinal bulkheads.
- c_1 = 0.00 in way of centre tank of ships with two longitudinal bulkheads.
- c_1 = 0.00 for ships with a centreline longitudinal bulkhead.

b_{ctr} : Breadth of the centre tank, in m.

1.5.4 Deck transverses fitted above the upper deck

When deck transverses are fitted above the upper deck, the net section modulus and shear area of deck transverses are not to be less than Z_{n50} and $A_{shr\text{-}n50}$, in cm^3 and cm^2 respectively, as given by the following formulae. The required section modulus and shear area are to be maintained over the full length of span.

$$Z_{n50} = \frac{850|P|Sl_{bdg}{}^2}{f_{bdg}C_{s-pr}R_{eH}}$$

$$A_{shr-n50} = \frac{8.5f_{shr}|P|Sl_{shr}}{C_{t-pr}\tau_{eH}}$$

where:

P : Design pressure given in Table 1 for the design load set being considered, calculated at midpoint of effective bending span, l_{bdg} of the deck transverse located at mid tank, in kN/m2.

f_{bdg} : Coefficient taken as:

f_{bdg} = 12 for design load set OT-1, OT-2 and OT-3 as defined in Table 1.

f_{bdg} = 15 for design load set SEA-1 as defined in Table 1.

f_{shr} : Coefficient taken as:

f_{shr} = 0.5

l_{bdg} : Effective bending span of the deck transverse fitted above upper deck, in m, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

l_{shr} : Effective shear span of the deck transverse fitted above upper deck, in m, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

As an alternative, the required section modulus and shear area may be obtained by finite element method in accordance with Pt 1, Ch 7 and with in consideration of loading patterns A1, A2 or B1, B2 as defined in Pt 1, Ch 4, Sec 8, [3.2.9] with draught equal to T_{sc} and cargo density of 1.025 t/m^3.

1.5.5 Deck transverse adjacent to transverse bulkhead

The scantling of deck transverse adjacent to the transverse bulkhead is to comply with the requirements of [1.5.2] to [1.5.4] for design green sea pressure only.

1.6 Side transverses

1.6.1 Net shear area

The net shear area, $A_{shr\text{-}n50}$, in cm^2, of side transverses is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{s-pr}\tau_{eH}}$$

where:

Q : Design shear force as follows, in kN:

$Q = Q_u$ for upper part of the side transverse.

$Q = Q_l$ for lower part of the side transverse.

Q_u : Shear force, in kN, taken as:

$Q_u = S[\, c_u\, l_{st}\, (P_u + P_l)\, - h_u P_u]$

where a cross tie is fitted in a wing cargo tank and $l_{st\text{-}ct}$ is greater than $0.7l_{st}$, then l_{st} in the above formula is taken as $l_{st\text{-}ct}$.

Q_l : Shear force, in kN, taken as the greater of the following:

- $S[c_l l_{st}(P_u+P_l)-h_l P_l]$
- $0.35 c_l S l_{st}(P_u+P_l)$
- $1.2Q_u$

where a cross tie is fitted in a wing cargo tank and $l_{st\text{-}ct}$ is greater than $0.7l_{st}$, then l_{st} in the above formula is taken as $l_{st\text{-}ct}$.

P_u : Design pressure given in Table 1 for the design load set being considered, in kN/m^2, calculated at mid length of tank and at mid height of h_u.

P_l : Design pressure given in Table 1 for the design load set being considered, calculated at mid height h_l located at mid length of tank, in kN/m^2.

l_{st} : Length of the side transverse, in m, taken as follows:

- Where deck transverses are fitted below deck, l_{st} is the length between the flange of the deck transverse and the inner bottom, see Figure 3.
- Where deck transverses are fitted above deck, l_{st} is the length between the elevation of the deck at side and the inner bottom.

$l_{st\text{-}ct}$: Length of the side transverse, in m, taken as follows:

- Where deck transverses are fitted below deck, $l_{st\text{-}ct}$ is the length between the flange of the deck transverse and mid depth of cross tie, where fitted in wing cargo tank.
- Where deck transverses are fitted above deck, $l_{st\text{-}ct}$ is the length between the elevation of the deck at side and mid depth of the cross tie, where fitted in wing cargo tank.

h_u : Effective length of upper bracket of the side transverse, in m, taken as follows:

- Where deck transverses are fitted below deck, *hu* is as shown in Figure 3.
- Where deck transverses are fitted above deck:
  - When an inner hull longitudinal bulkhead is arranged with a top wing structure as follows, h_u is taken as the distance between the deck at side and the lower end of slope plate of the top wing structure:
    - The breadth at top of the wing structure is greater than 1.5 times the breadth of the double side and.
    - The angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and deck is 30 deg or more to vertical.
  - In the other cases: *hu* is taken as 0.

h_l : Height of bilge hopper, in m, as shown in Figure 3.

c_u : Coefficient defined in Table 4.

c_l : Coefficient defined in Table 4.

Values of c_u and c_l for side transverses **Table 4**

Structural configuration			c_u		c_l	
Number of side stringers			Less than three	Equal to or greater than three	Less than three	Equal to or greater than three
Ships with a centreline longitudinal bulkhead			0.12	0.09	0.29	0.21
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank					
	Cross ties in wing cargo tanks	Q_u or Q_l based on l_{st-ct}				
		Q_u or Q_l based on l_{st}	0.08		0.20	

1.6.2 Shear area over the length of the side transverse

The shear area over the length of the side transverse is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required shear area for the upper part is to be maintained over the upper 0.2 l_{shr}.
b) The required shear area for the lower part is to be maintained over the lower 0.2 l_{shr}.
c) Where Q_u and Q_l are determined based on l_{st-ct}, the required shear area for the lower part is also to be maintained below the cross tie.
d) For ships without cross ties in the wing cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid- span.
e) For ships with cross ties in the wing cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:

l_{shr} : Effective shear span of the side transverse, in m.

$l_{shr} = l_{st} - h_u - h_l$ where Q_u and Q_l are determined based on l_{st}.

$l_{shr} = l_{st-ct} - h_u$ where Q_u and Q_l are determined based on l_{st-ct}.

l_{st}, l_{st-ct}, h_u, h_l, Q_u, Q_l : Parameters defined in [1.6.1].

1.7 Vertical web frames on longitudinal bulkhead

1.7.1 Web depth

The web depth of the vertical web frame on the longitudinal bulkhead is not to be less than:

- 0.14 l_{bdg-vw} for ships with a centreline longitudinal bulkhead.
- 0.09 l_{bdg-vw} for ships with two longitudinal bulkheads.
- The web height required in [1.1.6].

where:

l_{bdg-vw} : Effective bending span, in m, defined in [1.7.2].

1.7.2 Net section modulus

The net section modulus, Z_{n50} in cm^3, of the vertical web frame is not to be less than:

$$Z_{net50} = \frac{850M}{C_{s-pr}\sigma_{yd}}$$

where:

M : Design bending moment, in kNm, as follows:

$M=c_uPSl^2_{bdg-vw}$ for upper part of the web frame.

$M=c_lPSl^2_{bdg-vw}$ for lower part of the web frame.

where a cross tie is fitted and $l_{bdg-vw-ct}$ is greater than $0.7l_{bdg-vw}$, then l_{bdg-vw} in the above formula is to be taken as $l_{bdg-vw-ct}$.

P : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of the effective bending span, l_{bdg-vw} of the vertical web frame located at mid tank, in kN/m^2.

l_{bdg-vw} : Effective bending span of the vertical web frame on the longitudinal bulkhead, between the deck transverse and the bottom structure, in m, see Figure 3.

$l_{bdg-vw-ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, between the

deck transverse and mid-depth of the cross tie on ships with two longitudinal bulkheads, in m.

c_u : Coefficient defined in Table 5.

c_l : Coefficient defined in Table 5.

Values of c_u and c_l for vertical web frame on longitudinal bulkheads Table 5

Structural configuration			c_u	c_l
Ships with a centreline longitudinal bulkhead			0.057	0.071
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M based on $l_{bdg\text{-}vw\text{-}ct}$	0.057	0.071
		M based on $l_{bdg\text{-}vw}$	0.012	0.028
	Cross ties in wing cargo tanks	M based on $l_{bdg\text{-}vw\text{-}ct}$	0.057	0.071
		M based on $l_{bdg\text{-}vw}$	0.016	0.032

1.7.3 Section modulus over the length of the vertical web frame

The section modulus over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required section modulus for the upper part is to be maintained over the upper 0.2 $l_{bdg\text{-}vw}$ or 0.2 $l_{bdg\text{-}vw\text{-}ct}$ as applicable.

b) The required section modulus for the lower part is to be maintained over the lower 0.2 $l_{bdg\text{-}vw}$ or 0.2$l_{bdg\text{-}vw\text{-}ct}$ as applicable.

c) Where the required section modulus is determined based on $l_{bdg\text{-}vw\text{-}ct}$, the required section modulus for the lower part is also to be maintained below the cross tie.

d) The required section modulus between the upper and lower parts is to be reduced linearly to 70% of the required section modulus for the lower part at mid-span.

where:

$l_{bdg\text{-}vw}$, $l_{bdg\text{-}vw\text{-}ct}$: Effective bending span, in m, defined in [1.7.2].

1.7.4 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of the vertical web frame is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

Q : Design shear force as follows, in kN:

$Q = Q_u$ for upper part of the web frame.

$Q = Q_l$ for lower part of the web frame.

Q_u : Shear force, in kN, taken as:

$Q_u = S[c_u l_{vw}(P_u+P_l)-h_u P_u]$

where a cross tie is fitted in a centre or wing cargo tank and $l_{vw\text{-}ct}$ is greater than $0.7l_{vw}$, then l_{vw} in the above formula is to be taken as $l_{vw\text{-}ct}$.

Q_l : Shear force, in kN, taken as the greater of the following:

- $S[c_l l_{vw}(P_u+P_l)-h_l P_l]$
- $c_w Sc_l l_{st}(P_u+P_l)$
- 1.2 Q_u

where a cross tie is fitted in a centre or wing cargo tank and $l_{vw\text{-}ct}$ is greater than 0.7 l_{vw}, then l_{vw} in the above formula is to be taken as $l_{vw\text{-}ct}$.

P_u : Design pressure given in Table 1 for the design load set being considered, calculated at mid-height of upper bracket of the vertical web frame, *hu* located at mid tank, in kN/m^2.

P_l : Design pressure given in Table 1 for the design load set being considered, calculated at mid-height of lower bracket of the vertical web frame, *hl* located at mid tank, in kN/m^2.

l_{vw}: Length of the vertical web frame, in m, between the flange of the deck transverse and the inner bottom, see Figure 3.

$l_{vw\text{-}ct}$: Length of the vertical web frame, in m, between the flange of the deck transverse and mid-depth of the cross tie, where fitted.

h_u : Effective length of upper bracket of the vertical web frame, in m, as shown in Figure 3.

h_l : Effective length of lower bracket of the vertical web frame, in m, as shown in Figure 3.

c_u : Coefficient defined in Table 6.
c_l : Coefficient defined in Table 6.
c_w: Coefficient taken as:

- c_w = 0.57 for ships with a centreline longitudinal bulkhead,
- c_w = 0.50 for ships with two longitudinal bulkheads.

Values of c_u *and* c_l for vertical web frame on longitudinal bulkhead Table 6

Structural configuration		c_u	c_l
Ships with a centreline longitudinal bulkhead		0.17	0.28
Ships with two longitudinal bulkheads	Qu or Q_l based on $l_{vw\text{-}ct}$		
	Q_u or Q_l based on l_{vw}	0.075	0.18

1.7.5 Shear area over the length of the vertical web frame

The shear area over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required shear area for the upper part is to be maintained over the upper 0.2 l_{shr}.
b) The required shear area for the lower part is to be maintained over the lower 0.2 l_{shr}.
c) Where Q_u and Q_l are determined based on $l_{vw\text{-}ct}$, the required shear area for the lower part is also to be maintained below the cross tie.
d) For ships without cross ties in the wing or centre cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid-span.
e) For ships with cross ties in the wing or centre cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:
l_{shr} : Effective shear span of the vertical web frame, in m.
$l_{shr} = l_{vw} - h_u - h_l$ where Q_u and Q_l are determined based on l_{vw}.
$l_{shr} = l_{vw} - c_t - h_u$ where Q_u and Q_l are determined based on $l_{vw\text{-}ct}$.
l_{vw}, $l_{vw\text{-}ct}$, h_u, h_l, Q_u, Q_l: Parameters defined in [1.7.4].

1.8 Horizontal stringers on transverse bulkheads

1.8.1 Web depth

The web depth of horizontal stringers on transverse bulkhead is not to be less than:

- $0.28l_{bdg\text{-}hs}$ for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads.
- 0.20 $l_{bdg\text{-}hs}$ for horizontal stringers in centre tanks of ships with two longitudinal bulkheads, but the web depth of horizontal stringers in centre tank is not to be less than required depth for a horizontal stringer in wing cargo tanks.
- 0.20 $l_{bdg\text{-}hs}$ for horizontal stringers of ships with a centreline longitudinal bulkhead.
- The web height required in [1.1.6].

where:
$l_{bdg\text{-}hs}$: Effective bending span, in m, defined in [1.8.2].

1.8.2 Net section modulus

The net section modulus, Z_{n50} in cm^3, of the horizontal stringer over the end 0.2 $l_{bdg\text{-}hs}$ is not to be less than:

$$Z_{n50} = \frac{850M}{C_{s-pr}R_{eH}}$$

where:
M : Design bending moment, in kNm.
P : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, $l_{bdg\text{-}hs}$ and at mid-point of the spacing, S of the horizontal stringer, in kN/m^2.
$l_{bdg\text{-}hs}$: Effective bending span of the horizontal stringer, in m, but is not to be taken as less than 50% of the breadth of the tank at the location being considered, see Figure 3.

c : Coefficient taken as:

- c = 0.073 for horizontal stringers in cargo tanks of ships with a centreline bulkhead.
- c = 0.083 for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads.
- c = 0.063 for horizontal stringers in the centre tank of ships with two longitudinal bulkheads.

1.8.3 Section modulus over the length of horizontal stringers

The required section modulus at mid effective bending span is to be taken as 70% of that required at the ends , intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

1.8.4 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of the horizontal stringer over the end 0.2 l_{shr} is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

Q : Design shear force, in kN.

$Q = 0.5PS_{hs}\, l_{shr}$

P : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, $l_{bdg\text{-}hs}$ and at mid-point of the spacing, S of the horizontal stringer, in kN/m^2.

S_{hs} : Spacing, in m, defined in [1.8.2].

l_{shr} : Effective shear span of the horizontal stringer, in m.

1.8.5 Shear area at mid effective shear span

The required shear area at mid effective shear span is to be taken as 50% of that required in the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

1.9 Cross ties

1.9.1 Maximum applied design axial load

The maximum applied design axial load on cross ties, W_{ct} is to be less than or equal to the permissible load,

$W_{ct\text{-}perm}$ as given by:

$W_{ct} \leqslant W_{ct-perm}$

where:

W_{ct} : Applied axial load, in kN.

$W_{ct} = Pb_{ct}S$

$W_{ct\text{-}perm}$: Permissible load, in kN.

$W_{ct\text{-}perm}=0.12A_{ct\text{-}n50}\eta_{all}\sigma_{cr}$

P : Maximum design pressure for all the applicable design load sets being considered given in Table 1, calculated at centre of the area supported by the cross tie located at mid tank, in kN/m^2.

b_{ct} : Span, in m, taken as:

- Cross tie fitted in centre cargo tank: $b_{ct} = 0.5l_{bdg\text{-}vw}$
- Cross ties fitted in wing cargo tanks:
  - $b_{ct} = 0.5l_{bdg\text{-}vw}$ for design cargo pressure from the centre cargo tank.
  - $b_{ct} = 0.5\, l_{bdg\text{-}st}$ for design sea pressure.

$l_{bdg\text{-}vw}$: Effective bending span, in m, defined in [1.5.2].

$l_{bdg\text{-}st}$: Effective bending span, in m, defined in [1.5.2].

η_{all} : Allowable buckling utilisation factor as defined in Pt 1, Ch 8, Sec 1, [3.3].

σ_{cr} : Critical buckling stress in compression of the cross tie, in N/mm^2, as calculated using the

net sectional properties in accordance with Pt 1, Ch 8, Sec 5, [3.1.1].

$A_{ct\text{-}n50}$: Net cross sectional area of the cross tie, in cm^2.

1.9.2 Welded connections

Special attention is to be paid to the adequacy of the welded connections for the transmission of the forces, and also to the stiffening arrangements, in order to provide effective means for transmission of the compressive forces into the webs.

Particular attention is to be paid to the welding at the toes of all end brackets of the cross ties.

1.9.3 Horizontal stiffeners

Horizontal stiffeners are to be located in line with, and attached to, the longitudinals at the ends of the cross ties.

2 VERTICALLY CORRUGATED BULKHEADS

2.1 Application

2.1.1

In addition to the requirements of Pt 1, Ch 6, Sec 4, [1], vertically corrugated bulkheads of oil tankers are also to comply with the requirements of [2.2].

2.2 Scantling requirements

2.2.1 Net plate thickness over the height

The net plate thicknesses as required by [2.2.3] and [2.2.4] are to be maintained for two thirds of the corrugation length, l_{cg} from the lower end. Above that, the net plate thickness may be reduced by 20% from the net thickness required in [2.2.3] for the mid part of the corrugation provided that the net section modulus of the upper end of the corrugation complies with [2.2.4].

2.2.2 Net web plating thickness over the height

The net web plating thickness of the lower 15% of the corrugation, *tw* in mm, is to be taken as the greatest value calculated for all applicable design load sets, as given in Pt 1, Ch 6, Sec 2, [2], and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_w = \frac{1000\left|Q_{cg}\right|}{d_{cg} C_{t-cg} \tau_{eH}}$$

where:

Q_{cg} : Design shear force imposed on the web plating at the lower end of the corrugation, in kN.

$$Q_{cg} = \frac{s_{cg} l_{cg} \left|3P_l + P_u\right|}{8000}$$

P_l : Design pressure given in Pt 1, Ch 6, Sec 2, Table 1 for the design load set being considered, calculated at the lower end of the corrugation, in kN/m^2.

P_u : Design pressures given in Pt 1, Ch 6, Sec 2,Table 1 for the design load set being considered, calculated at the upper end of the corrugation, in kN/m^2.

d_{cg} : Depth of corrugation, in mm, see Figure 4.

$C_{t\text{-}cg}$: Permissible shear stress coefficient:

$C_{t\text{-}cg}$ = 0.75 for acceptance criteria set AC-S.

$C_{t\text{-}cg}$ = 0.90 for acceptance criteria set AC-SD.

2.2.3 Net thicknesses of the flanges over the height

The net thicknesses of the flanges of corrugated bulkheads, *tf* in mm, for two thirds of the corrugation length from the lower end are to be taken as the greatest value calculated for all applicable design load sets, as given in Pt 1, Ch 6, Sec 2, [2], and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_f = \frac{6.57 b_{f-cg} \sqrt{\sigma_{bdg-max}}}{C_f} 10^{-3}$$

where:

$\sigma_{bdg\text{-}max}$: Maximum value of the vertical bending stresses in N/mm^2 in the flange. The bending stress is to be calculated at the lower end and at the mid span of the corrugation length.

$$\sigma_{bdg-\max} = \frac{M_{cg}}{Z_{cg-act}} 10^3$$

M_{cg} : Vertical bending moment, in kNm, as defined in [2.2.4].

$Z_{cg\text{-}act}$: Actual net section modulus at the lower end and at the mid length of the corrugation, in cm^3.

$b_{f\text{-}cg}$: Breadth of flange plating, in mm. See Figure 4.

$b_{w\text{-}cg}$: Breadth of web plating, in mm. See Figure 4.

C_f : Coefficient taken as:

$$C_f = 7.65 - 0.26(\frac{b_w}{b_f})^2$$

2.2.4 Net section modulus over the height

The net section modulus at the lower and upper ends and at the mid length of the corrugation (l_{cg} / 2) of a unit corrugation, Z_{cg} are to be taken as the greatest value calculated for all applicable design load sets, as given in Pt 1, Ch 6, Sec 2, [2] and given by the following.

$$Z_{cg} = \frac{1000 M_{cg}}{C_{s-cg} R_{eH}}$$

where:

M_{cg} : Vertical bending moment in kNm.

$$M_{cg} = \frac{C_i |P| s_{cg} l_0^2}{12000}$$

P : Averaged pressure in kN/m^2.

$$P = \frac{P_u + P_l}{2}$$

P_l, P_u : Design pressure given in Pt 1, Ch 6, Sec 2, Table 1 for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in kN/m^2:

- For transverse corrugated bulkheads, the pressures are to be calculated at a section located at b_{tk} / 2 from the longitudinal bulkheads of each tank.
- For longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e. the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead.

b_{tk} : Maximum breadth of tank under consideration measured at the bulkhead, in m.

l_o : Effective bending span of the corrugation, in m, measured from the mid depth of the lower stool to the mid depth of the upper stool. Where no lower or upper stool is fitted, l_o is to be measured to lower or upper end. See Figure 4.

C_i : Bending moment coefficient given in Table 7.

$C_{s\text{-}cg}$: Permissible bending stress coefficient at the mid-length of the corrugation length, l_{cg}:

$C_{s\text{-}cg} = c_e$ but not to be taken as greater than 0.75 for acceptance criteria set AC-S.

$C_{s\text{-}cg} = c_e$ but not to be taken as greater than 0.90 for acceptance criteria set AC-SD.

At the lower and upper ends of the corrugation length, l_{cg}:

$C_{s\text{-}cg}$ = 0.75 for acceptance criteria set AC-S.

$C_{s\text{-}cg}$ = 0.90 for acceptance criteria set AC-SD.

c_e : Coefficient taken as:

$$c_e = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \quad \text{for} \quad \geqslant 1.25$$

c_e=1.0 for < 1.25

β : Coefficient taken as:

$$\beta = \frac{b_{f-cg}}{t_f} \sqrt{\frac{R_{eH}}{E}}$$

$b_{f\text{-}cg}$: Breadth of flange plating, in mm, see Figure 4.
t_f : Net thickness of the corrugation flange, in mm.

Values of C_i **Table 7**

Bulkhead	At lower end of l_{cg}	At mid-length of l_{cg}	At upper end of l_{cg}
Transverse bulkhead	C_1	C_{m1}	0.65 C_{m1}
Longitudinal bulkhead	C_3	C_{m3}	0.65 C_{m3}

where:
C_1 : Coefficient taken as:

$$C_1 = a_1 + b_1\sqrt{\frac{A_{dt}}{b_{dk}}}$$ but taken not less than 0.60.

$$C_1 = a_1 - b_1\sqrt{\frac{A_{dt}}{b_{dk}}}$$ for transverse bulkhead with no lower stool, but taken not less than 0.55.

a_1 : Coefficient taken as:

$$a_1 = 0.95 - \frac{0.41}{R_{bt}}$$

a_1 =1.0 for transverse bulkhead with no lower stool.

b_1 : Coefficient taken as:

$$b_1 = -0.20 + \frac{0.078}{R_{bt}}$$

b_1 = 0.13 for transverse bulkhead with no lower stool.

C_{m1} : Coefficient taken as:

$$C_{m1} = a_{m1} + b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}}$$ but not taken less than 0.55.

$$C_{m1} = a_{m1} - b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}}$$ for transverse bulkhead with no lower stool, but not taken less than 0.60

a_{m1} : Coefficient taken as:

$$a_{m1} = 0.63 + \frac{0.25}{R_{bt}}$$

$a_{m\,1}$ = 0.85 for transverse bulkhead with no lower stool.

b_{m1} : Coefficient taken as:

$$b_{m1} = -0.25 - \frac{0.11}{R_{bt}}$$

b_{m1} = 0.34 for transverse bulkhead with no lower stool.

C_3 : Coefficient taken as:

$$C_3 = a_3 + b_3\sqrt{\frac{A_{dl}}{l_{dk}}}$$ but not taken less than 0.60.

$$C_3 = a_3 - b_3\sqrt{\frac{A_{dl}}{l_{dk}}}$$ for longitudinal bulkhead with no lower stool, but not taken less than 0.55.

$a3$: Coefficient taken as:

$$a_3 = 0.86 - \frac{0.35}{R_{bl}}$$

a_3 =1.0 for longitudinal bulkhead with no lower stool.

b_3 : Coefficient taken as:

$$b_3 = -0.17 + \frac{0.10}{R_{bl}}$$

b_3 =0.13 for longitudinal bulkhead with no lower stool.

C_{m3} : Coefficient taken as:

$C_{m3} = a_{m3} + b_{m3}\sqrt{\frac{A_{dl}}{l_{dk}}}$ but not taken less than 0.55

$C_{m3} = a_{m3} - b_{m3}\sqrt{\frac{A_{dl}}{l_{dk}}}$ for longitudinal bulkhead with no lower stool, but not taken less than 0.60

a_{m3} : Coefficient taken as:

$$a_{m3} = 0.32 + \frac{0.24}{R_{bl}}$$

a_{m3} =0.85 for longitudinal bulkhead with no lower stool.

b_{m3} : Coefficient taken as:

$$b_{m3} = -0.12 - \frac{0.10}{R_{bl}}$$

b_{m3} =0.19 for longitudinal bulkhead with no lower stool.

R_{bt} : Coefficient taken as:

$$R_{bt} = \frac{A_{bt}}{b_{ib}}\left(1 + \frac{l_{ib}}{b_{ib}}\right)\left(1 - \frac{b_{av-t}}{h_{st}}\right)$$ for transverse bulkheads

R_{bl} : Coefficient taken as:

$$R_{bl} = \frac{A_{bl}}{I_{ib}}\left(1 + \frac{l_{ib}}{b_{ib}}\right)\left(1 - \frac{b_{av-l}}{h_{sl}}\right)$$ for longitudinal bulkheads.

A_{dt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in m^2.

A_{dt} = 0 if no upper stool is fitted.

A_{dl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in m^2.

A_{dl} = 0 if no upper stool is fitted.

A_{bt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in m^2.

A_{bl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in m^2.

$b_{av\text{-}t}$: Average width of transverse bulkhead lower stool, in m. See Figure 4.

$b_{av\text{-}l}$: Average width of longitudinal bulkhead lower stool, in m. See Figure 4.

h_{st} : Height of transverse bulkhead lower stool, in m. See Figure 4.

h_{sl} : Height of longitudinal bulkhead lower stool, in m. See Figure 4.

b_{ib} : Breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in m. See Figure 4.

b_{dk} : Breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in m. See Figure 4.

l_{ib} : Length of cargo tank at the inner bottom level between transverse lower stools, in m. See Figure 4.

l_{dk} : Length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in m. See Figure 4.

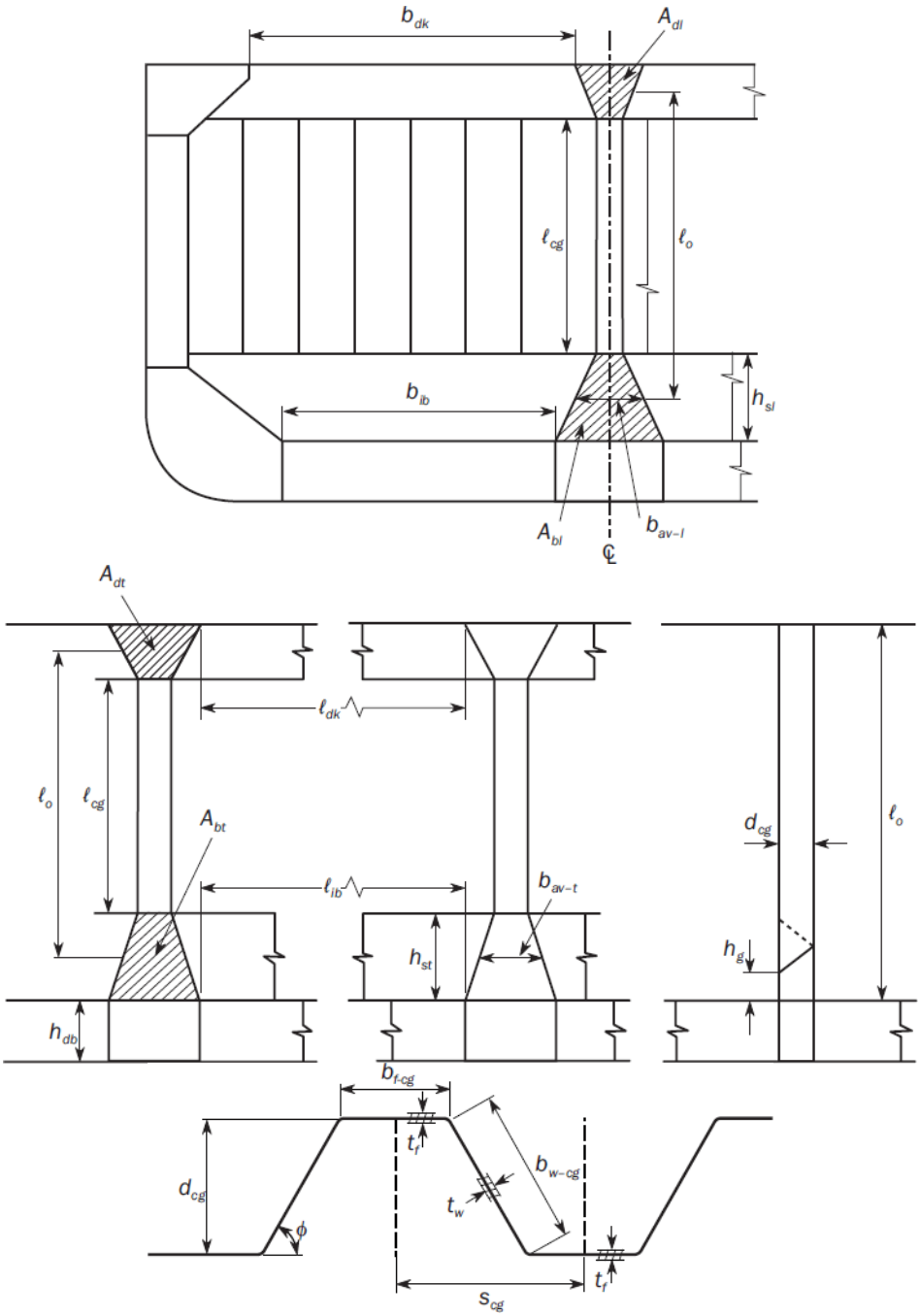


Figure 4 Definition of parameters for corrugated bulkhead (Tankers with longitudinal bulkhead at centreline)

SECTION 4 HULL OUTFITTING

1 SUPPORTING STRUCTURES FOR COMPONENTS USED IN EMERGENCY TOWING ARRANGEMENTS

1.1 General

1.1.1

It is the responsibility of the designer to provide emergency towing arrangements fitted at both the bow and stern of every tanker with a deadweight of 20,000 tonnes or more, as required by SOLAS, as amended.

1.1.2

The designer is reminded that design and construction of the towing arrangements are to be approved by the Flag Administration or the Society on their behalf.

1.2 Documents to be submitted

1.2.1

Plans showing details of the supporting structure for the emergency towing arrangement, including the connection to the deck, are to be provided for approval. Information on emergency towing arrangement showing sufficient detail to enable the position and direction of load actions to be ascertained is to be submitted for reference.

1.3 Structural arrangement

1.3.1 Continuity of strength

The structural arrangement is to provide continuity of strength.

1.3.2 Stress concentrations

The structural arrangement of the ship's structure in way of the emergency towing equipment is to be such that, abrupt changes of shape or section are to be avoided in order to minimise stress concentrations. Sharp corners and notches are to be avoided, especially in high stress areas.

1.4 Minimum thickness requirements

1.4.1 Deck plating

The deck in way of strong-points and fairleads is to have a minimum gross thickness of 15 mm.

1.5 Loads

1.5.1 Safe working loads

Safe working load of emergency towing arrangements is not to be taken less than:

- 1,000 kN for tankers having a deadweight greater than or equal to 20,000 t, but less than 50,000 t.
- 2,000 kN for tankers having a deadweight greater than or equal to 50,000 t.

1.5.2 Load case

The design load for the connection of the strong-point and fittings to the deck and its supporting structure is to be taken as twice the safe working load. Information on lines of action of the applied design load provided in emergency towing arrangement plan is to be taken into account.

1.6 Scantling requirements

1.6.1 General

The scantlings of the support structure are to be dimensioned to ensure that for the load cases specified in [1.5.2], the calculated stresses in the support structure do not exceed the permissible stress levels specified in [1.6.3].

The capacity of the structure to resist buckling failure is also to be assured.

1.6.2 Calculation procedure

These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two dimensional grillage or finite element analysis using gross scantlings.

1.6.3 Permissible stresses

For the design load given in [1.5.2], the shear stresses and normal stresses, including bending stresses induced in the supporting structure and welds, in way of strong-points and fairleads, are not to be exceed the permissible values given below based on the gross thickness of the structure:

- Normal stress, 1.00 R_{eH}.
- Shear stress, 0.58 R_{eH} .

Allowable buckling utilization factor is to be used as given in Ch 8, Sec 1, Table 1, for static and dynamic load scenario, S+D. Buckling assessment method is to be used according to Pt 1, Ch 8, Sec 4, [2].

2 MISCELLANEOUS DECK ATTACHMENTS

2.1 Cargo manifolds

2.1.1 Cargo manifold support

The design of the cargo manifold support is to be such as to distribute the loads imposed on the pipework into the ship structure in seagoing or in harbour operations during loading and unloading. To achieve this, the connection of the cargo manifold support to the deck is to be arranged to align with stiffening members of the main hull structure or stiffening is to be fitted in order to avoid the creation of hard points. Attention is to be paid to the detail design of the structure forming the deck attachment in order to minimise the effects of change of section. The arrangement of such details and their approval is considered on a case-by-case basis by the Society.

CCS 2.1.1a The connection structures of hull outfitting equipment to the deck are to comply with the requirements of CCS 6.1.1b in Section 4, Chapter 11 of PART 9-1.

3 GUARD RAILS AND BULWARKS

3.1 General

3.1.1

Generally, open guard rails are to be fitted on the upper deck. Plate bulwarks, with a 230 mm high continuous opening, at the lower edge, may be accepted provided the arrangement allows for the acceptable handling of spillage on deck and minimises the possibility for accumulation of volatile gas.

3.1.2

Deck spills are to be prevented from spreading to the accommodation and service areas and from discharge into the sea by a permanent continuous coaming with a minimum height of 100 mm surrounding the cargo deck. Along the sides at the aft end of the cargo deck of oil tankers, the coaming is to have a minimum height of 300 mm extending a minimum of 4.5 m forward from each corner. At the aft end of the cargo deck, the coaming is to have a minimum height of 300 mm and is to extend from side to side of the ship.

3.1.3

Scupper plugs of mechanical type are to be provided. Means of draining or removing oil or oily water within the coaming are also to be provided.

CCS Appendix A IACS REC.14 - HATCH COVER SECURING AND TIGHTNESS

(CORR.1 OCT. 2005)

1 Application

1.1

The following recommendations apply to steel hatch covers that are fitted to hatch openings on weather decks.

1.2

The recommendations, when relevant, also apply to the non-weathertight hatch covers which are accepted on container ships in accordance with the UI LL 64.

1.3

Where large relative movements between cover and ship structure or between cover elements are expected for ships having comparatively long/wide hatch ways, the application of these arrangements specified in the Recommendations for the gasket and securing arrangements are to be specially considered.

2 Design and Weathertightness

2.1 General

2.1.1

The weight of covers and any cargo stowed thereon, together with inertial forces generated by ship motions, are to be transmitted to the ship structure through suitable contact, such as continuous steel to steel contact of the cover skirt plate with the ship's structure or by means of defined bearing pads.

2.2 Weathertight Hatch Covers

2.2.1

The arrangement of weathertight hatch covers is to be such that weathertightness can be maintained in all sea conditions.

2.2.2

Weathertight sealings are to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements. Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and are to be made of a corrosion-resistant material.

2.2.3

The gasket material is to be of a quality suitable for all environmental conditions likely to be experienced by the ship, and is to be compatible with the cargoes carried. The material and form of gasket selected is to be considered in conjunction with the type of cover, the securing arrangement and the expected relative movement between cover and ship structure. The gasket is to be effectively secured to the cover.

3 Drainage Arrangement

3.1 General

3.1.1

Drain openings are to be arranged at the ends of drain channels and are to be provided with effective means for preventing ingress of water from outside, such as non-return valves or equivalent.

3.2 Weather tight Hatch Covers

3.2.1

Drainage is to be arranged inside the line of gasket by means of a gutter bar or vertical extension

of the hatch side and end coaming.

3.2.2
Cross-joints of multi-panel covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

3.2.3
If a continuous outer steel contact between cover and ship structure is arranged, drainage from the space between the steel contact and the gasket is also to be provided.

4 Securing Devices
4.1 General
4.1.1
Devices used to secure hatch covers, i.e. bolts, wedges or similar, are to be suitably spaced along the coamings and between cover elements.

4.1.2
The minimum gross sectional area of each securing device is not to be less than:

$$A = \frac{1.4\bar{a}}{f} \quad \text{cm}^2$$

where:

$\bar{a}$ *= half the distance between the two adjacent securing devices, measured along hatch cover periphery, see Fig. 1, m*

$$f = (\sigma_F/235)^m$$

σ_F *= minimum upper yield stress of the material, not to be taken greater than 70% of the ultimate tensile strength, N/mm*^{2}

m = 0.75 for σ_F *>235 N/mm*^{2}

m = 1.00 for σ_F *α235 N/mm*^{2}

Where the packing line pressure (see 4.2.2) exceeds 5 N/mm, the cross-sectional area of the securing devices is to be increased in direct proportion.
Rods or bolts are to have a minimum gross diameter not less than 19 mm for hatchways exceeding 5 m^2 *in area.*

4.1.3
Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

4.1.4
Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

4.1.5
Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

4.2 Weathertight Hatch Covers
4.2.1
Arrangement and spacing of securing devices are to be determined with due attention to the effectiveness for weathertightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices.

4.2.2
Between cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by the securing devices. The packing line pressure is to be specified.

4.2.3

The cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The gross moment of inertia of edge elements is not to be less than:

$I = 6\ pa^4\ \ cm^4$

where:

p *= packing line pressure, with* $p \geqslant 5$ *N/mm*

a *= maximum of the distances,* a_i*, between two consecutive securing devices, measured along the hatch cover periphery (see Figure 1), not to be taken as less than 2.5* a_c*, m*

a_c *: max* $(a_{1.1}, a_{1.2})$ *, m*

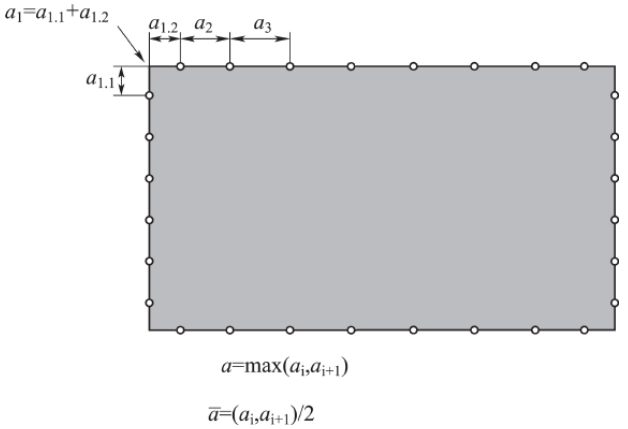


Figure 1 Distance between securing devices, measured along hatch cover periphery

When calculating the actual gross moment of inertia of the edge element, the effective breadth of the attached plating of the hatch cover, in m, is to be taken equal to the lesser of the following values:

- *0.165 a*
- *half the distance between the edge element and the adjacent primary member*

4.2.4

The angle section or equivalent section bearing the rubber seal is to be of adequate size and well integrated with the cover edge element structure to ensure uniform sealing pressure all along the line of contact

5 Securing Arrangement for Hatch Covers carrying Deck Cargo

5.1

In addition to the recommendations given in 4, all hatch covers, especially those carrying deck cargo are to be effectively secured against horizontal shifting due to the horizontal forces arising from ship motions.

5.2

To prevent damage to hatch covers and ship structure, the location of stoppers is to be compatible with the relative movements between hatch covers and ship structure. The number should be as small as practically possible.

5.3

Considerations are to be given for assessment of cargo loads that towards the end of the ship vertical acceleration forces may exceed the gravity force. The resulting lifting forces must be considered when dimensioning the securing devices according to 4. Also lifting forces from cargo secured on the hatch cover during rolling are to be taken into account.

5.4

Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers.

5.5

At cross-joints of multi-panel covers vertical guides (male/female) are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.

5.6

In the absence of hatch cover lifting under loads arising from the ship's rolling motion, securing devices for non-weathertight hatch covers may be omitted. In such cases, it is to be proven by means of grillage and/or finite element analyses that an equilibrium condition is achieved using compression-only boundary elements for the vertical hatch cover supports. If securing devices are omitted, transverse cover guides are to be effective up to a height h_E above the hatch cover supports, where h_E must not be less than:

$h_E = 1.75(2se + d^2)^{0.5} - 0.75d$ *mm*

$h_{E,min}$ *= height of the cover edge plate +150 mm*

where:

e = largest distance from the inner edges of the transverse cover guides to the ends of the cover edge plate, mm

s = total clearance within the transverse cover guide, with $10 \leqslant s \leqslant 40$*, mm*

d = distance between upper edge of transverse stopper and hatch cover supports, mm

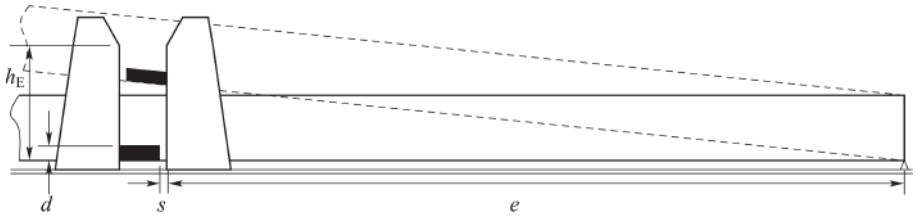


Figure 2 Height of transverse cover guides

The transverse cover guides and their substructure are to be dimensioned in accordance with the transverse loads acting at a height h_E and an allowable stress defined by each Classification Society.

6 Tightness Testing of Weathertight Hatch Covers

6.1

Upon completion of installation of hatch covers, a chalk test is to be carried out.

6.2

This is to be followed by a hose test with a pressure of water not less than 200 kN/m^2.

The following may be assumed for guidance:

Nozzle diameter: minimum 12 mm

Water pressure: sufficient for a free height of water with the stream directed upwards of 10 meters maximum

Distance to structure: maximum 1,5 meters

6.3

Alternative methods of tightness testing will be considered.

7 Operation Test

7.1

All hatch covers are to be operationally tested.

8 Operation and Maintenance

8.1

It is recommended that ships with steel hatch covers are supplied with an operation and maintenance manual including:

- *Operating and closing instructions*
- *Maintenance requirements for packings, securing devices and operating items*
- *Cleaning instructions for the drainage system*
- *Corrosion prevention instructions*
- *List of spare parts.*

CCS Appendix B IACS REC.34 - Standard Wave Data (CORR. Nov. 2001)

1

This recommendation is valid for ships carrying goods at sea, excluding vessels that operate at a fixed location (for example FPSO s), specifically aiming at ships as covered by UR S11, and focusing on extreme wave loads.

2

Wave data as described by the scatter diagram given in TABLE 1, describe the wave data of the North Atlantic as defined in FIGURE 1, covering areas 8,9,15 and 16, as defined in Global Wave Statistics/1/ with changes according to /2/.

3

When calculating design wave bending moments, it is recommended to use a return period of at least 20 years, corresponding to about 10^{-8} probability of exceedance per cycle.

4

When calculating the pressure head from green seas on horizontal deck plates and hatch covers, the relative motion in the undisturbed wave at the centre line for the considered area, at a return period of 20 years, can be applied as a first approximation.

5

Combination of loads should be performed, preferably using simultaneous values, to ensure application of the design loads at a consistent probability level.

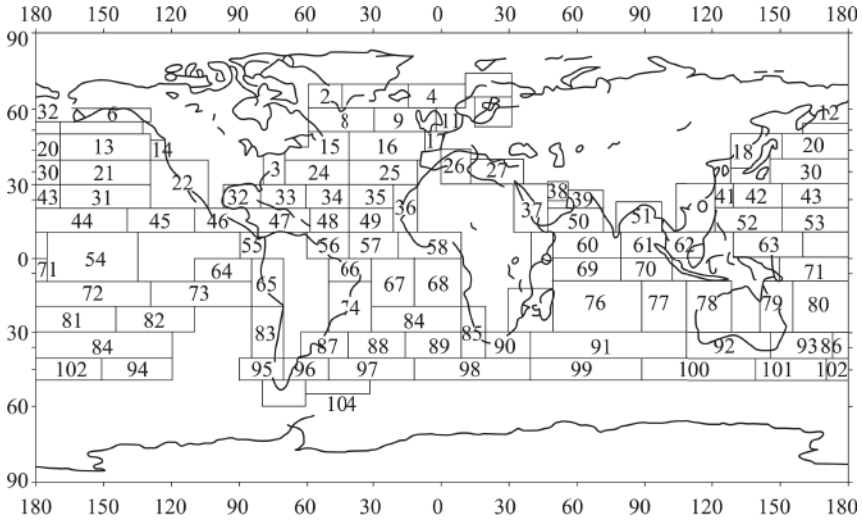


Figure 1 Definition of the extent of the North Atlantic

The Table 1 Probability of sea-states in the North Atlantic described as occurrence per 100000 observations.

Derived from BMT's Global Wave Statistics

Hs/Tz	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	SUM
0.5	0.0	0.0	1.3	133.7	865.6	1186.0	634.2	186.3	36.9	5.6	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	3060
1.5	0.0	0.0	0.0	29.3	986.0	4976.0	7738.0	5569.7	2375.7	703.5	160.7	30.5	5.1	0.8	0.1	0.0	0.0	0.0	22575
2.5	0.0	0.0	0.0	2.2	197.5	2158.8	6230.0	7449.5	4860.4	2066.0	644.5	160.2	33.7	6.3	1.1	0.2	0.0	0.0	23810
3.5	0.0	0.0	0.0	0.2	34.9	695.5	3226.5	5675.0	5099.1	2838.0	1114.1	337.7	84.3	18.2	3.5	0.6	0.1	0.0	19128
4.5	0.0	0.0	0.0	0.0	6.0	196.1	1354.3	3288.5	3857.5	2685.5	1275.2	455.1	130.9	31.9	6.9	1.3	0.2	0.0	13289
5.5	0.0	0.0	0.0	0.0	1.0	51.0	498.4	1602.9	2372.7	2008.3	1126.0	463.6	150.9	41.0	9.7	2.1	0.4	0.1	8328
6.5	0.0	0.0	0.0	0.0	0.2	12.6	167.0	690.3	1257.9	1268.6	825.9	386.8	140.8	42.2	10.9	2.5	0.5	0.1	4806
7.5	0.0	0.0	0.0	0.0	0.0	3.0	52.1	270.1	594.4	703.2	524.9	276.7	111.7	36.7	10.2	2.5	0.6	0.1	2586
8.5	0.0	0.0	0.0	0.0	0.0	0.7	15.4	97.9	255.9	350.6	296.9	174.6	77.6	27.7	8.4	2.2	0.5	0.1	1309
9.5	0.0	0.0	0.0	0.0	0.0	0.2	4.3	33.2	101.9	159.9	152.2	99.2	48.3	18.7	6.1	1.7	0.4	0.1	626
10.5	0.0	0.0	0.0	0.0	0.0	0.0	1.2	10.7	37.9	67.5	71.7	51.5	27.3	11.4	4.0	1.2	0.3	0.1	285
11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.3	13.3	26.6	31.4	24.7	14.2	6.4	2.4	0.7	0.2	0.1	124
12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	4.4	9.9	12.8	11.0	6.8	3.3	1.3	0.4	0.1	0.0	51
13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.4	3.5	5.0	4.6	3.1	1.6	0.7	0.2	0.1	0.0	21
14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.2	1.8	1.8	1.3	0.7	0.3	0.1	0.0	0.0	8
15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.6	0.7	0.5	0.3	0.1	0.1	0.0	0.0	3
16.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	1
SUM:	0	0	1	165	2091	9280	19922	24879	20870	12898	6245	2479	837	247	66	16	3	1	100000

The Hs and Tz values are class midpoints

6

For evaluation of extreme global bending moments it is recommended to use zero speed, provided the vessel does not have a service restriction, in which case the limitation should be checked as well. The effect of forward speed (2/3 of design speed) is recommended to be checked, especially for local dynamic pressures.

7

The Bretschneider or two parameter Pierson-Moskowitz spectrum is recommended for the North Atlantic, described by the following expression:

$$S(\omega) = \frac{H_S^2}{4\pi}(\frac{2\pi}{T_Z})^4 \omega^{-5} \exp(-\frac{1}{\pi}(\frac{2\pi}{T_Z})^4 \omega^{-4})$$

where:
H_s = The significant wave height (m)
ω = Angular wave frequency (rad/s)
T_Z = The average zero up - crossing wave period (s)

$$T_Z = 2\pi(\frac{m_2}{m_0})^{1/2}$$

The spectral moments of order n of the response process for a given heading may be described as

$$m_n = \int_\omega \sum_{\theta_0-90°}^{\theta_0+90°} f_s(\theta)\omega^n \cdot S(\omega / H_S, T_Z, \theta)\mathrm{d}\omega$$

using a spreading function usually defined as $f_s(\theta)=k\cos^2\theta$
where k is selected such that:

$$\sum_{\theta_0-90°}^{\theta_0+90°} f_s(\theta) = 1$$

where:
θ_0=main wave heading
θ=relative spreading around the main wave heading

8

In long term calculations, all wave headings (0-360 °) can be assumed to have an equal probability of occurrence and at most 30 °spacing between headings should be applied.

9

When calculating vertical bending moments (Sag and Hog) proper corrections for non-linear effects are to be applied.

10

The dynamic sea pressure can be derived above the mean waterline (WL) based on linear calculation methods by a reduction of 1-one meter pressure head per meter distance from the mean WL using a dynamic sea pressure at a return period of 20 years, corresponding to about 10^{-8} probability per cycle. In case dynamic sea pressures at 10^{-4} probability per cycle are applied, a reduction of 1/2-half meter pressure head per meter distance above the mean WL should apply to ensure dynamic sea pressures at sufficient height above the mean WL.

11

When calculating design sea pressures at ship ends, due consideration should be taken to the occurrence of non-linearity s such as slamming on the bottom and non-vertical ship sides.

References

/1/ British Marine Tec hnology (Primary contributors Hogben N., Da Cunha, L.F. and Oliver, H.N.). "Global Wave Statistics", Unwin Brothers Limited, London 1986.
/2/ Bitner-Gregersen, E.M., Cramer, E.H., Korbijin, F., "Environmental Description for Long-term Load Response of Ship Structures", ISOPE June 1995, The Hague, The Netherlands.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2025

PART TEN SHIPS IN RESTRICTED SERVICE

CONTENTS

CHAPTER 0 GENERAL 10-1
Section 1 GENERAL PROVISIONS 10-1
CHAPTER 1 SURVEYS AFTER CONSTRUCTION OF SHIPS ENGAGED ON NON-INTERNATIONAL VOYAGES 10-2
Section 1 GENERAL PROVISIONS 10-2
Section 2 HULL AND EQUIPMENT SURVEYS 10-2
Section 3 SURVEYS OF MACHINERY 10-16
Section 4 SURVEYS OF ELECTRICAL INSTALLATIONS 10-19
Section 5 INITIAL CLASSIFICATION SURVEY 10-20
Appendix 1 CORROSION AND WASTAGE CONTROL OF HULL STRUCTURE 10-24
Appendix 2 MINIMUM INSULATION RESISTANCE OF ELECTRICAL EQUIPMENT AND CIRCUITS IN HOT CONDITION 10-26
Appendix 3 MARKING OF LOAD LINES 10-27
CHAPTER 2 HULL 10-30
Section 1 GENERAL PROVISIONS 10-30
Section 2 SHIP TYPE REQUIREMENTS 10-32
CHAPTER 3 MACHINERY INSTALLATIONS 10-34
Section 1 GENERAL PROVISIONS 10-34
Section 2 MACHINERY INSTALLATIONS 10-34
CHAPTER 4 ELECTRICAL INSTALLATIONS 10-36
Section 1 MAIN SOURCE OF ELECTRICAL POWER 10-36
Section 2 EMERGENCY SOURCE OF ELECTRICAL POWER 10-36
Section 3 MISCELLANEOUS 10-37
CHAPTER 5 REFRIGERATED CARGO INSTALLATIONS 10-38
Section 1 GENERAL PROVISIONS 10-38
Section 2 REFRIGERATING PLANT 10-38
Section 3 CARRIAGE OF REFRIGERATED CONTAINERS IN CARGO HOLDS 10-38
CHAPTER 6 FIRE PROTECTION, DETECTION AND EXTINCTION 10-39
Section 1 GENERAL REQUIREMENTS 10-39
CHAPTER 7 ADDITIONAL REQUIREMENTS 10-40
Section 1 ADDITIONAL REQUIREMENTS FOR OPEN-TOP CONTAINER SHIPS 10-40
Section 2 ADDITIONAL REQUIREMENTS FOR PUSHER TUG-BARGE COMBINATIONS 10-42
Section 3 ADDITIONAL REQUIREMENTS FOR PETROLEUM ASPHALT CARRIERS 10-47

CHAPTER 0 GENERAL

Section 1 GENERAL PROVISIONS

0.1.1 Scope of application

0.1.1.1 The provisions of this PART apply to ships navigating and/or operating in restricted service, including ships engaged on international and non-international (domestic or regional) voyages and/or operation.

0.1.1.2 Where not covered by this PART, the relevant provisions of PART ONE to PART EIGHT of the Rules are to be complied with.

0.1.1.3 Where relevant provisions for ships engaged on non-international voyages in this PART are not consistent with the requirements of the Administration of the flag State, the requirements of the Administration of the flag State are to be satisfied and relevant requirements of this PART may not be satisfied.

0.1.2 Definitions

0.1.2.1 Restricted service is a generic term of the service categories 1, 2 and 3. For limitation for navigation of each service category, see Table 2.1.3.1, Section 1, Chapter 2, PART ONE of the Rules.

0.1.3 Class notations

0.1.3.1 Ships complying with this PART, except for the provisions for ships engaged on non-international voyages in restricted service, will be asssigned one of the following notations:

(1) Service category 1: R1;

(2) Service category 2: R2;

(3) Service category 3: R3.

0.1.3.2 Ships complying with the provisions for ships engaged on non-international voyages in restricted service of this PART will be suffixed D after the corresponding service category notations: R1(D), R2(D), R3(D).

0.1.3.3 For ships assigned with notations R1, R2, R3, the survey after construction is to comply with the relevant requirements of PART ONE of the Rules; for ships assigned with notations R1(D), R2(D), R3(D), the survey after construction is to comply with the relevant requirements of Chapter 1 of this PART.

0.1.3.4 For engineering ships whose operation areas are different from transiting areas, the areas applicable for transiting and operation may be identified separately, e.g.: R2 for Transiting and R3 for Operation.

0.1.3.5 Other service restriction or limitaton notations are given in Table C, Appendix 1, Chapter 2, PART ONE of the Rules.

CHAPTER 1 SURVEYS AFTER CONSTRUCTION OF SHIPS ENGAGED ON NON-INTERNATIONAL VOYAGES

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 For merchant ships rented or owned by the government and used for military purposes, special consideration may be given to the application of relevant requirements of this Chapter.

Section 2 HULL AND EQUIPMENT SURVEYS

1.2.1 General provisions

1.2.1.1 Unless provided otherwise, this Chapter applies to surveys of hull and equipment of all ships.

1.2.1.2 CCS will arrange an overall survey for the items related to the certificates, as appropriate, to confirm compliance with CCS rules.

1.2.1.3 Meetings for survey plans of oil tankers, bulk carriers and chemical tankers:

(1) The establishment of proper preparation and the close cooperation between the attending Surveyor(s) and the owner's representatives onboard prior to and during the survey are an essential part in the safe and efficient conduct of the survey. During the survey on board safety meetings are to be held regularly.

(2) Prior to commencement of any part of the special survey, a survey planning meeting is to be held between the attending Surveyor(s), the owner's representative in attendance, the thickness measurement company operator (as applicable) and the master of the ship or an appropriately qualified representative appointed by the Company so as to ensure the safe and efficient conduct of the survey work to be carried out.

(3) The following is an indicative list of items that are to be addressed in the meeting:

① provisions and arrangements for thickness measurements (i.e. access, cleaning/de-scaling, illumination, ventilation, personal safety);

② extent of the thickness measurements;

③ acceptance criteria;

④ extent of close-up survey and thickness measurement considering the coating condition and suspect areas/areas of substantial corrosion;

⑤ execution of thickness measurements;

⑥ taking representative readings in general and where uneven corrosion/pitting is found;

⑦ mapping of areas of substantial corrosion;

⑧ communication between attending Surveyor(s), the thickness measurement company operator(s) and owner's representative(s) concerning findings.

1.2.1.4 Documentation on board

(1) General requirements

① For oil tankers, bulk carriers and chemical tankers, the documentation specified in 1.2.1.4(2) is to be kept on board in the lifetime of the ship, which is to be readily available for the Surveyor.

② A thickness measurement report is to be a part of the documentation on board.

(2) Supporting documents

① The following additional documentation is to be available on board:

a. main structural plans of cargo oil and ballast tanks;

b. previous repair history;

c. cargo and ballast history;

d. inspection by ship's personnel with reference to:

i. structural deterioration in general;

ii. leakages in bulkheads and piping;

iii. condition of coating or corrosion protection, if any;

e. extent of use of inert gas plant and tank cleaning procedures (for oil tankers);

f. any other information that will help identify suspect areas requiring inspection.

1.2.1.5 The inspection of Watertight Cable Transits is to be carried out in accordance with Chapter 5,

PART ONE of the Rules.

1.2.2 Annual surveys

1.2.2.1 General requirements

(1) During the annual survey, conventional examinations are to be carried out by means of visual inspections and necessary tests to confirm whether the general condition of the ship is acceptable or whether the ship is under normal maintenance.

(2) Conventional external inspections and tests are specified so far as practicable in the items listed below.

1.2.2.2 The survey of all ships is to cover:

(1) Hull

① inspection of side shell and closing appliances above waterline;

② inspection of freeboard deck, weather deck and superstructure deck;

③ inspection and operational test of watertight doors on watertight bulkheads; Confirmation of closing appliance of shell plating opening below freeboard deck;

④ inspection of penetrations of watertight bulkheads, so far as practicable;

⑤ confirming, when appropriate and as far as is practicable when examining internal spaces on oil tankers and bulk carriers, that the means of access to cargo and other spaces remain in good condition;

⑥ examining cargo hold water level detectors and their audible and visual alarms on single skin &single-hold cargo ships;

⑦ confirming that no new installation of materials containing asbestos is on board.

(2) Protection of cargo hatches

① checking that no unapproved changes have been made to the hatch covers, hatch coamings and their securing and sealing devices since the last survey;

② examining exposed hatch covers to confirm the structural integrity and capability of maintaining watertightness. Where extensive areas of wastage and/or substantial corrosion of steel hatch covers are found, thickness measurements are to be carried out to confirm the extent of wastage or corrosion, and renewals or repairs are required where wastage exceeds allowable margins;

③ where mechanically operated steel covers are fitted, checking the satisfactory condition of:

a. hatch covers including plating and stiffeners;
b. weathertight devices of covers (gaskets, gasket slots, drainage channels);
c. clamping devices, including bolts, cleating, retaining bars;
d. track wheels, guide rails, chains (or wires) and guide devices;
e. operating systems, including hydraulic systems and power units (if fitted).

④ where portable covers, wooden or steel pontoons (plus tarpaulin) are fitted, checking the satisfactory condition of:

a. wooden covers (including metallic end sheathing) and portable beams, carriers or sockets for the portable beams, and their securing devices;
b. steel pontoons, including chocks;
c. waterproof hatch cover tarpaulin (of at least 2 layers);
d. hatch compression bars and wedges;
e. cleats.

⑤ checking hatch coamings including deck connection, stiffeners, pillars, dunnage, wooden wedges;

⑥ checking draining non-return devices on hatch coamings.

(3) Protection of other openings

① examining flush scuttles, manholes, skylights and other watertight closing appliances;

② examining the circular openings of engine room casings, boiler casings and funnels, skylights, companionways on freeboard deck and weather deck, and boundary bulkheads, openings and weathertight closing appliances of deckhouse;

③ examining cargo hold hatches and other openings on weather deck, and coaming, closing and securing means thereon;

④ examining side scuttles and deadlights, windows, other openings and their closing devices;

⑤ examining ventilators including their closing appliances and flame screens, and air pipes and vents;

⑥ examining ends of enclosed superstructures;

⑦ examining all weathertight doors and their closing appliances of above spaces, including stiffeners, hinges and sealing devices; confirming operational condition of weathertight doors and their closing appliances.

(4) Discharges

① scuppers and sewage discharges with valves and controls on their pipelines;

② freeing ports and their protective bars and dampers.

(5) Suspect areas

① Suspect areas of the hull are to be examined, including those suspect areas which were identified at previous intermediate and/or special surveys. Where extensive areas of wastage are found, thickness measurements are to be carried out and renewals or repairs are required where wastage exceeds allowable margins.

(6) Steering gear

① general external examination of steering gear, accuracy of rudder angle indicator, and performance test.

(7) Anchoring equipment

① external examination of anchoring equipment for cracks, bending and twisting, loosening and detachment of stock, and secure connection to deck.

(8) Mooring equipment

① general external examination of mooring equipment.

(9) Fire safety

① confirming so far as practicable that no substantial change has been made to the fireproof structure and arrangement;

② operational test of manual and/or automatic fire doors (if fitted);

③ confirming that fire control plans are posted and kept as required;

④ testing of fire detectors and/or smoke detectors and alarms, so far as practicable;

⑤ examining fire pumps, hoses, nozzles and international shore connections, confirming that each fire pump, including the emergency fire pump, can by operated separately, and confirming that two jets of water are produced simultaneously from different hydrants at any part of the ship whilst the required pressure is maintained in the fire main;

⑥ checking the provision and randomly examining the condition of all portable and non-portable fire extinguishers, and checking appropriate maintenance information;

⑦ examining the fixed fire-fighting system for the machinery, cargo, vehicle, special category and ro-ro spaces, as appropriate, and confirming that its means of operation are clearly marked;

⑧ confirming that the fire fighter’s outfits and EEBDs are complete and in good condition and that the cylinders, including the spare cylinders, of any required self-contained breathing apparatus are suitably charged;

⑨ confirming that the firefighters' outfits including its self-contained compressed air breathing apparatus and emergency escape breathing devices (EEBDs) are complete and in good condition, that the cylinders, including the spare cylinders, of any required self-contained breathing apparatus are suitably charged, and that on board means of recharging breathing apparatus cylinders used during drills or a suitable number of spare cylinders to replace those used are provided, and for ships the keels of which are laid on or after 12 November 2016, provision of two-way portable radiotelephone apparatus of an explosion-proof type or intrinsically safe;

⑩ examining closing means of ventilators, funnels, skylights, doorways and shaft tunnels (if fitted);

⑪ examining the fire protection arrangements in cargo, vehicle and ro-ro spaces and confirming, as far as practicable and as appropriate, the operation of the means for closing the various openings;

⑫ examining, where appropriate, the special arrangements for carrying dangerous goods, including checking of the electrical equipment and wiring, the ventilation, the provision of protective clothing and portable appliances, and the testing of water supply, bilge pumping and any water spray system.

(10) Securing of containers

① examining securing fittings and means of containers.

1.2.2.3 In addition to the applicable requirements in 1.2.2.2, the following items are to be added for passenger ships (including ro-ro passenger ships and passenger ferries):

(1) The survey of watertight bulkheads and their arrangements is to:

① examine, so far as practicable, collision bulkhead and watertight bulkheads and confirm that their watertight integrity is not damaged;

② examine whether the diagram in the navigation bridge correctly shows the location of each watertight door and the OPEN/CLOSE indicators;

③ test the operation of locally or remotely controlled watertight doors, giving particular attention to audible and visual alarms activated on each side of the bulkhead and their operating mechanisms (if required or fitted);
④ confirm the operation of watertight doors after cutoff of main and emergency sources of power;
⑤ confirm that notices are posted at the appropriate places.

(2) The examination of shell openings is to include:
① closing appliances of side scuttles and deadlights, discharges, sewage drainages and similar openings as well as other water inlets and outlets below the margin line of shell;
② confirmation that side shell doors, cargo ports below the margin line can be effectively closed, and that the inboard end of cinder and garbage discharge chute is fitted with watertight seal;
③ general inspection of valves and pipelines of cross-flooding fittings, and operational test of remote control system.

(3) Verification that the emergency escape routes including related stairways and stairs in passenger and crew spaces are free from obstruction.

1.2.2.4 In addition to the applicable requirements in 1.2.2.2, the following items are to be added for oil tankers (including ore/bulk/oil carriers and ore/oil carriers) and chemical tankers:

(1) The examination of weather deck is to include:
① cargo tank openings including gaskets, covers, coamings and flame screens
② ventilation arrangement of cargo tanks, including overpressure/low pressure alarm (if fitted) and pressure/vacuum valves and flame screens;
③ flame screens on vents to all bunker, oily ballast, oily slop tanks and void spaces, so far as practicable;
④ cargo oil, crude oil washing, bunker, ballast and vent piping systems, including vent masts and headers.

(2) The examination of cargo pump rooms and pipe tunnels (if fitted) is to include:
① confirmation that no potential sources of ignition such as loose gear, excessive bilge accumulation, excessive vapour, combustible materials, etc., are present in or near the cargo pump room and that access ladders are in good condition;
② pump room bulkheads for signs of leakage or fractures, and in particular, the sealing arrangements of all penetrations in these bulkheads;
③ performance test of bilge pumping system of pump room;
④ confirmation that the pump room ventilation system is operational, ducting intact, dampers operational and screens are clean.

1.2.2.5 In addition to the survey items in 1.2.2.2, the following items are to be added for ro-ro ships and other similar ships having bow doors (outer and inner doors), side shell doors and stern doors:

(1) verifying the doors and their surrounding structure;
(2) verifying the operation of doors and their dynamic devices;
(3) examination of sealing devices of doors, including airtight devices and related appliances;
(4) examination of locking and securing devices of doors;
(5) examination of local and/or remote controls of the locking/securing devices;
(6) examination of opening and closing of doors and associated securing attachments, such as wires, chains, track wheels, bars, guide plates and shackles;
(7) verifying tightness of doors;
(8) examination and testing of remote operating panel and associated indicator lights, television surveillance system, water leakage detectors, lighting and alarm system;
(9) examination of other necessary items and entries in logbook;
(10) verifying sewage disposal systems between inner and bow doors as well as in vehicle deck space;
(11) verifying that an approved operating and maintenance manual is available on board the ship.

1.2.3 Intermediate surveys

1.2.3.1 General requirements

(1) In addition to the applicable items specified for annual surveys in 1.2.2, intermediate surveys are to cover the structure of the ship to an extent sufficient for confirming good condition of the structure.

(2) Intermediate surveys are to be carried out in conjunction with surveys of the outside of the ship's bottom and related items in so far as practicable.

1.2.3.2 The scope of survey for all ships is to cover:

(1) Water ballast tanks

① For ships over 5 but less than or equal to 10 years of age, representative ballast tanks except for double bottom tanks are to be selected by the Surveyor for a general, internal examination. If there is no protective coating or any structural defect is found, the internal examination is to be extended to other water ballast tanks of the same type.

② For ships over 10 years of age, a general, internal examination of all salt water ballast tanks is to be carried out, and tightness test of inner bottom of cargo spaces within double bottom water ballast tanks is to be carried out.

(2) Cargo spaces

For ships over 15 years of age, at least 1 fore hold and 1 aft hold are to be selected by the Surveyor for internal examination.

(3) Thickness measurements

Where extensive areas of substantial corrosion are found, thickness measurements may be required and renewals are required where corrosion exceeds specified limits (see Appendix 1 of this Chapter).

(4) Examination of anchoring equipment

Partial test of slipping and hauling anchors by windlass.

(5) Fire-fighting equipment

Check of quantity and efficiency of medium of fixed fire-extinguishing arrangements, examination and testing of fire-extinguishing system.

1.2.3.3 In addition to the applicable requirements in 1.2.3.1 and 1.2.3.2, the following items are to be added for oil tankers (including ore/bulk/oil carriers and ore/oil carriers):

(1) The examination of weather deck is to include:

① cargo oil, crude oil washing, bunker, ballast, steam and vent piping systems, including vent masts and headers. Where deemed necessary by the Surveyor, pressure test or thickness measurement or both may be required for such piping systems.

(2) The examination of cargo piping is to include:

① cargo, crude oil washing, bunker, ballast, steam and vent piping systems on weather deck and in cargo pump room. If there is any doubt as to the condition of the piping, pressure test or thickness measurement or both may be required for such piping systems;

② cargo and stripping pumps including foundations, sealing, remote operation and quick-closing means;

③ confirmation that pressure gauges on cargo lines and level indicator systems are operational.

(3) Examination of cargo tanks

① For oil tankers of more than 10 years of age, the intermediate survey is also to include an internal examination of at least 3 cargo tanks located respectively at middle, port and starboard, if applicable.

② For oil tankers of more than 15 years of age, cargo tanks and ballast tanks may be pressure tested as appropriate.

1.2.4 Special surveys

1.2.4.1 General requirements

(1) Special surveys are to include examinations to an extent sufficient for confirming that the hull structure is in good condition and fit for the intended purpose.

(2) The examinations of the hull are to be supplemented by thickness measurements and testing as deemed necessary, to ensure that the structural integrity remains effective, and to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration.

(3) The owner is to provide the necessary facilities for a safe and efficient execution of the survey.

(4) The owner is to make preparations for survey according to the type and age of the ship and the items required for the special survey (including the extent of thickness measurements, necessary tests and compartments to be generally examined), and is to ensure:

① opening and cleaning of cargo holds, engine room, boiler room and other similar spaces including drainage channels, bilges and bilge wells, partial removal of wood sheathing (if required), derusting of steel plates and steel members;

② emptying, degassing and cleaning of double bottom tanks, topside tanks and deep tanks, derusting of rusted portions thereof and sufficient internal illumination therein.

(5) Special surveys are to include the items specified for intermediate and docking surveys in this Chapter. Docking surveys and relevant project surveys completed within the 15 months before the date due of special survey may be accepted as surveys simultaneous with special surveys.

1.2.4.2 The scope of survey for all ships is to cover:

(1) For all ships less than or equal to 5 years of age, the following items are to be additionally included:

① anchors and chain cables are to be pulled out, ranged and examined to verify their quantities and condition;

② all cargo holds, between decks, fore and aft peaks, engine and boiler rooms, cofferdams, decks and superstructures as well as other spaces are to be examined;

③ wood sheathing and other covering on deck and on inner bottom of holds are to be removed, as appropriate, to examine the steel structure thereunder;

④ examination of corners of large opening of holds, non-continuous structures, connection of stringer plates to sheer strakes;

⑤ thickness measurement of suspect areas, as required by the Surveyor;

⑥ masts, derrick posts, standing rigging, and derrick and windlass foundations are to be examined. Where extensive areas of wastage are found, thickness measurements are to be carried out and renewals or repairs are required where wastage exceeds allowable margins;

⑦ examination of hatch covers and coamings of holds:

a. an overall examination, according to the annual survey items listed in this Section, for determining wastage of steel plates, structural members, gaskets and locking devices. Where extensive areas of wastage are found, thickness measurements may be required and renewals are required where wastage exceeds allowable margins (see Appendix 1 of this Chapter). For hatch covers of the ships with reduced freeboard, particular attention is to be given to weathertightness and strength of hatch covers;

b. hatch covers of all holds are to be subject to hose testing or equivalent[①] for confirming watertightness of the covers;

⑧ internal examination of tanks:

a. in respect to peak tanks, double bottom tanks, topside tanks and hopper tanks used for water ballast, at least 1 representative tank of each type is to be selected for internal examination. Where extensive breakdown of protective coating is found, or where protective coating was not applied from time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the Surveyor;

b. overall examination of areas which are not coated or the coating of which has broken down, and no crack, excessive deformation and corrosion is allowed for structural skeleton, inner bottom, outer bottom, floors, girders and bulkheads. Attention is to be given to the plating of watertight bulkheads, floors, girders and the plating adjacent to heating coils in the fuel oil tank;

c. pipelines in tanks are to be examined, with attention being given to bent portions thereof. The wastage and technical condition of clamps, flanges, bolts, suctions and filters of pipelines and striking plate below all sounding pipes are also to be examined. Various valves of the pipelines are to be operationally tested, e.g. the collision bulkhead valve in fore peak. Attention is to be given to oil, water traces in cofferdams and if there are such traces, the cause of their existence is to be sought;

⑨ Tank test is to include:

a. boundaries of double-bottom tanks, deep tanks, water ballast tanks, and peak tanks used as liquid tanks and other tanks, including holds adapted for the carriage of salt water ballast, are to be tested with a head of liquid to the top of air pipes or to near the top of hatches for ballast/cargo holds;

b. boundaries of fuel oil, lube oil and fresh water tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil, lube oil and fresh water tanks may be specially considered based on a satisfactory external examination of the tank boundaries by the surveyor, and a confirmation that the pressure testing has been carried out according to the requirements with satisfactory results.

c. tanks are to be subject to hydraulic test after structural repairs affecting integrity.

(2) For ships over 5 but less than or equal to 10 years of age, in addition to the items listed in 1.2.4.2(1), the following items are to be included:

① all cargo holds, cofferdams, decks and superstructures are to be examined. In cases where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is inspected, tested by beating and chipping,

① Small access opening covers may be verified by chalking.

and found sound and adhering satisfactorily to the steel;

② examination of anchoring equipment:

a. the anchors and chain cables are to be pulled out, cleaned, ranged and examined, and the weight of anchors is to be checked. Chain cables are to be gauged and if any length of chain cables is found to be reduced in mean diameter[①] at its most worn part by more than 15% from its nominal diameter as required, it is to be renewal;

b. the chain locker and its discharge means, holdfasts, hawse pipes, chain stoppers and windlass are to be examined and pumping arrangements of the chain locker are to be tested;

③ comprehensive internal examination of all water ballast spaces. Upon satisfactory completion of the above external examination, hydraulic test and internal examination, the internal examination of other tanks may be dispensed with.

(3) For ships over 10 years of age, in addition to the items listed in 1.2.4.2(1) and (2), the following items are to be included:

① the condition of air pipes, sounding pipes, steam pipes and other pipelines is to be examined;

② wood sheathing or other coverings on decks and linings of side scuttle are to be partially removed to inspect the steel plating thereunder;

③ examination of spaces used for water ballast:

a. for ships over 10 but less than or equal to 15 years of age, in addition to the requirements in (2) ③, at least 1 of the fuel oil tanks fitted with oil heating means is to be internally examined. Upon satisfactory completion of the above external examination, hydraulic test and internal examination, the internal examination of other tanks may be dispensed with;

b. for ships over 15 but less than or equal to 20 years of age, in addition to the requirements in (2) ③a, at least 2 of the fuel oil tanks fitted with oil heating means are to be internally examined. Upon satisfactory completion of the above external examination, hydraulic test and internal examination, the internal examination of other tanks may be dispensed with;

c. for ships over 20 years of age, all tanks (including oil tanks, water tanks and voids) are to be subject to external examination, hydraulic test and internal examination.

④ At special survey No.3 and subsequent special surveys, structural downflooding ducts and structural ventilation ducts are to be internally examined.

(4) Extent of thickness measurement:

① Unless expressly provided otherwise, minimum requirements for thickness measurements of ships are given in Table 1.2.4.2(4)①.

Minimum Requirements for Thickness Measurements at Special Surveys of Ships Other Than Otherwise Expressly Provided Table 1.2.4.2(4)①)

Age ≤ 15	15 < Age ≤ 20	Age >20
a Suspect areas throughout the ship	a Suspect areas throughout the ship	a Suspect areas
	b Wind and water strakes at each side, and at least 2 points on each strake of strength deck beyond line of openings, within amidships 0.5L	b Wind and water strakes at each side, and at least 2 points on each strake of strength deck beyond line of openings, within amidships 0.5L
	c Shell and deck plating, longitudinal and transverse members in one transverse section, within amidships 0.5L	c Shell and deck plating, longitudinal and transverse members in two transverse sections of different holds, within amidships 0.5L; only 1 section to be measured for ships less than 100 m in length

② Thickness measurements are normally to be carried out by a CCS-approved company. The required thickness measurements, if not carried out by CCS itself, are to be witnessed by an attending Surveyor of CCS. The measurement is to be done by means of drilling or ultrasonic test equipment. The accuracy of the equipment is to be confirmed by the Surveyor as satisfactory. The test personnel are to hold a qualification certificate acceptable to CCS. A thickness measurement report is to be prepared to indicate measurement positions, thicknesses measured, corresponding initial thicknesses

① The mean diameter is half the value of the sum of the minimum diameter found in one cross section of the link and of the diameter measured in a perpendicular direction in the same cross section.

and maximum allowable diminution, and date of measurement, type of measurement equipment as well as expiry date of test, name of measurer and qualification. The surveyor is to review the final thickness measurement report and countersign on the cover. The surveyor may sample the measurement results.

③ Thickness measurements may be carried out at the commencement of the special survey, or the thickness measurement report prepared within 15 months before the due date of the special survey may be taken as the thickness measurement report of the special survey.

④ The Surveyor may extend the thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of thickness measurements is to be increased to determine areas of substantial corrosion. Table 1.2.4.2(4)② may be used as guidance for the additional thickness measurements. These extended thickness measurements are to be carried out before the survey is credited as completed.

Guidance for Additional Thickness Measurements in Way of Substantial Corrosion

Table 1.2.4.2(4)②

Structural member	Extent of measurement	Pattern of measurement
Plating	Suspect area and adjacent plates	5-point pattern over 1 square meter
Stiffeners	Suspect area	3 measurements each in line across web and flange

1.2.4.3 The additional survey scope of passenger ships and ro-ro passenger ships may cover:

(1) Lightweight survey for verification of light displacement and the change of longitudinal centre of gravity. Where the deviation of lightweight exceeds 2% or the deviation of longitudinal center of gravity exceeds 1% L[①], the inclining test is to be carried out again.

(2) The extent of thickness measurements of passenger ships and ro-ro passenger ships is given in Table 1.2.4.3(2).

Minimum Requirements for Thickness Measurements at Special Surveys of Passenger Ships, Ro-Ro Passenger Ships

Table 1.2.4.3(2)

Age ≤ 5	5 < Age ≤ 20	10 < Age ≤ 15	Age >15
a Suspect areas throughout the ship	a Suspect areas throughout the ship	a Suspect areas throughout the ship	a Suspect areas throughout the ship
	b One transverse section of deck within amidships 0.5L	b Two transverse sections of deck of different ballast tanks, within amidships 0.5L	b Transverse sections of deck of at least three ballast tanks, within amidships 0.5L
	c Wind and water strakes	c Internals in fore peak ballast tank	c Internals in fore and aft peak ballast tanks
		d Wind and water strakes	d All exposed main deck and vehicle deck, full length
			e Representative exposed superstructure deck
			f All wind and water strakes, port and starboard, full length
			g All keel plates, full length. Also, additional bottom plates in way of aft end of tanks and machinery space
			h Bow, stern and side shell doors used as vehicle ramps

1.2.4.4 Supplementary requirements for oil tankers (including double hull oil carriers):

(1) General requirements:

① Items of special surveys of “all ships” in this chapter are to be included.

② Cargo piping on deck, including crude oil washing (COW) piping, cargo and ballast piping within all cargo tanks, ballast tanks, including double bottom tanks, pump rooms, pipe tunnels, cofferdams and

① L refers to the length defined by regulation 3 of the Load Line Convention.

void spaces bounding cargo tanks are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces, and Surveyors are to be advised on all occasions when this piping, including valves and fittings are open during repair periods and can be examined internally

③ A survey in dry dock is to be a part of the special survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions (lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.) of the cargo tanks and ballast tanks are to be carried out in accordance with the applicable requirements for special surveys, if not already performed.

(2) Tank protection:

① Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined.

② A ballast tank is to be examined at subsequent annual intervals where:

a. a hard protective coating has not been applied from the time of construction, or

b. a soft or semi-hard coating has been applied, or

c. substantial corrosion is found within the tank, or

d. the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurements are to be carried out as deemed necessary by the Surveyor.

(3) Extent of overall surveys

① For oil carriers (including double hull oil carriers) of 12 years and more in age, an overall survey of all tanks and spaces is to be carried out at each special survey.

② The Surveyor may carry out the close-up survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:

a. in particular, tanks having structural arrangements or details which have suffered defects in similar tanks or on similar ships according to available information;

b. in tanks which have structures approved with reduced scantlings due to an approved corrosion control system.

(4) Scope of thickness measurement

① At special surveys, the minimum requirements for thickness measurement are listed in Table 1.2.4.4(4) ①.

② The increased extent of thickness measurements for substantial corrosion is to be in accordance with the relevant requirements for "all ships". These extended thickness measurements are to be carried out before the survey is credited as complete. Suspect areas identified at previous surveys are to be examined; Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

③ The Surveyor may further extend the thickness measurements as deemed necessary.

④ For areas in tanks where hard protective coatings are found in a GOOD condition, the extent of thickness measurements according to Table 1.2.4.4(4) ① may be specially considered.

⑤ Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

⑥ In cases where two or three sections are to be measured, at least one is to include a ballast tank within 0.5*L* amidships.

Minimum Requirements for Thickness Measurements at Special Surveys of Oil Tankers (including double hull oil tankers), Ore/ Oil Ships, etc.

Table 1.2.4.4(4) ①

Age ≤ 10	10 < Age ≤ 15	Age > 15
1 Suspect areas throughout the ship	1 Suspect areas throughout the ship	1 Suspect areas throughout the ship
	2 In cargo areas: a) each deck plate; b) two transverse sections; c) all wind and water strakes	2 In cargo areas: a) each deck plate; b) three transverse sections; c) each bottom plate
	3 Selected wind and water strakes outside the cargo area	3 For combination carriers, all hatch covers and hatch coamings (plate and stiffener) of all cargo holds

Age ≤ 10	10 < Age ≤ 15	Age > 15
		4 Internals in forepeak and afterpeak ballast tanks
		5 All exposed main deck full length
		6 Representative exposed superstructure deck (poop, bridge, and forecastle deck)
		7 Lowest strake and centre strake in way of all transverse bulkheads in cargo spaces together with internals in way
		8 All wind- and water strakes, port and starboard, full length
		9 All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks
		10 Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor

(5) Extent of tank testing

① The minimum requirements for ballast tank testing are given in ③ of this paragraph and Table 1.2.4.4(5)①; the minimum requirements for cargo tank testing are given in ④ of this paragraph and Table 1.2.4.4(5)①. Cargo tank testing carried out by the ship's crew under the direction of the Master may be accepted by the Surveyor provided the following conditions are complied with:

a. a tank testing procedure has been submitted by the Owner and reviewed by CCS prior to the testing being carried out;

b. there is no record of leakage, distortion or substantial corrosion that would affect the structural integrity of the tank;

c. the cargo tank testing has been satisfactorily carried out within a special survey window not more than 3 months prior to the date of the survey on which the overall or close-up survey is completed;

d. the satisfactory results of the testing is recorded in the ship's logbook;

e. the internal and external condition of the tanks and associated structure are found satisfactory by the Surveyor at the time of the overall and close-up survey.

② The Surveyor may extend the tank testing as deemed necessary.

③ Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

④ Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions.

⑤ For double hull oil tankers, the testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

⑥ Tanks may be pressure tested while the ship is afloat provided that their internal examination is also carried out while the ship is afloat.

Minimum Requirements for Tank Testing at Special Surveys of Oil Tankers (including double hull oil tankers), Ore/ Oil Ships, etc.

Table 1.2.4.4(5) ①

Special Survey No.1 Age ≤ 5	Special Survey No.2 and Subsequent Age > 5
1. All ballast tank boundaries 2. Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump rooms or cofferdams	1. All ballast tank boundaries 2. All cargo tank bulkheads

(6) Examination of emergency towing arrangements (if fitted):

① Confirming that strong points, towing pennants, towing connection, pick-up gear, chafing gear and mark buoys are in good and efficient condition.

② Verifying that wear of towing pennant, pick-up gear and chafing gear is under permissible limits.

③ Verifying that fairleads are maintained in a normal condition as required.

(7) The availability and normal maintenance of bow and stern loading/unloading arrangements (if fitted) are to be verified.

1.2.4.5 Additional requirements for bulk carriers (including double skin bulk carriers):

(1) General requirements:

① Items of special surveys of "all ships" in this Chapter are to be included;

② All piping systems (or ballast piping systems in the case of double skin bulk carriers) within the above spaces are to be examined and operationally tested in working condition to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.

③ The survey extent of ballast tanks converted to void spaces is to be specially considered in relation to the requirements for ballast tanks.

④ A survey in dry dock is to be a part of the special survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and ballast tanks (Note: Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line) are to be carried out in accordance with the applicable requirements for special surveys, if not already performed.

(2) Tank protection:

① Where provided, the condition of the corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom tanks, where a hard protective coating is found in POOR condition and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the Surveyor.

② When such breakdown of hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

③ Where a hard protective coating is provided in cargo holds also used as salt water ballast and is found in GOOD condition, the extent of close-up surveys and thickness measurements may be specially considered.

(3) Hatch covers and coamings:

① Checking of the satisfactory operation of all mechanically operated hatch covers is to be made, including:

a. stowage and securing in open condition;

b. proper fit and efficiency of sealing in closed condition;

c. operational testing of hydraulic and power components, wires, chains, and link drives.

② Checking the effectiveness of sealing arrangements of all hatch covers by hose testing or equivalent.

③ Thickness measurement of the hatch cover and coaming plating and stiffeners is to be carried out for bulk carriers and double skin bulk carriers as given in Table 1.2.4.5(5)①.

(4) Extent of overall surveys

① For bulk carriers (including double skin bulk carriers) of 18 years and over in age, an overall survey of all tanks and spaces is to be carried out at each special survey.

② The Surveyor may carry out the close-up survey as deemed necessary taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.

(5) Extent of thickness measurement

① The minimum requirements for thickness measurement at special survey are given in Table 1.2.4.5(5)① for bulk carriers and double skin bulk carriers.

② Extended measurements for areas with substantial corrosion are in accordance with the relevant provisions for "all ships". These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

③ The Surveyor may further extend the thickness measurements as deemed necessary.

④ For areas in tanks where hard protective coatings are found in a GOOD condition, the extent of thickness measurement according to Table 1.2.4.5(5) ① may be specially considered.

⑤ Transverse sections are to be chosen where largest reductions are suspected to occur or are revealed from deck plating measurements.

Minimum Requirements for Thickness Measurements at Hull Special Surveys of Bulk Carriers (including double skin bulk carriers)

Table 1.2.4.5(5) ①

Age ⩽ 10	10 < Age ⩽ 15	Age > 15
1 Suspect areas throughout the ship	1 Suspect areas throughout the ship	1 Suspect areas throughout the ship
	2 Within the cargo length: a. Each deck plate outside line of cargo hatch openings. b. Two transverse sections, one in the amidship area, outside line of cargo hatch opening. c. All wind and water strakes	2 Within the cargo length: a. Each deck plate outside line of cargo hatch openings. b. Three transverse sections, one in the amidship area, outside line of cargo hatch opening. c. Each bottom plate
	3 Selected wind and water strakes outside the cargo length area	3 All hatch covers and hatch coamings (plate and stiffener) of all cargo holds
		4 Internals in forepeak and afterpeak ballast tanks
		5 All exposed main deck full length
		6 Representative exposed superstructure deck (poop, bridge, and forecastle deck)
		7 Lowest strake and centre strake in way of all transverse bulkheads in cargo spaces together with internals in way
		8 All wind- and water strakes, port and starboard, full length
		9 All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks
		10 Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor

(6) Extent of tank testing

① All boundaries of water ballast tanks, deep tanks and cargo holds used for water ballast within the cargo length area are to be pressure tested. For fuel oil tanks, only representative tanks are to be pressure tested.

② The Surveyor may extend the tank testing as deemed necessary.

③ Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

④ Boundaries of holds jointly used as sea water ballast are to be tested with a head of liquid to near to the top of hatches.

⑤ The testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

1.2.4.6 Additional requirements for chemical tankers:

(1) General requirements:

① Items of special surveys of “all ships” in this Chapter are to be included.

② Cargo piping on deck and cargo and ballast piping within the above tanks and spaces are to be examined and operationally tested to working pressure to attending Surveyor’s satisfaction to ensure that tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces, and Surveyors are to be

advised on all occasions when this piping, including valves and fittings are open during repair periods and can be examined internally.

③ A survey in dry dock is to be a part of the special survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks (Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.) are to be carried out in accordance with the applicable requirements for special surveys, if not already performed.

(2) Tank protection:

① Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined. A ballast tank is to be examined at subsequent annual intervals where:

a. a hard protective coating has not been applied from the time of construction, or
b. a soft or semi-hard coating has been applied, or
c. substantial corrosion is found within the tank, or
d. the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurements are to be carried out as deemed necessary by the Surveyor.

(3) Extent of overall surveys

① For chemical tankers of 12 years and over in age, an overall survey of all tanks and spaces is to be carried out at each special survey. The survey of stainless steel tanks may be carried out as an overall survey supplemented by close-up survey as deemed necessary by the surveyor..

② The Surveyor may extend the close-up survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:

a. in particular, tanks having structural arrangements or details which have suffered defects in similar tanks or on similar ships according to available information;
b. in tanks which have structures approved with reduced scantlings due to an approved corrosion control system.

(4) Extent of thickness measurement

① The minimum requirements for thickness measurement are given in Table 1.2.4.6(4) ①. Thickness measurement of stainless steel hull structure and piping may be waived, except for clad steel plating.

Minimum Requirements for Thickness Measurements at Special Surveys of Chemical Tankers

Table 1.2.4.6(4) ①

Age ⩽ 10	10 < Age ⩽ 15	Age > 15
1 Suspect areas throughout the ship	1 Suspect areas throughout the ship	1 Suspect areas throughout the ship
	2 Within the cargo area: a) each deck plate; b) two transverse sections; c) all wind and water strakes	2 Within the cargo area: a) each deck plate; b) three transverse sections; c) each bottom plate
	3 Selected wind and water strakes outside the cargo area	3 Internals in forepeak and afterpeak ballast tanks
		4 All exposed main deck full length
		5 Representative exposed superstructure deck (poop, bridge, and forecastle deck)
		6 Lowest strake and centre strake in way of all transverse bulkheads in cargo spaces together with internals in way
		7 All wind- and water strakes, port and starboard, full length
		8 All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks
		9 Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor

② Extended measurements for areas with substantial corrosion are in accordance with the relevant provisions for “all ships”. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

③ The Surveyor may further extend the thickness measurements as deemed necessary.

④ For areas in tanks where hard protective coatings are found in a GOOD condition, the extent of thickness measurement according to Table 1.2.4.6(4) ① may be specially considered.

⑤ Transverse sections are to be chosen where largest reductions are suspected to occur or are revealed from deck plating measurements.

⑥ In cases where two or three sections are to be measured, at least one is to include a ballast tank within 0.5*L* amidships.

(5) Extent of tank testing

① The minimum requirements for ballast tank testing are given in ③ of this paragraph and Table 1.2.4.6(5)①; the minimum requirements for cargo tank testing are given in ④ of this paragraph and Table 1.2.4.6(5)①. Cargo tank testing carried out by the ship’s crew under the direction of the Master may be accepted by the Surveyor provided the following conditions are complied with:

a. a tank testing procedure has been submitted by the Owner and reviewed by CCS prior to the testing being carried out;

b. there is no record of leakage, distortion or substantial corrosion that would affect the structural integrity of the tank;

c. the tank testing has been satisfactorily carried out within a special survey window not more than 3 months prior to the date of the survey on which the overall or close-up survey is completed;

d. the satisfactory results of the testing is recorded in the ship’s logbook;

e. the internal and external condition of the tanks and associated structure are found satisfactory by the Surveyor at the time of the overall and close-up survey.

② The Surveyor may extend the tank testing as deemed necessary.

③ Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

④ Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions.

⑤ The testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

⑥ Tanks may be pressure tested while the ship is afloat provided that their internal examination is also carried out while the ship is afloat.

Minimum Requirements to Tank Testing at Special Survey of Chemical Tankers

Table 1.2.4.6(5) ①

Special Survey No.1 Age ≤ 5	Special Survey No.2 and Subsequent Age > 5
1. All ballast tank boundaries. 2. Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump rooms or cofferdams	1. All ballast tank boundaries. 2. All cargo tank bulkheads

(6) Chemical tankers over 10 years in age

① Selected steel cargo pipes outside cargo tanks and ballast pipes passing through cargo tanks are to be:

a. thickness measured at random or selected pipe lengths to be opened for internal inspection;

b. pressure tested to the maximum working pressure.

Special attention is to be given to cargo/slop discharge piping through ballast tanks and void spaces.

1.2.4.7 Additional thickness measurement requirements for ships of 35 years and over in age:

(1) Ship length L≥65m: measure 3 transverse sections, among which one is within amidships 0.5L; ship length L＜65m: measure 2 transverse sections;

(2) Internals in forepeak and afterpeak tanks;

(3) All exposed main deck full length;

(4) Representative exposed superstructure deck;

(5) All wind- and water strakes, port and starboard, full length;

(6) All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks;
(7) Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor.

Section 3 SURVEYS OF MACHINERY

1.3.1 General provisions

1.3.1.1 Unless provided otherwise, the requirements of this Section apply to machinery surveys of all ships after construction.
1.3.1.2 For ships with machinery automation notations, the machinery installations are to comply with the requirements of 5.9.4.4, Chapter 5, PART ONE of the Rules.
1.3.1.3 The owner or manager of the ship is to make preparations for survey according to the type and items of survey, e.g. cleaning of parts to be dismantled, availability of drawings, information, certificates and reports needed for survey, safe access to survey location and safety facilities.
1.3.1.4 Machinery surveys are generally to be carried out in conjunction with corresponding hull surveys.

1.3.2 Annual surveys

1.3.2.1 General requirements
(1) Machineries and boilers are normally not required to be opened up during annual surveys, and sufficient items may be examined in working condition. Locations of machinery and shafting are to be examined to confirm their satisfactory condition, including interview of related crew members on service of main machineries and if necessary, check of engine room logbook and measurement records, etc.
1.3.2.2 Survey items
(1) General examination of machinery and boiler spaces, in particular examining the means for the operation of the main and auxiliary machinery essential for the propulsion and the safety of the ship, including, when applicable, the means of remotely controlling the propulsion machinery from the navigating bridge (including the control, monitoring, reporting, alert and safety actions) and the arrangements to operate the main and other machinery from a machinery control room, confirming that there is no existence of any fire and explosion hazards, particularly in way of inner bottom and bilge wells and that moving parts and hot surfaces will not injure personnel.
(2) Verification that escape routes in machinery spaces are free from obstruction.
(3) Testing of the means of communication between the navigation bridge and machinery control rooms, steering gear compartment and where fitted, emergency steering positions.
(4) Examination of the bilge pumping systems and bilge wells, including operation of pumps and where fitted, level alarms, as far as practicable; operational testing of emergency bilge pumping systems of passenger ships.
(5) External examination of all accessible parts of the main and auxiliary steering gears.
(6) Action test of remote closing valves of fuel oil and lubricating oil tanks.
(7) Performance test and closing and shutoff tests are to be carried out from outside the machinery space for fans, remote oil pump cutoff devices in the engine room.
(8) General examination of dynamic positioning system or side thrust system onboard.
(9) Confirmation of implementation of planned maintenance scheme, if applicable.
1.3.2.3 For oil tankers, in addition to the requirements of 1.3.2.2, cargo oil pump room, pump room bilge system, ventilation system of cargo oil pump room and associated equipment are to be generally inspected and safety alarm system, if fitted, operationally tested.

1.3.3 Intermediate surveys

1.3.3.1 Survey items
(1) The items in 1.3.2.2 of this Chapter applicable to the ship.
(2) Prime movers of driving generators are to be operationally tested under working conditions to verify that they are in a good working condition.
(3) When the ship is in dock, all openings and valves of machinery spaces and pump rooms at the ship's side together with their fasteners connected to the shell plating are to be examined.

1.3.4 Special surveys

1.3.4.1 Survey items

(1) The items in 1.3.3.1 of this Chapter applicable to the ship.
(2) When the ship is in dock, all sea connection openings, including sewage discharges and other overboard discharges, together with valves and fasteners on the shell plating, are to be examined internally and externally.
(3) Pumps and pumping systems, including valves, cocks, pipes and filters, are to be examined. Nonmetallic hose expansion pieces of the main circulating system are to be examined. Bilge system is to be confirmed in good condition and if deemed necessary, other systems are to be operationally tested.
(4) Thrust shaft and intermediate shaft and their bearings are to be opened up for examination.
(5) Foundations (including foundation bolts and packing blocks) of main and auxiliary engines are to be examined.
(6) All shafts (excluding screwshaft, tubeshaft, directional propeller and water jet propulsion arrangements) and bearings of the main propulsion system are to be examined. The lower half of the bearings may be sampled if crankshaft deflection of the main engine and wear of bearings are found in order.
(7) Heat exchangers and other non-burner pressure vessels with working pressures over 0.7 MPa are to be opened up and examined and where deemed necessary, pressure tested, and associated relief valves are to be checked; the evaporator of the casing need not be opened up and acceptance may be based on satisfactory external examination and operation record review.
(8) Air compressors, air receivers with associated pipes are to be examined; if the internal examination of air receivers is impracticable, this may be replaced by hydraulic test; the working condition of relief valves and safety devices is to be examined.
(9) Examination of steering arrangements, including operational test and check of relief valve setting, is to be carried out. A hydraulic test may be performed by using the power of the steering system to set the relief valve.
(10) Where necessary, gearboxes are to be opened up and examined to confirm the condition of pinions and wheels, shafts, bearings, and lubricating system. For conventional gear units of 1,120 kW and below and all epicyclic gear units, where the shipowner can provide satisfactory operation records, then they may not necessarily be opened for examination.
(11) Examination of windlass, including operational check, check of the brake and testing of safety devices, is to be carried out.
(12) For diesel engines including main and auxiliary engines, the following parts (if fitted) are to be disassembled or opened up for examination:

① cylinders, cylinder liners, cylinder covers, valves and their transmitting gear;
② high pressure oil pumps, scavenging pumps and superchargers;
③ pistons, crossheads, connecting rods;
④ crankshafts including crankpins and bearings, main journals and associated bearings;
⑤ reverse gears, air compressors and intercoolers;
⑥ retightening of stay bolts as necessary, tightness check of bolts of frames and entablatures;
⑦ measurement of crankshaft deflection of engines having a speed of 300 r/m or below;
⑧ examination of all parts. However, those parts which need not be re-examined in 15 months may be specially considered;
⑨ the survey of diesel engines with bores of 300 mm or below may be replaced by review of maintenance records, including records of lubrication servicing, provided that such engines are maintained according to the manufacturer’s scheduled maintenance program;
⑩ essential components of the oil fuel system of diesel engines, including oil separator, oil fuel servicing pump and heater are to be opened up and examined.

(13) Electric propulsion plant: see relevant requirements of Section 4 of this Chapter.
(14) For steam turbines including main and auxiliary turbines, the following parts are to be opened out for examination:

① rotor with blading and shrouding and bearings;
② nozzles, stationary blading, interstage packing and gland seals with oil barriers;
③ bleed controls and foundation expansion arrangements;
④ throttle valves are to be operationally tested and opened up for examination as deemed necessary.

In general, lifting of the main propulsion turbine casing may be waived for new-installed ones within 5 years, provided the turbines are fitted with rotor position indicators and vibration indicators of an approved type, as well as steam pressure measuring equipment at appropriate locations in the steam flow path. Rotor bearings, thrust bearings and the flexible coupling are to be opened and examined. The low pressure turbine

exhaust trunk is to be opened for examination of the last row of low pressure and astern wheels. Turbine operating records are to be reviewed. The arrangements for changeover in case of emergency operation of the plant are to be readily available. The turbines are to be operationally tested.
Turbine casings are to be lifted for confirming the effectiveness of the maintenance arrangement at the special survey after 10 years. However, the lifting of main propulsion turbine casings may be waived at the special survey after 15 years and subsequent special surveys, provided that:

a. an approved preventative maintenance arrangement has been established, including vibration monitoring, lubricating oil analysis and rotor position checks;
b. the rotor journal bearings, thrust bearings and flexible couplings are opened up for examination, the low-pressure turbine exhaust trunk is opened for examination of the last row of low pressure and astern wheels;
c. the turbine operating records are reviewed and all considered satisfactory by the Surveyor, at least in compliance with the manufacturere recommendations;
d. the turbines are to be operationally tested.

(15) For gas turbines, the followings are to be opened out for examination:

① Gas turbines are to be opened up and maintained in accordance with the manufacturer's recommendations. For each type of turbines, the owner is to submit maintenance schedules for checking combustion, hot-gas-path and other items as specified in proposed service intervals.

② For units in continuous service, at least one hot-gas-path examination is to be scheduled each survey period, including examining turbine rotors, nozzles (fixed blading), combustors, inlet casings, exhaust casings, air control valves and protective apparatus. Other parts and associated equipment are to be examined as necessary.

③ Opening of compressor sections can be scheduled in conjunction with other items, provided that examination of the blades visible from the inlet plenum during the hot-gas-path examination reveals no evidence of defects.

④ The required examinations of auxiliary gas turbine units, at least once each period, are to be based on manufacturer's recommendations, as appropriate for the actual operating hours and conditions, together with an operation test including protective apparatus.
Where units are arranged such that the unit is removed from the vessel and dismantled at another facility, the internal examination may be carried out at the facility. The reinstallation is to be carried out to the satisfaction of the Surveyor.
Upon reassembly/reinstallation, all fuel lines, lube oil piping, the unit itself and exhaust system are to be checked under full speed operational conditions for leakage. All shielding and fuel oil double wall piping is to be examined.

⑤ Cylinders, pistons, end covers, valves and valve gear, pumps and fittings, synchronizing and control gear, cooling system, explosion relief devices including bypass arrangements of free piston gas generators are to be opened out and examined.

⑥ Air compressors of gas generator in combustion chamber, including rotors and casings, combustion chambers, burners, intercoolers, heat exchangers, gas and air piping of gas turbines are to be opened out and examined.

1.3.4.2 As part of the Special Survey of Machinery, a dock trial is to be carried out to attending Surveyors' satisfaction to confirm satisfactory operation of main and auxiliary machinery. If significant repairs are carried out to main or auxiliary machinery or steering gear, consideration should be given to carrying out a sea trial to attending Surveyors' satisfaction.
1.3.4.3 If the significant repairs as stated in 1.3.4.2, is considered by CCS to have any impact on response characteristics of the propulsion systems, then the scope of sea trial is also to include a test plan for astern response characteristics based on those required for such an equipment or systems when fitted to the new ship. Refer to 1.2.4, Chapter 1, PART THREE of the Rules for astern testing requirements.
The tests are to demonstrate the satisfactory operation of the equipment or system under realistic service conditions at least over the manoeuvring range of the propulsion plant, for both ahead and astern directions. Depending on the actual extent of the repair, CCS may accept a reduction of the test plan.

1.3.5 Surveys of propeller shafts and tube shafts

1.3.5.1 Relevant requirements for surveys of propeller shafts and tube shafts are given in Section 12, Chapter 5, PART ONE of the rules.

Section 4 SURVEYS OF ELECTRICAL INSTALLATIONS

1.4.1 General requirements

1.4.1.1 This Section applies to surveys of electrical installations for all ships after construction.

1.4.2 Annual surveys

1.4.2.1 Survey items

(1) Operational test of the means of communication between the navigation bridge and machinery control stations, steering gear compartment and where fitted, emergency steering positions.

(2) General examination of the electrical equipment and cables forming the main and emergency electrical installations in working condition, so far as practicable.

(3) Confirming that main power source, emergency power source (including the standby power source equivalent to the emergency power source), the electrical equipment essential to safety in an emergency, e.g. emergency lighting, general emergency alarm system, are in good working condition. Where these power sources are automatically controlled, the test is to be carried out in automatic mode.

(4) Examination of bonding straps for the control of static electricity and earthing arrangements where fitted.

(5) General examination of control systems and associated machinery of electric propulsion plant, dynamic positioning system and/or auxiliary thrusters of position-keeping mooring system.

(6) Confirming that motors driving the pumps serving main propulsion machinery and auxiliary machineries together with controls are in good condition.

(7) Confirming voyage repairs made by crew.

(8) Confirming that the electrical equipment installed in areas where flammable gas or vapour and/or flammable dust may accumulate is in good condition and well maintained.

(9) Confirming that no potential sources of ignition (e.g. no loose gear, excessive bilge oil or oily vapour) exist in cargo oil pump rooms of oil tankers.

(10) Where the electrical distribution system on board a ship includes harmonic filters, the total harmonic distortion (THD) recorded onboard the ship is to be checked.

1.4.3 Intermediate surveys

1.4.3.1 Survey items

(1) The applicable items in 1.4.2 of this Chapter;

(2) For oil tankers:

① electrical equipment an cables in dangerous zones are to be examined to confirm that there are no defective, improperly installed equipment and dead end wiring;

② insulation resistance of electrical circuits terminated in or passing through dangerous zones is to be tested (see Appendix 2 of this Chapter). Where spaces are not gas-freed, the existing record of testing may be accepted.

1.4.4 Special surveys

1.4.4.1 General requirements

(1) The owner is to provide the necessary conditions and safety facilities for the survey, e.g. disassembling or opening and cleaning, safe access to and illumination for survey items.

1.4.4.2 Survey and test items

(1) The applicable items in 1.4.3 of this Chapter.

(2) Insulation resistance of electrical equipment and circuits are to be tested.

(3) The fittings on the main switchboard, emergency switchboard (including emergency battery charging and discharging panel), section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

(4) Circuit breakers of generators are to be tested, so far as possible, to confirm that protective devices including preferential trip relay (if fitted) are in good working condition.

(5) Cables are to be examined without damaging their fasteners or protective casings so far as possible, except when they are to be opened up as deemed necessary upon examination or test results of (2).

(6) Motors and their auxiliary control and switch gear for essential services are to be examined, and tested operationally in working condition so far as possible. All generators and steering motors are to be examined and tested in working condition. However, they need not be tested at the rated load test or simultaneously.

(7) Where transformers of essential power supply are of wet type, the owner is to submit the liquid sample to an authoritative institution for testing its breakdown voltage, acidity and moisture. The report of test results is to be submitted to the Surveyor.
(8) Emergency power source (including the standby power source equivalent to the emergency power source) together with its automatic control gear and associated circuits are to be tested.
(9) Emergency lighting, temporary emergency lighting, supplementary emergency lighting (if fitted) and general emergency alarm system are to be tested in so far as practicable.
(10) For electrically propelled ships, the propulsion motors, generators, cables and all ancillary electrical equipment, exciters and associated ventilators (including coolers) are to be examined and their insulation resistance relative to earth tested. Particular attention is to be given to examination of windings, commutators and slip rings. Protective devices and alarms are to be operationally examined as far as possible. Where insulating oil is used, the test is to comply with provisions of (7). Interlocks fitted to prevent unsafe operation or unauthorized use are to be checked for normal function.
(11) The electrical equipment and cables installed in areas possibly containing flammable gas and vapour and/or flammable dust are to be examined as follows:

① the integrity of explosion-proof electrical equipment will not be damaged due to corrosion, fallen bolts, etc.;
② no excessive dust accumulation exists in or on dust explosion proof equipment;
③ cables are to be examined so far as possible to confirm that they are perfectly sheathed and armoured and that their fasteners are in good condition;
④ bonding straps for the control of static electricity are to be tested to confirm their effectiveness;
⑤ alarms and interlocks corresponding to spaces under pressurized protection and their pressurizing equipment are to be tested to confirm their proper working condition.

Section 5 INITIAL CLASSIFICATION SURVEY

1.5.1 Initial classification of existing ships

1.5.1.1 General requirements
(1) For the purpose of this Section, existing ships include the following ships in service:

① ships which have been surveyed by classification societies and other survey organizations accepted by CCS;
② ships which have been surveyed by other classification societies not accepted by CCS;
③ ships which have been surveyed by CCS.

(2) The classification stated in this paragraph covers also class notations.
1.5.1.2 Initial classification of ships which have been surveyed by classification societies and other survey organizations accepted by CCS
(1) Initial classification of ships under construction

① Submission of plans
CCS requirements for surveys of ships under construction are to be complied with, i.e. all plans, calculations and other technical documents for construction (approved by other survey organizations according to their rules) are to be submitted to CCS for check. The construction of these ships may, in general, continue in accordance with the approved plans.
② In addition to the normal items for newbuildings, the following items are to be checked (unless they have been checked and relevant records made by classification societies accepted by CCS):
a. the shipyard is to submit records of the checked or confirmed items for review;
b. the Surveyor is to carry out an overall survey of the compartments, spaces and installations which have been inspected and confirm that materials, scantlings, workmanship and arrangements are in compliance with the approved plans;
c. the information on the attended inspections and tests of compartments is to be accepted when such information is confirmed as authentic. When some of the compartments are to be tested again, e.g. functional tests during sea trial and in particular the inspection and testing of cargo holds and ballast tanks, the new tests are to be attended;
d. the records of NDTs are to be checked and sampled. Any NDT is to comply with the rule provisions;
e. the materials (including forgings and castings) used for construction, and manufacturing and

testing of anchors and anchor chains are to meet the requirements of the accepted standards;

f. main propulsion machinery and essential auxiliaries are to be manufactured, installed and tested in accordance with CCS rules or the standards acceptable to CCS;

g. the anchors and anchor chains are to be inspected and certified in accordance with CCS rules, if they have not been delivered to the shipyard;

h. all outstanding recommendations are to be completed.

(2) Initial classification of ships of which the construction has been completed but which have not been put into service

① Submission of plans

a. The owner applying for an initial survey of a ship which has been certified by another survey organization, is to submit at least one copy each of the plans, calculations and other technical documents to CCS for check:

(a) general arrangement;
(b) capacity plan;
(c) hydrostatic curves;
(d) loading manual (if required);
(e) transverse midship section;
(f) construction profile, including longitudinal section, decks, inner bottom structure, superstructure and upper deck structure;
(g) transverse bulkhead;
(h) shell expansion;
(i) rudder and rudder stock;
(j) hatch covers;
(k) engine room arrangement;
(l) intermediate shaft, thrust shaft and propeller shaft;
(m) propeller;
(n) main engine, propulsion machinery and clutch systems (or manufacturer, model and specifications);
(o) in addition, main boiler, superheater and economizer (or manufacturer, model and specifications) and steam piping for steam turbine ships;
(p) bilge and ballast piping diagram;
(q) electrical system;
(r) steering gear piping system and arrangement, manufacturer and model;
(s) torsional vibration calculations;
(t) elastic coupling of propulsion shafting and/or shaft torque limiter (or manufacturer, model and specifications) additionally required for ships with ice class notation;
(u) additional plans required for oil tankers:
i) pumping arrangement at the forward and after ends and drainage of cofferdams and pump rooms;
(v) additional plans required for periodically unattended machinery spaces:
i) measuring instruments and checklist of alarms;
ii) arrangement of fixed fire detection and alarm system;
iii) diagram of automatic safety function tests;
(w) any other information requested by the Flag State Administration;
(x) calculations of damage stability, if required;
(y) approval documents of alternative design and arrangement, if any.

b. For ships which have not been certified by other survey organizations, plans and information are to be submitted in accordance with 1.5.1.2(2)①a.

② Scope of surveys

a. The scope of surveys and examinations of ships which have been certified by other survey organizations are to cover at least the following (unless they have been checked and relevant records made by other survey organizations):

(a) main engines and essential auxiliary machineries, including steering gear, are to be examined under working conditions, and essential automatic controls and alarms are to be subject to functional test;
(b) main boilers, auxiliary boilers for essential services, economizers and steam generators are to be internally examined, safety valves and main attachments opened up and examined;
(c) if the propeller shaft is fitted with oil seal, the aft end and bearings of the shaft are to be

examined;

(d) pumping systems, in particular bilge pumps, are to be tested;

(e) insulation resistance of electrical installations is to be tested;

(f) when the duration exceeds 12 months from the date of the ship's launching, a docking survey is to be carried out;

(g) essential equipment is to be subject to function test and the machinery opened for examination when the Surveyor considers it necessary;

(h) compliance of all pressure vessels with the drawings and certificates provided is to be confirmed.

b. The scope of surveys and examinations of ships which have not been certified by classification societies accepted by CCS are to cover at least the following:

(a) the scope of surveys and examinations is to be in accordance with 1.5.1.2(2)②a;

(b) the owner is to submit records and reports related to surveys, testing and measurement during original construction as well as certificates, test information, etc. for main marine products;

(c) the Surveyors are to examine main structural dimensions to confirm compliance with relevant provisions of the Regulations;

(d) if necessary, test and/or survey for confirmation are to be carried out.

(3) Initial classification of ships which have been put into service

① Submission of plans

a. When applying for an initial survey, the owner is to submit at least one copy each of the plans, calculations and other technical documents specified in 1.5.1.2(2) ① a to CCS for check. However, the submission of torsional vibration calculations may be exempted for ships over 2 years of age.

b. Where the plans and documents can not be submitted according to (a) above, CCS may accept other relevant information as equivalent.

c. Where the information on stability including intact, subdivision and damage stability and the loading manual have been approved by the Flag State Administration or an organization authorized by it and compliance of the arrangement on board the ship with the approved information has been confirmed by CCS, CCS may accept the approved information as the basis for assigning class or issuing certificates.

② Scope of surveys

a. In addition to the items corresponding to ship's age and losing class/survey organizations status, the scope of surveys is to cover the following:

(a) Hull:

a) for ships of less than 5 years of age, an annual survey is to be carried out;

b) for ships 5 years and over but less than 10 years of age, an annual survey and an inspection of an appropriate number of representative ballast tanks, including fore peak tank, after peak tank, top side tank, bottom side tank and double bottom tank, are to be carried out;

c) for ships of 10 years and over but less than 20 years of age, an annual survey and an inspection of an appropriate number of representative ballast tanks and cargo spaces are to be carried out;

d) for ships of 15 years and over but less than 20 years of age, the requirements for special or intermediate surveys (whichever is due) are to be complied with;

e) for ships of 20 years and over, the requirements for special surveys are to be complied with;

f) the latest dry-dock survey report of the losing classification society/survey organization may be accepted if found in compliance with CCS rules upon review.

(b) Machinery (including electrical installations):

a) for ships of less than 10 years of age, an annual survey is to be carried out;

b) for ships of 10 and over but less than 15 years of age, in addition to the requirement under a) above, representative cylinders of main and auxiliary engines are to be lifted and examined;

c) for ships of 15 and over but less than 20 years of age, the requirements for special or intermediate surveys (whichever is due) are to be complied with;

d) for ships of 20 years and over, the requirements for special surveys are to be complied with.

(c) Any conditions of class or recommendations and overdue items previously issued by the losing society/survey organization are to be completed, unless not required by the Regulations.

③ After the plan check and surveys stated in 1.5.1.2(3)① and ②, the interval between surveys may be corresponding to that of the losing society/survey organization.

1.5.1.3 Initial classification of ships which have been surveyed by classification societies not accepted by CCS

(1) Ships under construction

① Submission of plans

CCS requirements for surveys of ships under construction are to be complied with, i.e. all plans, calculations and other technical documents for construction are to be submitted to CCS for approval. Where any change is made in the originally approved plans as the result of the examination, the construction is to be rectified in accordance with the re-approved plans.

② Surveys

a. In addition to the normal items for newbuildings, the following items are to be checked:

a) the shipyard is to submit records of the checked or confirmed items for review; CCS will sample a certain portion of such items, depending on their respective importance levels;

b) the Surveyor is to carry out an overall survey of the compartments, spaces and installations which have been inspected and confirm that materials, scantlings, workmanship and arrangements are in compliance with the approved plans;

c) the information on the attended inspections and tests of compartments is to be accepted when such information is confirmed as authentic. When some of the compartments are to be tested again, e.g. functional tests during sea trial and in particular the inspection and testing of cargo holds and ballast tanks, the new tests are to be attended;

d) the records of NDTs are to be checked and sampled. Any NDT is to comply with the rule provisions;

e) the materials (including forgings and castings) used for construction, and manufacturing and testing of anchors and anchor chains are to meet the requirements of the accepted standards;

f) main propulsion machinery and essential auxiliaries are to be manufactured, installed and tested in accordance with CCS rules or the standards acceptable to CCS;

g) the anchors and anchor chains are to be inspected and certified in accordance with CCS rules, if they have not been delivered to the shipyard;

h) all outstanding recommendations are to be completed.

(2) Initial classification of ships of which the construction has been completed but which have not been put into service

① Submission of plans

When applying for an initial survey, the owner is to submit one copy each of the plans, calculations and other technical documents specified in 1.5.1.2(2)①a to CCS for approval. In general, such ships are to comply with the present rules of CCS, at least with CCS rules effective during construction of the ships.

② Scope of surveys

Survey items are to be in accordance with 1.5.1.2(2)②.

(3) Initial classification of ships which have been put into service

① Submission of plans

When applying for an initial survey, the owner is to submit one copy each of the plans and documents specified in 1.5.1.2(2)①a to CCS for check. Where CCS is authorized to issue statutory certificates, the stability information including intact, subdivision and damage stability and the loading manual are to be examined and approved by CCS.

② Scope of surveys

The scope of surveys in accordance with the requirements of the Regulations for ships of the same type and age, is to include special survey, dry-dock survey and surveys of screwshaft, stern tube shaft and boilers.

1.5.1.4 Initial classification of ships which have been surveyed by CCS

(1) Ships are to be inspected for compliance with the requested characters of classification and class notations and upon confirmation of such compliance, classification certificates may be issued.

(2) Where a new class notation or a change of the service category is intended for the ship, relevant drawings and documents are to be provided by the owner for approval. When the ship is inspected and

found to be in compliance with relevant requirements, the classification certificate may be issued.
(3) Where any outstanding item affecting classification exists, an occasional survey is to be carried out and upon confirmation of completion of such item, the classification certificate may be issued.

Appendix 1 CORROSION AND WASTAGE CONTROL OF HULL STRUCTURE

1 Criteria for longitudinal strength

1.1 For ships of 65 m and over in length, the hull girder section modulus at deck and bottom within 0.4L amidships is not to be less than 0.9 times the hull girder section modulus required for ships of each service category in Rules for Construction of Sea-Going Ships Engaged on Domestic Voyages, unless provided otherwise.

1.2 For bulk carriers, passenger ships, container ships of 65 m and over in length and of 20 year of age or over, oil tanker of 15 years of age or over and dry cargo ships and other ships of 25 years of age or over, the minimum midship section modulus of corroded members is to be calculated according to thickness measurement results and checked according to the above criteria, at special surveys. Where any limit is exceeded, repairs are to be made to strengthen the structure in compliance with the requirements for longitudinal strength. In the case of excessively corroded members, the minimum midship section modulus is to be calculated and the longitudinal strength checked, regardless of the ages specified above.

2 Criteria for local strength

2.1 For ships constructed in accordance with CCS Rules for Construction of Sea-Going Steel Ships Engaged on Domestic Voyages and CCS Rules for the Construction and Classification of Sea-Going Steel Ships of versions 1996 and 2001, the renewal thickness of hull plating and structural members is not to be less than the value obtained by multiplying their as-built thickness by the relevant percentage shown in Table 2.1 below.

2.2 For ships constructed in accordance with CCS Rules for the Construction and Classification of Sea-Going Steel Ships published before 1996, the renewal thickness of hull plating and structural members is not to be less than the value obtained by multiplying their as-built thickness by the relevant percentage shown in Table 2.2 below.

2.3 For ships constructed in accordance with CCS Rules for the Construction and Classification of Sea-Going Steel Ships published of versions 2006 and later, relevant provisions in PART ONE of the Rules are to be complied with.

Table 2.1

Structural member	Minimum renewal thickness	
	L ⩾ 90 m	L < 90 m
① Strength deck plating, side shell, top strake, bilge strake, bottom shell, flat plate keel, inner bottom, continuous longitudinal bulkhead, hopper tank and topside tank plating. ② Main longitudinal continuous members, e.g. deck girders, hatch side girders, side girders, bottom girders, bulkhead girders, continuous hatch coamings. ③ Main transverse members, e.g. side frame webs, deck transverses, double plate floors, bulkhead webs, watertight and oiltight transverse bracket plates. ④ Transverse bulkhead plating in holds, upper and lower bulkhead stool sloping plating, watertight bulkhead plating in deep tanks	80%	75%
Other plating and structural members, e.g. deck within line of openings, deck longitudinals, side longitudinals, bottom longitudinals, inner bottom longitudinals, bulkhead longitudinals, face plates of side frames, brackets of structural members, hatch covers, non-continuous hatch coamings, sea chests	75%	70%
Note: For bulk carriers designed in accordance with the Rules for Construction of Sea-Going Ships Engaged on Domestic Voyages and assigned the class notations of “Strengthened for Heavy Cargoes”, the minimum renewal thickness of inner bottom may be taken as the value obtained by multiplying the as-built thickness and 75%		

Table 2.2

Structural member	Minimum renewal thickness		
	Service category beyond service category 1	Service category 1	Service categories 2 and 3
Strength deck plating, side and bottom shell;	75%	70%	65%
Continuous longitudinal strength members and web frames;	75%	70%	65%
Foundations of main engines, cranes and windlasses	75%	75%	75%
Other structural members defined in the Rules for the Construction and Classification of Sea-Going Steel Ships	70%	60%	55%

2.3 The thickness reduction of hull plating and structural members caused by corrosion and wastage is not to be more than required by CCS rules.

2.4 For bulk carriers contracted for construction on or after 1 July 2017 and complying with Section 8, Chapter 8, PART TWO of CCS Rules for Construction of Sea-Going Steel Ships Engaged on Domestic Voyages, corrosion allowance and renewal requirements for the hatch covers and coamings are as follows:

2.4.1 Hatch cover:

For single skin hatch covers, the corrosion allowance t_s for all structures (plate and frame) is 2.0mm;

For double skin hatch covers, the corrosion allowance t_s for top or bottom plating is 2.0mm and the corrosion allowance t_s for internal structure is 1.5mm.

For plating of double skin hatch covers and single skin hatch covers, renewal is required where the gauged thickness is less than t_{net} + 0.5 mm. Where the gauged thickness is t_{net} +0.5mm and over but less than t_{net} +1.0mm, coating or annual gauging may be adopted as an alternative to renewal. The coating is to be maintained in "GOOD" condition, which refers to condition with only minor spot rusting.

For the internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when deemed necessary, at the discretion of CCS Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, renewal for the internal structures is required where the gauged thickness is less than t_{net}.

2.4.2 Hatch coaming

Corrosion allowance t_s for hatch coaming structure and coaming stay is 1.5mm.

Renewal is required where the gauged thickness is less than t_{net} + 0.5 mm. Where the gauged thickness is t_{net} +0.5 mm and over but less than t_{net} +1.0 mm, coating or annual gauging may be adopted as an alternative to renewal. The coating is to be maintained in "GOOD" condition.

2.5 For ships other than bulk carriers, ore carriers and combination carriers, contracted for construction on or after 1 July 2017 and complying with Section 20, Chapter 2, PART TWO of the Rules for Construction of Sea-Going Ships Engaged on Domestic Voyages, and for all weathertight steel cargo hatch covers on exposed decks, steel renewal is required where the gauged thickness of the plating of double skin hatch covers, single skin hatch covers, hatch coamings, coaming stays and stiffeners is less than t_{net} + 0.5 mm. Where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, coating (the coating is to be maintained in "GOOD" condition, meaning condition with only minor spot rusting) or annual gauging may be adopted as an alternative to steel renewal. For the internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when deemed necessary, at the discretion of CCS Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than t_{net}. For corrosion addition t_s = 1.0 mm, the thickness for steel renewal is t_{net}, and when gauged thickness is between t_{net} and t_{net} + 0.5 mm, coating or annual gauging may be adopted as an alternative to steel renewal, where t_{net} being the net thickness, to be calculated in accordance with 2.20.2, Section 20, Chapter 2, PART TWO of the Rules for Construction of Sea-Going Ships Engaged on Domestic Voyages.

Appendix 2 MINIMUM INSULATION RESISTANCE OF ELECTRICAL EQUIPMENT AND CIRCUITS IN HOT CONDITION

The test results of insulation resistance of electrical equipment and circuits, as required by 1.4.3.1(2)② and 1.4.4.2(2) are in general not to be less than the following values.

Item	Insulation resistance in hot condition(MΩ)	
	Working voltage ≤ 100 V	Working voltage > 100 V
Motor	—	0.5
Propulsion motor	—	3U/(1000 + P)
Exciters, excitation winding and control gear for electrical propulsion	—	1.0
Various switchboards	—	0.5
Final sub-circuit of lighting distribution boards (except for fan and small electrical appliance)	0.2	0.5
Transformers	—	1.0
Control gear	0.2	0.5
Internal communication and alarm systems	0.3	0.5
Heating appliances	—	0.5
Circuits of navigation lights	—	1.0

Notes:

① *U* is the rated working voltage (V) and *P* the rated capacity in kW or kVA.

② For working voltage of 100 V or over, the insulation resistance is to be measured with a D.C. 500 V megger at least. For working voltage less than 100 V, the insulation resistance is to be measured with a D.C. 250 V megger.

③ The insulation resistance of electrical equipment may be measured only between polarity (phase) and earth.

④ The resistance of turbo-generator rotors is to be measured at the rated speed.

Appendix 3 MARKING OF LOAD LINES

1 Application

1.1 The requirements of this Appendix apply to classed ships engaged on non-international voyages.

2 Load line marks

2.1 The load line mark for ships not carrying timber deck cargoes is shown in Figure 2.1.

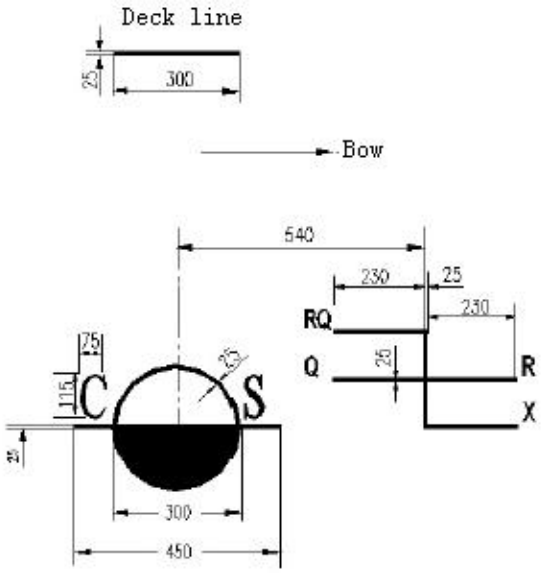


Figure 2.1 Freeboard Mark for Ships not Carrying Timber Deck Cargoes (in mm)

2.2 The load line mark for ships carrying timber deck cargoes is shown in Figure 2.2.

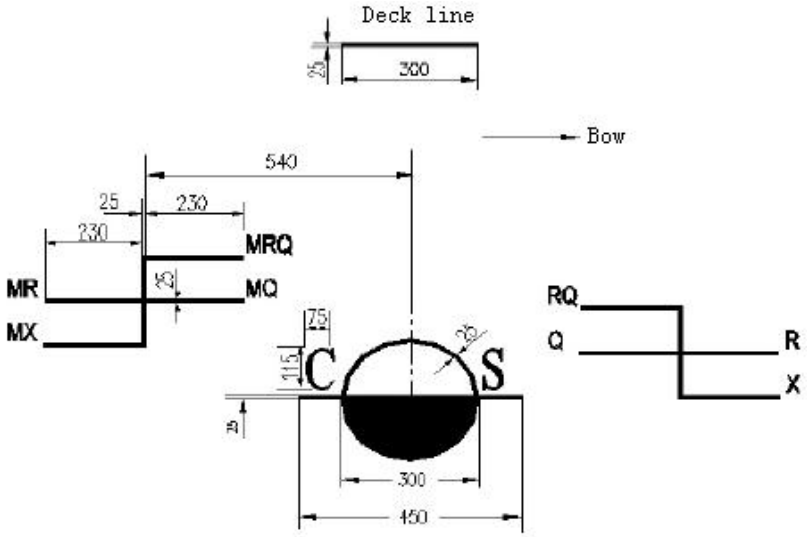


Figure 2.2 Freeboard Mark for Ships Carrying Timber Deck Cargoes (in mm)

2.3 Where a ship is assigned a greater than minimum freeboard so that the load line is marked at a position corresponding to, or lower than, the lowest seasonal load line assigned at minimum freeboard as specified in the LL Convention, only the Fresh Water Load Line need be marked. In such a case, the load line mark is as shown in Figure 2.3 and may also be marked in accordance with Figure 2.1.

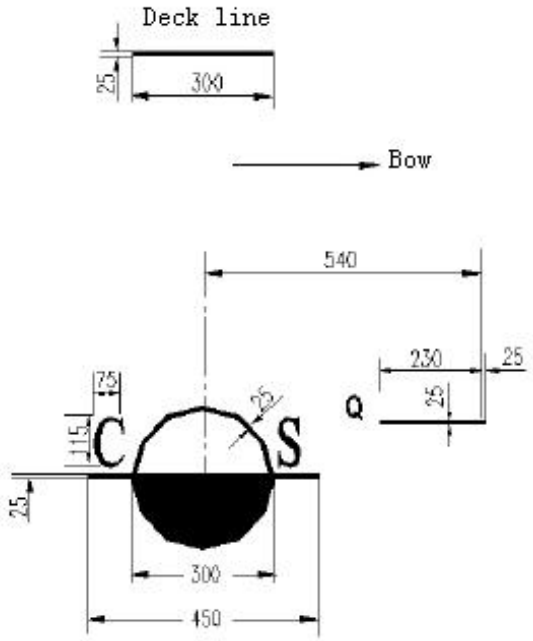


Figure 2.3 Fresh Water Load Line Only (in mm)

2.4 The subdivision load line mark for passenger ships is shown in Figure 2.4.

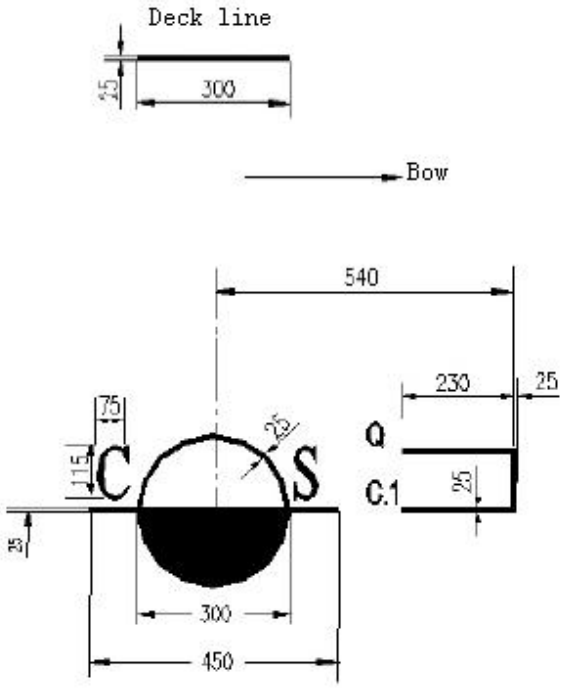


Figure 2.4 Subdivision Load Line Mark for Passenger Ships (in mm)

The symbols in Figures 2.1 to 2.4 are defined as follows:
CS — China Classification Society;
RQ — Tropical Fresh Water Load Line;
Q — Summer Fresh Water Load Line;
R — Tropical Load Line;
X — Summer Load Line;
MRQ — Tropical Fresh Water Timber Load Line;
MQ — Summer Fresh Water Timber Load Line;
MR — Tropical Timber Load Line;
MX — Summer Timber Load Line;

C.1 — Passenger Ship Subdivision Load Line.

3 Marking

3.1 The Load line mark is to consist of a ring 300 mm in outside diameter and 25 mm wide which is intersected by a horizontal line 450 mm in length and 25 mm in breadth; the upper edge of horizontal line passes through the center of the ring. The center of the ring is to be placed on each side of the ship at the middle of the length as defined in LL Convention, and the vertical distance from the upper edge of the deck line to the center of the ring is equal to the assigned summer freeboard. The ring, lines and letters are to be painted in white or yellow on a dark ground or in black on a light ground. They are to be permanently marked on both sides of the ship and clearly visible.

CHAPTER 2 HULL

Section 1 GENERAL PROVISIONS

2.1.1 General requirements

2.1.1.1 The definition of restricted service is given in Section 1, Chapter 0 of this PART.

2.1.1.2 The environmental conditions corresponding to restricted services are given in Table 2.1.1.2.

Table 2.1.1.2

Restricted service	Significant wave height
Service category 1	0.78C
Service category 2	0.74C
Service category 3	0.69C

C —coefficient to be obtained from the following formulae:

$C = 0.0412L + 4$ for $L<90$ m;

$C = 10.75 - \left(\frac{300 - L}{100}\right)^{3/2}$ for $90 \le L \le 300$ m;

$C = 10.75$ for $300 < L < 350$ m;

$C = 10.75 - \left(\frac{L - 350}{150}\right)^{3/2}$ for $350 \le L \le 500$ m.

L— length of ship, in m, see 1.1.2.1, Section 1, Chapter 1, PART TWO of the Rules.

2.1.1.3 For passenger ships, ferries, traffic ships and public affair ships engaged in restricted service that are not high-speed and whose main hull is made of aluminum alloy, hull structures are to comply with the requirements of CCS Guidelines for Structure of Non-High-Speed All-Aluminum Alloy Sea-Going Ships.

2.1.2 Longitudinal strength

2.1.2.1 The values of the minimum midship section modulus W_0 for the calculation of longitudinal strength in accordance with the requirements of Section 2, Chapter 2, PART TWO of the Rules may be reduced by:

(1) 5% for ships intended for service category 1;

(2) 10% for ships intended for service category 2;

(3) 15% for ships intended for service category 3.

2.1.2.2 For the check of longitudinal strength of ships in accordance with the requirements of Section 2, Chapter 2 or Sections 2 and 10, Chapter 7 of PART TWO of the Rules, the wave bending moment and wave shear force may be reduced by:

(1) 10% for ships intended for service category 1;

(2) 15% for ships intended for service category 2;

(3) 20% for ships intended for service category 3.

2.1.2.3 For engineering ships assigned with different notations for transiting and operation, the wave bending moment and wave shear force reduction requirements of the corresponding area are to be used in different conditions to check longitudinal strength of ships.

2.1.3 Reduction of rule scantlings of structural members

2.1.3.1 For ships intended for navigating in restricted service, the scantlings of structural members, as calculated in accordance with the requirements of PART TWO of the Rules other than those of 2.1.3.2 and 2.1.3.3 of this Section, refer only to the Rule plate thickness, sectional area and section modulus of structural members, and may be reduced by:

(1) 5% for ships intended for service category 1;

(2) 10% for ships intended for service category 2;

(3) 15% for ships intended for service category 3.

The scantlings of structures after reduction are to comply with the requirements of 2.1.3.4 of this Section.

2.1.3.2 For ships equal to or greater than 65 m in length, where the values of the reduction factors F_d and/or F_b required in Section 2 of Chapter 2 of PART TWO are less than 1, the following requirements are to be complied with when calculating the thickness of shell plating and main deck within 0.4L amidships:

(1) where the value of F_d is less than 1, the thickness of main deck and sheer strake is not to be reduced in

accordance with the requirements of 2.1.3.1 of this Section;
(2) where the value of F_b is less than 1, the thickness of bottom plating and bilge strake is not to be reduced in accordance with the requirements of 2.1.3.1 of this Section;
(3) where the value of F_d or F_b is less than 1, the thickness of side shell plating is not to be reduced in accordance with the requirements of 2.1.3.1 of this Section.
2.1.3.3 The rule scantlings in the following conditions are not to be reduced in accordance with the requirements in 2.1.3.1: the rule minimum thickness, scantlings of structural members for which ice strengthening and strengthening of bottom forward are required, and bulkhead, structural members of deep tanks and cargo tanks, inner bottom plating and framing for loading heavy cargoes, cargo deck framing, vehicle decks, pillars, stems, stern frames, propeller shaft brackets, main engine seating structures, rudders, etc.
2.1.3.4 For ships of less than 65 m in length and engaged in restricted service, the minimum requirements for thickness of plating is to comply with the following requirements:
(1) the thickness of shell plating is to be not less than 5 mm;
(2) the thickness of strength deck is to be not less than 5 mm and the thickness of other decks is to be not less than 4 mm;
(3) the thickness of inner bottom plating in double bottom is to be not less than 5 mm;
(4) the thickness of weather tight steel hatch covers is to be not less than 5 mm.
2.1.3.5 For ships of less than 40 m in length, the spacing s of frames may be taken as the full-scale spacing of frames when calculating the thickness of transversely framed bottom plating.
2.1.3.6 The thickness of the plate keels is not to be less than the calculated value of rule required thickness of the bottom plating plus 1.5 mm, and in no case less than that of the adjacent bottom plating.
2.1.3.7 Ships intended for service category 2 or 3 need not meet the requirements of fore deck fittings in Section 7, Chapter 1, PART TWO of the Rules.
2.1.3.8 Ships intended for service category 2 or 3 need not meet the requirements for strengthening of bottom forward in Section 15, Chapter 2, PART TWO of the Rules.
2.1.3.9 Ships engaged on non-international voyages need not meet the requirements for strengthening of grabs in Section 23, Chapter 2, PART TWO of the Rules depending on a voluntary basis by the shipowner.
2.1.3.10 Bulk carriers engaged on non-international voyages need not meet the requirements of Sections 8, 9, 10, 12, 13 and 15, Chapter 8, PART TWO of the Rules.

2.1.4 Anchoring equipment

2.1.4.1 The number of pieces of the anchoring equipment required in Section 2, Chapter 3, PART TWO of the Rules may be reduced in accordance with the following requirements:
(1) Except as required in (2) of this paragraph, the anchoring equipment of ships intended for service category 2 may be selected one grade lower than required by the equipment number N. For traffic boats or ferry boats less than 30 m in length, one single bower anchor and one half of the required length of chain cable will be acceptable.
(2) For floating cranes, floating pile drivers or other similar working ships and trailing suction dredgers intended for service category 2, the anchoring equipment may be selected two grades lower than required by the equipment number N.
(3) For ships intended for service category 3, the anchoring equipment may be selected two grades lower than required by the equipment number N. For traffic boats or ferry boats of less than 30 m in length, one single bower anchor and one half of the required length of chain cable will be acceptable.
(4) For ships intended for operations in harbours with breakwater, the anchoring equipment may be selected a half grade lower than required by the equipment number N and one half of the required length of chain cable will be acceptable.
2.1.4.2 The ultra high holding power anchors may be used as bower anchors for ships navigating in restricted service. The mass of each ultra high holding power anchor may be 50% of that of an ordinary stockless bower anchor as specified in Table 3.2.1.1(2), Chapter 3, PART TWO of the Rules. The mass of each ultra high holding power anchor is generally not to exceed 1,500 kg, for details see Section 1, Chapter 10 of PART ONE of CCS Rules for Materials and Welding.

2.1.5 Stability, load line and structural arrangement

2.1.5.1 The stability, load line and structural arrangement of ships engaged on non-international voyages are to comply with the relevant provisions of the flag State Administration.

2.1.6 Loading manual and loading instrument

2.1.6.1 Ships of service category 2 and service category 3 may not be provided with a loading instrument.
2.1.6.2 For ships engaged on non-international voyages, the loading manual, output results of loading instrument and operation manual are to use the language that users can understand. Where this language is not English, English translation may not be required.

2.1.7 Direct calculations
2.1.7.1 When the requirements of Section 5 Direct strength calculations, Chapter 1, PART TWO of the Rules are applicable to ships in restricted service, the requirements of 2.1.7.2 are to be satisfied.
2.1.7.2 The service coefficient f_r , is to be taken as follows:
f_r=0.90, for service category 1;
f_r=0.85, for service category 2;
f_r=0.80, for service category 3.

2.1.7.3 When the requirements of 2.2.9 Direct calculation of wave loads, Section 2, Chapter 2, PART TWO of the Rules are applicable to ships in restricted service,the prediction of wave loads is required to be based on wave statistics of the sea areas in which such ships operate and where there are more than one set of wave statistics, the most severe one is to be used.

Section 2 SHIP TYPE REQUIREMENTS

2.2.1 Ro-ro ships, passenger ships, ro-ro passenger ships and ferries
2.2.1.1 When the requirements of Section 4 Bow doors and inner doors, Section 5 Side shell and stern doors of Chapter 9 of PART TWO of the Rules are applicable to ships in restricted service, the requirements of 2.2.1.2 are to be satisfied.
2.2.1.2 The design load coefficient λ is to be determined in accordance with the following requirements:
λ=1.0, for ships intended for service category 1;
λ=0.8, for ships intended for service category 2;
λ=0.5, for ships intended for service category 3.
2.2.1.3 For passenger ships intended for service category 2 or 3, and of less than 65 m in length, the superstructure and deckhouse of tier 2 and above and not participating in hull girder longitudinal bending may use aluminium alloy reinforced plate. For passenger ships of 65 m and more in length, special consideration may be given to the superstructure and deckhouse not participating in hull girder longitudinal bending.
2.2.1.4 Where aluminium alloy reinforced plate is used in the superstructures and deckhouses mentioned in 2.2.1.3 above, the thickness of the plate may be determined in accordance with the principle of strength equivalence as specified in Section 17, Chapter 2 and Section 2, Chapter 9, PART TWO of the Rules, but not less than 5 mm.

2.2.2 Barges
2.2.2.1 When the requirements of Appendix Method of checking transverse strength of pontoon barges of Chapter 12 of PART TWO of the Rules are applicable to ships in restricted service, the requirements of 2.2.2.2 are to be satisfied.
2.2.2.2 For pontoon barges navigating only in restricted service, the value C used for the load due to external water pressuremay be reduced in accordance with the following provisions:
(1) for service category 1: 0.90;
(2) for service category 2: 0.85;
(3) for service category 3: 0.80.

2.2.3 Floating cranes
2.2.3.1 For floating cranes operating in restricted service, the following class notations are to be assigned:
(1) Operating in Service category 1: Lifting Within R1;
(2) Operating in Service category 2: Lifting Within R2;
(3) Operating in Service category 3: Lifting Within R3;
(4) Operating only within harbour: Lifting Within Harbour.
2.2.3.2 For the check of longitudinal strength of floating cranes under operating conditions in accordance with the requirements of Chapter 13 of PART TWO of the Rules, the wave bending moment and wave shear force may be reduced as follows:

(1) 15% for ships intended for service category 1;
(2) 30% for ships intended for service category 2;
(3) 45% for ships intended for service category 3;
(4) 70% for floating cranes intended for operations in harbours only.

2.2.4 Dredgers

2.2.4.1 Dredgers operating in restricted service are to be assigned one of the following class notations:
(1) Operating in service category 3: Dredging Within R3;
(2) Operating in service category 2: Dredging Within R2;
(3) Operating in service category 1: Dredging Within R1;
(4) Operating only within harbour: Dredging Within Harbour.

2.2.4.2 For the check of longitudinal strength of dredgers under operating conditions in accordance with the requirements of Chapter 14 of PART TWO of the Rules, the wave bending moment and wave shear force may be reduced as follows:
(1) 15% for ships intended for service category 1;
(2) 30% for ships intended for service category 2;
(3) 45% for ships intended for service category 3;
(4) 70% for dredgers intended for operations in harbours only.

2.2.5 Semi-submersible barges

2.2.5.1 For non-self-propelled semi-submersible barges designed for operation in service category 3 or in harbour, loads and calculation conditions of longitudinal strength under the operating condition may be calculated in accordance with relevant requirements of CCS Rules for Classification of Floating Docks.

2.2.6 Twin-hull craft

2.2.6.1 Where Section 3 Total load, Chapter 18, PART TWO of the Rules is applicable to ships in restricted service, the requirements of 2.2.6.2 are to be satisfied.

2.2.6.2 For twin-hull craft only intended for the restricted service, the service coefficient C_3 of calculation of loads may be reduced as follows:
(1) 0.8 for service category 1;
(2) 0.6 for service category 2;
(3) 0.5 for service category 3.

2.2.7 Container ships

2.2.7.1 Container ships engaged on non-international voyages need not comply with relevant requirements in paragraphs 6, 7 and 8 of Appendix 1 Container Securing, Chapter 7, PART TWO of the Rules.

CHAPTER 3 MACHINERY INSTALLATIONS

Section 1 GENERAL PROVISIONS

3.1.1 Scope of application

3.1.1.1 The provisions of this Chapter apply to machinery installations of ships in restricted service, which can replace relevant provisions in PART THREE of the Rules.

3.1.2 Ambient conditions

3.1.2.1 For machinery installations of ships in restricted service related to ship classification, the ambient temperature required in Table 1.2.1.2 of PART THREE of the Rules may be selected in accordance with the practical condition of service area.

3.1.2.2 In the case of ships for restricted service, the ambient conditions used for determining the rating of main and auxiliary diesel engines as required by 1.2.1.3 of PART THREE of the Rules are to be suitable for the geographical limits of the restricted service.

3.1.3 Fuel

3.1.3.1 With regard to the flash point required by 1.2.9.1 of PART THREE of the Rules, in ships engaged on non-international voyages, where additional precautions are taken so that the ambient temperature of the space in which oil fuel is stored or used will not be allowed to rise to within 10℃ below the flashpoint of the oil fuel, the use of oil fuel having a flashpoint of less than 60℃ but not less than 43℃ may be permitted.

Section 2 MACHINERY INSTALLATIONS

3.2.1 Dead ship starting

3.2.1.1 For cargo ships with service category 2 and lower than category 2 and passenger ships with service category 3 engaged on non-international voyages, dead ship starting in 1.2.6 of PART THREE of the Rules is not required.

3.2.2 Bilge suction arrangement in machinery spaces

3.2.2.1 For cargo ships with service category 2 and lower than category 2, the number of direct bilge suctions in Table 3.3.2.1 of PART THREE of the Rules may be 1.

3.2.2.2 For passenger ships engaged on non-international voyages of less than 100 gross tonnage or passenger ships with service category 3 and of less than 500 gross tonnage engaged on non-international voyages, emergency bilge suction as required in 3.3.3.1 of PART THREE of the Rules may be dispensed with.

3.2.3 Bilge pumps and bilge piping

3.2.3.1 With regard to the number of power bilge pumps and drive modes for each ship as specified in Table 3.4.1.1 of PART THREE of the Rules, for ships engaged on non-international voyages of less than 100 gross tonnage, carrying not more than 100 passengers, 2 independent bilge pumps may be provided if navigation period is less than 4 h.

3.2.4 Oil tank air pipes

3.2.4.1 Paragraph 3.10.2.5 of Chapter 3 of PART THREE of the Rules does not apply to ships with service category 2 and lower than category 2 engaged on non-international voyages,

3.2.5 Oil tank short sounding pipes

3.2.5.1 For ships engaged on non-international voyages, if high-level alarms are fitted in fuel oil tanks, when the sounding pipes are terminated in machinery spaces, only requirements of 3.10.10.1(2) and (3) of Chapter 3 of PART THREE of the Rules are to be met.

3.2.5.2 For fuel oil tanks in double bottom tanks, when the sounding pipes are terminated in machinery spaces, only requirements of 3.10.10.1(2) and (3) of Chapter 3 of PART THREE of the Rules are to be met for ships with service category 2 and lower than category 2 engaged on non-international voyages.

3.2.6 Fuel oil daily tank

3.2.6.1 For ships intended for navigating in restricted service engaged on non-international voyages, the capacity of each fuel oil daily tank required in 4.2.1.8 of Chapter 4 of PART THREE of the Rules may be reduced depending on different conditions but not less than 4 h.

3.2.6.2 The requirements of 4.2.1.8 of Chapter 4 of PART THREE of the Rules may not apply to ships with service category 3.

3.2.7 Oil burning units of boilers

3.2.7.1 For cargo ships with service category 1 and lower than category 1 and passenger ships with service category 3, for auxiliary boilers for essential services or auxiliary boilers supplying steam for heating heavy fuel oil as specified in 4.2.2.2 of PART THREE of the Rules, one oil supply unit will be accepted provided that one complete spare oil burning pump is carried on board and capable of being easily installed and connected.

3.2.8 Oil fuel booster pumps

3.2.8.1 For cargo ships with service category 1 and lower than category 1 and passenger ships with service category 3, for oil fuel booster pumps as required in 4.2.3.1 of PART THREE of the Rules, where one complete spare pump capable of being easily installed and connected or a suitable pump connecting to the system is provided, a standby pump may be dispensed with.

3.2.9 Feed water pumps for boilers

3.2.9.1 For cargo ships with service category 1 and lower than category 1 and passenger ships with service category 3, for auxiliary boilers for essential services or auxiliary boilers supplying steam for heating heavy fuel oil and cargo oil as specified in 4.4.1.1 of PART THREE of the Rules, where one feed water pump capable of being easily installed and connected is provided, only one feed water pump fitted is acceptable.

3.2.10 Feed water systems for boilers

3.2.10.1 For auxiliary boilers fitted with only one feed water pump as required in 3.2.9.1 of this Section, the requirements for provision of two independent feed water systems in 4.4.2.1 of Chapter 4 of PART THREE of the Rules may not be applied.

3.2.11 Condensate pumps

3.2.11.1 For cargo ships with service category 1 and lower than category 1 and passenger ships with service category 3, if not propelled by steam, the standby pump within condensate pumps required by 4.4.4.1 of PART THREE of the Rules may be one spare pump capable of being easily installed and connected.

3.2.12 Cooling water pumps

3.2.12.1 For cargo ships with service category 1 and lower than category 1 and passenger ships with service category 3, the standby cooling water pump as required in 4.5.1.1 of PART THREE of the Rules may be substituted by other pump with sufficient discharge capacity or a complete spare pump capable of being easily installed and connected.

3.2.13 Lubricating oil pumps

3.2.13.1 For ships intended for navigating in restricted service, where the power of single main engine is less than 440 kW, the standby pump as required in 4.6.1.1 of Chapter 4 of PART THREE of the Rules may be dispensed with.

3.2.14 Alternative power supply for steering gear

3.2.14.1 The requirements in 13.1.8.6 of Chapter 13 of PART THREE of the Rules may not apply to ships with service category 3 engaged on non-international voyages.

CHAPTER 4 ELECTRICAL INSTALLATIONS

Section 1 MAIN SOURCE OF ELECTRICAL POWER

4.1.1 Generating sets

4.1.1.1 Ships engaged on non-international voyages with the total capacity of the main generating sets of 500 kVA or less need not comply with the provisions in 2.1.1.1(4)② of Chapter 2, PART FOUR of the Rules.

4.1.1.2 At least one generating set is to be provided in cargo ships engaged on non-international voyages in category 3 service.

4.1.1.3 At least one generating set is to be provided in passenger ships engaged on non-international voyages in category 3 service where the auxiliary machineries serving the main engine, steering gear oil pumps, fire pumps and bilge pumps are driven by the main engine.

Section 2 EMERGENCY SOURCE OF ELECTRICAL POWER

4.2.1 Period of power supply

4.2.1.1 For domestic ships engaged on non-international voyages, the period of power supply of the emergency source of electrical power as required in 2.2.2.1 and 2.2.3.1(2) to 2.2.3.1(5) of Chapter 2 of PART FOUR of the Rules may be reduced to:

(1) category 1 service: 12h for passenger ships and 6h for cargo ships;

(2) category 2 service: 6 h for passenger ships and 3 h for cargo ships;

(3) category 3 service: 3 h for passenger ships and 3 h for cargo ships.

4.2.1.2 For passenger ships engaged regularly in international voyages of short duration and proceeding not more than 20 n miles off shore, CCS, if satisfied that the same level of safety would be attained, may accept a lesser period than the 36 h period required in 2.2.2.1(1) to (4), Chapter 2 of PART FOUR of the Rules, but not less than 12 h.

4.2.1.3 For cargo ships engaged regularly in international voyages of short duration and proceeding not more than 20 n miles off shore, CCS, if satisfied that the same level of safety would be attained, may accept a lesser period than the 18 h period required in 2.2.3.1(2) to (5), Chapter 2 of PART FOUR of the Rules, but not less than 12 h.

4.2.2 Reserve power source

4.2.2.1 For ships engaged on non-international voyages in category 3 service, the emergency source of electrical power as required in Section 2, Chapter 2 of PART FOUR of the Rules may not be fitted provided that an independent reserve power source in compliance with the following requirements is fitted.

(1) The reserve power source is to be the accumulator battery in compliance with the following requirements:

① located not in the same space as the main source of electrical power and located above the uppermost continuous deck as far as practicable;

② complying with the requirements of 2.2.1.4(1), (2) and 1.2.1.1(2) of PART FOUR;

③ capable of providing immediately power supply for any equipment as required in 4.2.1.1(2) of this Section.

(2) The capacity of the reserve power source is to be sufficient to supply the following equipment for at least 3 h:

① lighting at muster and embarkation stations, over the sides, in all alleyways, stairways and exits, in cabins accommodating more than 16 persons, and at the main switchboard, reserve power source and control stations;

② navigation lights and other signal lights as required in the International Regulations for Preventing Collisions at Sea;

③ internal communication equipment required in emergency;

④ fire detection and fire alarm system (if any);

⑤ daylight signalling lamp, the ship's whistle, the manually operated call points (if any) in intermittent

operation and all internal signals that are required in an emergency (e.g. general emergency alarm system, etc.);

⑥ radio communications on board.

Section 3 MISCELLANEOUS

4.3.1 Transformer

4.3.1.1 Requirements of 2.1.3.1(1) and (2), Chapter 2 of PART FOUR of the Rules may not be met for domestic cargo ships engaged on non-international voyages in category 3 service.

.

CHAPTER 5 REFRIGERATED CARGO INSTALLATIONS

Section 1 GENERAL PROVISIONS

5.1.1 General requirements

5.1.1.1 Any proposed addition to or relaxation of the requirements of PART FIVE of the Rules in respect to ships navigating in restricted service, to installations of small capacity, or to other special cases is subject to agreement of CCS. In such cases a service limitation may be made to the ship.

5.1.1.2 Cargo chambers are in general not to be refrigerated by the direct expansion pipe grid system when ammonia is used as refrigerant. However, in the case of a ship navigating in restricted service where the total capacity of its refrigerated cargo chambers is less than 500 m^3, a direct expansion ammonia pipe grid system may be adopted.

Section 2 REFRIGERATING PLANT

5.2.1 Number of units

5.2.1.1 In ships classed for restricted service where the total capacity of the refrigerated chambers is less than 1,500 m^3, only one complete refrigerating unit may be provided, but a standby compressor is to be fitted as an addition.

Section 3 CARRIAGE OF REFRIGERATED CONTAINERS IN CARGO HOLDS

5.3.1 Ventilation within holds

5.3.1.1 When Chapter 4 Carriage of refrigerated containers in cargo holds of PART FIVE of the Rules is applicable to ships of restricted service, the ventilation of holds carrying refrigerated containers is to be determined mainly according to size, type, number of containers, type of refrigerated cargo to be carried and service area of the ship.

CHAPTER 6 FIRE PROTECTION, DETECTION AND EXTINCTION

Section 1 GENERAL REQUIREMENTS

6.1.1 Fire protection, detection and extinction of ships engaged on non-international voyages are to satisfy relevant requirements of CCS Guidelines for Statutory Surveys of Sea-Going Ships Engaged on Non-International Voyages or standards accepted by the Administration of the flag State.

CHAPTER 7 ADDITIONAL REQUIREMENTS

Section 1 ADDITIONAL REQUIREMENTS FOR OPEN-TOP CONTAINER SHIPS

7.1.1 General requirements

7.1.1.1 This Section applies only to open-top container ships engaged in restricted service.

7.1.1.2 The relevant definitions and the required plans and documents are the same as those given in Section 1, Chapter 6, PART EIGHT of the Rules.

7.1.2 Freeboard

7.1.2.1 The freeboards are to be in compliance with the requirements of the flag Administration. Where not required by the Administration, the minimum freeboard of ships engaged in restricted service may be determined by either:

(1) sea keeping characteristics (model test), intact stability and structural strength; or

(2) minimum geometrical freeboard, intact stability and structural strength.

Where the hull or hatch coaming of open-top container ships is fitted with freeing ports or scuppers, however, the minimum freeboard is to be determined in accordance with (1) of this paragraph.

7.1.2.2 Where the freeboard is determined according to 7.1.2.1(1), the significant wave height for model test and the permissible hourly rate of ingress of green water in any one open hold (hourly rate of shipped green water = open area of hold × hourly down flooding height) are to be in accordance with Table 7.1.2.2:

Table 7.1.2.2

Service	Significant wave height for test① (m)	Hourly down flooding height (mm/h)
Service category 1	7.5	300
Service category 2	5.5	200
Service category 3	3.5	150

Note: ① The significant wave height for model test may be determined according to wave statistics of service areas, subject to agreement of CCS.

The procedure of model tests is to be in accordance with 6.1.6 of Section 1 of Chapter 6 of PART EIGHT of the Rules.

7.1.2.3 Where the freeboard is determined according to 7.1.2.1(2), the minimum freeboard is to be not less than the minimum geometrical freeboards given in Table 7.1.2.3:

Table 7.1.2.3

Service	Minimum geometrical freeboard (m)
Service category 1	0.035 L_L
Service category 2	0.030 L_L
Service category 3	0.0275 L_L

where: L_L– ship's length measured to load line, in m.

7.1.2.4 The minimum bow height is not to be less than that required by the LL 1966, assuming hatch covers being fitted.

7.1.3 Arrangement

7.1.3.1 Where the freeboard is determined according to 7.1.2.1(2),the hull or hatch coaming is not to be fitted with freeing ports or scuppers.

7.1.3.2 A deckhouse, forecastle or breakwater, the width of which is to be not less than that of front coaming of the open-top No.1 hold, is to befitted forward of that hold.

7.1.3.3 The height of the rear top of the deckhouse or forecastle and the top of the breakwater above the summer waterline is to be not less than the values given in Table 7.1.3.3:

Table 7.1.3.3

At forward perpendicular	0.25 L aft of forward perpendicular
F_b + 2.35	F_{min} + 1.75

where: F_b — minimum bow height specified according to 7.1.2.4, in m;

F_{min} — freeboard, in m, determined according to Regulations 27 to 30 of Annex I to the LL 1966, assuming hatch covers being fitted; to be determined by linear interpolation if the top is between the two positions given in the Table.

7.1.3.4 The breakwater structure is to be in compliance with the requirements for hold hatch coamings.

7.1.4 Intact stability

7.1.4.1 The intact stability is to be calculated and checked in accordance with the requirements for general cargo ships in Section 9, Chapter 1 of PART TWO of the Rules.

7.1.4.2 The intact stability in full-load complete flooded condition is to be calculated and checked in accordance with the following requirements.

(1) The full-load complete flooded condition is a full load condition of the ship, assuming open-top holds being flooded to the extent given in Table 7.1.4.2 (in the case of a ship fitted with cargo hold freeing ports, to the level of those ports):

Table 7.1.4.2

Service	Down flooding height of open-top holds (% hold depth*)
Service category 1	85
Service category 2	70
Service category 3	55

* Hold depth is the distance measured from the upper surface of inner bottom of a hold to that of strength deck.

(2) For ships engaged in service of category 1, the intact stability in the complete flooded loading conditions stated in (1) above is to comply with the following criteria:

① the range of stability is to be not less than 20°, and the angles of immersion of openings including ventilators, doors and hatch covers, which cannot be closed weather tight, are to be greater than this value;

② the maximum positive righting lever within the range specified in ① above but not greater than 20° is not to be less than 0.1 m.

(3) For ships engaged in service of category 2 or 3 or equivalent to 3, the intact stability in the complete flooded loading conditions stated in (1) above is to comply with the following criteria:

① the range of stability is to be not less than 15°, and the angles of immersion of openings including hatch coaming top, ventilators, doors and hatch covers, which cannot be closed weather tight, are to be greater than this value;

② the area A_{min} under the righting lever GZ curve within the range of stability which complies with ① above is not to be less than the value obtained as follows:

$$A_{min} = 0.025 + 0.005\ (20° - \theta_f) \quad \text{m·rad}$$

where: θ_f — angle of heel at which openings in hull, superstructures or deckhouses which cannot be closed weather tight immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

7.1.5 Damage stability

7.1.5.1 The damage stability is to be in accordance with 6.1.9 of Section 1 of Chapter 6 of PART EIGHT of the Rules or the relevant requirements specified by the flag Administration for conventional container ships.

7.1.6 Strength and construction

7.1.6.1 The longitudinal strength and local strength of the hull are to be checked in accordance with Chapters 2 and 7 of PART TWO of the Rules.

7.1.6.2 In addition, the loading conditions for the check of the longitudinal strength and local strength are to include the full-load complete flooded condition indicated in 7.1.4.2, wherein the assumed down flooding height is to be determined according to Table 7.1.4.2. In loading conditions indicated in 7.1.4.2, the following requirements are to be satisfied:

(1) Where the still water bending moment in flooded condition exceeds the allowable value, or the draught in flooded condition is greater than the scantling draught, the actual still water bending moment and/or draught in flooded condition is to prevail. Hull girder longitudinal strength (including ultimate strength) is to be checked in accordance with Section 2, Chapter 7, PART TWO of the Rules.

(2) Where the draught in flooded condition is greater than the scantling draught, the former is to prevail. Local strength is to be checked in accordance with relevant sections of Chapters 2 and 7, PART TWO of the Rules.

(3) For hull structures forming watertight boundaries of open-top holds, requirements in Section 13 Deep

Tanks, Chapter 2, PART TWO of the Rules are to be satisfied, where the design pressure head h is the vertical distance from the calculation point to the highest point of down flooding height specified in 7.1.4.2.
7.1.6.3 When checking the longitudinal strength, the hatch deformation due to hydrodynamic torque need not be considered.

7.1.7 Bilge dewatering system

7.1.7.1 Where the freeboard is determined according to 7.1.2.1(1), the capacity of the bilge pumping system is to be determined in accordance with the relevant requirements of 6.1.10 of Section 1 of Chapter 6 of PART EIGHT of the Rules.
7.1.7.2 Where the freeboard is determined according to 7.1.2.1(2), the capacity of the bilge pumping system is to be not less than the greatest of the values obtained as follow:
(1) four-thirds of the amount of water required for fire-fighting purposes in the largest hold;
(2) an amount equal to the capacity required for ships with closed cargo holds;
(3) down-flooding height of open-top holds as listed in Table 7.1.7.2 multiplied by open hatch area:

Table 7.1.7.2

Service	Down-flooding height of open-top holds
Service category 1	150 mm/h for No.1 hold, 100 mm/h for other holds
Service category 2	130 mm/h for No.1 hold, 100 mm/h for other holds
Service category 3	100 mm/h for all holds

7.1.7.3 The ship is to be fitted with at least three bilge pumps for pumping open-top hold bilges.
7.1.7.4 The capacity and arrangement of the bilge pumps are to comply with the following requirements:
(1) At least one of these pumps is to have a capacity of not less than the required capacity as defined in 7.1.7.1 or 7.1.7.2 and is to be used for bilge and ballast service. This pump may also be used as an emergency fire pump. The pump is to be located in such a way that it will not be affected by a fire or other casualty to the space containing the pumps required in (2) below or the space containing the main source of power and is to be supplied from the emergency source of power complying with Sections 1 and 2, Chapter 2 of PART FOUR of the Rules or any source of power other than the main source of power. Where the pump is also used as an emergency fire pump, the relevant requirements for emergency fire pumps are to be complied with.
(2) The combined output of at least two further pumps is not to be less than the required capacity as defined in 7.1.7.1 or 7.1.7.2. These pumps are to be supplied from the main source of power complying with Section 1, Chapter 2 of PART FOUR of the Rules, or any source of power other than the emergency source of power.
7.1.7.5 The bilge pumping system is to be arranged to be effective with the ship in upright position and heeled up to 22.5°, or trimmed by bow or stern up to 10°, or with any combination of inclination angles within these scopes. The open hold bilge wells are to be readily accessible for dredging and cleaning.
7.1.7.6 All open cargo holds are to be fitted with high bilge level alarms. The alarms are to initiate visual and audible warnings in the engine room and the manned control locations (navigation bridge or control stations) and be independent of bilge pump controls.

7.1.8 Fire protection

7.1.8.1 Open-top cargo holds are to be protected by a water sprinkler or spray system. The system is to be capable of sprinkling/spraying water into the cargo hold from deck level downward. The system is to be designed and arranged to take account of the specific hold configuration so that the sprinkled/sprayed water will cover the complete hatch of the open hold.
7.1.8.2 At least one dedicated fire-extinguishing pump for the hold water sprinkler or spray system with a capacity to serve all container bays in any one open-top container hold simultaneously is to be provided. The uniform application density is to be not less than 1.1 *l*/min/m^2. The pump is to be installed outside the open-top area. In addition, the sprinkler or spray system is to be interconnected to an alternative source from the weather deck as backup means, the capacity of which is not to be 50% less than that of the dedicated pump.
7.1.8.3 For open holds of open-top container ships of less than 5,000 gross tonnage, deck fire main system may be an alternative to the sprinkler or spray system required by 7.1.8.1 and 7.1.8.2.

Section 2 ADDITIONAL REQUIREMENTS FOR PUSHER TUG-BARGE COMBINATIONS

7.2.1 General provisions

7.2.1.1 The scope of application of this Section is as follows:

(1) This Section applies only to pusher tug-barge combinations in restricted service.

(2) The pusher tug-barge combinations are to comply with the requirements of this Section and in addition, the applicable requirements in other Chapters of the Rules for single pusher tugs and barges, CCS Rules for Materials and Welding and the relevant requirements of the flag Administration (if any).

7.2.1.2 For the purpose of this Section:

(1) Rigidly connected pusher tug-barge combination is a combination of a pusher tug and a barge with the following characteristics:

The pusher tug is secured in the barge notch by mechanical means of any type whatsoever other than just wire ropes, chains, lines or other tackles, and there is no relative motion between the pusher tug and the barge. The pusher tug and the barge remain so connected throughout the voyage.

(2) Pusher tug-barge combination connected in articulated manner is a combination of a pusher tug and a barge with the following characteristics:

① the pusher tug is secured in the barge notch by mechanical means of any type whatsoever other than just wire ropes, chains, lines or other tackles;

② the articulated connector allows pitch between the pusher tug and the barge in one degree of freedom, i.e. rotation of the pusher tug/barge about the (transverse) axis of the connector. The combination is capable of being connected or disconnected remotely from the pusher tug or locally from the barge. The pusher tug and the barge remain so connected throughout the voyage;

③ when the articulated connector is disconnected, both the pusher tug and the barge may remain separately in mooring or operation.

(3) Length of combination (L_c) means the length of the pusher tug-barge combination acting as a single unit. The combined length L_c is to be taken as the distance, in m, measured on a waterline at 85% of the least molded depth of the barge (where the lowest point of freeboard deck of the pusher tug is at or above this waterline) or on the design waterline of the combination (where the lowest point of freeboard deck of the pusher tug is below this waterline), from the fore side of the stem of the barge to the after side of the rudder post or stern post of the pusher tug. Where there is no rudderpost or stern post, L_c is to be measured to the centerline of the rudder stock of the pusher tug. L_c, however, is not to be taken less than 96% and need not be taken greater than 97% of the total waterline length of the combination measured at 85% of the least molded depth of the barge.

7.2.1.3 In addition to the plans and documents required for pusher tugs and barges acting as single vessels in the Rules, the following ones are to be submitted to CCS for approval:

(1) Plan of strengthened hull structural portions in way of the connection of tug and barge for each vessel.

7.2.1.4 The following plans and documents are to be submitted to CCS for information:

(1) Provision and arrangement of connector of the combination;

(2) Connector load calculations;

(3) Diagram of mechanical principles of the connector;

(4) Analysis calculations of strengthened hull structural portions in way of the connection of tug and barge for each vessel;

(5) Operating manual for the connector, including instructions on operation, testing and maintenance.

7.2.1.5 Class notations are as follows:

(1) A rigidly connected pusher tug-barge combination complying with this Section is to be assigned the following class notations:

For pusher tug: Rigid Connection PB Combination — Pusher;

For barge: Rigid Connection PB Combination — Barge.

(2) An articulatedly connected pusher tug-barge combination complying with this Section is to be assigned the following class notations:

For pusher tug: Articulated Connection PB Combination — Pusher;

For barge: Articulated Connection PB Combination — Barge.

7.2.2 Freeboard, subdivision and stability, bilge pumping system

7.2.2.1 The freeboard, subdivision and stability, bilge pumping system of a pusher tug-barge combination

acting as a single unit and of pusher tugs and barges acting as single vessels are to comply respectively with the following requirements or the relevant requirements of the flag Administration (if any):
(1) The freeboard, subdivision and stability, bilge pumping system of pusher tugs and general barges acting as single vessels are to comply with the relevant requirements of the flag Administration.
(2) The freeboard, subdivision and stability, bilge pumping system of open-hatch container barges are to comply with the requirements for open-hatch container ships in Section 2 of this Chapter.
7.2.2.2 Freeboard and arrangement requirements are as follows:
(1) In addition to the requirements in 7.2.2.1(1), the freeboard and bow height of a barge are not to be less than those required for the combination acting as a single unit (general cargo ship).
(2) In all cases, a safe passage is to be available for crew between the aft part of the barge and the fore part of the pusher tug.
7.2.2.3 The intact stability of a combination acting as a single unit in full load condition (fully loaded pusher tug + fully loaded barge) is to comply with the requirements for general cargo ships.

7.2.3 Hull structure and outfitting

7.2.3.1 Requirements for hull structure are as follows:
(1) Hull structure of pusher tug
① A pusher tug acting as a single ship is to comply with the requirements for tugs specified in Chapter 10 of PART TWO of the Rules.
② When calculating the wave impact loading of superstructures and deckhouses, they are to be considered as those of the combination. However, the thickness of their decks and enclosures need not be greater than that of the main hull shell or deck of the pusher tug.
(2) Hull structure of barge
① A barge acting as a single ship is to comply with the requirements of Chapter 12 of PART TWO of the Rules.
② The collision bulkhead of the barge is to be located according to the length of combination L_c, i.e. at a distance, from the fore end of the barge, of not less than 0.05 L_c or 10 m, whichever is the lesser, and not more than 0.08 L_c.
③ Both the longitudinal and local strength of open-hatch container barges are to comply with the relevant requirements in Section 1 of this Chapter.
7.2.3.2 Requirements for outfitting are as follows:
(1) Outfitting of pusher tug
① A pusher tug acting as a single ship is to be provided with the anchoring and mooring equipment used for pusher tugs in accordance with the requirements for cargo ships specified in Chapter 3 of PART TWO of the Rules.
② The combination is to be considered as a single unit with regard to the rudder and steering gear to be provided on board.
(2) The combination is to be considered as a single unit with regard to the outfitting of the barge, and the anchoring and mooring equipment may be provided in accordance with the requirements for cargo ships specified in Chapter 3 of PART TWO of the Rules.

7.2.4 Electrical installations

7.2.4.1 The electrical installations of pusher tugs and barges are to comply with the applicable requirements of PART FOUR of the Rules and in addition, the requirements of this Section.
7.2.4.2 Requirements for pusher tugs are as follows:
(1) The calculation of power plant load of the pusher tug is to include the power consumption of the barge.
(2) The navigation bridge of the pusher tug is to be capable of initiating the following alarms on the barge:
① audible and visual alarm in case of high bilge level in hold of barges;
② audible and visual alarm in case of fault of any ship light on barges.
7.2.4.3 Requirements for barges are as follows:
(1) The barge may be served by the power plant of the pusher tug to which the barge is connected, and when at a port of call by a source on shore, as follows:
① A connection box is to be fitted at a suitable place on board the pusher tug for a flexible cable supplying power to the barge.
② A shore connection box complying with the relevant requirements of rules is to be fitted at a suitable place on board the barge for a flexible cable from an external power source. The shore connection box and the main switchboard on board the barge are to be connected by a fixed and

adequately rated cable.
(2) The barge is to be provided with accumulator batteries as standby power source for anchor lights in case of loss of power when anchoring separately. The power supply period of the batteries may be evaluated according to the possible duration of such case.
(3) Where refrigerated containers are carried in the barge, the power plant capacity calculation, power distribution, monitoring, socket type, etc. are to comply with the relevant requirements of Section 4, Chapter 4 of PART FIVE of the Rules.
7.2.4.4 Other requirements
(1) A multi-core flexible cable may be used to transfer monitoring and alarm signals between the pusher tug and the barge. Such cables are to be connected to the pusher tug and the barge via connector assemblies with a degree of protection of at least IP56.
(2) Means of interlock or alarm are to be used to prevent any damage to the flexible cable linking the pusher tug and the barge in case of disconnection of the connector between the two ships.

7.2.5 Connector and hull supporting structure

7.2.5.1 General requirements
(1) This paragraph contains only requirements for articulated connectors. Equivalent safety design may be used for rigid connectors.
(2) Indicators are to be fitted at the navigation bridge and local operation position to show the disconnected or connected status of the connector, and connecting/disconnecting operations are to be possible.
(3) The mechanical connection means (hereinafter referred to as connector) means the mechanical system used on the pusher tug for quick connection with the barge, including a telescopic connecting arm and all associated power and control parts.
(4) The connector is to be capable of being operated both locally and at the navigation bridge, and disconnected in less than 5 minutes in an emergency.
(5) The connector is to be capable of being operated at one side and at both sides.
(6) At least two separate power units are to be provided to serve the connector.
(7) An emergency disconnection of the connector is to be possible in case of loss of power.
(8) Means of communication are to be available between the space where the connector is located and the navigation bridge.
(9) The connector is to be fitted with a limiter to prevent the connecting arm from excessively stretching or retracting.
(10) For hydraulic connectors, the drawings and documents to be submitted, installing and arrangement, materials, structure and design, safety valve, monitoring and alarm, testing (including sea trial) may be dealt with in accordance with the appropriate requirements for steering gears specified in Chapter 13 of PART THREE of the Rules.
(11) The non-hydraulic connectors are to meet a standard equivalent to that for hydraulic ones.
7.2.5.2 Requirements for strength of connector and hull supporting structure
(1) Connector load

① The design of the connector is to take into account the quasi-static loads, including the buoyancy and propulsion forces, and the dynamic seaway loads, as well as the steering loads. The loads may be obtained either according to ② below or by model test, or calculated by an empirical method. The calculation results are to be submitted to CCS for check.

② The maximum lifetime connector loads may be used for the design of the connection system between the tug and barge. The maximum lifetime value is to be determined based on a prediction method for the long-term extreme value with an acceptable probability level. The methods of determining the maximum lifetime connector loads can be identified:

a) through a scale model test program covering a range of wave frequencies and headings so as to obtain the connector load response amplitude operators (RAOs) and then by analysis to identify the worst heading and predict the long term extreme connector load for that heading, or

b) by a motion response analysis, using a suitable sea keeping analysis program that can handle multiple bodies linked by articulation, in connection with a long term extreme analysis, and taking the wave data of the sea area where the pusher tug-barge combination is to operate into calculation.

③ The design calculation of the connector loads is to be documented and submitted for information.

(2) Specification of the connector system is to be submitted for information together with the design load calculations for the connector loads.
(3) Structure and strength of connection means

① Stress analysis is to be performed according to the load stated in 7.2.5.2(1) above to obtain loads acting on individual components of the connector. Strength calculations are to be provided for essential components of the system in accordance with the following criteria:

$$\sigma \le \frac{R_{eH}}{n}$$

$$\tau \le \frac{0.58R_{eH}}{n}$$

where: σ — positive stress, in N/mm^2;
R_{eH} — yield stress of material of components, in N/mm^2;
τ — shear stress, in N/mm^2;
n — safety factor, taken as 2.5.

② For components subjected to composite stress, the equivalent stress is to comply with the following formula:

$$\sigma_e = \sqrt{\sigma^2 + 3\tau^2} \le 1.1\frac{R_{eH}}{n}$$

where: σ_e —equivalent stress, in N/mm^2;
R_{eH}, σ, τ, n — the same as above.

(4) Main hull supporting structure and strength

① For the supporting structure of the means connecting the pusher tug and the barge, stress analysis is to be performed in respect to the load transmitted by the connector. The analysis is to follow the conventional engineering practice and is to be submitted for check. The connector loads applied are to be in accordance with the loads determined from 7.2.5.2(1) above. In the case of notch type connections, an analysis of the barge wing walls is to take into account torsional shear as well as primary and secondary shear and bending stresses. The results of the structural analysis are to be assessed for yielding and buckling failures.

② The structure in the bow of the pusher tug and the stern of the barge is to be suitably reinforced both in the athwart ship and fore and aft directions with a system of webs, stringers, bulkheads, etc. to withstand the forces developed at these locations due to the connection and also to transmit these forces into the main body of the ships. The hull structure adjacent to the connector is to be suitably reinforced, and assessed by fine finite element direct calculation. The fine finite element model is to be based on the following principles:

a) a separate fine finite element model may be used, with boundary conditions being obtained from analysis of a coarse finite element model; alternatively, direct calculation may be performed via a fine finite element model fitted in a coarse finite element model;

b) the fine finite element area is to be such that stress of the area will not be affected by the boundary conditions of displacement and those of forces. The fine finite element model is to be such that its refined edges are supported by primary members, e.g. girders, horizontal girders and floors in cargo area;

c) the size of meshes of the fine finite element area adjacent to the connector is to be taken as 50 mm × 50 mm. 4-node or 8-node hull elements are to be used, and the use of any triangular element is to be prevented. The weld geometry and structural alignment are not to be taken into account;

d) the permissible yield stress of structural members are to be in accordance with Table 7.2.5.2(4);

e) buckling assessment may be carried out in accordance with the methods provided in Section 5, Chapter 1, PART TWO of the Rules.

Permissible Equivalent Yield Stress [σ_e]① (N/mm^2) **Table 7.2.5.2(4)**

Model / Element	Local fine finite element model (based on 50 mm × 50 mm mesh size)
Plate element	1.36 R_{eH} (single element)② 1.0 R_{eH} (area average)③

Notes: ① The plate element is to be considered according to the equivalent stress (Von Mises stress), i.e.:

$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2}$ N/mm^2, the median plane stress at centroid of the plate element (membrane stress) is to be considered

where: σ_x — element stress in x direction, in N/mm^2;
σ_y — element stress in y direction, in N/mm^2;
σ_{xy} — element shear stress in xy plane, in N/mm^2.

② R_{eH}— yield stress of material, in N/mm^2.

③ The area average means the average of the Von Mises stress of the element considered in the fine finite element area and that of the element in the connecting node.

Section 3 ADDITIONAL REQUIREMENTS FOR PETROLEUM ASPHALT CARRIERS

7.3.1 General provisions

7.3.1.1 Ships specialized in carrying melted petroleum asphalt in bulk in restricted service are to be in accordance with relevant requirements of Chapter 10 of PART EIGHT of the Rules.